Sustainability assessment in Luxembourgish dairy production by CONVIS: A tool to improve both environmental and economical performance of dairy farms.

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Abstract
The paper describes the sustainability assessment tool developed by CONVIS s.c., a Luxembourgish farm cooperative active in the field of animal husbandry. After giving an overview of the components of the tool, the paper shows how data are collected, processed and reported. A concrete example of results is given for dairy farms, illustrating the relation between GHG-emissions and economic profitability of farm groups. In particular, it was found that the farms with the best environmental performance also tend to have the best economic results. Finally, the paper describes how these results are used to improve sustainability of dairy farms and points out the potential of the tool for supporting long term changes in various environmental fields.

1. Introduction

CONVIS s.c., a Luxembourgish cooperative society for cattle and pig breeders, has been carrying out a sustainability assessment for member farms since 1996. At departure the aim was to improve both environmental and economical efficiency of these farms but also to improve the image of the agricultural sector in general and of animal husbandry in particular. The sustainability assessment was originally carried out for a label of beef meet production in Luxembourg and for a special program co-financed by the Luxemburgish State with the specific aim to improve environmental performances of agricultural farms. These two main application fields are still running today. In the last 4 years, the sustainability monitoring was carried out also for a dairy producer cooperative which aims to achieve marketing advantages by applying the assessment on farm and by communicating sustainability results to the consumer. For more information on the tool see the short video on YouTube (https://www.youtube.com/watch?v=HcolpJDRlGw).

The sustainability assessment is developed and carried out by the advice department staff of CONVIS. As shown in Fig.1.1, the self-concept of the advice department is as an institution dedicated to filling the gap between the research and the practice level in agriculture by organizing the knowledge transfer between these two levels. The sustainability assessment of CONVIS is an essential tool to implement such knowledge transfer and was consistently developed and improved in the course of time. At present, the assessment includes energy, nutrient and humus balance (arable land) at farm level, as well as calculation of feedstuff self-reliance (autarchy), GHG-emissions and an economic analysis of costs and incomes for the principal farm production branches (milk, beef meat, cereals). In addition, specifically for dairy production, the sustainability assessment also takes into account parameters which illustrate the consumption level of the most important production means (feedstuffs, fertilizers, fuel, electricity, investments), thus showing the resource efficiency of dairy farms. The proposed contribution will give an overview of the sustainability assessment carried out by CONVIS s.c. (data sampling, data processing and data reporting). Furthermore, using the relation observed between environmental (mainly greenhouse gas emissions) and economic results for dairy farms, tries to show how recommendations for improving sustainability of dairy production in Luxembourg could be used to achieve changes in the agricultural practice.

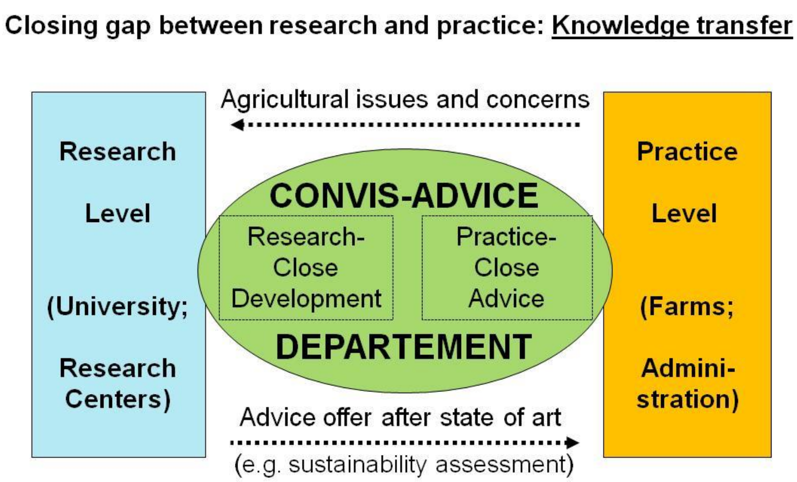


Fig.1.1: Self-concept of CONVIS-Advice Department

2. Material and methods

2.1 The CONVIS sustainability assessment for agricultural farms

To assess the sustainability of farms (in this specific case: dairy farms) CONVIS developed a tool capable of estimating their efficiency of resource use, environmental impact and economic results. Thanks to software developed for this specific purpose, data are collected from the book keeping as well as from the fertilization planning of the farm (Fig.2.1). The software was programmed taking into account the structure of the book keeping: Especially concerning data of surfaces, livestock, input (production means) and output (products), there is absolute coherence between the way the data are organized in the book keeping and the input mask of the software. Thus, it is possible to reduce the time for collecting data to a minimum.

