From evaluating sustainability performance to supporting agricultural management

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Abstract

We performed an integrated evaluation of the sustainability performance of 10 intensive grazing and 10 zero-grazing specialised Flemish dairy farms, using a selection of sustainability indicators from MOTIFS (Monitoring Tool for Integrated Farm Sustainability). We put special effort in formulating useful management advice for farmers of both groups. Therefore, we used multiple regression to identify the most influential factors (independent variables) for each indicator value (dependent variable) and, through correlation analysis, related the selected factors to specific farm management indicators such as farm intensity or concentrate use; they were used to formulate general management advice. More detailed site- and case specific advice was delivered to the 20 participating farmers through an extended feedback report including a detailed representation of the MOTIFS results and comparison of the farm results to the means of the grazing and zero-grazing group. Afterwards, all farmers were invited to participate in a discussion group with the researchers, farm advisors and an invited expert. Through this approach, we addressed the suggestions made in previous validation studies of MOTIFS (i) to combine a detailed analysis of the sustainability indicator values with an intensive interaction between researchers and farm advisors and (ii) to support social learning among farmers through a discussion meeting with an invited expert. This allowed us to focus on the essential farm management aspects with the highest potential to increase farm sustainability and to provide a better translation of the indicator results into practical advice for farmers.

1. Outline

In this paper we wish to describe our experiences with developing and validating a sustainability monitoring tool for Flemish dairy farms called MOTIFS and demonstrate how we applied this validated tool to advice farmers concerning sustainability of grazing versus full-time housing of dairy cows. In this paper we therefore refer to previously publised work; for more detailed information, please read Meul et al. (2008), Meul et al. (2009), De Mey et al. (2011) and Meul et al. (2012).

2. Development of MOTIFS

MOTIFS is an indicator-based sustainability monitoring tool for Flemish dairy farms. It allows to monitor farm progress towards integrated sustainability, i.e. taking into account economic, ecological as well as social aspects, using a set of relevant indicators. The tool offers a visual aggregation of indicator scores into an adapted radar graph, considering ten sustainability themes related to ecological, economic and social aspects (Figure 1). To aggregate the indicators for different sustainability themes, benchmarks were defined to rescale indicator values into scores between 0 (indicating a worst-case situation) and 100 (indicating assumed maximum sustainability). Since the aim of MOTIFS was to effectively communicate to farmers and advise them on several aspects of farm sustainability, we chose to aggregate the indicators in a graphical way, where all relevant themes are presented individually, instead of combined into a single aggregated index. This allows for a comprehensive overview and mutual comparison of the indicators for different sustainability themes. We further focused on a user-friendly and communicative design of the tool by providing the ability to add the average indicator scores of a group of comparable farms and by visualizing the indicator weights. That way, a farmer can readily distinguish which indicators are considered more or less important when evaluating the sustainability of a specific theme.

