In: Grassland Science in Europe, 20, 637-640.

Quantifying sustainability of dairy farms with the DAIRYMAN-Sustainability-Index (DSI)

Elsaesser M.[1], Jilg, T.[1], Herrmann, K.[1], Boonen, J.[2], Debruyne, L.[3], Laidlaw, S.[4], Aarts, F.[5]

[1]Agricultural Center Baden-Wuerttemberg (LAZBW, D); [2]Lycée Technique Agricole, LU; [3)]Instituut voor Landbouw-en Visserijonderzoek (ILVO, B); [4]Agri-Food and Biosciences Institute (AFBI, NIR-UK); [5]Wageningen-UR (NL)

Abstract

DAIRYMAN was an EU-Interreg IVB project for Northwest Europe which ran from 2009 to 2013 involving 10 regions. A pilot farm network was set up, comprising 127 dairy farms covering the partner regions. The farms were optimized regarding economic, ecological and social aspects, to provide a measure of sustainability. The collected data provided a clear overview of current production systems and the future potential in Northwest Europe. This paper describes the application of a multi-annual data-set used to assess and analyze development of sustainability of an individual farm. A multi-criteria assessment tool has been developed, the DSI, incorporating economic, ecological and social indicators to describe and comprehend the complexity of the farm as a production system. Moreover this tool can visualize individual farm development and differences in milk production systems over time and between regions.

Keywords: sustainability, dairy systems, indicator, Dairyman sustainability index

Introduction

Dairy farming is an important economic activity in Northwest Europe (Aarts, 2013). Although the climatic conditions are well suited and the infrastructure is excellent for dairying, the environmental performance of dairy farming is low. Aarts (2013) has considered that NWE dairy farming has very low efficiency in the use of fertilizers and feed. The poor utilization of these increasingly expensive resources threatens the economic viability of dairy farms. This raises questions about the sustainability of dairy farming in NWE. According to the Brundtland Commission (1987) the definition of sustainability of a system includes economic, ecological and social aspects. This means that sustainable dairy farms should be environmentally compatible, economically viable and socially acceptable (Dubois, 2002). Sustainability, as a special criterion for assessment of agricultural practices, has been a topic of discussion for many years (Briemle et al., 1996; Vavra, 1996). Von Wiren-Lehr (2001) pointed out that it is not possible to accurately evaluate sustainability even if complex models are deployed or time consuming measurements are taken. Sustainability assessment tools can be classified by a diverse range of criteria, e.g. goal, intended end-users, geographical scope, data and time requirements. More specifically for dairy farming, a large set of indicators focusing on specific, mainly environmental, sustainability aspects has been proposed (e.g. Breitschuh et al., 2001; Bockstaller et al., 1997; Girardin, 2001; Kopfmueller et al., 2001; Schroeder, 2003; Huelsbergen, 2003; Belanger et al., 2012; Arnould et al., 2013; Gaudino et al., 2014). Guillaumin et al. (2007) and Lebacq et al. (2012) have overviewed sustainability indicators for livestock farming.

DAIRYMAN was an EU Interreg NWE IVB project which ran from 2009 to 2013 and included 14 partners in 10 regions of Northwest Europe (The Netherlands (NL), Pays de la Loire (FL), Bretagne (FB), Nord Pas de Calais (FN), Northern Ireland (IN), Ireland (IR), Flanders (BF), Wallonie (BW), Luxembourg (LU), Baden-Wuerttemberg (GE)). The objective of the project was to investigate the state of sustainable milk production in the main milk producing regions of Europe and to compare production conditions in these areas. Within the project a network of 127 pilot dairy farms was set up and data from the farms were recorded following a standardized protocol (Boonen et al., 2013a) during three years (2009, 2010 and 2011). All farms created an individual management plan, including their targets for farm development within the time frame of the project. Additionally, a general report on the sustainability of milk production in each region was written and management tools to improve sustainability of dairy farms were tested. In order to compare current dairy farming systems, the project team initially considered single indicators e.g. farm income or surpluses of nutrient balances, but concluded sustainability can be assessed more satisfactorily with an integrated system and a combination of indicators, instead of using single indicators. From several comparisons of available assessment tools and systems (Gasparatos et al., 2008; Schader et al., 2014; Marchand et al., 2014), and from the evaluation of a tool development process (Triste et al., 2014), some general requirements were identified for potential sustainability assessment tools. Issues included creating ownership amongst stakeholders to increase likelihood of adoption of the tool in practice and the fact that the tool design had to be in accordance with aim (e.g. farm management vs. policy support) and function (e.g. rapid assessment vs. monitoring) of the tool. At the start of the project in 2009 several sustainability assessment methods had been already, or at least partly, developed, e.g. REPRO (Christen et al., 2009), KSNL (Breitschuh et al., 2008), RISE (Grenz et al., 2009), IDEA (Zahm et al., 2008) or MOTIFS (Meul et al., 2008; De Mey et al., 2011). However, as none of these methods completely fulfilled our criteria, we opted to create a new system, fulfilling the specific DAIRYMAN requirements. This paper will describe the development process of the Dairyman Sustainability Index (DSI) and some comparisons between the regions.

