

## The impact of farm size on sustainability of dutch dairy farms

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### ABSTRACT

Sustainable milk production systems require economically viable, environmentally sound and socially acceptable practices. This study compared the economic, environmental and societal impact of large-scale farms with other dairy farms in the Dutch Farm Accountancy Data Network (FADN). Moreover the integrated sustainable performance of large-scale dairy farms was explored. To quantify the impact of farm size on economic performance, we used net farm income (NFI), labour productivity and solvency. We quantified environmental performance using indicators on non-renewable energy use, greenhouse gas (ghg) emissions, phosphorus surplus and pesticides use. To quantify societal performance, we used indicators on milk quality, cow lifetime and grazing hours.

Large-scale dairy farms had a higher labour productivity and NFI than other dairy farms, without compromising on phosphorus surplus, energy use or ghg emission. Higher profits were accompanied by a lower solvency ratio on large-scale farms. Pesticides use, however, was higher on large-scale dairy farms due to a lower share of grassland. Large-scale farms had a shorter cow lifetime and applied less grazing compared to other dairy farms.

For societal performance, current FADN does not have the potential to assess animal welfare using preferred animal-based indicators.

**KEYWORDS:** FADN; sustainability; effects of scale; dairy farming

### 1. Introduction

Since the introduction of milk quota by EU-regulation in 1984, the number of Dutch dairy farms decreased, maintaining an equal level of milk production on sector level, i.e. increased farm size. Increasing farm size is a continuing process in Dutch agricultural and horticultural sector (Van der Meulen *et al.*, 2011). To reduce fixed costs per kilogram of milk, further increase in farm size is necessary (Anonymous, 2009a). The abolishment of milk quota in the EU-27 by 2015, will further strengthen an increase in farm size and lead to a growth of Dutch milk production from 11.5 billion kg currently, up to 14 billion kg in 2020 (Anonymous, 2009a).

Sustainable milk production systems require economically viable, environmentally sound and socially acceptable practices (Thomassen *et al.*, 2009). Over the last decades, sustainable milk production became increasingly important (Anonymous, 2009b). The Dutch Dairy Association and the Dutch Organisation for Agriculture and Horticulture, therefore, joined forces in the Sustainable Dairy Chain initiative. Via the Sustainable Dairy Chain initiative, the processing industry and farmers aim to strengthen future support within the market and society (Reijs *et al.*, 2013).

In the Netherlands, perceptions on large-scale agriculture are diverse and trigger public discussion. Moreover, sustainable development of the production chain is included in policymaking increasingly (Boone and Dolman, 2010). Therefore, there is need for a clear view on the relation between farm size and sustainability impact. Several studies explored combined economic, environmental, and societal performance of animal production systems (Dolman *et al.*, 2012a; Meul *et al.*, 2008; Van Calker *et al.*, 2006). To our knowledge, however, no scientific publication exists that explored the impact of increasing farm size on integrated economic, environmental, and societal performance. The objective of this study, therefore, is to compare the economic, environmental and societal impact of large-scale farms with other dairy farms and explore the integrated sustainable performance of large-scale dairy farms.

### 2. Material and methods

We quantified economic, environmental and societal performance of specialized dairy farms in the Dutch Farm Accountancy Data Network (FADN) for 2011. The Agricultural Economics Research Institute

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continuously collects technical and economic data from a large sample of Dutch farms recorded in FADN, providing a wide range of economic, environmental and societal performance indicators. In 2011, FADN provided data from 298 dairy farms. To exclude effects of non-dairy activities, we selected dairy farms when at least 75% of the farm size, measured in standard output (SO), originated from dairy activity and data on all economic, environmental and societal performance indicators were available. Hence, we quantified the effect of farm size for 160 specialized dairy farms.