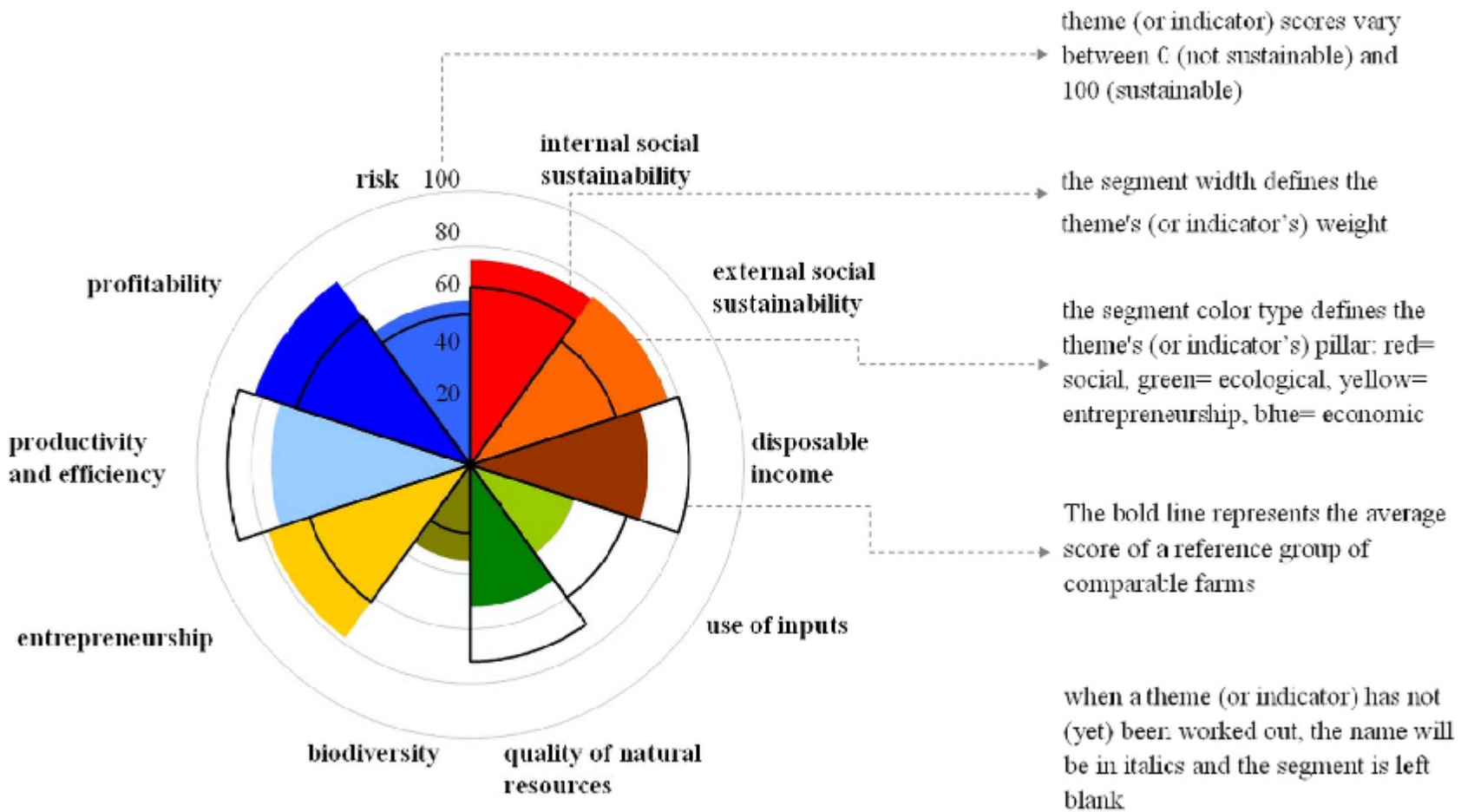

Figure 1. MOTIFS, graph and instructions on the reading and interpretation

Stakeholder participation and expert consulting played an important role in the development of MOTIFS:

- The ten sustainability themes are based on core principles of sustainable agriculture in Flanders, as defined during a multi-stakeholder vision development process described by Nevens et al. (2008). In this process, about 130 people, directly or indirectly involved in Flemish agriculture, participated in three workshops where different techniques and group methods for facilitation of interactive processes were applied to discover core values and core purposes ('mission') and elaborate vivid descriptions of sustainable farming types, guided by clear, non-overlapping principles complying with the triple bottom line of sustainable development.
- Stakeholders (including experts) were consulted during the selection and design of relevant indicators, especially when scienific literature was missing – which was particularly the case for the social themes. Expert judgement was applied to define benchmarks of some indicators.

At this stage, MOTIFS was applied for the first time on 20 Flemish dairy farms participating in a European Leader+ project called 'Sterk met melk' (*Strong with milk*). During the period 2006–2008, a project leader visited the farmers, collected farm data, calculated indicators and made radar graphs with the results of each farm. Those results were then presented in a discussion group where the farmers could compare the weak and strong aspects of their farms and discuss possible actions to be taken. We used this practical application to develop and apply an extensive validation procedure for MOTIFS and its indicators, as described in the next section.

3. Validation of MOTIFS

To validate MOTIFS indicators, we considered two aspects: an evaluation of the indicators' accuracy and an evaluation of their credibility. Accuracy evaluation relates to the degree of correctness of an indicator with regard to its intended application, i.e. the degree to which the indicator reaches its intended goals. An indicator's credibility requires an evaluation of the indicator's end-use value – i.e. its usefulness to potential end-users – and an evaluation of the willingness of potential end-users to actually use it in practice. In the following, we discuss these validation aspects in greater detail.

