Carbon footprint and energy consumption of Luxembourgish dairy farms

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Abstract: The carbon footprint as well as the energy consumption of Luxembourgish dairy farms shows a high variability. There are farms with a very high imbalance between emitted and stored carbon and as a consequence also high levels of carbon footprint per kg ECM. On the other hand, there are farms which are capable to produce milk with a considerably lower carbon footprint due both to a high level of carbon storage and/or to lower emissions of CO_2-equivalents. Also in the case of energy consumption we observe a high spread between minima and maxima of obtained results. A very high gap in the efficiency of production mean use was found among the evaluated farms. Mainly the categories feedstuff, electricity, fuel and investments (building and machinery) are concerned. Finally, very important differences between farm groups were found concerning the accumulation of carbon credits among the farms: Farms with a high level of biogas production and or carbon storage into the soil have a considerably lower carbon footprint in comparison to other farms.

Keywords: Carbon footprint, energy efficiency, carbon storage, renewable energies

Introduction

CONVIS s.c. is an agriculture cooperative society active in the field of animal husbandry, principally dairy and suckler cows. Among the several services offered to the member farms CONVIS also gives advice for optimizing the use of production means (principally fertilizers, feedstuffs, electricity and fuel) and for reducing environmental impact in agriculture. To do so, every year energy and nutrient budgets as well as CO_2-balances for member farms are calculated. This allows evaluating both the efficiency and the environmental impact of the production process. The following results illustrate the net GHG-emissions (CO_2-balance) and the energy consumption of dairy farms members of CONVIS. This paper examines the different causes of the variability, e.g. differences among the farms in improving CO_2-balance via renewable energies such as biogas, in storing carbon into the soil via minimum tillage, and/or in mitigating CO_2-emissions throughout the efficient use of fossil energy sources and other production means, principally fertilizers and feedstuffs. Finally, recommendations for a sustainable footprint and energy efficiency in Luxembourgish dairy production will be derived from the main conclusions of the analysis.

Material and methods

Methodology applied

The GHG-emissions are estimated by collecting data in the farms and by applying emission factors from literature. This methodology was developed by CONVIS and considers the GHG-emissions resulting from production means, animal husbandry and plant production on the one hand, and the carbon credits deriving from carbon storage into the soil and from carbon saved via renewable energy on the other hand. The net GHG-emissions (CO_2-balance) are derived by subtracting the credits from the emissions. All the results presented here refer to the net GHG-emissions. To calculate the GWP the reference of UNFCCC (2014) was used. To estimate the results on dairy branch level also in farms with more than one production branch, several allocation keys for separating the different emission sources as well as the carbon storage were applied. An exhaustive description of the method applied including emission factors and allocation keys can be downloaded as PDF-file from: www.optenerges.eu (manuel méthodologique méthode CONVIS, in French, 32 pages). Here, we merely point out that the allocation of net GHG-emission inside of the dairy branch (milk and meet) was a protein allocation.

As for energy consumption, this was estimated by collecting data in the farms concerning use of production means and investments and by applying the relative energy factors from literature.

The investigated farms

The investigation was carried out for 41 Luxembourgish dairy farms members of CONVIS. These farms were monitored for 4 years (from 2008 until 2011), and the results refer to the average of these years. A detailed description of the evaluated dairy farms can be found in Tab.2.1 and Tab.2.2. We underline that the analysis was carried out on branch and not on farm level: Only in case there is exclusively dairy production on a farm, the branch and the farm level are the same. In the majority of CONVIS farms, dairy production is coexistent with other production branches (e.g. suckler cows and/or crop production), and this requires the separation of emissions and energy consumption sources of dairy branch from the other branches.

Tab.2.1: Whole farm and dairy branch indicators (mean values of the investigated farms)

Indicators	Unity	Whole Farm	Dairy branch	St. deviation
Size	ha	111	71	30
Forage surface	%	80%	100%	0%
Cereals	ha	23	6	5
Mays silage	ha	15	13	6
Other crops	ha	7	0,4	0,1
Temporary grassland	ha	10	7	3
Permanent grassland	ha	56	44	23
Animal density	LAU*/ha	1,21	1,38	0,27
Nitrogen excretion	kg N-org/ha	105	124	24
N-surplus (farm gate balance)	kg N/ha	112	126	27
Energy consumption	GJ/ha	32	36	10

*LAU: Large animal unit

Tab.2.2: Dairy production indicators (mean values of the investigated farms)

