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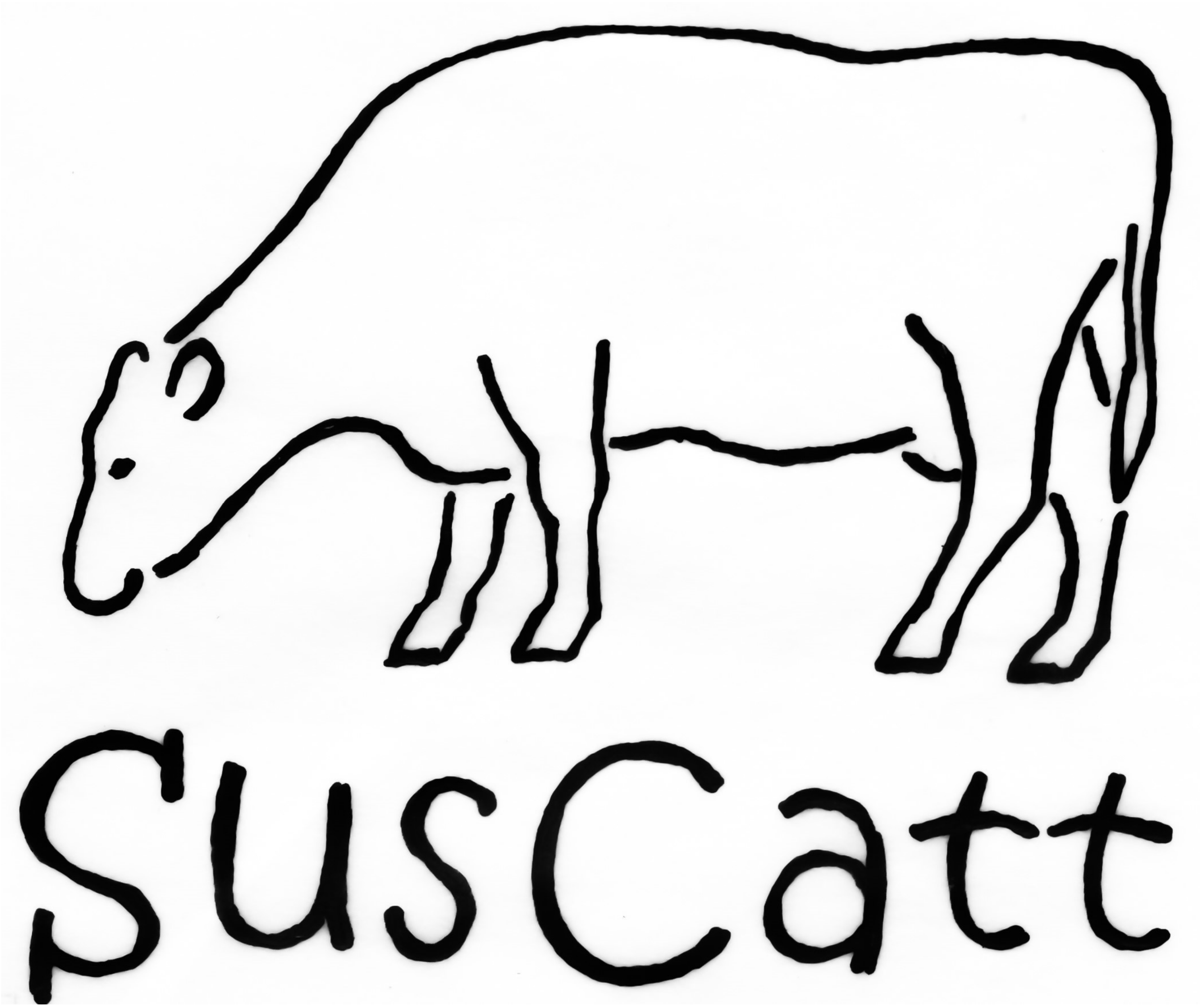
NIBIO REPORT | VOL. 7 | NO. 81 | 2021



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TITTEL/TITLE

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DATO/DATE:	RAPPORT NR./ REPORT NO.:	TILGJENGELIGHET/AVAILABILITY:	PROSJEKTNR./PROJECT NO.:	SAKSNR./ARCHIVE NO.:
22.04.2021	7/81/2021	Open	10897	17/01031