3.1. Accuracy evaluation

We combined the methodological principles proposed by Bockstaller and Girardin (2003) and Cloquell-Ballester et al. (2006) and used a transdisciplinary approach of expert and stakeholder participation to carry out a design and output validation of MOTIFS indicators. Design validation is used to evaluate whether an indicator is scientifically founded and can be carried out by submitting the design or construction of an indicator to a panel of experts. Another option is to use expert judgements during the design of the indicators (a priori validation). The main concern of output validation is to assess the soundness of the indicator output. Ideally, a comparison can be made of indicator outputs with measured field data, as proposed in model validation. However, since indicators are generally not used to predict an actual impact but to supply information about a potential impact, a linear relation between indicator output and field data cannot be expected (Bockstaller and Girardin, 2003). Therefore, other procedures are suggested. One option is to compare the indicator output with the output of other indicators that have the same purpose, but that are constructed in a different way. Another option is to compare the indicator output with values given by experts. A last possibility is to submit the indicator output to a panel of experts (for example a group of farmers) that evaluates its relevance and reliability.

For each indicator, feedback groups of experts and stakeholders discussed the (perceived) relevance and underlying methodological choices such as indicator design, data use, choice of benchmarks and weight. Generally, 10 to 20 experts and stakeholders – representatives of farmers' organisations, researchers, policy makers… – were brought together as a feedback group of a specific sustainability theme, e.g. energy use. These meetings were organised for every theme and they typically lasted half a day. After a detailed presentation of the proposed indicators and underlying methodology, specific questions were asked to the feedback group, concerning the indicators' methodological choices. Based on the group's remarks and discussions, possible adjustments to the indicators were made. This method was also used to validate the design of MOTIFS: a feedback group discussed the methodological choices concerning indicator aggregation (e.g. visual versus numerical) and aspects of design (e.g. adapted radar graph versus bar graph).

3.2. Credibility evaluation

An indicator's credibility evaluation relates to the degree of confidence potential end-users have in the indicator, and hence their willingness to effectively use it in practice. This involves an end-use validation (Bockstaller and Girardin, 2003), assessing the indicator's end-use value. Perhaps the most important asset of a sustainability indicator is its potential to trigger action, which determines its end-use value. The end-use validation of MOTIFS relates to the end-use value of the tool to make sustainability concrete, to guide farm management towards higher sustainability and its end-use value as an effective communication tool. We designed a test that allows for an evaluation of the end-use value of MOTIFS and its indicators, combined with an evaluation of the willingness of potential end-users to effectively use MOTIFS in practice. Hereby, we considered two potential end-user groups: Flemish dairy farmers and 'sustainability consultants', e.g. agricultural advisors assigned by farmers' organisations. Both potential end-user groups were represented in the Leader+ project 'Sterk met melk'. Due to the explorative nature of the test, a qualitative research approach involving semi-structured interviews was applied. During each of the interviews brief notes were taken, that were elaborated immediately after the interview. The data analysis consisted of sorting the responses to the questions into three pre-set categories, expressing the respective fields of interest of the end-use validation: (i) end-use value of the selected indicators as decision aid tools, (ii) end-use value of MOTIFS as a decision aid tool and communication tool and (iii) willingness to use MOTIFS in practice. For each category, we summarized the responses of the two potential end-user groups and singled out specific interesting remarks. Based on this analysis, we proposed some suggestions for improving the end-use value of the indicators and MOTIFS and for enhancing their practical application:

- MOTIFS was considered valuable to the potential end-users in feeding decisions and guiding actions. However, additional information ('the drivers behind the indicator') as well as hard figures - such as the absolute indicator values and additional farm-specific information – were considered necessary to enable specific and concrete farm advice, to decide on appropriate measures and to actually take action.
- The calculation of some indicators was new to farmers and farm advisors and hence interpretation of the results was not obvious. This should be kept in mind when the tool is presented to potential users for the first time; detailed training or guidance should be provided.
- Generally, the respondents found that ideally, communication about sustainability should be organised in two steps: (i) an individual discussion between farmer and advisor, using MOTIFS to highlight the strengths and weaknesses of the farm and (ii) a group discussion between farmers, where they can compare results, discuss technical aspects

of farm management and learn from each other. Especially this second step seemed to be very important for the farmers; they found these meetings very useful to learn from each other, to find solutions for specific problems, or just to hear each other's opinion on specific issues.