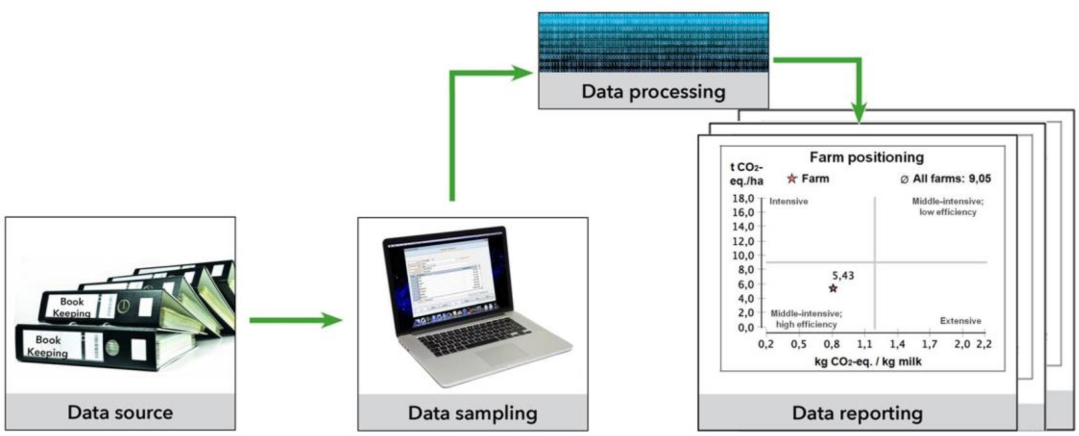
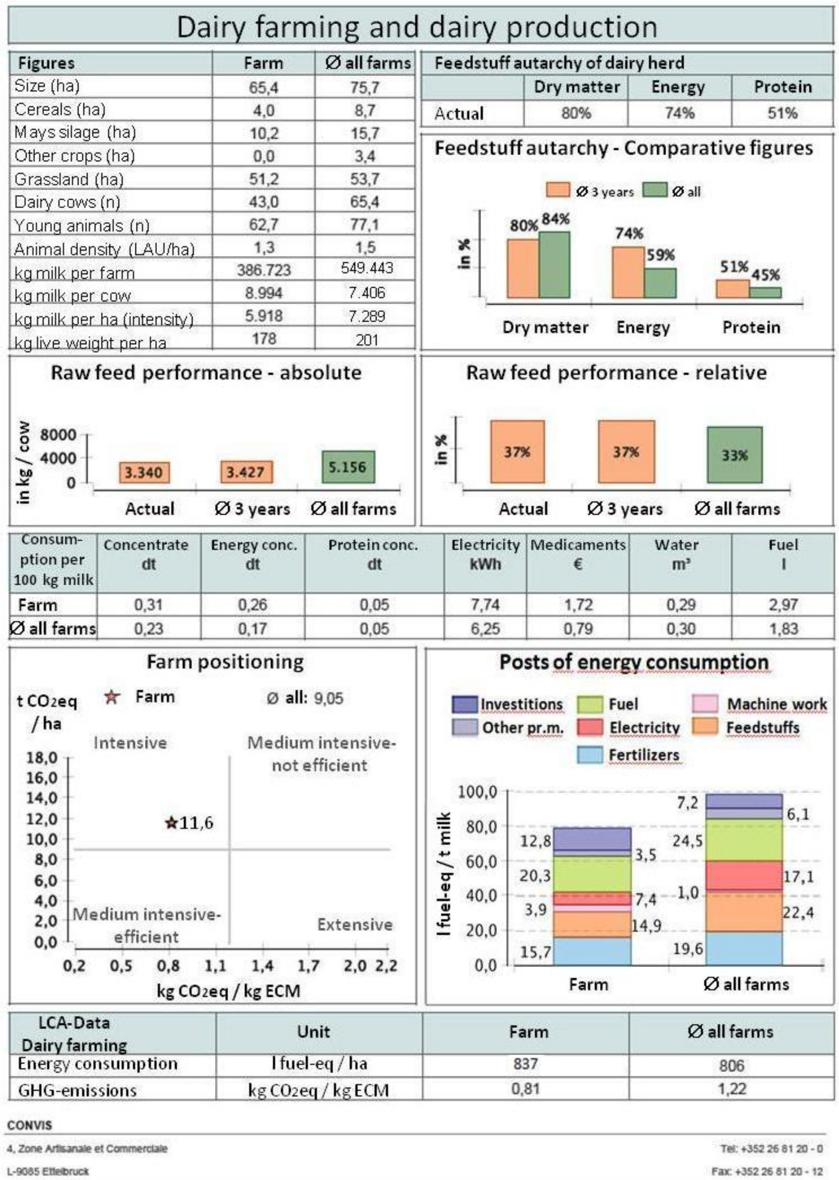


Fig.2.1: Scheme of dataflow in CONVIS sustainability assessment

Almost all farmers involved in the assessment dispose of book keeping carried out by accredited institutions. If this is not the case (rarely), the farmers are requested to fill in a form that has the same input mask as the software. In total, approx. 240 farms are assessed every year. These farms cover a bit less than a quarter of the agricultural area (cropland and grassland) of Luxembourg.

The data are sent via internet and processed in a few seconds by a provider. Finally, the results are summarized in a report which contains the most important technical, environmental and economic parameters of the farm for a given book keeping year. The duration of the whole process from data collecting to printing the report is about 1.5 to 2 hours. Depending on time disposal of the farmer, data collecting is carried out in CONVIS offices or directly on farm. After the collection, data are discussed with the farmer on the basis of the sustainability report (Fig.2.3 gives an example of the sustainability report part for dairy farmers).