Material and methods

Stages in the tool development process were:

1. Agreement on weighting of the ecological, economic and social aspects of sustainability
2. Choice of single indicators for each of the three sustainability aspects
3. Deciding on the contribution of each indicator within the appropriate sustainability aspect
4. Benchmarking (Determination of targets to attain of each indicator)

Weighting of aspects

Based on the sustainability definition, the Group agreed that the economic, ecological and sociological aspects would each be considered equally with 100 points (Table 3)

Choice of sustainability indicators

In the first phase of the project, indicators chosen for the DSI were selected by the project partner LAZBW in Aulendorf – after intensive discussion and relying on data from a questionnaire answered by pilot farmers, farm advisors and teachers of agricultural schools in that region. In this questionnaire the partner proposed single indicators that had already been calculated for the Dairyman pilot farms and existing common farm indicators from other systems. In the Dairyman project the following farm data were available for three accountancy years (2009-2011) for all pilot farms:

- Descriptive data: information on the farm structure and management strategies (workers, size of herds, land use, etc.)
- Economic data: information on sources of revenues (milk, animals, crops and subsidies), operating costs (related to herds, grassland, crops, buildings and management), depreciation, interest and taxes

- Ecological data: information on amount and composition of inputs (e.g. fertilization and feeding) and outputs (e.g. milk). These data allowed calculation of mineral balances (kg of N and P balance per ha), N and P efficiencies (ratio between output and input of nutrients at farm scale) and greenhouse gas emissions (only 2010)
- Biodiversity potential of 1-3 pilot farms per region for one year.

In the second step the Dairyman group discussed and modified the choice of indicators. All chosen indicators (Table 1) were clearly defined and could be easily calculated from the data already gathered from the pilot farm (Grignard et al., 2012; Elsaesser et al., 2013). Finally the retained indicators were:

Economic

For the economic indicators a net margin before taxes was calculated:

Net margin before taxes (NMBT) (€): $Revenues - Annual\ Expenses - Depreciation - Interest$ (1)

As a lot of pilot farms were mixed farms (with beef or crop production in addition to dairy), we considered three economic indicators at the dairy component of the farm ((2), (3), (6)) and two economic indicators were calculated at the whole farm level ((3) and (4)). The selected economic indicators were the following:

Income at dairy level (€ · 100 kg^{-1} FPCM): $\frac{(NMBT)_{dairy}}{\frac{Milk\ production\ (kg\ FPCM)}{100}}$ (2)

Family labour income at dairy level (€ · fLU^{-1}): $\frac{(NMBT)_{dairy}}{(Family\ Labour\ Units\ fLU)_{dairy}}$ (3)

Farm income (€ ·fLU^{-1}): $\frac{NMBT}{Family\ Labour\ Units}$ (4)

Dependency on subsidies (%): $\frac{Public\ payments}{NMBT}$ (5)

Exposure to price fluctuations d. level (%) $\frac{(Variable\ Costs + Depreciation + Interest - Paid\ Labour)_{dairy}}{(Revenues - Public\ Payments)_{dairy}}$ (6)

Ecological

1. N balance (kg · ha^{-1}): N input minus N output at farm level
2. N balance per kg milk (kg · 1000 kg^{-1} milk): N input minus N output at farm level
3. N efficiency (%): N output per N input at farm level
4. P balance per ha (kg · ha^{-1}): P input minus P output at farm level
5. P balance per kg milk (kg · 1000 kg^{-1} milk): P input minus P output at farm level
6. P efficiency (%): P output per P input at farm level
7. Payments for environmental activities: agro-environmental payments (€ · ha^{-1}) e.g. for cultivation of nature protection land, subsidies for no use of pesticides, (etc.)
8. Greenhouse gas emissions (kg CO_2-eq · Mg milk^{-1}): GHG emissions for the dairy component of the farm

Social aspects

As the Dairyman database had not included sociological factors, the Group developed a questionnaire, based on the original one developed by the LAZBW partner, and distributed it to every family worker on the 127 pilot farms. Answers to the questionnaire were scored and then integrated into the DSI. Some information concerning basic education, holidays, work load, employment had already gathered in the descriptive data set. The working conditions (quantity and quality) were most often cited as relevant social sustainability themes. The work load was the amount of working time on the farm. Work quality was taken to be the global perception of happiness at work (Coutey 2014), including e.g. pleasure at work. Wide differences in social perceptions were found between countries (Foray et al., 2013). Therefore taking account of both quantitative and perception data from farmers was justified.

