Multilevel sustainability assessment of farming systems: a practical approach

Steven Van Passel[a] and Marijke Meul[b]

[a]Hasselt University, Faculty of Business Economics, steven.vanpassel@uhasselt.be
[b]University College Ghent, Dept. of Biosciences and Landscape Architecture, marijke.meul@hogent.be

Abstract: *Sustainability assessment is needed to build sustainable farming systems. A broad range of sustainability concepts, methodologies and applications already exists. They differ in level, focus, orientation, measurement, scale, presentation, etc…. Instead of trying to construct the ideal and complete sustainability assessment tool, we suggest to combine existing methods. A smart combination of methods with different purposes makes sustainability assessment more profound and broadens the possible applications. To illustrate the suggested approach, a combination of the sustainable value approach (SVA) and MOTIFS is presented. SVA is used to support policy makers, while MOTIFS is used to support farmers towards sustainability. Using data of specialised dairy and arable farms in Flanders, the multilevel sustainability assessment is illustrated by applying both SVA and MOTIFS. The combined use widens the insights without losing the particularities of the different approaches. An interesting insight is that the same farm accountancy data can be used to feed different indicator systems with different complementary goals at different levels (such as policy and farm level).*

Keywords: *sustainability assessment, integrated sustainability, multilevel, sustainable value, MOTIFS*

Introduction

Sustainability can be seen as a key element towards a long term future. Intervention towards sustainability is therefore necessary, but in order to monitor how well we are doing, indicators are needed (Hanley, 2000). Two major indicator-based sustainability assessment systems exist: (i) a set of indicators, and (ii) a single, composite index. In the first system, sustainability indicators are listed or presented together within a single table or diagram (visual integration); in the second approach the indicators are combined into a single index of sustainability (numerical integration).

Well-known examples of sustainability indicator sets are developed by the UN (United Nations, 2001), OECD (OECD, 2006) and the EU (European Commission, 2005). Examples of such indicator frameworks for agriculture can be found in Smith and McDonald (1998), Van Cauwenbergh et al. (2007) and Meul et al. (2008). These indicator sets have a common aim to draw up lists or more diagrammatic formats of indicators informing decision makers about changes in paths of economic, social and environmental phenomena, without trying to summarize this complexity in a single composite measure of sustainability.

Sets of sustainability indicators are often long including both qualitative and quantitative factors. Furthermore, these sets contain sometimes trade-offs among issues that cannot be resolved simultaneously (Cornelissen et al., 2001). Therefore, the indicator sets are often integrated in one single or a limited amount of composite indicators. Aggregated sustainability indicators in a compact form are in particular useful to compare policy options, because they summarize complex or multidimensional issues and they provide the big picture, without the danger of information overload. Furthermore, aggregated indices can help to convey simple messages and to reach new audiences, but also run the risk of being misinterpreted. Well known examples of numerical integrated indicators are the Ecological Footprint (Wackernagel and Rees, 1997), and the Genuine Savings (Pearce and Atkinson, 1993).

Instead of striving for the construction of the ideal and complete sustainability assessment approach, a smart combination of existing methods (with different purposes) can result in a sound and useful sustainability measurement. In fact, a combination of numerical and visual integrated sustainability measurement can lead up to clear insights and to a higher use of sustainability assessment tools. In other words, a broader and more profound sustainability measurement can motivate and recruit more users (decision makers). In addition to this, the combined use of existing methods should minimize data and time requirement to realise the higher impact expected and thus optimise the equilibrium of accuracy and practicality.

To illustrate the general approach, this papers shows a multilevel sustainability assessment of farming systems by combining two existing sustainability assessment tools: SVA and MOTIFS. Both methods (SVA and MOTIFS) provide good guidance for decision making and make sustainability operational in a clear way. The Sustainable Value Approach (SVA) developed by Figge and Hahn (2004) is an interesting example of numerical integration. SVA is an improved eco-efficiency measure where economic, environmental and social resources are simultaneously taken into account. Applying opportunity cost thinking from financial economics to the use of all relevant resources, a relative measure (the sustainable value) is estimated to assess corporate sustainability. SVA aims to support policy making and proved to be suitable to assess farm sustainability in an integrated way (Van Passel et al., 2007). Moreover, we will show that SVA can be used to compare sustainability performance of different agricultural sectors. Besides the policy level, sustainability assessment at farm level is needed to guide farmers towards sustainability. An interesting example of visual integration is MOTIFS (MOnitoring Tool for Integrated Farm Sustainability; Meul et al., 2008), a user-friendly and strongly communicative tool that allows the measurement of progress towards sustainability at farm level.