ISBN:	ISSN:	ANTALL SIDER/ NO. OF PAGES:	ANTALL VEDLEGG/ NO. OF APPENDICES:
978-82-17-02831-4	2464-1162	17	

OPPDRAGSGIVER/EMPLOYER:	KONTAKTPERSON/CONTACT PERSON:
Research Council of Norway/ERA-NET SusAn	Håvard Steinshamn

STIKKORD/KEYWORDS:	FAGOMRÅDE/FIELD OF WORK:
Mjølk- og storfekjøttproduksjon, Berekraft, livsløpsanalyse	Husdyrbruk, Systemanalyse
Combined milk and beef production, sustainability, life cycle assessment	Animal husbandry, System analysis

SAMMENDRAG/SUMMARY:

To hundre mjølkebruk i Midt-Norge blei delt i tre nesten like store grupper; 'Låg' (68 gardar), 'Medium' (67 gardar) og 'Høg' (68 garder), etter årleg tildeling av kraftfôr til mjølkekyrne for å teste effekten av kraftfôrnivå på indikatorar for miljøpåverknad og økonomisk lønsemd. Gjennomsnittleg årleg kraftfôrnivå per ku var 15,4, 18,8 og 21,7 GJ nettoenergi laktasjon (NEL) og årleg avdrått i energikorrigert mjølk (EKM) per ku var 7868, 8421 og 8906 kg i høvesvis 'Låg', 'Medium'og 'Høg'. Standard livsløpsanalyse og dekningsbidrag blei brukt til å bestemme indikatorar for miljøpåverknad og økonomiske resultat av mjølk- og kjøttproduksjon. Den funksjonelle eininga var mengde 2,78 MJ spiseleg energi, tilsvarande 1,0 kg EKM eller 0,42 kg kjøtt eller en kombinasjon av mjølk og kjøtt som utgjer 2,78 MJ, altså EKM ekvivalent i mjølk og kjøtt levert EKM-eq. Det globale oppvarmingspotensialet, energiintensiteten og nitrogenintensiteten var i gjennomsnitt 1,46 kg CO_2-eq./kg EKM-eq., 5,61 MJ energibruk/kg EKM-eq., og 6,83 N input/N-produkt, og var ikkje forskjellig mellom gruppene. Gardar med 'Låg' kraftfôrtildeling brukte mindre areal av total arealbruk til dyrking av innkjøpt fôr utanfor garden enn de i 'Høg' (0,39 vs. 0,46 daa/daa), men det totale arealet som blei brukt per kg EKM-eq. var større ('Låg' 3,24 vs. 'Høg' 2,84 m^2/kg EKM-eq.). Dekningsbidraget per kg EKM-eq. levert var i gjennomsnitt høgare på 'Låg' gardar (6,57 NOK/kg EKM-eq.) enn 'Medium' (6,04 NOK/ kg EKM-eq.) og 'Høg' (5,73 NOK/kg ECM-eq.). Vår analyse viser at høgare kraftfôrnivå ikkje alltid gir mindre global oppvarmingspotensiale og mengd fossil energi per kg mjølk og kjøtt produsert samanlikna med lågare kraftfôrnivå.

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LAND/COUNTRY:	Norway
FYLKE/COUNTY:	Viken
KOMMUNE/MUNICIPALITY:	Ås
STED/LOKALITET:	Ås

GODKJENT /APPROVED	**PROSJEKTLEDER /PROJECT LEADER**
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Preface

The main objectives of the research project “Increasing productivity, resource efficiency and product quality to increase the economic competitiveness of forage and grazing based cattle production systems”, with the acronym SusCatt, were to evaluate the productivity, resource-use efficiency and consumers’ acceptability of a transition to high forage and pasture diets for European cattle.

The project focused on dairy, integrated dairy/beef and specialized beef production systems, addressing:

- Productivity, product, animal health and welfare, and economic performance,
- Resource use efficiency and environmental impacts, both assessed experimentally, by modelling and life cycle analysis,
- Consumers’ appreciation.