- Although the farmers expressed their interest in MOTIFS, they did not intend to use it if they would have to collect data, calculate the indicators and interpret the results themselves. This suggests that the best strategy for practical application of MOTIFS on Flemish farms would be to introduce the tool to farmers through farm advisors.

In a subsequent validation study of MOTIFS, De Mey et al. (2011) evaluated the critical success factors of MOTIFS as a social learning tool, in case MOTIFS would be used independently by farmers and farm advisors, and would be implemented in existing farm advisory networks without involvement of the tool's developers. In that case, the authors suggested to focus on improving the organization of the discussion sessions, in order to enhance their effectiveness: farm advisors should be trained to translate indicator results into advice, advisors' communication skills should be enhanced to facilitate interactive and flexible dialogues that lead to better learning among farmers, discussion sessions should be planned thoroughly, with clear goals for each session. Furthermore, involving experts on particular themes of MOTIFS would make the dialogues more profound and produce more tangible advice.

Based on the suggestions from these validation studies, we decided for the next application of MOTIFS in the grazing versus zero-grazing case-study (i) to perform a detailed analysis of the sustainability indicator values to provide the requested additional information behind the indicator scores, (ii) to perform the case-study in intensive interaction with farm advisors along the different stages of the project and (iii) to support social learning among farmers through a discussion meeting with an invited expert.

4. Application of the validated tool to evaluate sustainability and support agricultural management of grazing and zero-grazing Flemish dairy farms

We evaluated 20 specialized Flemish dairy farms, 10 with grazing and 10 with permanent housing of dairy cows, associated with the same private farm accountancy and consultancy organization. The zero-grazing farms were characterized by a significantly larger herd size, higher total milk production and higher use of concentrates and byproducts per cow, while the available grassland area per cow was significantly lower compared to the grazing farms (Table 1). Milk yield per cow was similar in both groups. All dairy cows were Holstein-Friesian breed housed in cubicle stables, except for one grazing farm with a tie-stall barn. Besides fresh grass during the grazing period for the grazing cows, the rations included a mixture of conserved forages such as grass and maize silage, byproducts such as beet pulp and brewers' grains and concentrates. Within the grazing group, a large variability in grazing period occurred and dairy cows were also housed for a longer time per year. Compared with average farm characteristics of a representative group of Flemish dairy farms all farms in our case-study can be considered large, intensive farms, since also the grazing farms are characterized by high milk productions, high milk yields per cow and high stocking densities.

Table 1. Mean value and range of farm characteristics of the grazing and zero-grazing case-study farms, based on farm accountancy data for 2009

	unit	zero-grazing farms		grazing farms		
Farm intensity and scale						
degree of specialisation	% of value added	91	(74-100)	94	(82-100)	
herd size	number of dairy cows	99	(52-127)	74	(43-100)	**
share of heifers	% of dairy cows	81	(59-115)	83	(59-99)	
stocking rate	cows per ha roughage area	2.12	(1.52-3.11)	1.87	(1.51-2.55)	
total milk production	ton milk	848	(403-1141)	619	(397-870)	**
milk yield per cow	kg milk per cow	8603	(7873-9542)	8697	(6551-10078)	
milk yield per ha	ton milk per ha roughage area	17.8	(13.7-25.5)	15.8	(12.6-23.5)	
Land use						
forage area[a]	ha	51	(18-83)	41	(17-57)	
forage area per cow	ha per cow	0.50	(0.32-0.66)	0.55	(0.39-0.66)	
grassland area per cow	ha per cow	0.21	(0.06-0.34)	0.29	(0.21-0.42)	**
Feeding strategy						
grazing period for dairy cows	hours per year	15	(0-150)	1463	(340-3366)	
use of concentrates and byproducts[b]	kg per cow per year	2690	(1768-3613)	2087	(1431-2796)	**

[a] comprises total grassland area and area used for forage crop production, mainly maize

[b] the use of different concentrates and byproducts was recalculated to a universal 88% dry matter content

** indicates significant differences between the means (P<0.05, ANOVA)

We used a selection of sustainability indicators from MOTIFS. Ecological performance of the farms was evaluated by their energy and nutrient use, economic performance by their productivity and profitability, and social performance was measured through labor efficiency and animal welfare. These specific sustainability themes were chosen because we expected them to be most affected by the type of production method, and because they can be influenced directly by farm management. Moreover, for the selected indicators we were confident that reliable and adequate data could be gathered, since they were already extensively validated and applied in previous applications (Meul et al. 2009, De Mey et al. 2011).