In other words, SVA and MOTIFS are complementary tools: SVA is especially useful at policy level while MOTIFS is more appropriate at farm level. To illustrate the approach, SVA is applied in a case-study to compare the sustainability of Flemish specialised arable and dairy farms. At farm level, indicators can be calculated using MOTIFS to guide individual farmers within their subsector (e.g. dairy farming) in taking the proper actions towards more sustainable farms.

In the following section, a description is given of the SVA and MOTIFS methodology and a schematic overview of combining SVA and MOTIFS at different levels is explained. Next, the practical multilevel sustainability assessment is illustrated by a case-study of 28 specialised farms in Flanders. A final section concludes.

Multilevel sustainability assessment combining SVA and MOTIFS

Sustainable Value Approach (SVA)

The sustainable value approach is developed by Figge and Hahn (2004, 2005) and applies the logic of opportunity costs to the valuation of resources using a capital approach (e.g. Atkinson, 2000). Using the sustainable value approach, we consider that a firm contributes to more sustainable development whenever it uses its resources (economic, environmental and social) more productively than other companies and the overall resource use is reduced or unchanged. The following steps are required to calculate the sustainable value of a company. First, the scope of the analysis needs to be determined (i.e. economic activity or activities or entity or entities). Second, the relevant critical corporate resources with regard to sustainability performance within the chosen scope need to be determined. Third, the benchmark level needs to be determined. The choice of the benchmark determines the cost of the resource needs of a company, in other words the productivity that a company has to exceed. In fact, the eco-efficiency (or productivity) of a certain corporate resource is compared to the one of a benchmark while keeping the overall resource amount constant. If the productivity of the firm exceeds the opportunity cost (productivity of the benchmark), the company contributes to sustainability for the concerned resource. The differences between the company and the benchmark are then summed up and divided by the amount of considered resources with the sustainable value (SV) as a result. An interesting methodological and conceptual discussion about using benchmarks to measure the sustainable value can be found in Kuosmanen and Kuosmanen (2010) and Figge and Hahn (2010).

The sustainable value approach is already used for several interesting applications such as the sustainability assessment of an oil company (Figge and Hahn, 2005), the European manufacturing companies (Advance, 2006), the automobile industry (Hahn et al., 2008), and farms (Van Passel et al. (2007); Van Passel et al. (2009)). Furthermore, the approach is recently used to assess the contribution of European countries to sustainability (Ang et al., 2010).

MOnitoring Tool for Integrated Farm Sustainability (MOTIFS)

MOTIFS is an indicator-based sustainability monitoring tool. It allows us 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 (Fig. 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). This allows for a comprehensive overview and mutual comparison of the indicators for different sustainability themes. MOTIFS is a visual multi-level monitoring tool. Level 1 gives an overview of the farm's overall sustainability (Fig. 1). Level 2 gives an overview of the sustainability themes within a specific sustainability dimension. In level 3, the indicator scores for a specific theme are visualised. So, starting from an overall view of his farm's sustainability, a farmer can zoom in on the underlying themes and indicators into as much detail as desired. This is shown in Fig. 2. A detailed description of MOTIFS and its underlying methodology is provided by Meul et al. (2008).