Indicators	Unity	Values	St. deviation
Dairy cows	n	58	24,3
Produced milk per farm	kg	434.626	187.570
Production intensity	kg/ha (dairy br.)	6.147	1.600
Cow performance	kg milk/year	7.522	956
Basic ration performance	kg milk/year	3.294	979
Basic ration performance	%	44%	12%
Concentrate per cow and day	kg	5,79	1,13
Concentrate per kg milk	kg	0,28	0,06
Concentrate per dairy farm	t	122	60,4

Results and discussion

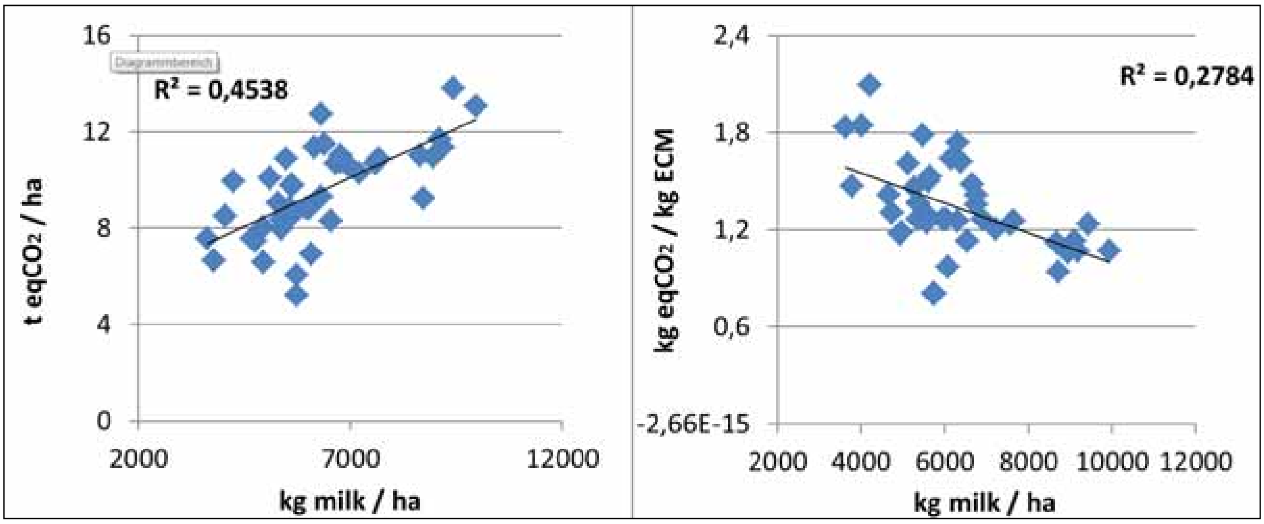
The carbon footprint of Luxembourgish dairy farms

The average levels of net CO_2-balances per ha and per product are shown in Tab.3.1. There is a high variability between maxima and minima of both values. In comparison with the results of other authors (Grignard et al. 2013, Ross et al. 2012) the CO_2-balances of Luxembourgish dairy farms are similar when related to the product, and lower when referred to the ha.. It is important to note the fact that, expressed in function of the production intensity, the CO_2-balances per ha show an increasing tendency, whereas the CO_2-balances related to the product show a decreasing tendency (Fig.3.1). As we remarked elsewhere (Lioy et al. 2012), the two balance types are complementary and should be considered together to avoid mistakes in the evaluation of farm sustainability.

Tab.3.1: Average, maximum and minimum value of CO_2-balances for the evaluated farms

	t eqCO2 / ha	kg eqCO2 / kg ECM
Average	**9,4**	**1,31**
Maximum	13,8	2,09
Δ% max.	147%	160%
Minimum	5,2	0,80
Δ% min.	56%	61%

Fig.3.1: Relation between CO2-balance per ha (first part), CO2-blance per kg ECM (second part) and production intensity

