

Ehrmann, Markus; Kleinhanß, Werner

Working Paper

Review of concepts for the evaluation of sustainable agriculture in Germany and comparison of measurement schemes for farm sustainability

Arbeitsberichte aus der vTI-Agrarökonomie, No. 14/2008

Provided in Cooperation with:

Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries

Suggested Citation: Ehrmann, Markus; Kleinhanß, Werner (2008) : Review of concepts for the evaluation of sustainable agriculture in Germany and comparison of measurement schemes for farm sustainability, Arbeitsberichte aus der vTI-Agrarökonomie, No. 14/2008, Johann Heinrich von Thünen-Institut (vTI), Braunschweig,
<https://nbn-resolving.de/urn:nbn:de:gbv:253-200909-dk041410-6>

This Version is available at:

<https://hdl.handle.net/10419/39397>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Review of concepts for the evaluation of sustainable agriculture in Germany and comparison of measurement schemes for farm sustainability

Markus Ehrmann, Werner Kleinhanss

Arbeitsberichte aus der vTI-Agrarökonomie

14/2008

This document presents results obtained within the EU project SSPE-CT-2006-44215 on Sustainable Value Analysis of Policy and Performance in the Agricultural Sector (<http://www.svappas.ugent.be>). It does not necessarily reflect the view of the European Union and in no way anticipates the Commission's future policy in this area

Markus Ehrmann und Dr. Werner Kleinhanß sind wissenschaftliche Mitarbeiter am Institut für Betriebswirtschaft des Johann Heinrich von Thünen-Instituts.

Adresse: Institut für Betriebswirtschaft
Johann Heinrich von Thünen-Institut (vTI),
Bundesforschungsinstitut für Ländliche Räume, Wald und Fischerei
Bundesallee 50
D-38116 Braunschweig

Telefon: (+49) (0)531 596-5165

E-mail: markus.ehrmann@vti.bund.de

Die *Arbeitsberichte aus der vTI-Agrarökonomie* stellen vorläufige, nur eingeschränkt begutachtete Berichte über Arbeiten aus dem Institut für Betriebswirtschaft, dem Institut für Ländliche Räume und dem Institut für Marktanalyse und Agrarhandelspolitik des Johann Heinrich von Thünen-Instituts dar. Die in den Arbeitsberichten aus der vTI-Agrarökonomie geäußerten Meinungen spiegeln nicht notwendigerweise die der Institute wider. Kommentare sind erwünscht und sollten direkt an die Autoren gerichtet werden.

Der vorliegende Arbeitsbericht kann unter http://www.vti.bund.de/de/institute/bw/publikationen/bereich/ab_14_2008_de.pdf kostenfrei heruntergeladen werden.

Zusammenfassung

Im Rahmen des EU-Forschungsprojekts SVAPPAS wird die Anwendung einer Methode für Nachhaltigkeitsbewertung, basierend auf Prinzipien von Finanzmärkten (Sustainable Value (SV)), im Bereich der Landwirtschaft getestet und weiter entwickelt. Für die vorliegende Analyse werden Daten aus dem deutschen Testbetriebsnetz verwendet. Sie zielt darauf ab, verschiedene in Deutschland verfügbare und im Rahmen des Projektes weiter entwickelte Bewertungskonzepte am Beispiel von Milchvieh haltenden Betrieben anzuwenden und zu testen. Die Ergebnisse der Data Envelopment Analyse (DEA) und es SV-Ansatzes führen zu ähnlichen Bewertungen. Im Gegensatz zur hohen Korrelation zwischen SV und DEA kann eine ziemlich niedrige Korrelation mit den ökologischen Indikatoren beobachtet werden; zudem sind Ergebnisse von SV und ökologischen Indikatoren entgegengesetzt.

Deshalb scheint es notwendig, mehrere Bewertungskonzepte zu verwenden, um ein umfassenderes Bild der einzelnen Dimensionen der Nachhaltigkeit zu bekommen.