1. Education (1.1 Basic education; 1.2 Training courses)
2. Working conditions (2.1 Personal satisfaction (work-life-balance? How often do you feel stressed? Are you happy with your salary? Activities outside the farm?); 2.2 Work load per family labour unit; 2.3 Holidays; 2.4 Free time)
3. Farm continuity (3.1 Preparation of farm succession; 3.2 Is there a potential successor?)
4. Social role and image: relation to neighbourhood, reputation within the area, organization of public events on the farm, etc.

Weighting of each indicator

In developing a multi-criteria index system it was important to attribute weights to the different indicators in the system. As explained before equal weights were assigned to ecological, economic and social aspects (Table 1). However, there was some discussion on whether different weights should be given to, for instance, different environmental indicators e.g. N efficiency may be less important than N balance. Taking into account the approach taken by Belanger et al. (2012), Larochelle et al. (2007) and Meul et al. (2008) and the requirement for the sum of the indicators of each sustainability aspect to be 100 points, the relative contribution of points assigned to each indicator is presented in Table 1. The results are based on subjective decisions. They are a compromise and may not be ideal for all regions. These values are still under discussion, as different objectives of the partner regions influence these weights. For example, Ireland consider phosphorus to be the most important nutrient emission, so they would place emphasis on indicators dealing with phosphorus whereas in the Netherlands, Germany or Brittany nitrogen is the most important nutrient and so their values would reflect this.

Table 1. Weightings for each sustainability indicator in the DSI

Economic aspects		Ecological aspects		Social aspects	
Income per kg milk	16%	N balance per ha	15%	Education	22%
Income per fLU	34%	N balance per kg milk	11%	Working conditions	42%
Total farm income	22%	N efficiency %	13%	Continuity of farm	16%
Dependency on subsidies	10%	P balance per ha	11%	Social role and image	20%
Exposure to price fluctuations	18%	P balance per kg milk	8%		
		P efficiency %	10%		
		Agri-env.pay. per farm	10%		
		GHG emissions	22%		
	100%		100%		100%

Benchmarking

A final step was the definition of benchmarks, and scoring of the indicators. A possible option was absolute reference values (for instance regulations, thresholds), but these do not exist for all indicators in the DSI system. As an alternative the research team decided to use the results of the 127 pilot farms for the determination of reference values to evaluate the sustainability of the individual farms for the quantitative indicator set. Based on the distribution of scores for each indicator for the 127 farms the means for the lowest 10% (10% quantile) and for the highest 10% (90% quantile) for the reference year (2010) were calculated as reference points for the minimum and maximum score. Between these points a linear progression was used for the individual scoring (Table 2).

Table 2. Statistical results (minimum and maximum value, 10 % and 90% quantiles) of the indicators of the 127 DAIRYMAN pilot farms (2010) (see text for explanation)

Indicator	Min. value	10% quantil	90% quantil	Max. value
Economy				
Income at dairy level (€ ·100 kg^{-1} milk)	-7.62	2.65	23.79	34.88
Income at dairy level (€ · family labour $unit^{-1}$)	-69427	13323	117466	202916
Total farm income (€ · family labour $unit^{-1}$)	-69427	18081	109313	188542
Dependency on subsidies (%)	-33	22	138	715
Exposure to price fluctuations (%)	42	53	104	149
Ecology				
N balance (kg · ha^{-1})	17.1	82.4	268.0	373.3
N balance (kg · 1000 kg^{-1} milk)	3.85	9.09	34.34	60.94
N efficiency (%)	11.79	19.41	47.54	64.40
P balance (kg ·ha^{-1})	-16.31	-4.62	17.88	43.90
P balance (kg · 1000 kg^{-1} milk)	-4.56	-0.63	2.97	8.53
P efficiency (%)	19.45	35.89	157.88	411.60
Agroenvironmental payments (€ · ha^{-1})	0.00	0.00	122.55	317.95
Greenhouse gas emissions (kg CO_2-eq · Mg^{-1} milk)	703.80	932.30	1427.,66	1816.89
Social aspects				
Holidays (days · $year^{-1}$)	0	0	20	35
Working time (hours· fLU^{-1})	330	1952	3310	5304

Results

Calculation of DSI

The total scores for economic, ecological and social aspects are calculated by multiplying the score (relative to the maximum of 1) with the weighting (proportion of the 100 points for the aspect of sustainability assigned to the indicator). For example, in Table 3, calculation of the 'Income per kg milk' score, included in the economic aspect of sustainability, is high as the value is close to the maximum and so is awarded 0.9. When multiplied by the proportion of the points awarded to 'Income per kg milk' i.e. 16, the weighted score is 14.4.