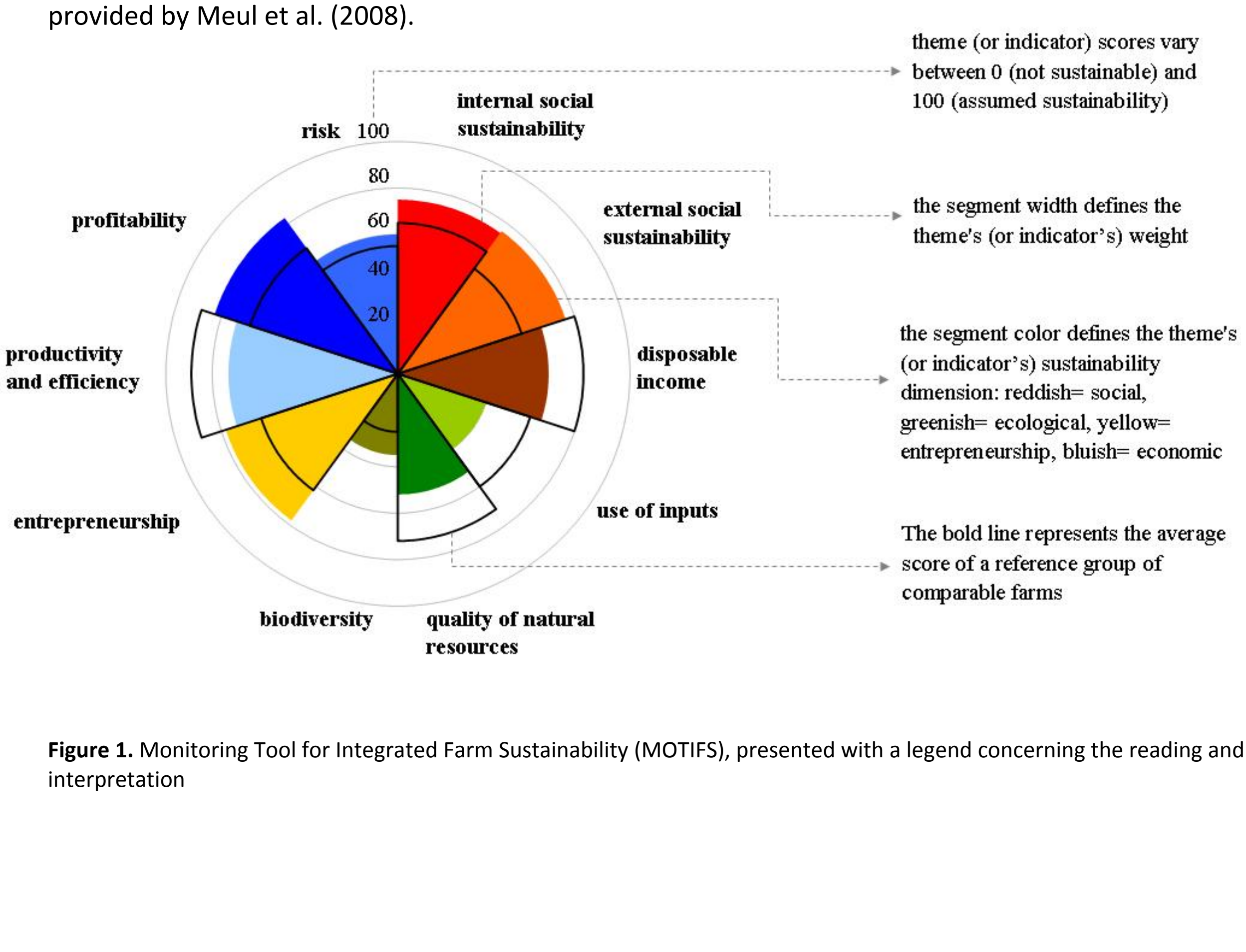

Figure 1. Monitoring Tool for Integrated Farm Sustainability (MOTIFS), presented with a legend concerning the reading and interpretation

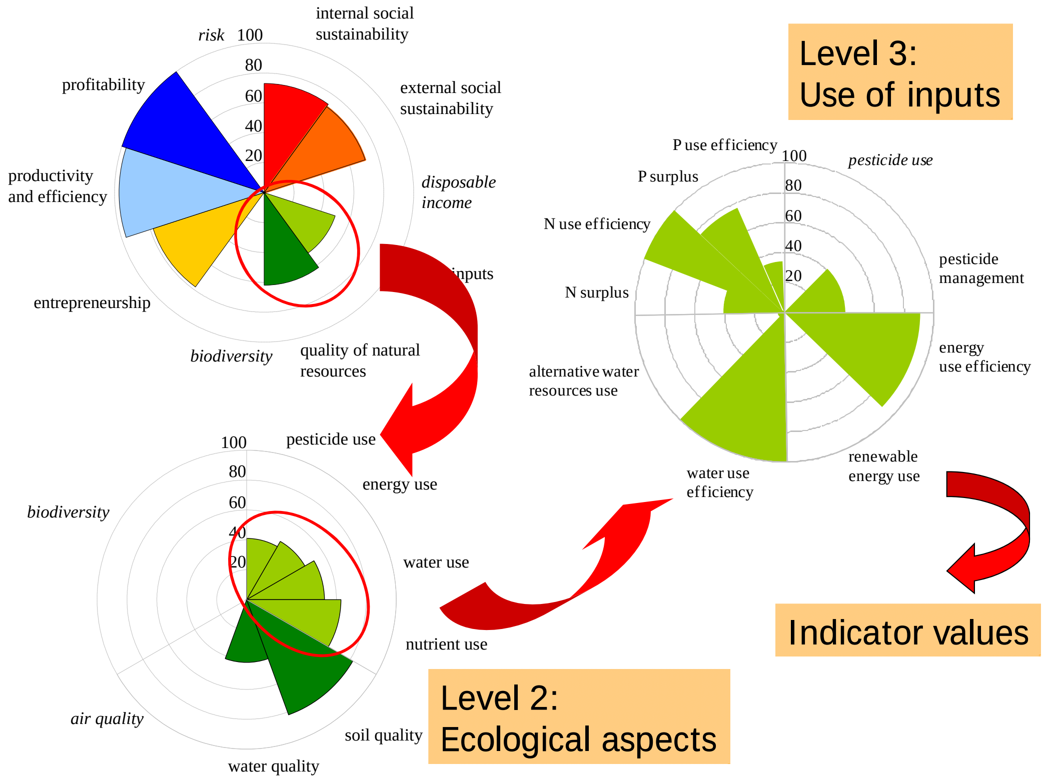

Figure 2. Multilevel application of MOTIFS, example of ecological aspects using the results of a case-study dairy farm