Dairy farming and dairy production

Figures	Farm	Ø all farms
Size (ha)	65,4	75,7
Cereals (ha)	4,0	8,7
Mays silage (ha)	10,2	15,7
Other crops (ha)	0,0	3,4
Grassland (ha)	51,2	53,7
Dairy cows (n)	43,0	65,4
Young animals (n)	62,7	77,1
Animal density (LAU/ha)	1,3	1,5
kg milk per farm	386.723	549.443
kg milk per cow	8.994	7.406
kg milk per ha (intensity)	5.918	7.289
kg live weight per ha	178	201

Feedstuff autarchy of dairy herd

	Dry matter	Energy	Protein
Actual	80%	74%	51%

Consumption per 100 kg milk	Concentrate dt	Energy conc. dt	Protein conc. dt	Electricity kWh	Medicaments €	Water m³	Fuel l
Farm	0,31	0,26	0,05	7,74	1,72	0,29	2,97
Ø all farms	0,23	0,17	0,05	6,25	0,79	0,30	1,83

LCA-Data Dairy farming	Unit	Farm	Ø all farms
Energy consumption	l fuel-eq / ha	837	806
GHG-emissions	kg CO_2eq / kg ECM	0,81	1,22

Fig.2.3: Example for sustainability assessment report for dairy farms/branches (translated from the original in German)

The major part of the graphs and tables of the report are self-explanatory. However, there is an important exception: The graph regarding farm positioning. This part of the report refers to the GHG emissions, one of the main environmental impacts of dairy farms. We will show and discuss here some important results related to the graph mentioned above beginning with the methodology used. Finally, we will illustrate how these results could be used to improve sustainability of dairy farms in Luxembourg.

The method used by CONVIS to estimate GHG-emissions considers the emissions resulting from production means, animal husbandry and plant production on the one hand, and the carbon credits resulting from the storage of carbon in the soil as well as via renewable energy, on the other hand. This means that the GHG-emissions shown are net emissions. An important particularity of the assessment method used by CONVIS is that many of the dairy farms in Luxembourg are mixed farms with more than one production branch. This means that GHG sources concerning dairy production have to be separated from those related to other production branches (e.g. beef meat or cash crop production). In order to do so, several allocation keys are applied to allow an automatic separation of energy and material flows among the branches of a farm. An exhaustive description of the method applied including emission factors and allocation keys can be downloaded as pdf-file from: www.convis.lu (Manuel méthodologique - Méthode CONVIS, see literature list). The only deviation from the method described is that minimum tillage is not considered in the present paper: There is now some evidence that minimum tillage only changes the distribution of carbon stock, but not its total amount in the soil profile (Powlson et al. 2014).

Apart from figures concerning environmental impact and efficiency use of production means, also economic figures of farms are produced by the data sampling, and allocation keys are used to separate the data of the dairy branch from other branches. The economic analysis is carried out here on the basis of incomes and costs, and the profitability of the farm (dairy branch) is defined only in terms of the difference between these two factors, not taking into account subsidies and calculating costs.

2.2 Main figures of the investigated farms

All the results presented here refer to the average of 50 CONVIS member farms which were monitored in the years 2013 and 2014 (the last two years before the withdrawal of the milk quota in the EU). The average size of the farms was 124 ha, of which 75 ha (60%) were used for dairy production, 27% for beef production and 13% for cash crops (Tab.2.1).

Indicators	Unit	Whole Farm	Dairy branch	St. deviation
Size	ha	124	75	49%
Forage surface	%	87%	100%	0%
Cereals	ha	23	6	111%
Silage maize	ha	18	14	56%
Other crops	ha	4	1	388%
Grassland	ha	80	54	48%
Animal density	LAU*/ha	1.47	1.61	19%
Nitrogen excretion	kg N-org/ha	124	147	19%
N-surplus (farm gate balance)	kg N/ha	120	134	31%
Energy consumption	GJ/ha	31	37	31%

Tab.2.1: Whole farm and dairy branch indicators (mean values of the investigated farms)
*LAU: Large animal unit

The dairy branch showed a higher animal density than the correspondent value of the whole farm. Consequently, also the nitrogen surplus of the dairy branch as well as its energy consumption were higher than the result on farm level.

Indicators	Unit	Values	St. deviation[1]
Dairy cows	n	74	55%
Milk produced per farm	kg	549.443	124%
Production intensity	kg milk/ha	7.289	30%
Cow performance	kg milk/year	7.406	15%
Basic ration performance	kg milk/year	2.941	35%
Basic ration performance	%	40%	35%
Protein autarchy	%	52%	27%
Concentrate per cow and day	kg	6.12	30%
Concentrate per kg milk	kg	0.30	23%
Concentrate per dairy farm	t	166	157%

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

In comparison with the long-term average data of CONVIS farms (Lioy et al. 2014), these farms showed a higher level of animal density and a higher importance of dairy production in comparison to other production branches. The figure of protein autarchy (Tab.2.2) refers to valorization of farm's own protein sources in feeding dairy herd. In the case of the investigated farms, only 52% of the protein needed by the cows came from farm sources, 48% from outside (concentrates).