Output

The DSI offers the possibility to portray relationships in different regions and between various farms. Assessment results vary between the project regions. In Figures 1 to 3, the actual data from each pilot farm in each region are presented as box plots in which the box represents the range for the middle 80% of the farms, the lower projection the lowest 10% (10% quantile) and the higher projection the highest 10% of values (90% quantile). The upper and lower filled circles are the maximum and minimum value, respectively. Figures 1 to 3, show an example each of data for an indicator for the economic, ecological and social aspects of sustainability i.e. the farm income per milk produced on dairy level (Fig.1), the N-balances (Fig. 2) and the number of free days (Fig. 3), respectively. It is important to emphasize that the values in Figs 1, 2 and 3 are not representative for the countries as a whole but relate only to each farm and the average for the pilot farms in that region. Scores for the DSI are calculated by combining the scores for indicators after their weighting and can show the present situation (Table 4) or the development of farms retrospectively (Fig. 4).

Table 3. Example of calculating the scoring points for economy with the DSI

Score	Income dairy (€ 100 kg milk^{-1})	Income dairy (€ fLU^{-1})	Farm income (€ fLU^{-1})	Dependency on subsidies (%)	Exposure to price fluctua-tions (%)
Minimum = 0	$\leq$ 2.65	$\leq$ 13326	$\leq$ 19184	$\geq$ 135.29	$\geq$ 103.65
Medium = 0.5	13.22	65462	66369	77.51	78.13
Maximum = 1	$\geq$ 23.79	$\geq$ 117567	$\geq$ 113553	$\leq$ 19.73	$\leq$ 52.61
Points (p)	max. 16 points	max. 34 points	max. 22 points	max. 10 p.	max. 18 p.
Real farm result	21.7	114400	75800	142	49
Score	0.9	0.97	0.6	0	1
Weighted	0.9*16=14.4	0.97*34=32.98	0.6*22.5=13.5	0*9.5=0	1*18=18
Total score	14.4 points	33 points	13.5 points	0 points	18 points
Sum of scoring points for economy in total: 78.9 points out of 100 possible points					

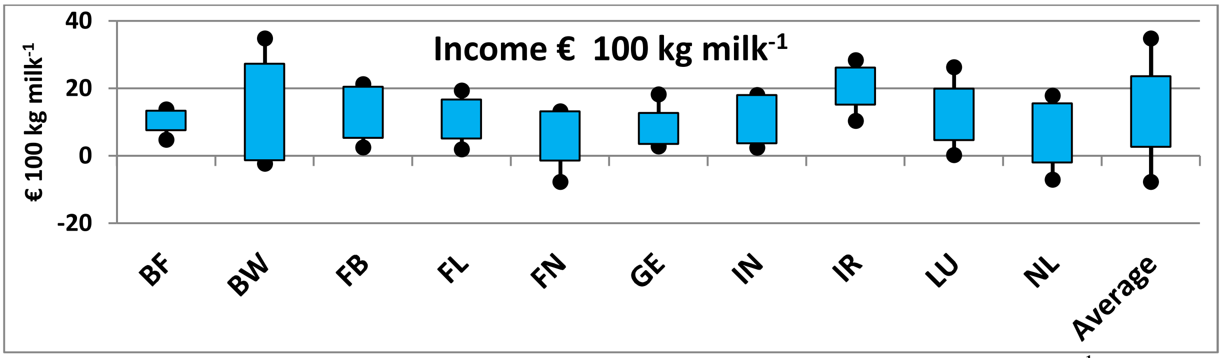

Figure 1. Example of an economic parameter of the DSI - Income in € 100 kg ECM^{-1} (2010)
(Abbreviations: BF = Belgium Flanders (Number of pilot farms: 13); BW = Belgium Wallonia (21); FB = France Brittany (11); FL = France Pays de la Loire (9); FN = France Nord Pas de Calais (7); GE = Germany Baden-Wuerttemberg (14); IR = Ireland (21); IN = UK Northern Ireland (9); LU = Luxembourg (6); NL = The Netherlands (16)) (Box plots are explained in the text)