The aim of MOTIFS is to guide farmers' management towards a higher level of sustainability. During the design phase of the tool, a pilot study took place in which a selection of sustainability themes extracted from MOTIFS was applied to 20 Flemish dairy farms. In this pilot application, regular discussion sessions were organized for the whole group of participating farmers, in which they could discuss their results for a specific sustainability theme with the project leader and an invited expert. Meul et al. (2009) used the pilot study to develop and apply an extensive validation procedure for MOTIFS. Based on this validation, Meul et al. (2009) advised to structurally include this learning process in the practical application of MOTIFS through discussion groups of farmers to establish case- and site-specific advice.

Multilevel approach combining SVA and MOTIFS

Figure 3 shows an illustration of a practical multilevel approach to assess sustainability combining SVA and MOTIFS. In a first step, the sustainable value of different agricultural activities can be calculated to evaluate the performance of different agricultural subsectors. In this way, policy makers can be supported to develop a well balanced and focused policy. In a following step, the sustainability of farms can be monitored using indicator values comparing the performance of farms with similar farms (and hence within an agricultural subsector). In other words, MOTIFS can be used to guide farms towards more sustainable practices.

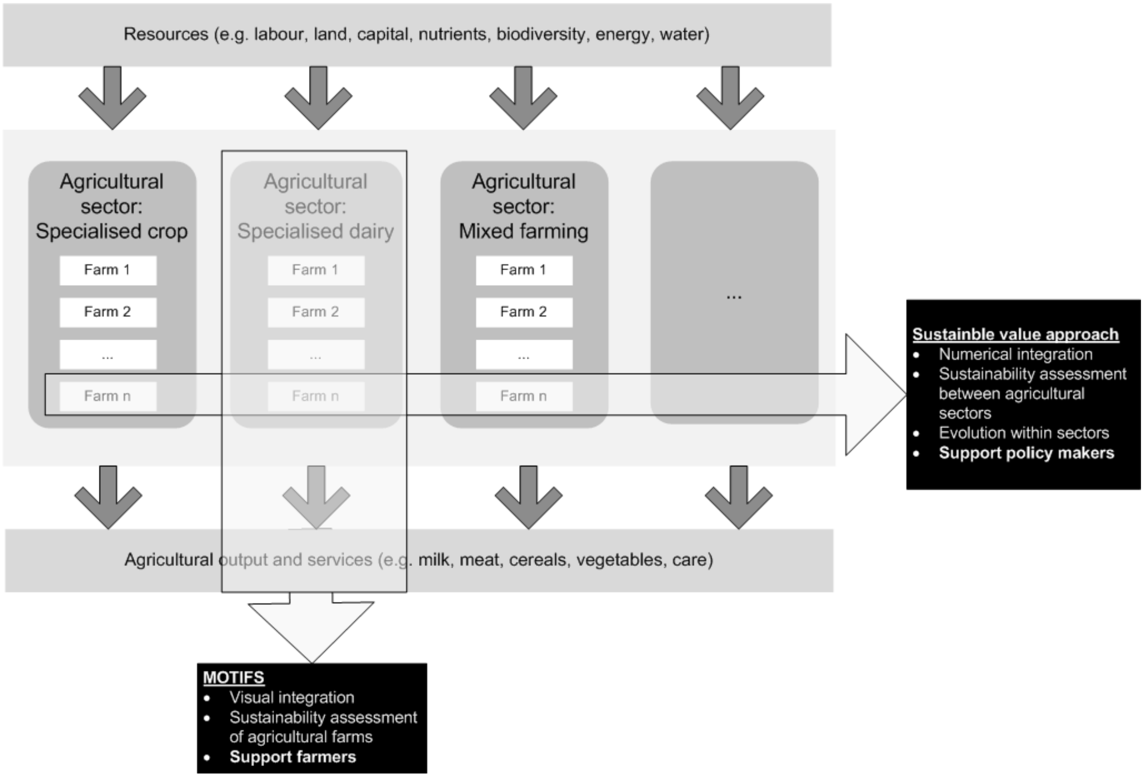

Figure 3. Multilevel sustainability assessment of farming systems.

Case-study: a practical multilevel sustainability assessment

Case-study farms

Farm accountancy data from specialised dairy and arable farms in Flanders (Belgium) are used. These data were collected by the European FADN database (Farm Accountancy Data Network). The Flemish FADN-data are collected and managed by the monitoring division of the Agricultural Monitoring and Study service of the Flemish Ministry for Agriculture. Both technical and economic data from a representative set of Flemish farms are available. We considered dairy farms as 'specialised' when at least 95% of the farm income originated from dairy activity. Specialised arable farms get at least 95% of the farm income from arable production. An overview of some average descriptive characteristics of the selected farms is presented in Table 1 and 2.