JEL: Q01, Q3, Q5, D24

Schlüsselwörter: Nachhaltigkeit, Effizienzanalyse, Indikatoren, Milchviehbetriebe

Summary

Within the EU research project SVAPPAS, a method of sustainability measurement based on principles of financial markets, will be tested wrt sustainability issues in agriculture, and further developed. This analysis is oriented to farm level approach based on FADN data. The study goes in two directions; first, measurement concepts available in German are reviewed, and second, the different methods are applied to a sample of dairy farms selected from the national FADN. The results of DEA, Sustainable Value and economic indicators lead to similar conclusions in most assessments. In contrast to the high correlation between Sustainable Value and DEA, a rather low correlation with the ecological indicators can be observed. Moreover, results of SV and economic indicators are generally contrary to ecological indicators. In each case it seems to be reasonable to use more than one approach for the assessment, to get a more detailed and comprehensive picture of the individual dimensions and issues of sustainability.

JEL: Q01, Q3, Q5, D24

Keywords: Sustainability, efficiency analysis, indicators, dairy farms

Content

Zusammenfassung/Summary	i
1 Introduction	1
2 Overview of concepts for the evaluation of sustainable agriculture in Germany	2
2.1 The method “Criteria for sustainable farming (KSNL)”	2
2.1.1 Criteria for an Ecologically Compatible Land Management (KUL)	3
2.1.2 Criteria for economic and social sustainability (KWL, KSL)	7
2.1.3 Conclusion with regard to the KSNL approach	9
2.2 The system “Reproduction of Soil Fertility (REPRO)”	10
2.3 The “DLG-Sustainability certificate”	17
2.4 Sustainable Value Approach	21
2.5 Data Envelopment Analysis	22
3 Comparison of selected measurement concepts for farm sustainability, a case study using FADN data	24
3.1 Data and methods	24
3.2 Results	26
3.2.1 Results of Sustainable Value Approach	26
3.2.2 Results of the Data Envelopment Analysis	28
3.2.3 Results of the indicator concept	29
3.3 Comparison of the selected approaches	32
3.3.1 Differences between the selected approaches	32
3.3.2 Correlations between sustainability concepts	34
4 Summary and conclusions	35
5 References	37

List of Figures

Figure 2.1:	Environmental concepts and criteria for environmental sustainability in KUL	4
Figure 2.2:	Principles of classification of sustainability criteria in KUL	5
Figure 2.3:	The farm as a system	11
Figure 2.4:	Structure of REPRO	13
Figure 2.5:	Relation between the dimensionless scale and the data of indicators	15
Figure 2.6:	Demonstration of the outcomes using the web-technique	16
Figure 2.7:	Nitrogen cycle inside a farm	16
Figure 3.1:	Frequency (%) and cumulative frequency (%) of Sustainable Value	27
Figure 3.2:	Frequency (%) and cumulative frequency (%) of Data Envelopment Analysis	29
Figure 3.3:	Frequency (%) and cumulative frequency (%) of ecological indicators (KUL)	31
Figure 3.4:	Frequency (%) and cumulative frequency (%) of the number of economic indicators inside tolerance ranges	31

List of Tables

Table 2.1:	Tolerance range and target values of ecological indicators (KUL)	6
Table 2.2:	Evaluation criteria of economic sustainability (KWL)	8
Table 3.1:	Results of the SV, DEA and indicator concepts by size classes and intensities	27
Table 3.2:	Results of SV, DEA and indicator concepts for different shares of LFA and organic and conventional production systems	30
Table 3.3:	Ranking of SV, DEA and indicator concepts by size classes	33
Table 3.4:	Spearman correlation between SV, return-to-cost ratio, DEA, economic and ecological indicators	34

1 Introduction

Sustainability is a multifunctional concept and thus not easy to assess or to evaluate. It includes the ecological, economic and social dimensions of sustainability (BARBIER, 1987). Sustainability follows a normative approach; the BRUNDTLAND COMMISSION (1987) defines sustainability as a concept which meets the present needs without compromising the needs of future generations.