Figure 2 summarizes the different steps applied during the evaluation of the sustainability performance and the formulation of management advice. Starting from the calculated indicator values, we identified a set of most influential management indicators. Therefore, we first used multiple regression to identify the most influential factors, i.e. independent variables, for each indicator value, i.e. dependent variable. For example, for the N-surplus indicator, the N inputs and outputs are the independent variables. We selected the independent variables associated with a P-value < 0.05 as the most influential factors for the indicator. Next, through correlation analysis, the selected factors were related to specific farm management indicators such as farm intensity or concentrate use. This analysis was performed using data from all 20 dairy farms and the resulting farm management indicators were used to formulate general management advice. More detailed site- and case specific advice was delivered to the 20 participating farmers through an extended feedback report including a detailed representation of the MOTIFS results and comparison of the farm results to the means of the grazing and zero-grazing group.

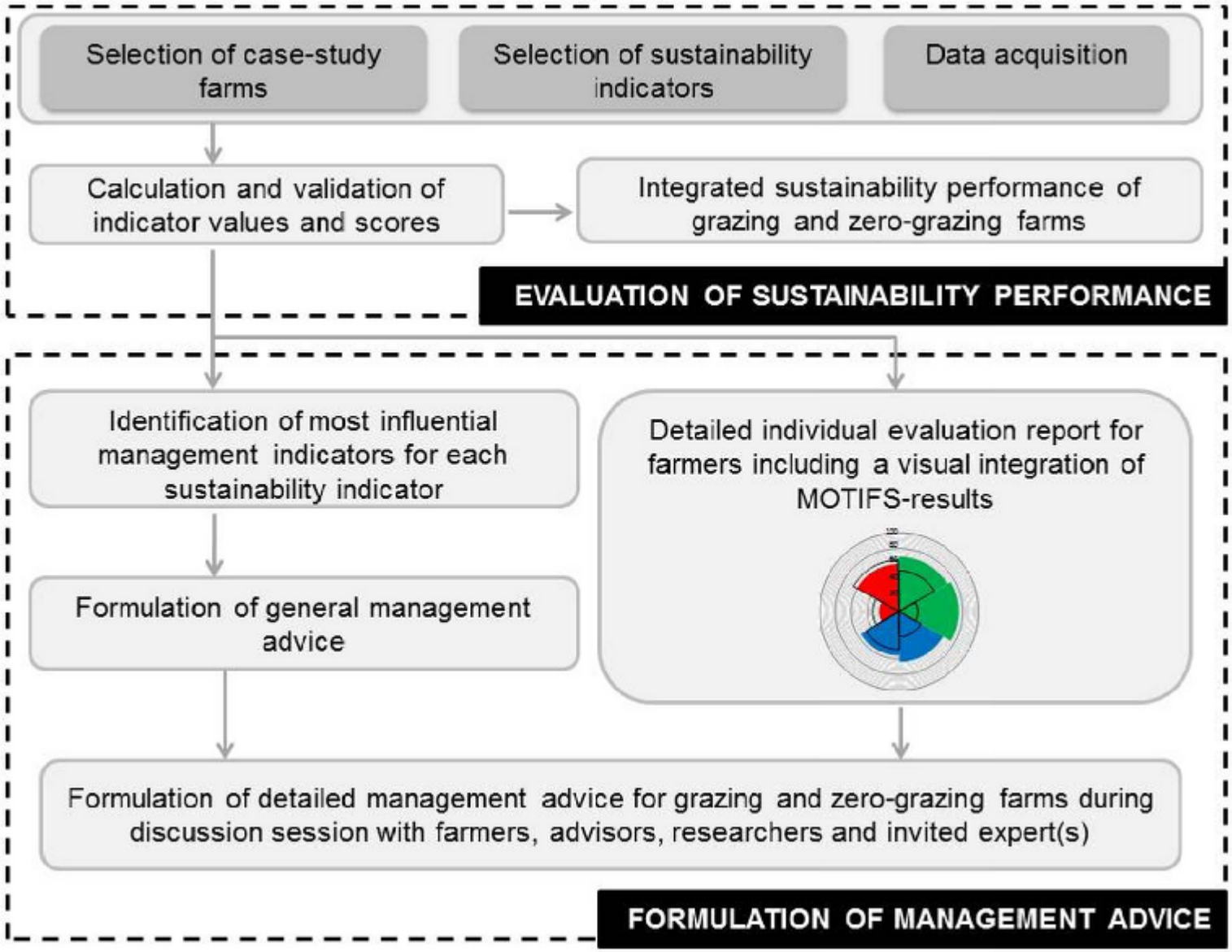

Figure 2. Applied methodology to evaluate sustainability performance and formulate

management advice

Afterwards, all farmers were invited to participate in a discussion group with the researchers, farm advisors and an invited expert. Stakeholder participation played an important role in our study: case-study farms were selected based on discussions between researchers and farm advisors. Farmers and farm advisors were involved in data acquisition, and farm advisors were consulted during identification of the most influential management indicators; they also facilitated the discussion session.

Results showed that, despite the large within-group variability, grazing farms scored systematically higher for all ecological and economic sustainability indicators. Zero-grazing farms on the other hand scored higher for labor efficiency, while surprisingly animal welfare was not significantly different between the two groups. The overall integrated sustainability score was significantly higher for grazing.

Regression analysis showed that energy productivity was highly determined by the input of energy from concentrates and byproducts and input from diesel (R^2=0.92). N surplus, P surplus and N use efficiency were highly determined by the input of nutrients from mineral fertilizers, concentrates and byproducts, forages and exported nutrients in milk and manure (R^2=0.93, 0.82 and 0.96 respectively). Energy and N input from concentrates and byproducts were significantly higher at the zero-grazing farms and these factors were strongly related to respectively the use of concentrates and byproducts per cow (R^2=0.79) and per ha (R^2=0.65). Hence, the significantly higher use of concentrates and byproducts at the zero-grazing farms (Table 1) resulted in an overall higher nutrient surplus and lower nutrient and energy use efficiency. The most influential factors of the farms' economic indicators were the income from sold milk, costs for concentrates and byproducts, forage production, maintenance, fertility and other variable costs. Hence, the significantly higher use of concentrates and byproducts per cow not only affected the ecological performance, but also resulted in a lower economic performance of this group.

An important management advice for farmers was therefore to decrease input of concentrates by including a higher proportion of forages in the feed ration. We saw a large variability in the use of concentrates and byproducts between farms with a comparable available forage area per cow. Some farms used a lot of concentrates and byproducts compared to other farms with the same available forage area per cow and applying the same production method. Including a higher proportion of forages in the diet can be realized through optimization of grassland management and forage production and use, and by avoiding losses during grazing, harvesting, preservation and feeding. This optimization potential was discussed in detail during the discussion meeting with the farmers, farm advisors and an invited expert in ration optimization and forage production. The farmers from the zero-grazing group with comparably high use of concentrates and byproducts declared that they preferred labor convenience over optimizing forage production and ration optimization and therefore didn't fully attend the potential forage yield and use at their farms. Most grazing farmers were able to better consolidate the available forage products because they paid more attention to ration optimization and grassland management. It was mentioned however that a good consolidation of the available forage area requires high management skills on the part of the farmers. During the discussion meeting, detailed and technical case-specific advice concerning grassland management and forage production and use was provided by the invited expert and specific questions of the farmers were answered.

5. Conclusions

Through our methodology applied in the grazing vs. zero-grazing case-study, evaluation of the sustainability performance was supplemented with the formulation of useful advice for farmers of both groups. This methodology considered suggestions made during previous applications and validation studies of MOTIFS. The translation of sustainability monitoring results into practical measures is considered an integral part of the application of MOTIFS and we think it is an essential step to make progress towards higher sustainability.

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