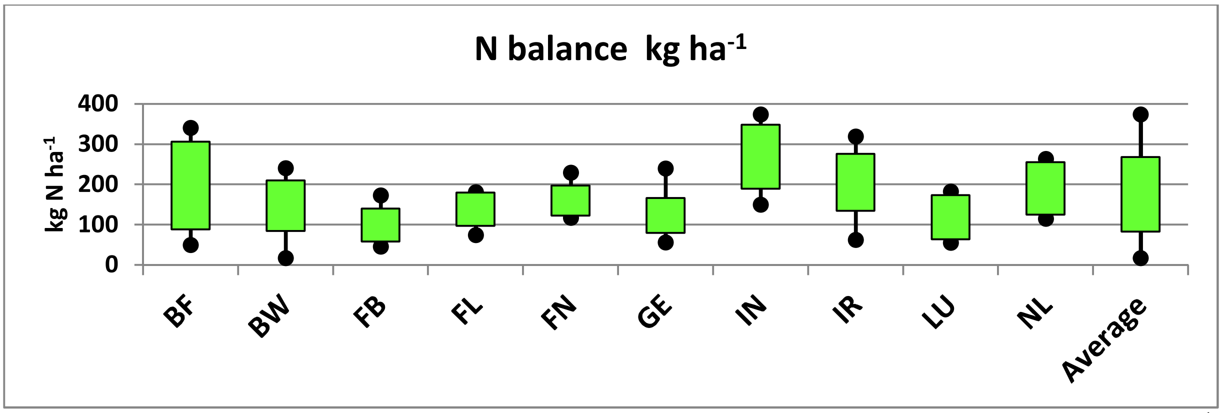

Figure 2. Example of an ecological parameter of the DSI - Nitrogen balance in kg N ha^{-1} (2010)

Farm development

Whereas comparisons of single indicators e.g. farm income, depend strongly on fluctuations of costs for resources or prices for products, a combination of indicators, such as with the DSI, shows much smaller effects of market fluctuations as other associated economic factors are taken into account, diluting the effect of any one indicator. The DSI calculated on a yearly basis provides an acceptable assessment of dairy farming systems, if the scores are used and underlined by the results of single indicators as in Table 4.

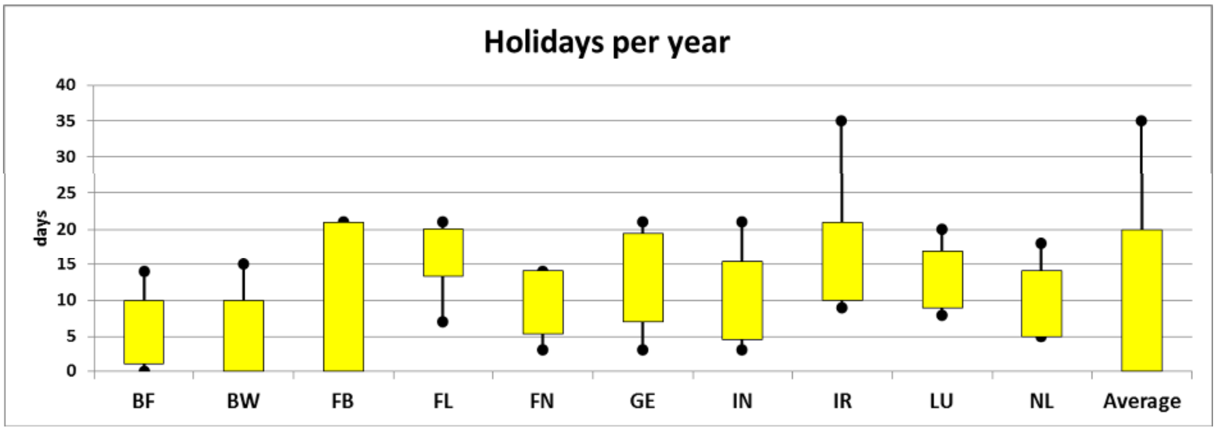

Figure 3. Example of a social parameter of the DSI - Holidays per year (d) (2010)

Table 4. Detailed analysis of results of an exemplary German pilot farm with individual scoring for one year (bars in graph for 'scale points' are 'scoring' as proportion of the maximum)

Indicator	farm value	scoring	max. points	points per farm	scale points
Income € 100 kg milk^{-1}	9.5	0.32	16	5.2	
Income € familiy worker^{-1}	123038	1	34	34	
Farm income € family labour unit^{-1}	174537	1	22	22	
Dependency on subsidies %	0.4	0.85	10	8.5	
Exposure to price fluctuations %	0.7	0.58	18	10.4	
Total economy		0.8	100	80.1	
N balance kg ha^{-1}	146	0.66	15	9.8	
N balance kg 1000 kg milk^{-1}	20.1	0.55	11	6	
N efficiency %	22.6	0.13	13	1.7	
P balance kg ha^{-1}	20	0.01	11	0.1	
P balance kg 1000 kg milk^{-1}	3	0	8	0	
P efficiency %	25.8	0	10	0	
Agroenvironmental payments € ha^{-1}	74.4	0.61	10	6.1	
Greenhouse gas emissions 1000 kg CO_2-eq t milk^{-1}	973	0.92	22	20.2	
Total ecology		0.44	100	43.9	
Education		0.75	20	15	
Working conditions		0.67	39	26.3	
Continousity of farm		1	14	14	
Social role and image		0.63	18	11.3	
Employment		0.6	9	5.4	
Total social aspects		0.72	100	71.9	