Environmental aspects are a main part of sustainability. Farming affects nature and is thus responsible for changes and burdens of ecosystems. The utilised agricultural area (UAA) of Germany amounts to almost half of the total area (BMELV, 2006). Therefore the agricultural sector significantly affects sustainable development. An aim of German agricultural policy is to measure and support sustainable development of farms (BMELV, 2008).

In Europe more than 40 approaches for the assessment of sustainable issues in agriculture are available. Concepts for holistic evaluations of sustainability are developed and tested; not all of them are practicable, yet.

Different approaches can be used to measure sustainability at the farm level e.g. (HÜLSBERGEN, 2003; SCHAFFNER and HÖVELMANN, 2007; TLL, 2006b). One of these methods, the Sustainable Value Approach (SV) is expressed as monetary value. This methodology “borrows the idea from financial economics that the return on capital has to cover the cost of capital. Capital costs are determined as opportunity costs” (FIGGE HAHN, 2005). To verify this method, comparisons are made with other methods, e.g., indicator methods and Data Envelopment Analysis (DEA). Embedded in an EU research project “SVAPPAS”, the SV approach will be tested, further developed and applied for the agricultural sector. This working paper contains preliminary outcomes. Aim of the project is the development of a method for the assessment of sustainable performance and policy in agriculture.¹

The paper is structured as follows: in the first part concepts developed and used in Germany so far are briefly described. The second part focuses on the application and comparison of different measurement concepts, based on a sample of dairy farms included in the national Farm Accounting Data Network. Conclusions are drawn in Chapter 4.

¹ For further information: www.svappas.ugent.be

2 Overview of concepts for the evaluation of sustainable agriculture in Germany

During the last 10 years different indicator concepts were developed in Germany and tested at the farm level. In the following, main concepts being applied in Germany are described briefly: KUL (Criteria for an Ecologically Compatible Land Management), REPRO (Reproduction of Soil Fertility) and the DLG sustainable performance certificate. Additionally two efficiency approaches will be presented: Data Envelopment Analysis and a rather new concept in the agricultural sector, the Sustainable Value Approach.

2.1 The method “Criteria for sustainable farming (KSNL)”

The assessment system KUL (Criteria for an Ecologically Compatible Land Management) has been developed by the Thueringer Landesanstalt fuer Landwirtschaft (TLL) since 1994. In an earlier stage, it aimed at recording and assessing ecological damage by agricultural enterprises.

The system was further improved with regard to methods of measurement and selection of indicators by expert groups of the VDLUFA.² It is basis for the VDLUFA system USL (Environmental Safeguarding of Farming). Its main objectives are:

- Extension of the system to a country-wide application in Germany
- Creation of a certification system with regard to environmental compatibility

Up to now, KUL/USL has been used and tested in approximately 250 farms. Since 2004, KUL has been developed further by the TLL with regard to a comprehensive assessment of economic and social sustainability

- Criteria for economically sustainable farming (KWL)
- Criteria for socially compatible farming (KSL)