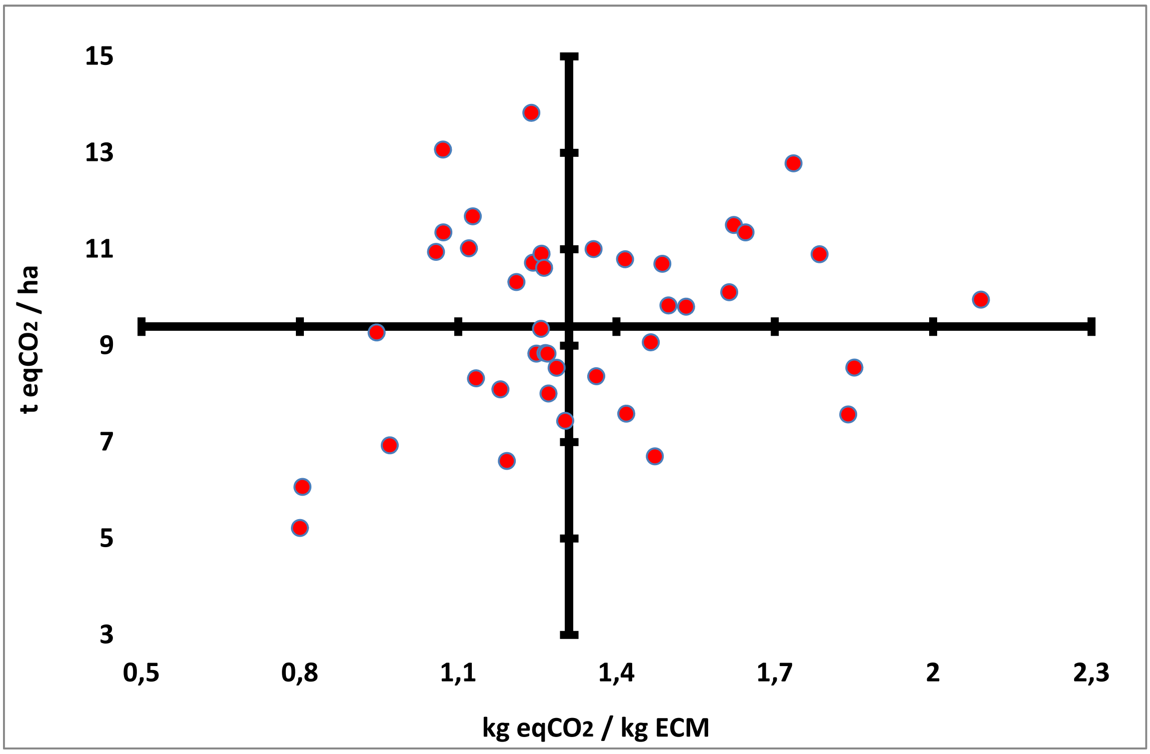


Thus, if we use the average value of both CO_2-balances as discriminant criteria, it is possible to divide all farms into four groups (Fig.3.2). We called these groups:

- Eco-Eff, if the result of both balances is better than the average.
- Eco-nEff, if only the surface related balance is better than the average.
- nEco-Eff, if only the product related balance is better than the average.
- nEco-nEff, if the result of both balances is worse than the average of all farms.

As can be seen in Tab. 3.2, the average CO_2-balance per ha of the nEco-Eff-Group as well as the average CO_2-balance per product of the Eco-nEff-group is worse than the relative CO_2-balances of the nEco-nEff-group. If we compare the dairy farm indicators of the four groups (Tab.3.3), we can see that the best (Eco-Eff) and the worst (nEco-nEff) group are very similar concerning the production intensity, and also the level of nitrogen excretion (an indicator for the animal density) is rather close together.

Figure 3.2: Repartition of dairy farms in groups in function of the average results



Tab.3.2: Average CO2-balances of different farm groups (mean values)

Farm group	% of farms	t eqCO2 / ha	St. dev.	kg eqCO2 / kg ECM	St. dev.
Eco-Eff	34%	7,8	1,3	1,12	0,18
Eco-nEff	15%	8,1	0,8	1,59	0,22
nEco-Eff	24%	11,2	1,1	1,17	0,08
nEco-nEff	27%	10,8	0,9	1,55	0,20