3. Results and discussion

The GHG-emissions (surface and product related, Tab.3.1) as well as the economic data of the farms investigated (Tab.3.2) showed a wide spread in the results. In the case of economic figures, the spreads of incomes and costs were relatively small, those of the profit, however, very large. The main aim of this section is to examine the origin of the variability, and especially the influence of farm structure and management on the result.

	t CO_2eq / ha	**kg CO_2eq / kg ECM**
Mean value	**10.3**	**1.22**
St. deviation	26%	21%
Max	22.5	1.82
Min	6.6	0.79

Tab.3.1: Surface and product related GHG-emissions of investigated farms

	Mean	**St dev.%**	**Max**	**Min**
Milk	40.51	3%	42.61	36.99
Meat	4.63	49%	11.96	1.92
Other incomes	2.45	107%	17.82	-0.01
Sum incomes (1)	**47.58**	**8%**	**65.16**	**42.77**
Farm feed production	16.01	24%	25.71	10.43
Feedstuff purchase	8.98	28%	17.18	5.02
Other costs for animal husbandry	10.40	27%	16.44	4.78
Other general costs	4.99	49%	12.27	1.60
Sum costs (2)	**40.38**	**18%**	**63.61**	**24.48**
Profit (1)-(2)	**7.21**	**92%**	**27.77**	**-3.85**

Tab.3.2: Economic figures of farms analysed (mean 2013-2014, values in €cent/kg ECM)

As in the past (Lioy et al. 2014, Lioy et al. 2012), we observed that the behavior of surface- and product-related emissions were divergent, if expressed in function of the production intensity (kg milk/ha, Fig.3.1).

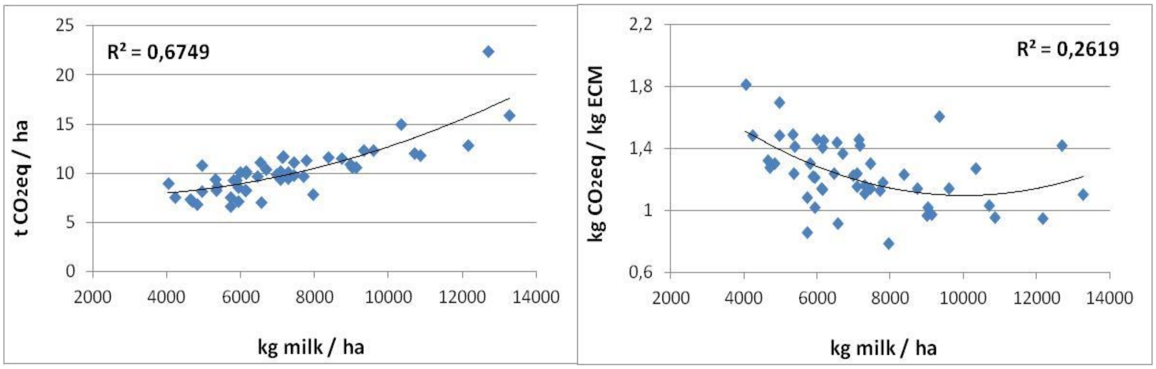


Fig.3.1: Behavior of surface and product related GHG-emissions in function of production intensity

This observation led us to divide the farms into 4 groups in function of their results in surface- and product-related emissions in comparison to the mean value of all farms (Fig.3.2).

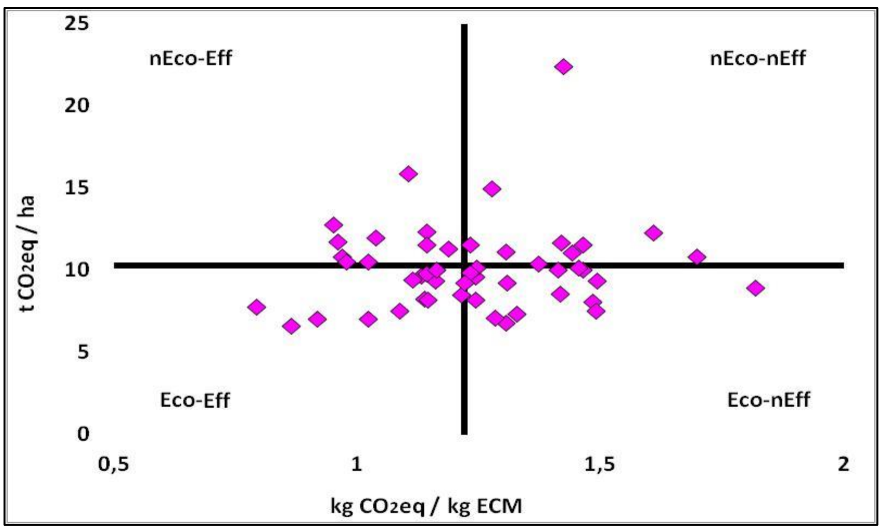


Fig.3.2: Division of the farms examined in groups in function of their position in relation to the mean value

The first group (Eco-Eff) and the last group (nEco-nEff) showed results in GHG-emission per ha and per kg ECM respectively lower and higher than the average (Tab.3.3). The second and the third group had an intermediary position: nEco-Eff showed a higher result in surface-related GHG-emissions and a lower result in product-related ones; Eco-nEff behaved antithetically to nEco-Eff.