The project involved modelling, experimental and participatory R&D activities and covered contribution from SMEs (farmers, advisory service) and pooled expertise from seven academic centres of excellence in six European countries. The project was organised in 4 work packages; two focusing on beef and milk production, feeding into one work package on overall assessment of economic, resource-use efficiency and societal acceptance and the fourth was dedicated to disseminating our findings.

This report covers the findings from work package 3 task 3, assessing forage proportion in the diet of dairy cows in Central Norway on indicators for economic and environmental sustainability.

The research was made possible by funding from SusAn, an ERA-Net co-fund action under the European Union’s Horizon 2020 research and innovation program (www.era-susan.eu), Grant Agreement n°696231, with funds from national funding bodies; Research Council of Norway (RCN, Norway), the Swedish Region Västra Götaland and Swedish Research Council (FORMAS, Sweden), Department for Environment, Food & Rural Affairs (DEFRA, UK), Ministry of Agricultural, Food and Forestry Policies (MiPAFF, Italy), National Centre for Research and Development (NCBR, Poland), and the Federal Ministry of Food and Agriculture (BMEL, Germany).

Tingvoll, Norway, 19th April 2021

Håvard Steinshamn

Project leader

Content

Summary

Two hundred dairy farms in Central Norway were categorised into three nearly equal sized groups; 'Low' (68 farms), 'Medium' (67 farms) and 'High' (68 farms), according to the annual allowance of concentrate feeds by the dairy cows to test effect of concentrate allowance on indicators of environmental impact and financial performance. The average annual concentrate allowance per cow was 15.4, 18.8 and 21.7 GJ net energy of lactation (NEL) and annual energy corrected milk (ECM) yield per cow were 7868, 8421, and 8906 kg in 'Low', 'Medium' and 'High', respectively. Standard life cycle assessment and economic analysis methods were used to determine some indicators of environmental impact of milk production and financial performance, and the functional unit used was the amount of 2.78 MJ edible energy, corresponding to 1.0 kg of energy corrected milk (ECM) or 0.42 kg of meat or any combination of milk and meat amounting to 2.78 MJ. The global warming potential, energy intensity and nitrogen intensity were on average 1.46 kg CO_2-eq./kg ECM-eq., 5.61 MJ energy use/kg ECM-eq., and 6.83 N input/N produce, respectively, and did not differ between the groups. Farms with 'Low' supply of concentrate used less land of total land use for growing purchased feed off-farm than those with 'High' (0.39 vs. 0.46 ha/ha), but the total land necessary per kg ECM-eq. delivered was greater ('Low' 3.24 vs. 'High' 2.84 m^2/kg ECM-eq.). Gross margin per kg ECM-eq. delivered was on average higher on 'Low' farms (6.57 NOK/kg ECM-eq.) than 'Medium' (6.04 NOK/ kg ECM-eq.) and 'High' (5.73 NOK/kg ECM-eq.). Our analysis does not support the general assumption that higher concentrate feeding, lowers global warming potential and fossil energy needed per kg of milk and meat produced compared with more extensive systems.

1 Introduction

Combined cattle milk and beef production is economically the most important sector in Norwegian agriculture (Knutsen, 2020). However, livestock is also the largest contributor of greenhouse gas (GHG) emission from agriculture (Norwegian Environment Agency, Statistics Norway, 2020). Estimates of GHG emission and other environmental impact indicators for different dairy milk and meat production systems can for example be found in the ecoinvent database or in Life Cycle Assessment (LCA) studies. Roer et al. (2013) modelled representative dairy farms in Norway and estimated that for each kg energy corrected milk (ECM) produced at the farm gate, 1.5 kg CO_2-eq. were emitted, and that 4.2 MJ non-renewable energy and 1.9 m^2 agricultural land were used. A follow up study tested various intensification measures to reduce the environmental impact of dairy production (Bakken et al., 2017). They found that increasing milk yield per cow reduced global warming potential (GWP) and agricultural land occupation (ALO) per litre of milk. However, Schueler et al., (2018) reported considerable variations between farms in GWP in a study of 20 Norwegian dairy farms. In order to reduce the environmental impact without compromising financial performance, it will be useful for farmers and their advisors to use farm specific data to identify relevant management factors. However, to utilize LCA for benchmarking and decision support, it is necessary to have access to farm records and to ease the process of data inventory for farm specific modelling and impact calculation. For example, this is enabled in the online Irish 'Carbon Navigator' tool, including comparison with the connected databases (Murphy et al., 2013). This is also the approach of the Norwegian 'Klimakalulator'[1], which was introduced in 2021.