Opportunities and limits of DSI

Several sustainability assessment systems have been developed over the last decade. Comparing, for example, the systems developed by Doluschitz and Hoffmann (2013) and by Schader et al. (2014) while they differ in a wide range of criteria, the overall target of both is similar i.e. to assess sustainability as a whole and comprehensive item.

Weaknesses of the system

The DSI has not yet been completed. It was designed for the special situation in the DAIRYMAN project and relied on the data that were collected from the pilot farms within the scope of the project. For example the assessment of biodiversity, soil quality and erosion, pesticide use or data on animal welfare are missing. Moreover the weighting was subjective and dependent on farm objectives. This was further complicated by the fact that different regions were involved, with differences in, for instance, legislative requirements or main environmental issues. In addition the different indicators have been scored exclusively with information from the 127 pilot farms. These farmers have been selected as frontrunners in developing their farms. For this reason a calculation of the DSI on a pool of other dairy farms would need a new definition of scores, especially when the data used do not cover our reference year (2010).

Strengths of the DSI

The discussion process in the project team was strongly stimulated by establishing the DSI. The process allowed a systematic investigation of production processes, and it stimulated the common discussions between project members and stakeholders, who were asked to evaluate and weight single indicators. Questions in the Group still remain such as whether the whole farm situation can be portrayed in this way and how missing data like e.g. biodiversity or efficiency of energy use can be handled. An important advantage is that combined data are less sensitive to, for example, milk price fluctuations. The summarization of single indicators in combined indexes has offered new perspectives on sustainability and confirmed previous DAIRYMAN results. It can be shown that highly autonomous farms (more extensive) are more resilient to milk price than more intensive farms (Boonen et al. 2013b; Grignard et al., 2013). The data have also shown that farm size was not a main criterion for dairy farm sustainability.

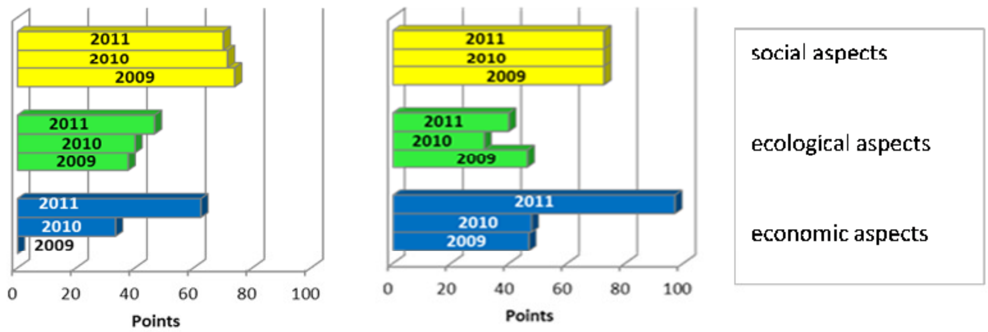

Figure 4. Development of two exemplary German DAIRYMAN pilot farms during the project time assessed with the DSI

While it seems to be unreasonable to express sustainability in one number, the German Agricultural Society (DLG) has adopted this approach based on more than twenty single indicators (DLG, 2015) for the sustainability of agriculture in Germany. Variation in the total DSI scores between years and regions will be used to offer a quick view on the consequence of changes made on farms to overall sustainability. This has potential for extension services and for farmers to monitor progress towards improving farm performance

Conclusion

The DSI index system was found to be well suited for monitoring the impact of management plans on the development of sustainability on farms or a group of farms in a defined region. Validation of the output of such a tool will always be problematic as there is no definitive quantifiable yardstick. However, in order to minimize bias exerted by specific single influences, we based the system on the arguments of several experts from different regions and the conclusions of an intensive discussion process within the DAIRYMAN team. The development of indicators and their evaluation stimulated discussion among project participants resulting in better understanding of complex farming systems. Sometimes wide differences exist between regions, so these comparisons are of interest. Therefore differences and special situations between regions should be taken into account. However, as the reference scores for sustainability indicators were collected from pilot farms and hence unlikely to be representative of these regions, we have deliberately not presented regional comparisons of DSI as conclusions may be misleading and could be inappropriately used.