Farm groups	t CO_2eq / ha	St.Dev.%	kg CO_2eq / kg ECM	St.Dev.%
All farms	**10.3**	26%	**1.22**	21%
Eco-Eff	8.5	14%	1.06	12%
nEco-Eff	12.0	13%	1.02	9%
Eco-nEff	9.0	13%	1.37	11%
nEco-nEff	12.7	29%	1.39	10%

Tab.3.3: Mean values of GHG-emissions of farm groups in comparison with to mean value of all farms

To characterize the four generated groups more precisely, it is helpful to have a look at the values of their production intensity (Tab.3.4). The groups nEco-Eff and Eco-nEff had an intensity which was farther from the mean value. For simplicity, we will subsequently call these farm groups **intensive** (nEco-Eff) and **extensive** (Eco-nEff). The intensity of the other two groups (Eco-Eff and nEco-nEff) was closer to the main value of all farms. We will from now on call these last two groups **medium intensive-efficient** (Eco-Eff) and **medium intensive-not efficient** (nEco-nEff) farms.

Farm groups	kg milk/ha	StDev%
All farms	**7,289**	**30%**
Eco-Eff (*medium intensive-efficient*)	6,721	12%
nEco-Eeff (*intensive*)	10,280	17%
Eco-nEff (*extensive*)	5,546	16%
nEco-nEff (*medium intensive-not efficient*)	8,000	28%

Tab.3.4: Production intensity (kg milk/ha) of different farm groups

As we can observe in Fig.3.3, the intensity minimum value of the intensive farms was higher than the maximum value of the extensive farms. This means that these two farm groups were well separated in terms of production intensity and it could be expected that the results of these two farm groups were mainly influenced by the farm structure. The other two groups were positioned in the middle of the intensity (medium intensive farms). Given the lower difference of structure described by the production intensity, the difference in the results of the medium-intensive groups could be influenced mainly by the farm management.

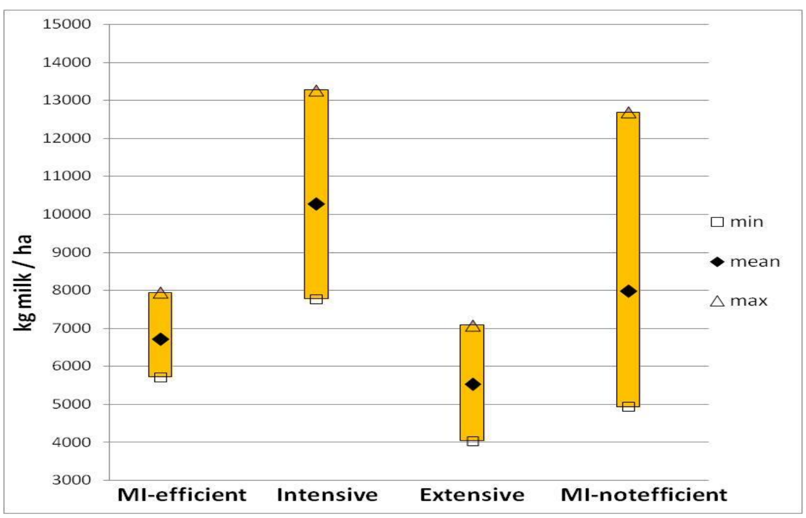


Fig.3.3: Mean value and spreads of production intensity of farm groups

We now take a look at the economic results of the four farm groups. It can be observed (Tab.3.4) that the mean value of the profit was higher (medium intensive-efficient) respectively lower (medium intensive-not efficient) in the farm groups with the medium production intensity. Intensive and extensive farms occupied a middle position, with slightly better scores for the intensive ones. In addition, medium intensive-efficient had the lowest level of costs, but not the higher level of incomes, which was reached by the extensive farm group. The variability of the results was lower in the group medium intensive efficient, although, as shown in Fig. 3.4, the spread between minimum and maximum reached the highest level in this group (medium intensive-efficient).

	All farms	Medium intensive-efficient	Intensive	Extensive	Medium intensive-Not efficient
Sum incomes (1)	**47.6**	47.0	46.9	48.3	48.0
Sum costs (2)	**40.4**	36.8	38.9	41.9	43.2
Profit (1)-(2)	**7.2**	10.2	7.9	6.5	4.9
St. dev.%	**92%**	74%	89%	89%	118%