In the present study, we updated the FARMnor model, developed by Schueler (2019), to utilize existing financial, animal health and production data from the farm advisory service of the central Norwegian dairy cooperative Tine (Tine Mjølkonomi) to conduct farm specific LCAs for many dairy farms in Norway.

The specific objective was to test if the management factor "Concentrate level per cow" is correlated with score on environmental impact categories and financial performance using Mjølkonomi data from dairy farms in Central Norway. Based on previous Norwegian modelling studies, we hypothesised that farms with higher concentrate feeding per cow produce milk and meat with lower GWP and ALO and higher financial margins than farms with medium or low concentrate levels.

[1] Carbon- calculator: https://klimasmartlandbruk.no/klimakalkulatoren/

2 Material and methods

Data covering farm accountancy, herd health and production were collected by Tine Mjølkonomi, from dairy farms in the counties of Central Norway, 'Møre og Romsdal' and 'Trøndelag'. Only farms participating during all three fiscal years 2014-2016 were included and data were averaged across the years to reduce interannual variation. Farms with profound changes in management during these three years were omitted, e.g. a change from tie stall barns to loose housing, from conventional to automatic milking system or changes in management structure. We ended up with records from 200 dairy farms which were categorised into three nearly equal sized groups: 'Low' (68 farms), 'Medium' (67 farms) and 'High' (68 farms), according to the annual intake of concentrate feeds (MJ net energy of lactation (NEL)/cow/year). In the 'Low' and 'Medium' groups, 14 and one farms were certified organic, respectively. Mean annual concentrate supplementation in the three groups was equivalent to 2.2 ('Low'), 2.7 ('Medium') and 3.1 ('High') tonnes DM per cow with corresponding forage intakes estimated as 63%, 56% and 52% of total net energy intake (Table 1).

Table 1. Farm characteristics

Item	Unit	Concentrate level cows			SEM	*p*-value
		Low	Medium	High		
Number of farms	n	68	67	68		
Concentrate per cow/year	MJ NEL/MCU	15427^{c}	18849^{b}	21663^{a}	240	<0.001
Concentrate per cow/year	kg DM/MCU	2173^{c}	2655^{b}	3051^{a}	34	<0.001
Forage intake per cow/year	MJ NEL/MCU	26839^{a}	24620^{b}	23861^{c}	597	<0.001
Forage in diet, cows	MJ/total MJ	0.63^{a}	0.56^{b}	0.52^{c}	0.007	<0.001
Pasture in diet, cows	MJ/total MJ	0.10^{a}	0.07^{b}	0.05^{b}	0.008	<0.001
Dairy cows	MCU/farm	29.7^{b}	35.4^{ab}	37.7^{a}	2.5	0.010
Farm agricultural area	ha/farm	41.3	45.6	47.9	4.2	0.353
Stocking density	MCU/ha	1.13^{b}	1.26^{ab}	1.29^{a}	0.60	0.022
Milk quota	1000 L/farm	210.1^{c}	270.3^{b}	293.9^{a}	19.3	<0.001
Quota fill	Proportion	0.93	0.93	0.93	0.01	0.971
Milk yield produced	kg ECM/MCU	7868^{c}	8421^{b}	8906^{a}	123	<0.001
Concentrate per kg ECM	MJ NEL/kg ECM	2.04^{c}	2.32^{b}	2.54^{a}	0.039	<0.001
Meat delivered	kg/MCU cattle	130	135	136	10.7	0.835
Age cows	Months	46.6	46.3	46.5	0.67	0.931
Age at first calving	Months	25.6	25.4	25.6	0.24	0.661
Calving interval	Months	12.3	12.3	12.2	0.11	0.685
Replacement rate	%	46.3	46.5	46.4	1.86	0.998
Milk somatic cell count	1000	111^{b}	122^{ab}	129^{a}	4.6	0.003