## Performance indicators

### Economic performance

To quantify the impact of farm size on economic performance, we quantified net farm income (NFI), labour productivity and solvency. NFI is often used as an indicator for profitability (Blank *et al.*, 2009; Dekker *et al.*, 2011; Van Calster *et al.*, 2008). We defined NFI as the remuneration for management, family labour and capital that is left after all other costs are deducted (EC 2011). To correct for differences in farm size, we expressed NFI per unpaid annual working unit (awu). To give insight in the labour effort to realize the NFI, a measure of labour productivity is required (Dolman *et al.*, 2012a). Labour productivity is a ratio of volume of output per unit of labour input (OECD, 2001). To enable a comparison of labour productivity among farms differing in scale, we expressed labour productivity in the average number of cows per annual working unit.

Solvency deals primarily with the firm's ability to meet total claims (Barry *et al.*, 2000). A farm business is insolvent if sale of all assets fails to generate sufficient cash to pay all liabilities. We defined solvency as the ratio of total owners' equity as a per cent of total farm assets (equity-to-asset ratio) (Barry *et al.*, 2000). The smaller the safety margins of equity, the greater the financial risk.

### Environmental performance

We quantified environmental performance using indicators on non-renewable energy use, greenhouse gas (ghg) emissions, phosphorus surplus and pesticides use. Two main environmental objectives within the Sustainable Dairy Chain initiative are decreasing non-renewable energy use and climate change per kg of milk produced and was therefore available within FADN. Dutch FADN recorded non-renewable energy use at farm level, while ghg emissions were derived from a cradle-to-farm-gate life cycle assessment (LCA) (Reijs *et al.*, 2013). For policy evaluation purposes, FADN provided phosphorus surplus per hectare as a measure for eutrophication and pesticide use per hectare as a measure for eco-toxicity.

### Societal performance

We quantified societal performance using indicators on milk quality, cow persistency and grazing. These societal indicators were included within the Sustainable Dairy Chain initiative and therefore available in FADN. As a measure of milk quality, we used the somatic cell count.

High levels of somatic cell count relate to clinical and subclinical mastitis, which is the most important reason for early culling of dairy cows (Reijs *et al.*, 2013). We quantified cow persistency using the average cow lifetime (years), from birth until culling. Extended average cow lifetime indicate improvement in animal health. The number of hours grazing is included as an indicator for animal welfare and social perception (Dolman *et al.*, 2012b).

## Integrated assessment

To explore the impact of farm size on integrated economic, environmental and societal performance we compared 15% (n=24) largest dairy farms by average number of cows with the rest of the group (n=136). Several studies described an approach to aggregate values of performance indicators of livestock systems into a total score on sustainability (Dolman *et al.*, 2012a; Meul *et al.*, 2008; Van Calster *et al.*, 2006). We used an approach based on Meul *et al.* (2008) to compute the integrated performance on the ten economic, environmental and societal indicators. The performance was normalized on a scale from 0 through 100, whereby a score of 100 per indicator was assumed to be sustainable. Similar to Meul *et al.* (2008), a 10% and 90% percentile was used as a minimum and maximum value respectively. Using the 10<sup>th</sup> and 90<sup>th</sup> percentile tackles the problem of outliers in the linear approach. We visualized differences in integrated economic, environmental and societal performance using a benchmark diagram of the 15% largest dairy farms with the rest of the dairy farms. Differences between groups were tested using an independent sample t-test (P<0.05).

## 3. Results

### Descriptive

The 15% large-scale dairy farms had a higher total milk production, a larger cultivated area and a higher number of cows (P<0.001) than other farms (Table 1). Moreover, large-scale dairy farms had a higher production per hectare (P<0.001) than other dairy farms, whereas milk production per cow was equal on both group of farms.

With 80% of total revenues origination from milk production, large-scale farms were more specialized than the rest of the farms. Furthermore, the percentage of grassland area was lower on large-scale farms (P<0.05) than other dairy farms.

### Economic, environmental and societal performance

For economic performance, large-scale dairy farms realized a higher labour productivity and NFI per unpaid awu, whereas solvency (57%) was lower than on other farms (P<0.01) (Table 2, Figure 1). For environmental performance, pesticide use (P<0.01) was higher for large-scale farms. For societal performance, average cow lifetime (P<0.05) and grazing hours (P<0.01) were lower for large-scale dairy farms.