Table 1. Descriptive statistics of the data sample (data of the year 2000).

Characteristic	Unit	Average value
Arable farms	#	14
Cultivated area	Ha	34.4
Share of grain crops	%	46.0
Share of potatoes	%	16.1
Share of sugar beet	%	24.9
Share of maize	%	10.3
Yield of winter wheat	kg ha^{-1}	7488
Yield of sugar beet	kg ha^{-1}	64 486
Yield of potatoes	kg ha^{-1}	37 235
Value added	€	24 091
Labour	Hours $year^{-1}$	2825
Farm capital	€	161 467
Energy use (direct and indirect)	MJ	755 147
N surplus	kg N ha^{-1}	139
Age manager	Year	50
Higher education	%	36

Table 2. Descriptive statistics of the data sample (data of the year 2000).

Characteristic	Unit	Average value
Dairy farms	#	14
Utilised area	Ha	34.1
Milking cows	#	56
Milk production	l cow^{-1} $year^{-1}$	6350
	l ha^{-1} $year^{-1}$	11 380
Value added	€	54 120
Labour	Hours $year^{-1}$	4450
Farm capital	€	573 341
Energy use (direct and indirect)	MJ	1 289 397
N surplus	kg N ha^{-1}	288
Age manager	Year	41
Higher education	%	80

Sustainable value approach: dairy farms versus arable farms

As in Van Passel et al. (2007, 2009), we consider five resources: (i) farm labor, (ii) farm capital, (iii) farm land, (iv) nitrogen surplus and (v) energy consumption (direct and indirect). Capital, land and labor can be seen as traditional economic resources, while nitrogen surplus and energy consumption are important environmental aspects in farming. Note that for both specialised dairy farms and arable farms the same relevant resources are selected. The relevant resources are based on literature and the availability of data. Data on other relevant sustainability resource such as for example the emissions of greenhouse gasses or on animal welfare (for dairy farms) were not available. The data sample contains dairy farms and arable farms with similar regional, soil and land use characteristics. In this way, a general comparison with regard to the sustainability performance (based on a limited amount of resources) is possible. In our application, we opt as benchmark for the average return on resource of the whole sample of 28 farms (14 dairy and 14 arable farms). As already explained, the sustainable value can be calculated by comparing the eco-efficiencies (or productivities) of each farm with the eco-efficiency of the proposed benchmark. In fact, the sustainable value estimations indicate how much more or less return has been created with the resources available in comparison with the benchmark. To take the company size into account, we can calculate the return-to-cost ratio (RtC), by dividing the value added of a company by the cost of the sustainable resources. The cost of sustainable resource use is given by the difference between the value added and the sustainable value. The return-to-cost ratio equals unity if the value added corresponds to the cost of all resources. A return-to-cost ratio higher than one means that the company is overall more productive than its benchmark. The return-to-cost ratio shows by which factor the farm exceeds or falls short of covering its cost of economic, environmental and social resources or in other words by which factor it exceeds or falls short compared with the benchmark productivity

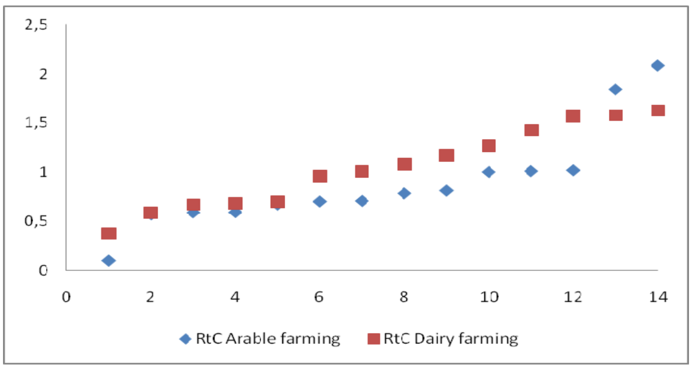

Figure 4. Return-to-Cost ratio using weighted average benchmarks.

Figure 4 shows the sustainability performance (return-to-cost ratio) of the specialised dairy (14) and arable farms (14). The performance of arable farms is on average lower than the performance of the dairy farms. However, the two best performing farms are arable farms. Figure 4 also shows that larger differences exist within the arable farms (range RtC: 0.1 – 2.1) compared to the dairy farms (range RtC: 0.4 – 1.6). Note that this analysis is rather descriptive and one should be careful with generalization of the results.