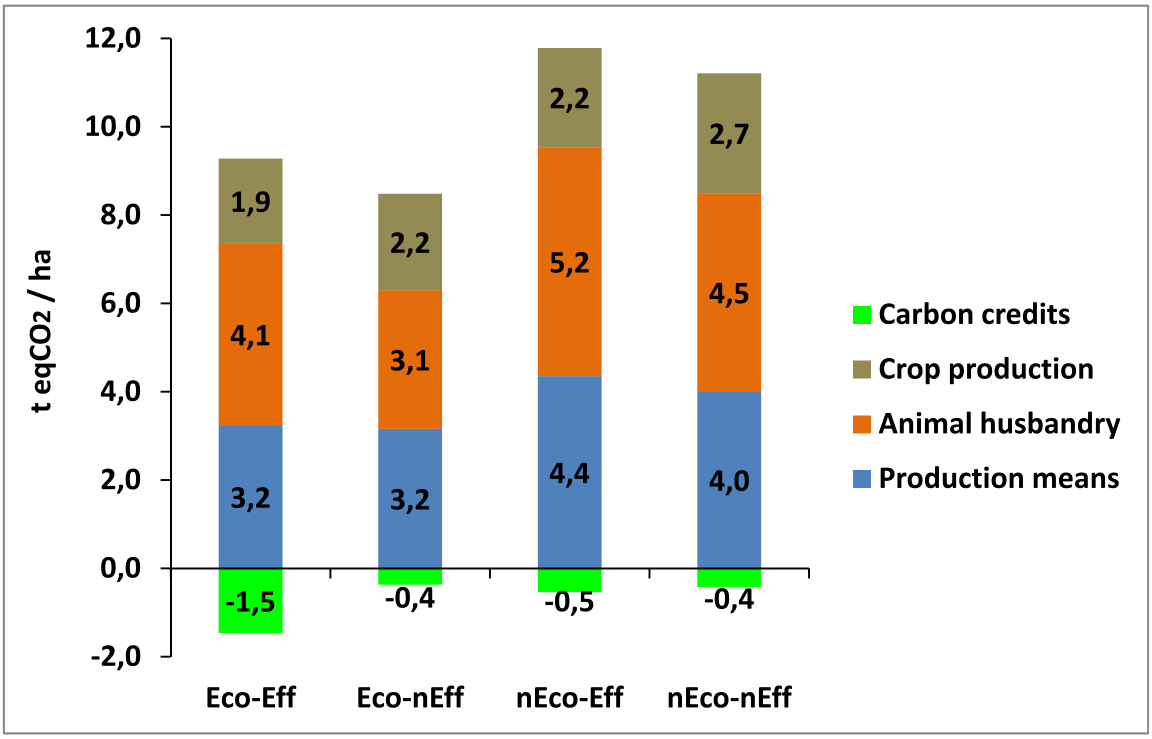
Tab.3.3: Dairy farm indicators of different farm groups (mean values)

Indicator	Dairy branch size ha	Production intensity kg milk / ha	Animal density kg N-org/ha	St. dev. kg N-org/ha
Average all	**71**	**6.147**	**124**	**24**
Eco-Eff	72	5.854	119	14
Eco-nEff	90	4.397	93	10
nEco-Eff	63	8.218	152	17
nEco-nEff	72	6.066	129	16

This last observation makes clear that the origin of the variability in the results between the groups should not be looked for in the level of intensity but, as suggested by Fig.3.3, mainly in the efficiency of use of production means. Indeed, the level of the GHG-emissions of the two groups deriving from the modules production means and crop production is very different in contrast to the level of GHG-emissions deriving from the module animal husbandry, where the difference is considerably lower. We underline here that the level of GHG-emission from crop production is closely related to the one from production means: The main difference between the two emission groups is that the emissions from the module production means are produced outside, whereas the emissions from the module crop production are produces inside the farm.

In a similar way, the difference between the mentioned groups in accumulating carbon credits is also very high (Fig.3.3): The best group (Eco-Eff) accumulates tree times more credits than the worst group (nEco-nEff). The accumulation of carbon credits is the most effective option to mitigate the CO_2-balance of dairy farms. The accumulation of carbon credits in this group of farms is mainly due to the production of biogas by dairy cow slurry and secondly to the storage of carbon in the arable land of these farms. The storage of carbon in arable soils is discussed controversially in literature (Powlson et al., 2011). However, the articles 3.3 and 3.4 of the Kyoto protocol (compare UNFCCC, 2014 bis) allow the accounting of such credits, so that in absence of a definitive confutation we decide to maintain their accounting. When we look at the results of the intermediate groups (nEco-Eff and nEco-Eff), we observe differences principally in the level of GHG-emissions deriving from animal husbandry (to disadvantage of the very animal-intensive nEco-Eff group) and only in a smaller degree in the level of GHG-emissions coming from the module production means.