Tab.3.5: Incomes, costs and profit (all in €cent / kg milk) of farm groups

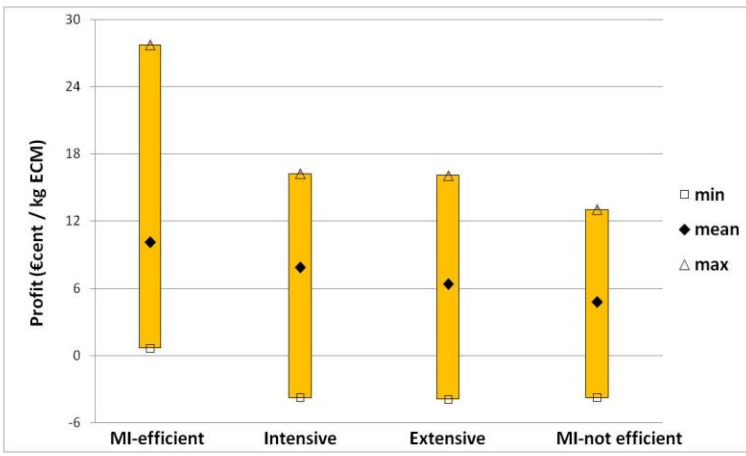


Fig.3.4: Mean value and spreads of profit of farm groups

How can the observed hierarchy of results be explained? In both GHG-emissions and economic figures, we observe that the farm group with the best results in the mean value was the medium intensive-efficient one, followed by the groups intensive, extensive and medium intensive-not efficient. We can characterize the different farm groups with the help of Tab.3.6, which gives an overview of principal farm indicators. The first observation is that the best group (medium intensive-efficient) had the smallest size of all. In addition, the total amount of kg milk produced per farm as well as the number of dairy cows was the smallest in the group medium intensive-efficient compared to all other groups. In terms of intensity, the animal density confirms that the second group (intensive) contained the most intensive farms. It seems that smaller farms are under stronger pressure to produce efficiently, in particular concerning the use of concentrate and raw feed performance.

The farm group with the best results (medium intensive farms) purchased less concentrate than the other groups, and had as a consequence the best raw feed performance (milk produced from grass and silage maize) as well as the best protein autarchy (valorization of own farm protein sources). In the other groups, the extensive farms had a better raw feed performance than the intensive farm, and the last group (medium intensive-not efficient farms), although less intensive on average than the intensives, had the lowest level of feeding efficiency, revealed by a small value in raw feed performance and protein autarchy.

Indicator	All	M. intensive-efficient	Intensive	Extensive	M. intensive-not efficient
Size (ha)	75.4	56.0	79.3	85.3	79.8
Cereals (%)	8%	9%	7%	8%	8%
Mays silage (%)	19%	18%	21%	15%	23%
Grassland (%)	73%	73%	72%	75%	68%
Dairy cows (n)	74	54	93	70	89
Produced milk per farm (kg)	549.443	376.375	815.682	472.838	638.421
Prod. Intensity (kg milk/ha)	7.289	6.721	10.280	5.546	8.000
kg milk/cow/year	7.406	6.979	8.767	6.750	7.198
Animal density (LAU/ha)	1.61	1.57	1.83	1.41	1.80
Concentrate (kg/cow/day)	6.12	4.57	7.50	5.16	7.16
Concentrate (kg/kg milk)	0.30	0.24	0.31	0.28	0.36
Concentrate per dairy farm (t)	166	90	255	132	232
Raw feed performance (1)	2.941	3.641	3.289	2.981	1.971
Raw feed performance (%)	40%	52%	38%	44%	27%
Protein autarchy (%)	52%	66%	45%	59%	39%

Tab.3.6: Indicators of different farm groups – (1) in kg milk/cow/year

When we look at the cost and income structures of the farm groups (Fig.3.5), we find that the costs for purchasing concentrates were lowest in the medium intensive-efficient group. Although the intensity difference between the better group (medium intensive-efficient) and the group with the worst mean values (medium intensive-not efficient) was the smallest, we observe the highest difference in the total amount of costs between these two groups of farms. Still with regard to the purchase of concentrates, the last group had costs higher almost 50% than the best group. There was a huge efficiency gap between the best and the worst farm group.

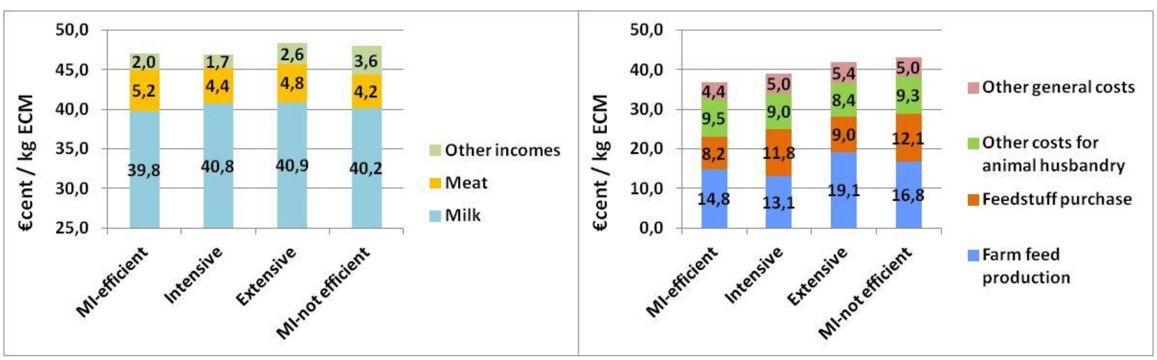


Fig. 3.5: Income and cost structure of farm groups

The results of the intermediate groups (intensive and extensive) are a bit more difficult to explain. The one group (intensive farms) had lower total costs than the other (extensive farms). The greatest difference was related to the costs for the farm feed production, which was considerably higher in the extensive farms. This could be explained by the bigger size of the latter farms and with their higher grassland surface, which caused higher costs than silage maize. The higher costs for the group extensive in comparison with the intensive group was not compensated by a higher income, so that the main value of profit for the extensive farms was lower than the correspondent value for the intensive farms (see also Tab.3.5).