Table 3 shows that dairy farms have a very high land productivity compared to arable farms, and a higher labour productivity and eco-efficiency of the energy use. On the other hand, arable farms clearly outperform dairy farms with regard to capital productivity and eco-efficiency of N surplus. Policies with a clear focus on the reduction of the N surplus on dairy farms are important to strengthen the sustainability performance. Arable farming in Flanders has clearly limitations due to space constraints. However, increasing labour productivity and value added is possible as shown by two arable farms with a high RtC (Figure 4). In other words, a straightforward policy conclusion comparing the agricultural subsectors is to focus on the reduction of N surplus of dairy farms (e.g. feed optimisation) and to focus on higher value creation on arable farming (e.g. on farm sales).

Table 3. Resource productivities and eco-efficiencies.

	Labor productivity (€ / hours labour)	Capital productivity (€/€)	Land productivity (€/ha)	Eco-efficiency energy use (€/MJ)	Eco-efficiency N surplus (€/kg N)
Arable farms	9.17	0.18	713.48	0.03	9.37
Dairy farms	11.3	0.10	1568.94	0.04	6.21

Table 4 shows the differences of farm characteristics between high (RtC>1) and low (RtC≤1) performing farms. The weighted average benchmarks are used to calculate the sustainable value and the return-to-cost ration (RtC) (as in Fig. 4). Table 4 shows that the majority of arable farms have a RtC≤1, while the majority of the dairy farms have a higher RtC. In general, younger farm managers obtain better results, while educational level and solvency has no impact on the sustainability performance. A straightforward policy suggestion is to stimulate succession and to rejuvenate farming towards specialised dairy activities.

Table 4. Descriptive statistics of all farms, frontrunners and laggards (average values).

Variables	All farms	Farms with a RtC≤1	Farms with a RtC>1
Sustainable value (Euro)	0	-14 156	+14 157
Age of manager (years)	45	49	42
Solvency (%)	65	64	67
Share higher education (%)	57	57	57
Share arable farms (%)	50	64	36

MOTIFS: sustainability of dairy farms and arable farms

In the application of MOTIFS, farm results are compared within each farm agricultural subsector, contrary to the application of the SVA method, where the dairy farms and arable farms are compared to one another. For all farms of both farm types (dairy and arable), the following indicators could be calculated based on the FADN data: N surplus, N use efficiency, direct and indirect energy use efficiency are used to perform an evaluation of the ecological sustainability of the farms, while productivity and profitability indicators are used to evaluate their economic sustainability. Indicators for social sustainability aspects – as well as other ecological indicators – could not be calculated, because of the lack of the necessary data. Since all FADN-farms are anonymous and we can only work with the data provided in the FADN, only a selection of MOTIFS indicators could be calculated. Some indicators – e.g. concerning animal welfare or landscape management – require qualitative data from questionnaires or checklists. Hence, these indicators cannot be calculated based on the quantitative FADN data. An overview and description of the MOTIFS indicators used in the case-study can be found in Nevens et al. (2006), Meul et al. (2007) and Meul et al. (2008).

In this section, we describe the results of the MOTIFS application to the selected dairy farms. The indicator values can be found in Table 5. The application and use of the MOTIFS-tool to arable farms is completely similar.

Table 5. Indicator values dairy farms.

		Lowest value	Average value	Highest value
Economic analysis				
Labour productivity	*€/MWU[a]*	*7248.61*	*27 232.02*	*53 724.80*
Capital productivity	*€/€*	*0.04*	*0.10*	*0.18*
Land productivity	*€/ha*	*588.50*	*1568.94*	*2509.92*
Labour profitability	*€/MWU[a]*	*-34 951.96*	*-1512.83*	*13 708.18*
Return on equity	*€/€*	*-0.52*	*-0.17*	*-0.01*
Return on assets	*€/€*	*-0.15*	*-0.06*	*0.00*
Ecological analysis				
N surplus	*kg N/ha*	*144.43*	*287.65*	*598.35*
N use efficiency	*l milk/kg N surplus*	*20.62*	*40.90*	*58.28*
Direct energy use efficiency	*l milk/ 100 MJ direct energy use*	*48.73*	*86.48*	*177.61*
Indirect energy use efficiency	*l milk/ 100 MJ indirect energy use*	*30.51*	*41.19*	*58.91*

[a]*MWU*= Man-Work Unit. 1 MWU is the equivalent of 2400 working hours

For each indicator, we converted the value into a score between 0 and 100, by using respectively the results of the lowest-performing and best-performing case-study farm as benchmark values. This choice of benchmarks was made based on the validation results, where users of the tool expressed their appreciation of using indicator values of the 10% best performing and 10% lowest performing farms as benchmarks, since this results in a dynamic and motivating tool for farmers, setting realistic goals (Meul et al., 2009). For each farm, indicator scores were integrated in a MOTIFS graph. Figure 5 shows the MOTIFS results for four case-study dairy farms as an example. For each indicator, the average score of large representative group of FADN dairy farms is indicated by the black bold line.

