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# Variations in nitrogen utilisation on conventional and organic dairy farms in Norway

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ABSTRACT

Reduced N-surpluses in dairy farming is a strategy to reduce the environmental pollution from this production. This study was designed to analyse the important variables influencing nitrogen (N) surplus per hectare and per unit of N in produce for dairy farms and dairy systems across 10 certified organic and 10 conventional commercial dairy farms in Møre og Romsdal County, Norway, between 2010 and 2012. The N-surplus per hectare was calculated as N-input (net N-purchase and inputs from biological N-fixation, atmospheric deposition and free rangeland) minus N in produce (sold milk and meat gain), and the N-surplus per unit of N-produce as net N-input divided by N in produce. On average, the organic farms produced milk and meat with lower N-surplus per hectare (88 ± 25 kg N·ha$^{-1}$) than did conventional farms (220 ± 56 kg N·ha$^{-1}$). Also, the N-surplus per unit of N-produce was on average lower on organic than on conventional farms, 4.2 ± 1.2 kg N·kg N$^{-1}$ and 6.3 ± 0.9 kg N·kg N$^{-1}$, respectively. All farms included both fully-cultivated land and native grassland. N-surplus was found to be higher on the fully cultivated land than on native grassland. N-fertilizers (43%) and concentrates (30%) accounted for most of the N input on conventional farms. On organic farms, biological N-fixation and concentrates contributed to 32% and 36% of the N-input (43 ± 18 kg N·kg N$^{-1}$ and 48 ± 11 kg N·kg N$^{-1}$), respectively. An increase in N-input per hectare increased the amount of N-produce in milk and meat per hectare, but, on average for all farms, only 11% of the N-input was utilised as N-output; however, the N-surplus per unit of N in produce (delivered milk and meat gain) was not correlated to total N-input. This surplus was calculated for the dairy system, which also included the N-surplus on the off-farm area. Only 16% and 18% of this surplus on conventional and organic farms, respectively, was attributed to surplus derived from off-farm production of purchased feed and animals. Since the dairy farm area of conventional and organic farms comprised 52% and 60% of the dairy system area, respectively, it is crucial to relate production not only to dairy farm area but also to the dairy system area. On conventional dairy farms, the N-surplus per unit of N in produce decreased with increasing milk yield per cow. Organic farms tended to have lower N-surpluses than conventional farms with no correlation between the milk yield and the N-surplus. For both dairy farm and dairy system area, N-surpluses increased with increasing use of fertilizer N per hectare, biological N-fixation, imported concentrates and roughages and decreased with higher production per area. This highlights the importance of good agronomy that well utilize available nitrogen.

## 1. Introduction

Livestock accounts for approximately 34% of human protein supply worldwide (Schader et al., 2015); however, N losses from the livestock sector also contribute to local- and global-scale environmental pollution (Steinfeld et al., 2006). Nitrogen, in particular, contributes to both eutrophication and greenhouse gas emissions. Reducing N-losses is a strategy designed to address these problems and represents an important approach for improving efficiency and productivity in agriculture (Gerber et al., 2013). Depending on the chosen system boundaries, the environmental impact of N can be assessed in relation to unit of product or hectare of agricultural area used, which can include only the farm or the entire system area (Halberg et al., 2005; Oudshoorn et al., 2011).

In the last 20 years, many studies on N-balances, N-efficiencies, and life cycle assessments have been performed on dairy farming in Europe.

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Some of these studies have compared organic and conventional farms (Cederberg and Flysjö, 2004; Cederberg and Mattsson, 2000; Dalgaard et al., 1998; Haas et al., 2001; Nielsen and Kristensen, 2005; Thomassen et al., 2008; van der Werf et al., 2009) and have found differences in N-efficiencies, which were invariably higher on organic farms than on conventional farms.

In this study, we aimed to determine the most important variables that influence the N-surplus per hectare and per produced unit, for organic and conventional commercial dairy farms at both the dairy farm and dairy system level. N-surplus per hectare at the farm level and N-surplus per produced unit at the dairy system level were considered as the main nitrogen indicators (Bleken et al., 2005). In the dairy system, all the N-inputs for the off-farm production of feed and heifers were also included. The amount of nitrogen used in inputs for the production of 1 kg of N for human consumption (Bleken et al., 2005) was used to identify how well the different inputs are utilised.

At the dairy farm level, we also calculated the N-surpluses per hectare for fully-cultivated land, as well as for native grassland. Local effects can be expressed as impact per hectare and global effects as impact per product (Haas et al., 2000), with N-surplus per hectare being closely related to nitrate leaching to groundwater (Verloop et al., 2006). On the basis of the studies by Thomassen et al. (2008), Huysveld et al. (2015), and Marton et al. (2016), we propose the hypothesis that when evaluating the utilisation of nitrogen and the area demand for producing milk, it is crucial to take into consideration not only the dairy farm but also the entire dairy system area.