It was our common objective to develop a management tool which is suitable for all partners in order to evaluate dairy farm sustainability as a combination of single indicators. Moreover this tool should visualize individual farm development and show differences in milk production systems. The DSI is a first approach, exploiting the large data set of DAIRYMAN. It is not the ´one and only´ solution, but it can be a first step in the right direction to simplify and to understand complex systems like dairy farms and to evaluate and visualize the efforts of farmers. The farm situation can be described more comprehensively by factor aggregation instead of only single indicators. The DSI is a first step in scoring the farm success. It is not yet finished but it is worth further development.

Acknowledgements

We thank the EU Interreg IVB program for the support and the participating regions for the additional financial support. We thank all collaborators in the DAIRYMAN team for their help and their willingness for discussions.

References

Aarts H.F.M. (2013) DAIRYMAN for a more efficient use of resources by dairy farms. *Grassland Science in Europe* 17, 753-755.

Arnould V., Reding R., Bormann J., Gengler N. and Soyeurt H. (2013) Review: milk composition as management tool of sustainability. *Biotechnologie Agronomie Societe et Environnement* 17, 613-621.

Bélanger V., Vanasse A., Parent D., Allard G. and Pellerin D. (2012) Development of agri-environmental indicators to assess dairy farm sustainability in Quebec, Eastern Canada. *Ecological indicators* 23, 421-430.

Bockstaller C., Girardin P. and van der Werf H.M.G. (1997) Use of agro-ecological indicators for the evaluation of farming systems. *European Journal of Agronomy* 7, 261-270.

Boonen J., Kohnen H., Hennaert S., Humphries J., Jilg T. and Oenema J. (2013a) Data set of the DAIRYMAN project. A practical manual to assess and improve farm performances. DAIRYMAN Report Nr. 2.

Boonen J., Kohnen H., Grignard A., Planchon V., Stilmant D., Hennart S. and Beguin E. (2013b) Analyse de la diversité de systèmes laitiers en Europe du Nord-Ouest sur base de leurs performances économiques et environnementales. Carrefour des productions animales 18, pp. 1-14.

Briemle G., Elsaesser M., Jilg T., Mueller W. and Nussbaum H.J. (1996) Nachhaltige Gruenlandbewirtschaftung in Baden-Wuerttemberg. In: Linckh G., Sprich H., Flaig H. and Mohr H., (eds.): Nachhaltige Land- und Forstwirtschaft – Expertisen, Springer-Verlag, Heidelberg, pp. 215-263.

Breitschuh G., Eckert H. and Heissenhuber A. (2001) Ökonomische, ökologische und soziale Kriterien zur Beurteilung einer nachhaltigen Landwirtschaft. *KTBL-Schrift* 400, 7-21.

Breitschuh G., Eckert H., Matthes E. and Struempfel J. (2008) Kriteriensystem nachhaltige Landwirtschaft (KSNL). *KTBL-Schrift* 466, KTBL Darmstadt.

Brundtland G.H. (1987) Our common future. World Commission on Environment and Development, 383, Oxford University Press, Oxford.