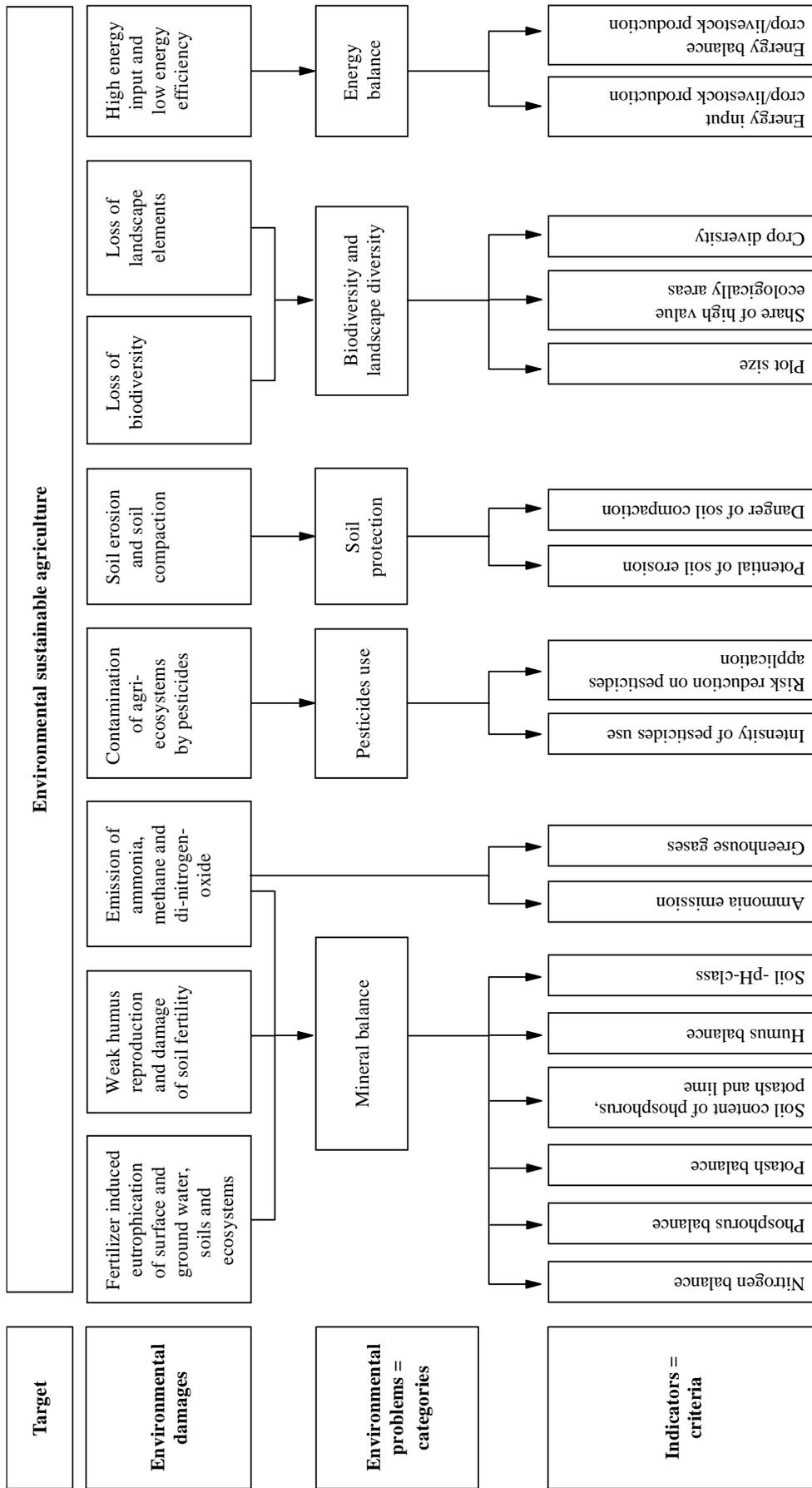
The whole system is referred to as KSNL (Criteria for sustainable farming).

² Verband Deutscher Untersuchungs- und Forschungsanstalten

2.1.1 Criteria for an Ecologically Compatible Land Management (KUL)

KUL is characterised as a criterion system to assess ecologically compatible farming. It covers the relevant environmental damages from agriculture (soil, water, air, biodiversity, use of energy) determined by the National Council of Environment (SRU RAT VON SACHVERSTÄNDIGEN FÜR UMWELTFRAGEN 1985). Referring to the scheme of ROEDENBECK (2004), problem areas are differentiated as follows: nutrient balances, pesticide use, soil conservation, landscape and crop diversity as well as energy balance (Figure 2.1). A number of indicators from these categories (criteria) are assigned in KUL (at present 17), aiming at the measurement and validation of environmental sustainability.