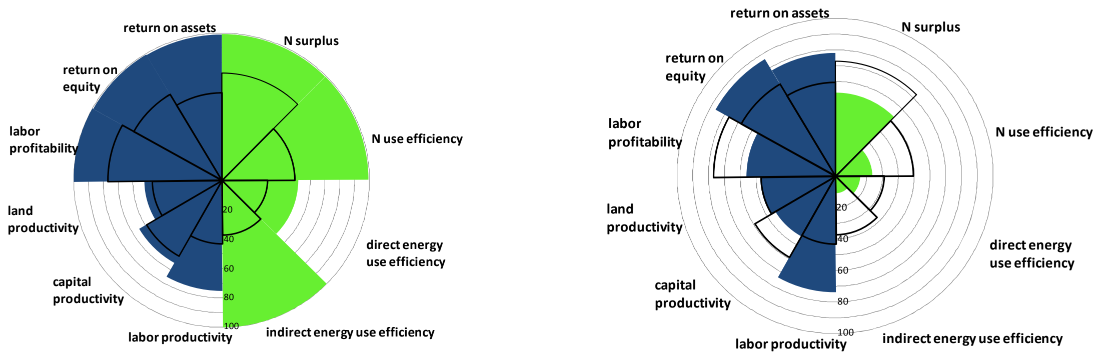

Figure 5. MOTIFS results of four dairy farms.

Application of MOTIFS involves the discussion of the MOTIFS results in a discussion group, in which the 14 dairy farmers participate. During these discussions, farmers can exchange knowledge and expertise and discuss the background of the indicator results with an expert. For example, using the results shown in Fig. 5, the top left farm could be set as an example for the considered economic and ecological sustainability aspects. Experiences and management practices of that farmer – combined with an expert opinion – can be an inspiration for the other farmers and give them insights into management aspects or innovations that could be applied to their own farm, in order to improve the sustainability.

Conclusion and discussion

Without integrated information on sustainability problems, awareness of these issues will be limited and the formulation and monitoring of responses will be difficult. An important step is to move from trying to define sustainability towards developing concrete tools for measuring and promoting achievements in sustainability. In fact, this means that sustainability has to be defined in considerably narrower terms in order to establish operational rules. Hence, sustainability assessment is inevitably based on strong simplifications both of the theoretical paradigm and of the characteristics of systems of concern. Several approaches can be distinguished to integrate the sustainability dimensions: (i) a set of indicators (visual integration) and (ii) a single, composite index or a limited amount of aggregated indicators (numerical integration).

Instead of trying to develop the perfect and complete sustainability assessment tool, we propose to combine existing methods. Therefore, we combined two different approaches: SVA (numerical integration of sustainability dimensions) and MOTIFS (visual integration of sustainability dimensions). The sustainable value approach (SVA) is used to support policy makers, while MOTIFS is used to guide farmers towards sustainability. In this way, a practical approach on different levels is developed to assess farming systems. This multilevel approach is illustrated in a case-study of specialised dairy and arable farms in Flanders. The sustainable value of 14 dairy farms is compared with the sustainable value of 14 arable farms. The dairy farms in our sample have on average a higher sustainability performance than the arable farms. In other words, dairy farms realise relatively more sustainable value using their resources (both economic and ecological). Note that the sustainable value integrates the performance (productivity and eco-efficiencies) of different resources. In this case, the relatively good performance of dairy farms of using labour, land and energy outweighs the low performance of using capital and N surplus compared to arable farms. Hence, a straightforward policy advice using SVA is to stimulate the development of well-balanced dairy farms with a clear focus on reducing the N surplus. On farm level, MOTIFS can be used to compare the sustainability performance within a discussion group of comparable farms (e.g. specialised dairy farms). In our illustration, indicator scores of the dairy farms are calculated and integrated in a MOTIFS graph. Farmers discuss the background of their indicator results with other farmers and experts. Farm experiences and management practices together with expert opinions, motivates and stimulates farmers to improve their sustainability. More concrete, dairy farmers can exchange practices and knowledge to reduce the amount of N surplus. On the other hand, analysing the sustainable value, dairy farmers can recognize that the N surplus of specialised arable farms is clearly lower than the N surplus of dairy farms. In the other way around, farm level sustainability analysis using MOTIFS can help policy makers, using SVA, by formulating within discussion groups useful policy ideas or targets for example to reduce N surplus.