Christen O., Hoevelmann L., Huelsbergen K.J., Packeiser M., Rimpau J. and Wagner B. (2009) Nachhaltige landwirtschaftliche Produktion in der Wertschoepfungskette Lebensmittel. Erich Schmidt Verlag, Berlin.
Coutey L. (2014) Development of a sustainability assessment methodology for European dairy farms using automatic milking systems and grazing. Master thesis, ESA Angers.
De Mey K., D´Haene K., Marchand F., Meul M. and Lauwers L. (2011) Learning through stakeholder involvement in the implementation of MOTIFS: an integrated assessment model for sustainable farming in Flanders. *International Journal of Agricultural Sustainability* 9, 350-363.
DLG (2015) Nachhaltigkeitsbericht. Deutsche Landwirtschaftsgesellschaft, Frankfurt (a.M.) www.DLG.org
Dubois D. (2002) Gedanken zur Forschung für eine nachhaltige Landwirtschaft. *Agrarforschung*, 9, 188-193.
Doluschitz R. and Hoffmann C. (2013) Überblick und Einordnung von Bewertungssystemen zur Nachhaltigkeitsmessung in Landwirtschaft und Agribusiness. *KTBL-Schrift* 500, 34-47.
Elsaesser M., Herrmann K. and Jilg T. (2013) The DAIRYMAN-Sustainability-Index (DSI) as a possible tool for the evaluation of sustainability of dairy farms in Northwest-Europe. *DAIRYMAN Report* Nr. 3, Technical report LAZBW Aulendorf, 20 p.
Foray S., Beguin E., Ferrand M., Perrot C., Dolle J.B., Bechu T., Hennart S., Boonen J., Tirard S., Morin C. and Castellan E. (2013) Sustainability assessment of dairy farms in north-west Europe. *Renc. Rech. Ruminants* 20, 217-220.
Gaudino S., Goia I., Grignani C., Monaco S. and Sacco D. (2014) Assessing agro-environmental performance of dairy farms in northwest Italy based on aggregated results from indicators. *Journal of Environmental Management* 140, 120-134.
Gasparatos A., El-Haram M., and Horner M. (2008) A critical review of reductionist approaches for assessing the progress towards sustainability. *Environmental Impact Assessment Review* 28, 286-311.
Grignard A., Bailey J.S., Boonen J., Stilmant D. and Hennart S. (2013) The potential for improving the economic and environmental sustainability of dairy farming via farm diversification. *Grassland Science in Europe* 18, 96-98.
Grignard A., Bailey J.S., Bijttebier J., Boonen J., Castellan E., Tirard S., Lorinquer E., Jilg T., De Haan M., Mihailescu E., Stilmant D. and Hennart S. (2012) The farm management plan: a tool to support dairy farmers in their strategic decisions and to guide research centers in the definition of their research thematic. *Renc. Rech. Ruminants* 19, 269-272.
Girardin P. (2001) Französische Verfahren zur Bewertung von Umweltwirkungen landwirtschaftlicher Betriebe. *ITADA - Forum „Nachhaltige Landwirtschaft"*, Sissach (CH), IfuL Müllheim, 31-38.
Grenz J., Thalmann C., Staempfli A., Studer C. and Haeni F. (2009) RISE – a method for assessing the sustainability of agricultural production at farm level. *Rural Development News* 1, 5-9.
Guillaumin A., Hopquin J.P., Desvignes P. and Vinatier J.M. (2007) Caractériser la participation des exploitations agricoles d'un territoire au développement durable. Dictionnaire des indicateurs. Institut de l'Elevage, (F) .
Huelsbergen K.-J. (2003) Entwicklung und Anwendung eines Bilanzierungsmodells zur Bewertung der Nachhaltigkeit landwirtschaftlicher Systeme. Shaker-Verlag, Aachen.
Kopfmueller J., Brandl V., Joerissen J., Paetau M., Banse G., Coenen R. and Grundwald A. (2001) Nachhaltige Entwicklung integrativ betrachtet. Konstitutive Elemente, Regeln, Indikatoren. Berlin: edition sigma (Global zukunftsfaehige Entwicklung - Perspektiven für Deutschland, Bd. 1).
Larochelle D.L., Parent D.P., Allard G.A. and Pellerin D.P. (2007) Dairy farm sustainability: The economic component indicators. *Journal of Animal Science* 85, Suppl. 1, 330-331.
Lebacq T., Baret P.V. and Stilmant D. (2012) Sustainability indicators for live-stock farming. A review. *Agronomy for Sustainable Development* 33, (2), 311-327.
Marchand F., Debruyne L., Triste L., Gerrard C., Padel S. and Lauwers L. (2014) Key characteristics for tool choice in indicator based sustainability assessment at farm level. *Ecology and Society* 19, 3, 46 http://dx.doi.org/10.5751/ES-06876-190346.
Meul M., Van Passel S., Nevens F., Dessein J., Rogge E., Mulier A. and Van Hauwermeiren A. (2008) MOTIFS: a monitoring tool for integrated farm sustainability. *Agronomy for Sustain. Development* 28, 321-332.
Schader C., Grenz J., Meier M.S. and Stolze M. (2014) Scope and precision of sustainability assessment approaches to food systems. *Ecology and Society* 19(3), 42.
Schroeder D. (2003) Nachhaltigkeitsindikatoren für die Landwirtschaft und EU-Agrarpolitik. *Schule und Beratung* 2, II-1 bis II-5.
Triste L., Marchand F., Debruyne L., Meul M. and Lauwers L. (2014) Reflection on the development process of a sustainability assessment tool: learning from a Flemish case. *Ecology and Society* 19, 3, 47.
Vavra M. (1996) Sustainability of Animal Production Systems: An Ecological Perspective. *Journal of Animal Science* 74, 1418-1423.
Von Wiren-Lehr S. (2001) Sustainability in agriculture - an evaluation of principal goal-oriented concepts to close the gap between theory and practice. *Agriculture, Ecosystems and Environment* 84, 115-129.
Zahm F., Viaux P., Vilain L., Girardin P. and Mouchet C. (2008) Assessing Farm Sustainability with the IDEA Method - from the Concept of Agriculture Sustainability to Case Studies on Farms. *Sustainable Development* 16, 271-281.