The structure of CO_2-balance of the different farm groups (Fig.3.6) allows to confirm that there is a gap in the efficiency of the resource use between the medium intensive-efficient and the medium intensive-not efficient groups, given that the intensity of the two groups was relatively close. Nevertheless, in all the figures of the CO_2-balance, the medium intensive-not efficient group had higher amounts of GHG emissions, no matter whether these are expressed per ha or per kg ECM. In the other two cases, the structure of the farm (intensity) played a very important role: In the case of more intensive farms we can expect that the result is better if related to the product and that in the case of extensive farms, the result is better if related to the surface. We would like to stress that for a correct interpretation of the environmental impact specifically of these farms, both functional units are needed.

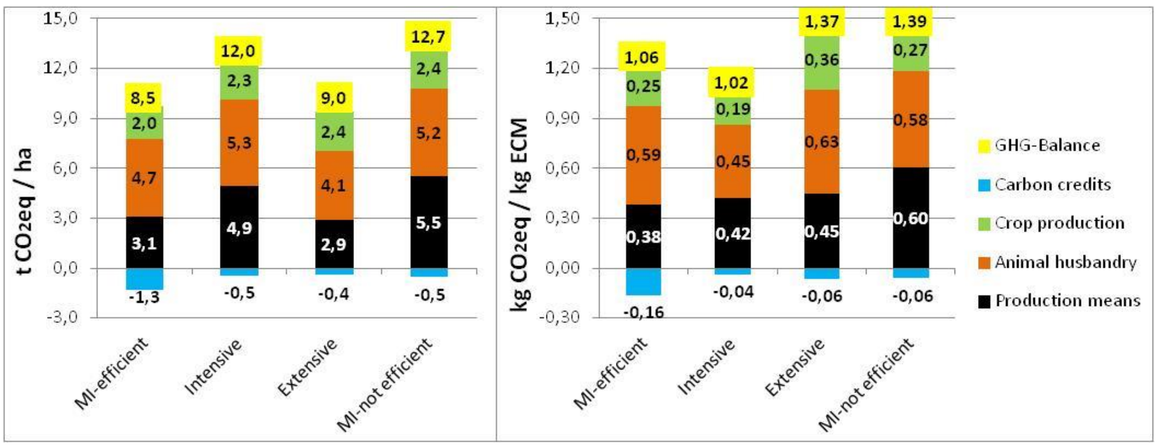


Fig.3.6: Structure of CO_2-Balance of farm groups

4. Main conclusions

- The sustainability assessment of dairy farms carried out with the CONVIS-methodology allows evaluating the optimization potential in dairy production. The estimation concerns GHG-emissions as well as economic figures.
- To correctly assess the improvement potential of CO_2-balance, a combined analysis of both surface and product-related emissions is necessary. With the method illustrated here, it is possible to divide farms into homogeneous groups depending mainly on the structure (e.g. production intensity) of dairy farms.
- The farms with a medium intensity of production differed mainly by the efficiency of production mean use, while the result of the most intensive or most extensive farms was mainly influenced by their structure.
- The basic ration performance and the protein autarchy were key management indicators for a good (or bad) CO_2-balance as well as for a good (or bad) economic result. Farms with the best indicators in this field work efficiently both in the environment as well as in economic terms.
- The same rank of results was observed in both fields (environment and economics), with better performances for efficient medium-intensive farms followed by intensive, extensive and not efficient medium-intensive farms.
- The results which are presented here refer to the last two years before the withdrawal of milk quota rule in the EU. It is also necessary to extend the analysis to the years after the

withdrawal of the milk quota in order to find out whether intensive farms can exploit their higher cost reducing potential and thus improve their position.

5. How results will be used to achieve practical changes

The results presented in this paper will be disseminated in several ways, addressing various target groups:

a) Individual on-farm consulting on the basis of sustainability assessment report (240 farms).
b) Publication of results in the CONVIS's quarterly magazine "de Lëtzebuerger Ziichter". This magazine can also be found online on the website of CONVIS (www.convis.lu). Addressees of the magazine are not only farmers, but also consultants and other stakeholders in the agriculture sector.
c) CONVIS organizes an annual one day info-event where important results are showed and discussed with farmers, consultants and administration.
d) Specifically for the dairy producer cooperative mentioned earlier in this paper, an info-meeting will be organized in 2016.