^{abc} Values within rows with different superscript differs significantly (p<0.05).
NEL is net energy lactation. MCU is Milking Cow Unit, equivalent to one dairy cow staying in the herd for 365 days, standardised to an annual NEL requirement of 42,000 MJ. The whole herd on each farm is calculated to MCU.
ECM is Energy Corrected Milk.
SEM is standard error of the mean.
^{abc} Means within a row with different superscript differ significantly (P<0.05)

The environmental performance was calculated for milk and meat[2] delivered at farm gate, using the FARMnor model (Schueler et al. 2018) to conduct a Life Cycle Assessment (LCA), using ISO 14040 (ISO, 2006a) and ISO 14044 (ISO, 2006b) as framework. In FARMnor, the environmental

[2] Also including the estimated amount of meat from sold live animals.

performance is calculated in a cradle to farm-gate life cycle assessment approach using the basic flows in the hierarchically structured model shown in Figure 1. Inventory flows and emissions from external inputs like imported diesel, electricity, fertilizer, lime, silage-foil, chemicals, machinery, buildings, and imported feed ingredients were approximated, using the ecoinvent life cycle inventory (LCI) database (Frischknecht et al., 2005). Methane emissions were assessed with a Tier 2 approach, based on the specific algorithms for Norwegian conditions as per Storlien et al.(2014), while emissions from manure storage were calculated on IPCC (2019). The amount of manure was calculated based on (Karlengen et al. 2012). For N-inputs from mineral fertilizer (emission factor 1, EF1), organic fertilizers (EF2), and crop residues (EF3) used the same emission factor, named EF1 in Paustian et al. (2006). Harvested and grazed forage yields are estimated by difference in TINE Mjølkonomi based on the total net energy requirement for milk and meat production and concentrates used, accounting for harvesting and preservation losses (Steinshamn et al., 2004). The FARMnor model has been improved to automatically read data for each farm, calculate, and save the environmental performance and to proceed to the next farm.

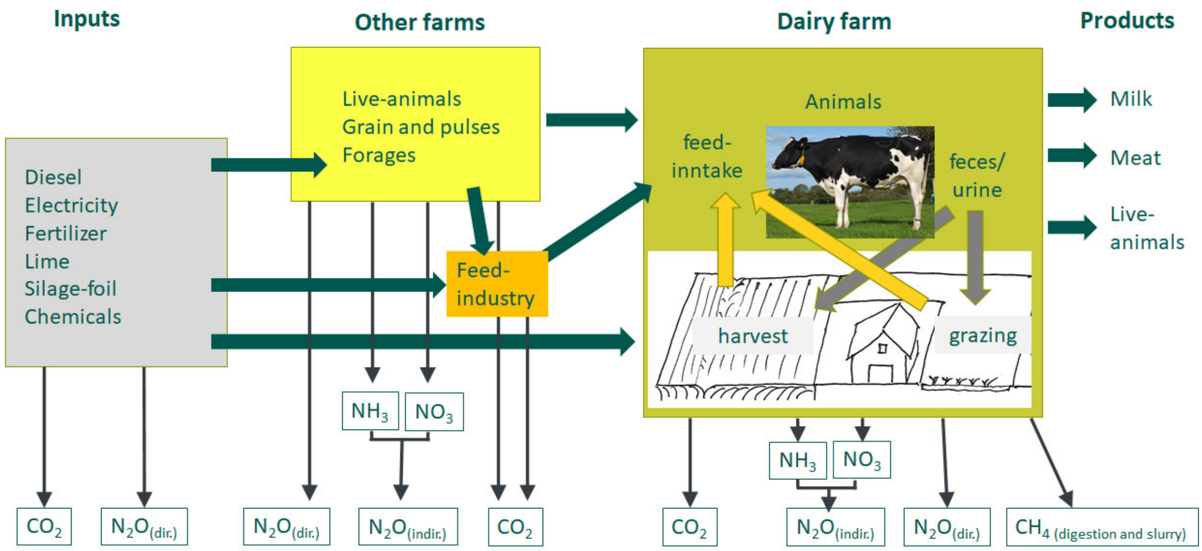

Figure 1. Basic flows, inputs, land area occupation and products in the FARMnor model