Figure 2.1: Environmental concepts and criteria for environmental sustainability in KUL

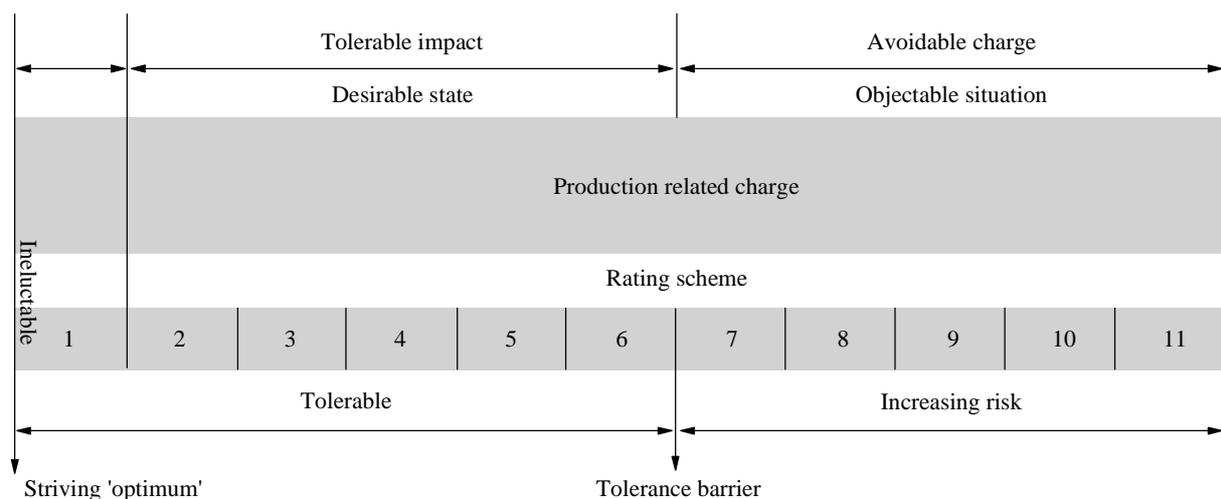


Source: Roedenbeck (2004).

Indicators/criteria are related to the whole farm. Charge indicators are used which are described as Driving-Force Indicators (OECD nomenclature). Indicators are derived as measurable values and compared with optimal conditions or tolerance ranges. Deviations going beyond the tolerance limits are mentioned as damage potential. With regard to comparability, the indicators are transformed into a uniform scale (rating) ranging from 1 to 11 (Figure 2.2):

- Optimum conditions are defined as management practises with a level of ecological damage which are considered as 'indispensable' (Rating 1).
- Furthermore a 'tolerance range' is defined in which the greatest tolerable charges get the rating 2 to 6.
- Charges exceeding the tolerance range are described as potential damage (Rating 7 to 11).

Figure 2.2: Principles of classification of sustainability criteria in KUL



Source: Breitschuh (2006).

Intermediate scales within the tolerance range are based on a linear deviation from the optimum, while those beyond are based on a logarithmic deviation. The tolerance range for the majority of indicators includes positive and negative deviations from the optimum. For approximately half of the indicators the optimum values are modified by farm specific location factors. KUL criteria and their dimensions, optimum values, tolerance range and modifications due to location factors are summarized in Table 2.1.

Table 2.1: Tolerance range and target values of ecological indicators (KUL)

Criteria	Dimension	Optimum (Rate 1)	Tolerable level	Modification factor
Mineral balances				
Nitrogen balance	kg N/ha·a	0 ... 20	-50 ... +50	Leakage water
Phosphorus balance	kg P/ha·a	0	-15 ... +15	P-class
Potash balance	kg K/ha·a	0	-50 ... +50	K-class
Ammonia emission	kg N/ha·a	< 25	< 50	
Soil-pH-class	A ... E	C	C ... D	Subsoil rocks
Humus balance	kg C/ha	0	-75...+300	Content class
Soil protection				
Soil erosion	t/ha·a		3.1 / 8	Losses
Soil compaction	Quotient	1.0	1.0 ... 1.25	
Pesticides use				
Intensity of pesticides use	€/ha·a	< 70	< 120	Share of arable cops
Integrated pesticide management	Index	17	10 ... 17	
Biodiversity/landscape				
Share of high value ecological areas	%	9 ... 22	6 ... 15	Location
Crop diversity	Index	> 2.2	> 1.25	Median of plot size
Plot size	ha	< 20	< 40	Location
Energy balance				
Energy input (crops)	GJ/ha·a	< 3 ... 10	< 5 ... 15	Grassland share
Energy balance (whole farm)	GJ/ha·a	> 80	> -20	Livestock density
Energy balance (crop)	GJ/ha·a	> 80	> 50	
Energy balance (livestock)	GJ/GV	> 0	> -10	