Fig. 3.3: GHG-emissions from different modules and carbon credits of the farm groups



The energy consumption of Luxembourgish dairy farms

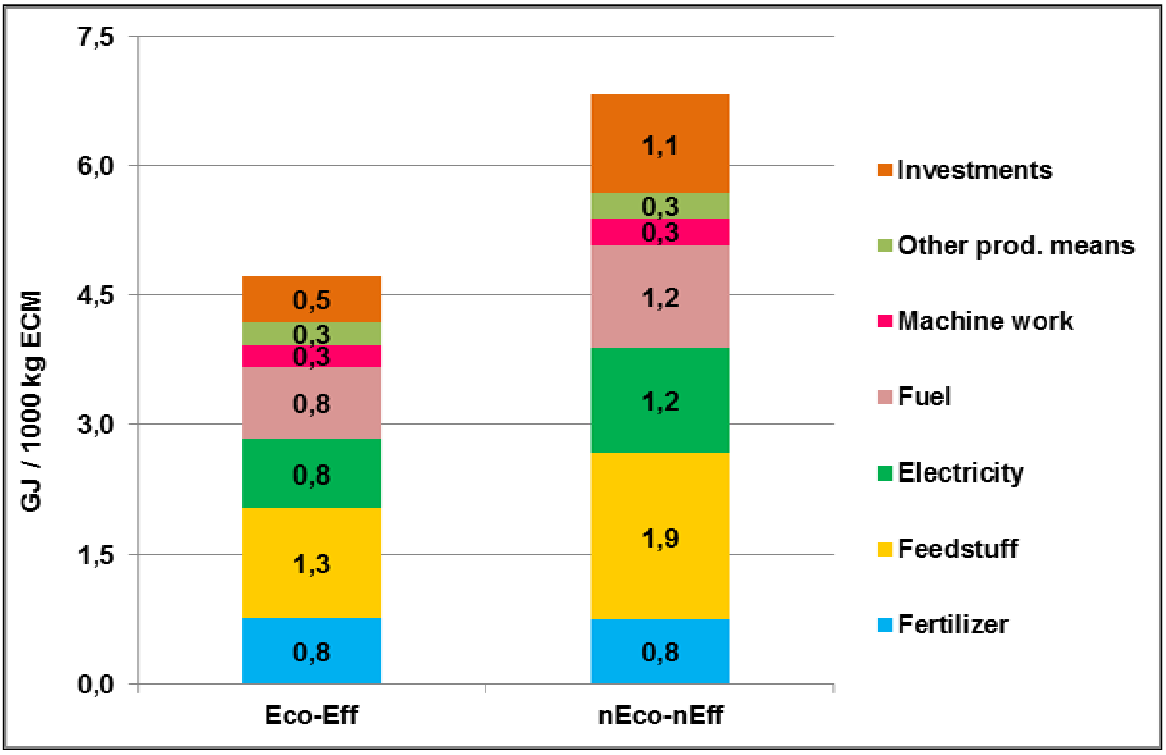
The results of the energy consumption of the Luxembourgish dairy farms show, similar to the CO_2-balance, a high variability (Tab.3.4). The results presented here (mainly concerning the energy consumption related to the product) are close to other results from literature (Nemecek, 2009). We stress that the energy consumption allows a sort of fine tuning of the differences in production mean use between the farm groups.

Tab.3.4: Average, maximum and minimum value of energy consumption for the evaluated farms

	GJ / ha	GJ / 1000 kg ECM
Average	**36**	**4,96**
Maximum	63	9,86
Δ% max.	175%	199%
Minimum	22	3,20
Δ% min.	61%	65%

With focus on the product-related energy consumption (Fig.3.4) there are considerable differences between the two extreme groups (Eco-Eff and nEco-nEff) mainly in the use of feedstuffs, in the direct energy use (fuel and electricity) as well as in the level of investments (buildings and machinery). When we consider that the level of animal density and in general the production intensity between the two groups is very close to each other, we can exclude that there is an influence on the results of farm production intensity and that the differences between the farm groups are related to the ability of the farmers to use their production means correctly. If the best farm group is exemplary, the worst group clearly needs advice in this field.

Fig.3.4: Energy consumption from different categories of the farm groups



Conclusions

The difference between best and worst dairy farms concerning the carbon footprint is related mainly to the efficiency of use of production means and not to the intensity of production. This means that the worst farms need intensive advice work to improve their production means efficiency.

In the case of intermediate farm groups the carbon footprint could be also improved by improving production mean efficiency, but principally by intensification of production in extensive farms and by de-intensification of production in intensive farms. In the first case this could lead to conflicts with the work organization inside the farm, in the second case this could generate problems related to the profitability of the dairy production.

The results of the energy consumption allow showing where it is possible to increase efficiency of production mean use. Feedstuffs, fuel, electricity and investments (buildings as well as machinery) are the most important categories concerning this issue. The inadequate use of these production means causes not only environmental problems, but also important financial losses to the farms. It is an important task for the advice department of CONVIS to help farms to solve problems they have concerning production mean efficiency.

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