The environmental indicators and nitrogen balance/budget of farmed area were calculated based on atmospheric deposition, biological nitrogen fixation, use of fertilizer and manure (Koesling et al., 2017a). Enteric methane emission was calculated for the different cattle groups based on feed requirement, calculated from maintenance and weight gain and milk yield for lactating cows. Emissions from the production of purchased inputs were based on ecoinvent data, the quantity used and transportation distance to the farms. For concentrates, we used the specific formulations for the different concentrates as average for the years 2014-2016 given by the Norwegian Agricultural Purchasing and Marketing Cooperation (Felleskjøpet) and calculated the amount of the different ingredients used in conventional and organic concentrates. Data on feed ingredients, produced in other countries, were based on ecoinvent and (Nemecek et al. 2011), and for different Norwegian grain on (Korsaeth et al. 2014). On IPCC recommendations GWP was calculated for a 100-year period and contributions converted to CO_2-equivalent (IPCC, 2013). Both milk and meat production at farm-gate were calculated to ECM milk (Sjaunja et al. 1991) and meat equivalent based on edible energy, assuming 1.0 kg of ECM or 0.42 kg of meat or any combination of milk and meat amounting to 2.78 MJ edible energy (Koesling et al., 2017b), making the functional unit one kg energy-corrected milk and meat equivalent (ECM-eq.). Revenues, costs, and margins were also calculated and expressed at the functional unit ECM-eq.

Data were subjected to statistical analysis using the mixed model procedure of SAS (SAS Institute Inc., 2011) with "Concentrate level" for dairy cows ('Low', 'Medium' or 'High'), "Milking system" (AMS [automated milking system], milking parlour or pipeline) and "District Area Payment" zone (B, C, D, E or F) for Norwegian dairy farming (Hovland et al., 2018) as fixed effects and "Farm" as random effect. 'Concentrate level' by 'Milking system' interaction was also included as fixed effects. Treatment means were generated and separated, using the LSMEANS and adjusted Tukey options, respectively.

3 Results and Discussion

The differences reported and discussed are statistically significant. Whereas mean farm area was similar across groups (around 45 ha), farms with 'Low' concentrate feeding had fewer cows, and hence lower stocking density and milk quota than the farms with 'High' (Table 1). The dairy cows on 'Low' farms received on average 63% of their net energy intake from forage while the cows in 'High' received 52%. The 'Low' group had higher proportion of energy supply from grazed forage (pasture) than either 'Medium' or 'High' farms (which did not differ) (Table 1). Cows with 'High' concentrate level produced about 1 tonne more energy corrected milk (ECM) annually than cows on 'Low' farms. Milk production in Norway is restricted by quota, and farms in all three groups achieved a similar quota fill, on average 93%. Thus, it appears that the feeding strategy with concentrate, and milk production per cow, were closely linked to the quota held on the farm. For other animal health and production parameters there were only small differences between the groups, except for the milk somatic cell count, which was lower for 'Low' herds than the other groups.

Table 2. Effect of dairy cow concentrate level on economic performance (NOK/kg ECM-eq.)

	Concentrate level cows			SEM	*p*-value
	Low	Medium	High		
Revenues					
Milk	4.96^a	4.83^b	4.80^b	0.044	0.002
Meat	1.36	1.29	1.29	0.177	0.894
Other income	0.48	0.49	0.48	0.048	0.948
Payments	2.83^a	2.34^b	2.20^b	0.080	<0.001
Total revenues	9.63	8.94	8.77	0.296	0.413
Costs					
Concentrate purchase	1.64^b	1.70^{ab}	1.81^a	0.052	0.015
Forage cultivation	0.63^a	0.55^b	0.54^b	0.032	0.019
Other variable costs	0.79	0.65	0.69	0.080	0.163
Prod. dependent fixed costs	2.22^a	1.99^{ab}	1.95^b	0.110	0.048
Prod. independent fixed costs	1.20	1.04	1.10	0.070	0.106
Gross margin	6.57^a	6.04^b	5.73^b	0.121	<0.001
Contributing margin 1	4.35^a	4.05^{ab}	3.78^b	0.130	<0.001
Contributing margin 2	3.15^a	3.01^{ab}	2.68^b	0.16	0.021

Gross margins = Total revenues – Concentrate – Forage – other variable costs
Contributing margin 1 = Gross margin - Production dependent fixed costs
Contributing margin 2 = Contributing margin 1 - Production independent fixed costs
1 NOK ≈ 0.097 €
SEM is standard error of the mean.
^{ab} Means within a row with different superscript differ significantly (P<0.05)