## 2. Materials and methods

### 2.1. Location and farms

Data were collected from 10 certified organic and 10 conventional commercial dairy farms in the county of Møre og Romsdal, central Norway, between 2010 and 2012. This county is mainly located in a coastal area at approximately 63°N and is characterised by a considerably humid climate. The annual precipitation varies from 1000 to 2000 mm and is fairly evenly distributed throughout the year, with the highest amounts falling in coastal areas (Dannevig, 2009). The farmlands are spread from the coast to the valleys further inland. In January, the mean temperature near the coast and in the valleys is 2 °C and − 5 °C, respectively, whereas in July, the corresponding temperatures are 14 °C and 15 °C, respectively. The selected farms differed in dairy cow numbers, milking yield, farm area per cow, fertilisation, and forage to concentrate ratio, which reflect the variations across the county (Table 1).

The grazing period for dairy cows and heifers is typically up to three months and four months, respectively. They graze on fully cultivated and surface-cultivated land, native grassland, and free rangeland (Fig. 1 and 2.1.1 Farm areas). During the indoor season, the animals are mainly fed farm-grown roughage and imported concentrates. On cultivated areas, only grass and grass-clover leys are grown. Cereals can be used as a cover crop when establishing new leys and are harvested as silage.

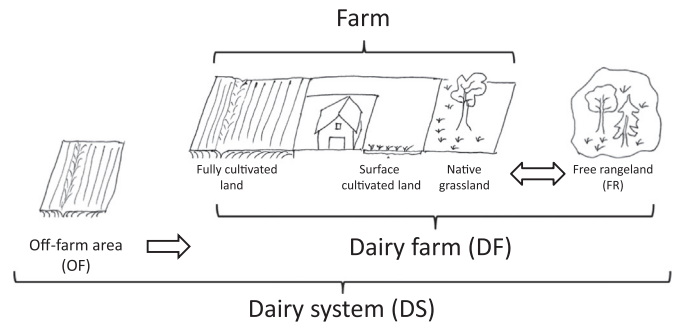


**Fig. 1.** Different categories of areas for the dairy farm and dairy system.

#### 2.1.1. Farm areas

The Norwegian Agriculture Agency distinguishes between three categories of utilised agricultural area: fully-cultivated land, surface-cultivated land, and native grassland (Fig. 1). On *fully-cultivated land*, ploughing, use of manure and mineral fertilizers, and harvesting with machines are all possible, and thus high yields can be achieved. On *surface-cultivated land*, ploughing is not possible, and yields are lower than those on cultivated lands. *Native grassland* can only be used for grazing and has the lowest yields among the three categories. Because of the differences in potential management practices and yields in these three area categories, we weighted the farm area by multiplying the fully cultivated land by 1, the surface-cultivated land by 0.6, and the native grassland by 0.3. The weighting of surface-cultivated land followed the guidelines of the Norwegian Agricultural Authority (2011); the factor for native grassland was set to represent an average of the potential grazing (Rekdal, 2008; Samuelsen, 2004). Only some farms had surface-cultivated land and the contribution to the entire dairy farm area was < 1%. When we refer to areas without weighting, we mention these areas as cartographic area.

In addition to their own land, most farms have access to *free rangeland*, which consists mainly of native woodland or alpine vegetation and can only be used for grazing. Thus, the free rangeland is a part of the dairy farm, but not a part of the defined dairy farm area. To indicate the contribution of this land to the feed supply, we calculated the

**Table 1**
Characteristics of the dairy farms.

| Parameters | Units[a] | Conventional | Standard deviation | Organic | Standard deviation |
|---|---|---|---|---|---|
| Number of farms | n | 10 | | 10 | |
| Dairy farm area (DF); weighted[b] | ha | 31.1 | 19.6 | 36.5 | 26.3 |
| Fully cultivated land | ha | 26.8 | 13.6 | 33.0 | 23.7 |
| Surface-cultivated land | ha | 0.3 | 0.4 | 0.2 | 0.5 |
| Native grassland | ha | 13.6 | 22.7 | 11.3 | 14.7 |
| Estimated utilised dry matter (DM) yield DF | t DM·ha$^{-1}$ | 3.5 | 0.9 | 2.7 | 0.6 |
| Cows per farm[c] | cows·farm$^{-1}$ | 29.5 | 16.4 | 29.4 | 17.3 |
| Live weight milking cow | kg | 570 | 40 | 545 | 75 |
| Milk yield per milking cow | t ECM·cow$^{-1}$ | 8.3 | 0.7 | 6.0 | 1.2 |
| Milk delivered per DF area | t ECM·ha$^{-1}$ | 7.2 | 2.2 | 4.6 | 1.1 |
| Milk fat | % | 4.09 | 0.25 | 3.89 | 0.22 |
| Milk protein | % | 3.39 | 0.08 | 3.28 | 0.12 |
| Replacement rate | % | 41.4 | 10.0 | 33.6 | 8.0 |

[a] Units of parameters are given. Numbers for participating farms are the means for average of calendar years 2010–12 with standard deviation.
[b] Weighted area = Fully cultivated land + 0.6 Surface−cultivated land + 0.3 Native grassland.
[c] The number of cows per year is defined as the number of cows per 365 days, independent of live weight.