**Table 1:** Comparison between farm characteristics for large-scale farms and other specialized Dutch dairy farms in 2011 (FADN)

Farm characteristic	Large-scale	Other	Sig. <sup>a)</sup>
No. of farms	24	136	
Cows (#)	202	78	***
Total milk production (kg)	1,714,093	635,083	***
Cultivated area (ha)	94	48	***
Grassland (%)	76	83	*
Milk production per cow (kg)	8,500	8,143	ns
Milk production per ha (kg)	18,311	13,343	***
Milk revenues in total turnover (%)	80	77	*

a) \*= $P < 0.05$ ; \*\*= $P < 0.01$ ; \*\*\*= $P < 0.001$ ; t-test: ns: not significant.

## 4. Discussion

### Indicator selection

The basis for the selection of indicators was availability of data in the Dutch FADN and relevance within the Sustainable Dairy Chain initiative. For economic sustainability a large number of indicators are available to measure profitability. We choose NFI and labour productivity because other suggested attributes as liquidity are highly interrelated and linked to NFI (Van Calker *et al.*, 2005).

We quantified environmental performance using indicators on non-renewable energy use, greenhouse gas (ghg) emissions, phosphorus surplus and pesticides use. For ghg we quantified cradle-to-farm-gate performance. Other indicators, however, quantified only impact at farm level and did not take into account the impact occurring in early stages of the milk production chain, such as purchased feed and fertilizers. Including indirect impact for energy use, eutrophication or acidification might differ for large-scale farms compared to other farms. Thomassen *et al.* (2009) stated, for example, that a high levels of milk production per ha positively effects total environmental impacts.

Van Calker *et al.* (2005) divided societal sustainability in internal and external societal sustainability. Internal societal sustainability represents the farmers'

and employees working conditions, whereas external sustainability includes the societal concern about the impact of agriculture on the wellbeing of animals and people, such as animal welfare, food quality and spatial quality. FADN did not offer the possibility to quantify indicators for the farmers and employers working conditions. External societal performance of farms could be quantified based on FADN using somatic cell count, cow lifetime and grazing hours. We acknowledge that pasture hours is a simple indicator for welfare. Large dairy farms keep cows in the cowshed frequently. The modernity of cowsheds is higher on large dairy farms (Van der Meulen *et al.*, 2011). In this analysis no indicator was available for the relationship between animal welfare and housing systems. Current FADN does not have the potential to assess animal welfare using preferred animal-based indicators. We didn't report about one relevant societal issue, food safety. The use of antibiotics is a suitable indicator for food safety (Dolman *et al.*, 2012a). The use of antibiotics (daily dosages per animal year) is not reported, due to a lack of observations. Besides animal welfare and food quality, external sustainability includes spatial planning problems to cover the minimal aspects of societal performance. The effect on spatial quality is not quantifiable on farm level, and therefore, not included in the FADN sample (Dolman *et al.*, 2012a).

**Table 2:** Economic, environmental and societal performance of large-scale and other specialized Dutch dairy farms in 2011 (FADN)