6. Potential for catalyzing practical change of the CONVIS's sustainability assessment tool

Due to the fact that the evaluation method for GHG emissions of dairy farms presented here has been implemented in the CONVIS's sustainability assessment tool only since two years, it is not possible yet to present long term change effects. However, long term tendencies in neighboring environmental field analyzed by the CONVIS tool are available. Regarding nutrient farm gate balances (for example nitrogen, phosphorus, potassium, Fig.6.1), the average surpluses of the farms could be significantly reduced from 1996 to 2010 (the increase of the nutrient surpluses since 2011 can be explained by adverse weather conditions and by the fact that farmers purchased more production means in expectation of the withdrawal of milk quota system).

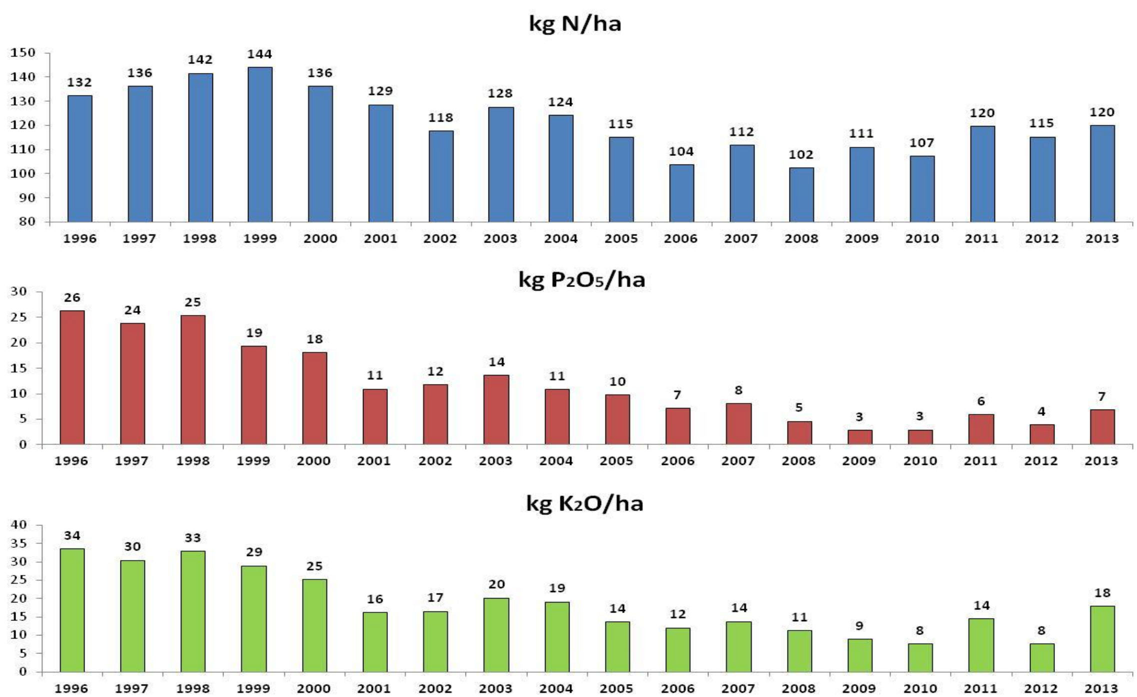


Fig.6.1: Long term nutrient farm gate balances of CONVIS assessed farms

In addition, the CO_2-balance at farm level could be significantly improved in the last 10 years (Fig.6.2). This improvement is not the result of reduction of GHG-emissions, but of the increase of carbon credits due to biogas production and more wide-spread of minimum tillage practices.

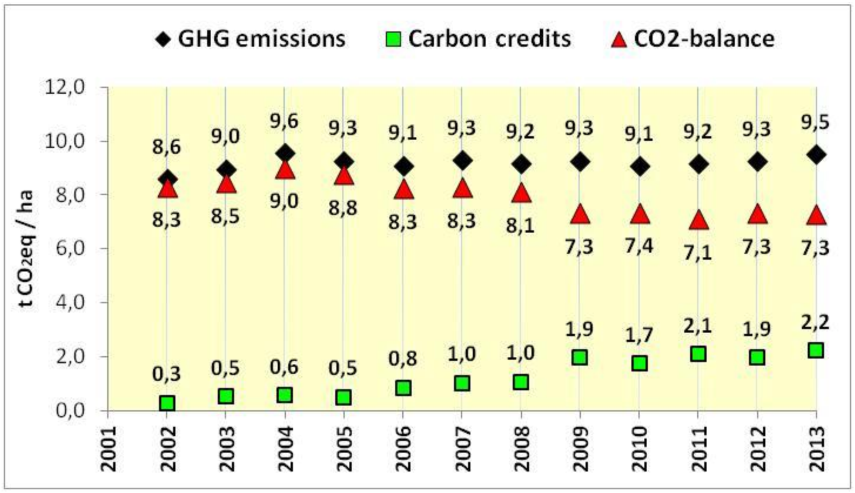


Fig.6.2: Long term CO_2-balance at farm level of CONVIS assessed farms

The CONVIS sustainability assessment tool allows to register changes and to address the direction of advice service in order to improve farm sustainability. We feel confirmed in our approach also because farmers react very positively to a tool were, as in our case, environmental and economic figures of the farm are closely linked. This helps to reduce the gap between research and practice and, as a consequence, to increase the acceptance of advice work.

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