Farms with a 'Low' concentrate feeding achieved a higher milk price than the other groups (Table 2). The price per litre depends on milk quality, including contents of protein, fat, and lactose, which did not differ between the groups (figure not shown), but also on the somatic cell count. The lower milk somatic cell count in milk from 'Low' farms (Table 1) had less deduction from top milk quality payment compared with that from the other groups (figures not shown). Regional payments for milk and meat production were similar among groups, but for other subsidies on average the 'Low' group received more than the other groups per kg ECM-eq., i.e., higher payment for cattle, operating payment, agri-environmental payments, and organic support (14 out of 68 farms in this group were organic). Therefore, the total subsidies per ECM-eq. were higher in the 'Low' than the other groups (Table 2). Total operating costs were similar although farms in the 'Low' group spent less money on concentrate but more on forage production than the others. Farms in the 'Low' group had higher total production dependent fixed costs, mainly because of the costs involved with forage production and machine maintenance. Despite higher production dependent fixed costs, farms with 'Low' concentrate level performed on average financially better, with higher gross margin and contributing margins than 'Medium' and 'High' farms per kg ECM-eq. (Table 2). However, it is important to note that farms' own labour was not recorded and hence not accounted for in this analysis.

We found no difference in GWP or energy intensity between the farm groups (Table 3). To compare GWP with other studies, also emissions solely allocated to milk were calculated and the average in the current study was 1.19 kg CO_2-eq./kg ECM. This result is higher than the 1.02 kg CO_2-eq./kg ECM-eq. reported by Bonesmo et al. (2013) based on 30 Norwegian dairy farms and the 0.9 kg CO_2-eq./kg ECM-eq. by Hansen et al. (2018). However, in the studies by Bonesmo et al. (2013) and Hansen et al. (2018) the impact of machinery and buildings was excluded, which partly explains the lower values. Our results are lower than the average for 10 farms reported by Schueler et al. (2018) (1.35 and 1.18 CO_2-eq./kg ECM-eq. for conventional and organic farms respectively), but the range in the current study (0.76 – 1.76 kg CO_2-eq./kg ECM-eq., not shown) is comparable to their findings (0.91 – 1.79 kg CO_2-eq./kg ECM-eq.) and larger than the one observed by Bonesmo et al. (2013) (0.82 – 1.36 kg CO_2-eq./kg ECM-eq.). Different results between studies may be due to methodological approach but also by the size of the study. The GWP estimates by Hansen et al. (2018) are based on 5 farms, Schueler et al. (2018) on 10 farms, and Bonesmo et al. (2013) on 30 farms, while the current study includes 200 farms.

Table 3. Effect of dairy cow concentrate level on environmental indicators

		Concentrate level cows			SEM	*p*-value
	Unit	Low	Medium	High		
Number of farms	n	68	67	68		
Global warming potential	kg CO_2-eq./kg ECM-eq.	1.51	1.43	1.45	0.04	0.201
Global warming potential (only milk)	kg CO_2-eq./kg ECM	1.22	1.16	1.19	0.04	0.103
Energy intensity[1]	MJ/kg ECM-eq.	5.87	5.46	5.50	0.21	0.119
Nitrogen intensity[2]	kg N/kg N	7.00	6.75	6.75	0.24	0.493
Area of purchased feed[3]	ha/ha	0.39^{b}	0.43^{ab}	0.46^{a}	0.01	<0.001
Land occupation total	m^2/kg ECM-eq.	3.24^{a}	2.88^{b}	2.84^{b}	0.10	<0.001
Land occupation farm	m^2/kg ECM-eq.	1.93^{a}	1.65^{b}	1.52^{b}	0.09	<0.001
Land occupation purchased feed	m^2/kg ECM-eq.	1.31	1.23	1.32	0.05	0.196

[1] Embodied energy needed for all inputs per kg ECM-eq.
[2] Nitrogen from purchased inputs, biological nitrogen-fixation and atmospheric N-deposition per kg ECM-eq.
[3] Area needed to produce purchased feed (off-farm area) in relation to total area needed (farm- and off-farm area)
[ab]Me Means within a row with different superscript differ significantly ($P<0.05$)
SEM is standard error of the mean.