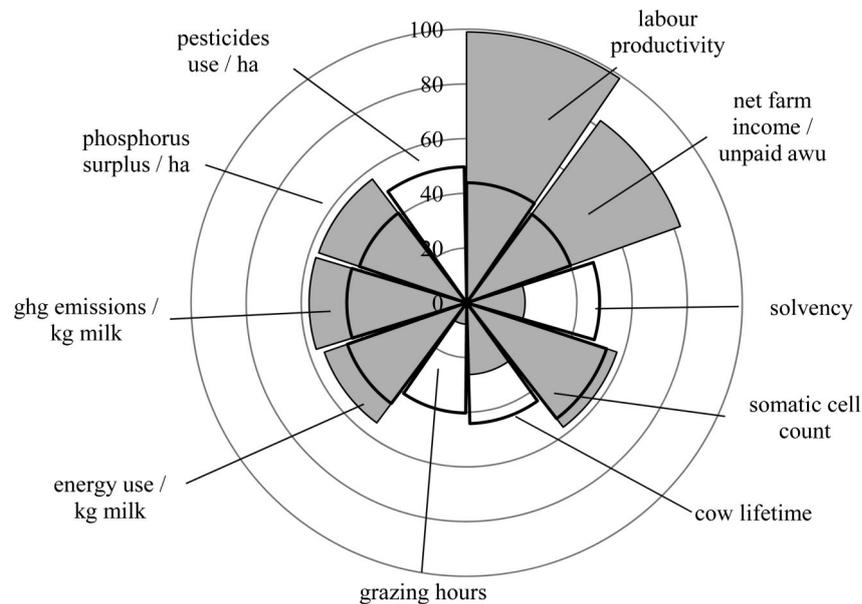
	Large-scale	Other	Sig. <sup>a)</sup>
<b>Economic</b>			
Labour productivity (cow/awu) <sup>b)</sup>	80	49	***
Net farm income (euro/unpaid awu)	72,840	31,368	***
Solvency (%)	57	70	***
<b>Environmental</b>			
Energy use (MJ/kg)	0.6	0.6	ns
Ghg emissions (kg CO <sub>2</sub> -eq./kg) <sup>c)</sup>	1.2	1.3	ns
Phosphorus surplus (kg/ha)	5	14	ns
Pesticides use (kg as/ha) <sup>d)</sup>	1.2	0.5	**
<b>Societal</b>			
Somatic cell count (average/year)	210	216	ns
Cow lifetime (years)	4.8	5.4	*
Grazing hours (hours/cow/day)	1	8	***

a) \*= $P < 0.05$ ; \*\*= $P < 0.01$ ; \*\*\*= $P < 0.001$ ; t-test: ns: not significant;

b) awu: annual working unit;

c) cradle-to-farm-gate greenhouse gas (Ghg) emissions;

d) as: active substance.



**Figure 1:** Comparison of indicator scores, 0 (not sustainable) and 100 (sustainable) of large-scale farms (grey wedges) with other specialized Dutch dairy farms in 2011 (FADN) (thick black line)

### Economic, environmental and societal performance

We used most recent available FADN data from one year, i.e. 2011. There were large fluctuations in NFI between years, which may affect the outcome of our analyses. The year 2011 was a relatively prosperous year, with a high milk price (Van der Meulen *et al.*, 2012). In a year with a low milk price, milk revenue and incomes will decline and significant differences on profitability caused by large-scale would be less.

Better economic results were accompanied by greater financial risks, i.e. lower equity-to-asset ratio. Large-scale farms had a lower solvency than other farms. The increased scale was mainly financed with bank loans. Higher funding makes large-scale farms vulnerable to price fluctuations in the future. The critical issue relating to solvency is the ability of the farm to generate cash to meet all expenses and service the debt with an acceptable margin of safety. Solvency ratios do not indicate an optimal level of leverage for a firm (Barry *et al.*, 2000). Many farm lenders prefer borrowers having at least as much investment in their own farm as their lenders do. Therefore, a standard rule of thumb for the minimum solvency-ratio is 50%. However, the solvency norm varies substantially among farm business and from one type to another. It is commonly accepted that larger farms can carry relatively greater debt loads (Barry *et al.*, 2000).

For environmental performance, we observed only a higher pesticides use on large-scale farms. Large-scale dairy farms had a lower share of grassland than other dairy farms. On large-scale dairy farms, grassland is more frequently rotated with maize resulting in a higher pesticides use compared with other dairy farms.

Large-scale dairy farms had an earlier culling age than other dairy farms. The high number of cows per awu, resulting in less available time to take care of sick cows, might cause this. Another explanation might be that large-scale dairy farms applied a lower grazing

frequency than other dairy farms. Grazing becomes more complicated with increasing herd size. Higher levels of grazing decrease leg and claw problems for housing systems with non-optimal housing systems (Van den Pol-van Dasselaar *et al.*, 2008).

### 5. Conclusion

Large-scale dairy farms had a higher labour productivity and NFI than other dairy farms, without compromising on phosphorus surplus, energy use or ghg emission. Higher profits were accompanied by a lower solvency ratio on large-scale farms. Pesticides use, however, was higher on large-scale dairy farms due to a lower share of grassland. Large-scale farms had a shorter cow lifetime and applied less grazing compared to other dairy farms.

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