Hence, using SVA combined with MOTIFS results in a sustainability multilevel assessment, strengthening and framing the assessment on the different levels without losing the particularities of the different approaches. A smart combination of methods with different aims makes sustainability assessment more profound and broadens the possible applications. An interesting insight is that for both methods – SVA and MOTIFS – the same data can be used. In other words, the same farm accountancy data can be used to feed different indicator systems with different complementary goals on different levels (e.g. policy support and farm support). In this way, using a combined approach does not require a significantly higher amount of time and data.

References

ADVANCE (2006) Sustainable Value of European Industry: a value-based analysis of the environmental performance of European Manufacturing companies. full-version report (http://www.advance-project.org)

Ang, F., Mathijs, E. and S. Van Passel (2010) Assessing Contributions of the EU-15 Countries to Sustainability with the Sustainable Value Approach. Submitted for publication in *Ecological Economics*

Atkinson, G. (2000) Measuring corporate sustainability. *Journal of Environmental Planning and Management* 43(2), 235-252

Cornelissen, A., van den Berg, J., Kroops, W., Grossman, M. and H. Udo (2001) Assessment of the contribution of sustainability indicators to sus tainable development: a novel approach using fuzzy set theory', *Agriculture, Ecosystems and Environment* 86: 173-185.

European Commission (2005) Measuring progress towards a more sustainable Europe: sustainable development indicators for the European Union. Technical report, Eurostat, Luxembourg.

Figge, F. and T. Hahn (2004) Sustainable value added – measuring corporate contributions to sustainability beyond eco-efficiency. *Ecological Economics* 48: 173-187

Figge, F. and T. Hahn (2005) The cost of sustainability capital and the creation of sustainable value by companies. *Journal of Industrial Ecology* 9(4): 47–58

Figge, F. and T. Hahn (2010) Not measuring sustainable value at all: A response to Kuosmanen and Kuosmanen. *Ecological Economics* (in press)

Hahn, T., Figge, F. and R. Barkemeyer (2008) Sustainable Value in Automobile Manufacturing.

Hanley, N. (2000) Macroeconomic measures of sustainability. *Journal of economic surveys* 14: 1-30

Kuosmanen, T. and N. Kuosmanen (2010) How not to measure sustainable value (and how one might). *Ecological Economics* (in press).

Meul, M., Nevens, F., Reheul, D. and G. Hofman (2007) Energy use efficiency of specialized dairy, arable and pig farms in Flanders. *Agriculture, Ecosystems and Environment* 119: 135-144

Meul, M., Van Passel, S., Nevens, F., Dessein, J., Rogge, E., Mulier, A. and A. Van Hauwermeiren (2008) MOTIFS: a monitoring tool for integrated farm sustainability. *Agronomy for Sustainable Development* 28: 321-323

Meul, M., Nevens, F. and D. Reheul (2009) Validating sustainability indicators: focus on ecological aspects of Flemish dairy farms. *Ecological Indicators* 9, 284-295.

Nevens, F., Verbruggen, I., Reheul, D. and G. Hofman (2006) Farm gate nitrogen surpluses and nitrogen use efficiency of specialized dairy farms in Flanders: evolution and future goals. *Agricultural Systems* 88: 142-155.

OECD (2006) OECD factbook 2006, economic, environmental and social statistics. 2nd ed., Organisation for Economic Co-operation and Development, Paris.

Pearce, D.W. and G.D. Atkinson (1993) Capital theory and the measurement of sustainable development: an indicator of weak sustainability. *Ecological Economics* 8: 103-108

Smith, C. and G. McDonald (1998) Assessing the sustainability of agriculture at the planning stage. *Journal of Environmental Management* 52: 15-37

Van Cauwenbergh, N., Bielders, K. B. C., Brouckaert, V., Franchois, L., Garcia Cidad, V., Hermy, M., Mathijs, E., Muys, B., Reijnders, J., Sauvenier, X., Valckx, J., Vanclooster, M., Van der Veken, B., Wauters, E. and A. Peeters (2007) SAFE - a hierachical framework for assessing the sustainability of agricultural systems. *Agriculture, Ecosystems and Environment* 120: 229-24.

Van Passel, S., Nevens, F., Mathijs, E. and G. Van Huylenbroeck (2007) Measuring farm sustainability and explaining differences in sustainable efficiency. *Ecological Economics* 62: 149-161

Van Passel, S., Van Huylenbroeck, G., Lauwers, L. and E. Mathijs (2009) Sustainable value assessment of farms using frontier efficiency benchmarks. *Journal of Environmental Management* 90 (10): 3057-3069.

United Nations (2001) Indicators of sustainable development: guidelines and methodologies. United Nations.

Wackernagel, M. and W.E. Rees (1997) Perceptual and structural barriers to investing in natural capital: economics from an ecological footprint perspective. *Ecological Economics* 20: 3-24

WBCSD (2000) *Eco-efficiency: creating more value with less impact*. World Business Council for Sustainable Development.