The cows in the group with 'High' concentrate feeding yielded more milk than the other two groups, and based on other studies (e.g. Gerber et al., 2011; Wettemann and Latacz-Lohmann, 2017; Yan et al., 2013), it could be expected that the GWP and energy intensity might be lower than for the other groups. As milk yield increase, the proportion of feed used (and hence methane) for maintenance falls, thereby diluting total methane produced over more kg of milk. However, in line with Koesling et al. (2017b), this was not found in this study, underlining findings by Bakken et al. (2017) that while high-yielding cows might produce less enteric methane per kg milk (and thus a lower GWP per kg milk), the effect can be offset by the burden from feed production. Another reason that we do not see this effect in our study may be because we lacked information on forage quality. We used feed intake data from Tine Mjølkonomi, estimating net energy intake based on the cows' requirements. When converting the

NEL intake to DM intake, necessary to estimate enteric methane production, we assumed the forage energy values were similar among the groups. However, it is likely that forage energy was underestimated for the 'High' group while overestimated in the 'Low' group since high yielding cows, as in 'High' group, need higher quality forage with than lower yielding cows.

Apart from the direct effect of feed intake on the methane emissions, feed sources and their production also have an environmental consequence. Both the quantity and composition of purchased concentrates affects their GWP contribution. For examples soybean from Brazil may have an extra environmental cost if it is produced on areas where it has caused rainforest deforestation, reflected in a higher value of GWP per kg soybean compared to other feeds. The organic concentrate had higher proportion of soybean-meal than the conventional concentrate in this study, which contributed to a higher environmental burden for the 'Low' group. In addition, lower yields for organic crops increases demands for production areas compared to conventional feeds.

Other factors influencing the environmental impacts of dairy production are fertilization, diesel consumption and grazing duration. In theory, higher proportion of concentrate feeding increases imported nutrients available for crop production on a farm but can result in higher nitrogen surplus if artificial fertiliser use is not reduced correspondingly. Furthermore, more feeding days in the barn instead of grazing or using round bales instead of bunker or tower silage can lead to greater diesel use for farm forage. Future research should analyse if an increased production efficiency, especially for forage production, as found by Hessle et al. (2017) is as important as high milk yield.

The 'Low' farms required a lower proportion of total land use for growing purchased feed off-farm than the other groups (Table 3) but the total land necessary per kg ECM-eq. delivered was greater for these farms than the two other groups. The greater land occupation on 'Low' farms may be due difference in forage yield since the estimated on-farm forage yield averaged 9% lower on 'Low' (31.3 GJ NEL/ha) than on 'Medium (34.6 GJ NEL) and 'High' (34.0 GJ NEL/ha) farms. This lower yield may be due less favourable soil-quality and/or local climate conditions compared with the two other groups and the fact that one fifth (20%) of these 'Low' farms were organic. Both on-farm forage yields and off-yields for purchased concentrate are usually lower on organic than conventional farms. Forage yields have been reported to be lower on organic farms (Smith et al 2015), and other studies have shown energy- and nitrogen intensity are lower and land occupation higher on organic than on conventional farms (Koesling et al., 2017b; Smith et al., 2015). We did not identify farms with the most grazing ('Low') to use less energy than the other groups (Table 1) as found in an Irish study (O'Brien et al., 2012). However, difference between the groups here were minor and the proportion of total dietary energy intake from grazing was low, between 5-10%, compared to 72% of total DM intake in Ireland.

4 Conclusion

Farms in Central Norway feeding more forage and pasture to their dairy cows achieved lower milk yield per cow but higher profitability than farms feeding more concentrate feeds, mainly because of higher governmental subsidies per kg milk and meat produced. Our analysis does not support the general assumption that higher concentrate feeding lowers global warming potential and energy needed per kg of milk and meat produced compared with more extensive systems.

5 Acknowledgements

This research was made possible by funding from SusAn, an ERA-Net co-fund action under the European Union's Horizon 2020 research and innovation programme (www.era-susan.eu), under Grant Agreement n°696231. Thanks to TINE advisory service for providing data from the Norwegian dairy herd recoding system. We are grateful to Gillian Butler for improving the English.

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