Source: TLL (2002), <http://www.tll.de/kul-old/use-02.htm>. and Umwelttestbetriebsnetz Thüringen 2003/04.

Principles for calculations of indicators and threshold values are worked out and fixed by TLL in cooperation with special committees of VDLUFA. Criteria are briefly described in the following:

- Mineral balances for nitrogen, phosphorus and potash describe fertilizer induced loads on surface and ground water and on the ecosystems. They are calculated as 'yard gate balance sheets' in which NH₃ is derived from animal manure. Reference quantity is related to Used Agricultural Area excluding fallow.
- NH₃ is calculated on the basis of animal manure supply.
- Humus balance serves as an indicator for soil fertility; it is derived from the supply / requirement of organic matter of crops. It is related only to arable land.
- Aspects of soil conservations are included by the indicators erosion disposal and soil compression. The former is calculated by the soil-loss function, while the latter is based on the weight and number of applications of machinery.

- Formerly, the intensity of pesticides and plant protection was derived from monetary farm accounts. It is replaced by a standardized treatment index, which is derived by the area treated with the respective pesticides, divided by total area of 11 main crops.
- Indicators for landscape and bio-diversity are based on the share of ecological and cultural landscape areas, block size and crop diversity measured by the Shannon Index.
- Indicators for energy use are energy input in crop production, energy balances at farm level and of crop and livestock production, respectively. They are based on direct and indirect use of fossil energy, as well as purchase and sales of crop and livestock products.

Farms are classified as 'environmentally sustainable' if the rating of each indicator is within the tolerance range. Indicator scales outside the tolerance range are interpreted as such that the farm is not in conformity with environment standards. The farms concerned receive consultancy with regard to appropriate adjustment strategies to reach the standards.

The basic data have to be supplied by participating farms, for which a respective questionnaire has to be completed. The questionnaire covers local conditions, farm structural data, livestock inventory and feeding, land use and yields, purchases and sales, technology use, plant protection, feedstuff and seed purchase, as well as the share of ecologically sensitive areas. Plausibility checks of data are realised by regional offices and then handed over to the central service responsible for data processing and evaluation.

At its beginning, the system was introduced for the recording and assessment of agricultural environmental damages. In a further step, the system was formally organised as USL 'environmental safeguarding farming' (VDLUFA 1998). If all 14 indicators are within the tolerance range for at least three succeeding years, farms receive the USL certification 'ecologically compatible land management'.

The application of the method in about 250 enterprises (ECKERT 2006) has shown that about half of farms exceed the tolerance range for nitrogen balance.

2.1.2 Criteria for economic and social sustainability (KWL, KSL)

With regard to a comprehensive assessment of sustainability, principles of 'economic sustainability' (KWL) and "socially compatible farming" (KSL) were worked out by TLL. Both systems are built up according to the principles of KUL:

- Specification of criteria for 'economic sustainability' (at present 10) or socially compatible farming (at present 9).
- Specification of optimal values and tolerance ranges.

The three systems KUL, KWL and KSL are integrated in the criterion system of sustainable agriculture (KSNL), containing 35 criteria.

Economic sustainability

Economic sustainability covers profitability, liquidity, stability and added value of farms. The criteria are calculated on the basis of farm accounting data³. For the individual criteria, ranges are defined as follows:

- 1: Optimum value
- 6: Upper range for economic sustainability
- 10: Economic sustainability strongly endangered.

Criteria, factors of evaluation and classifications are summarized in Table 2.2. The income criterion is based on farm income for several years. Averages of at least three years should be used to reduce impacts of price and yield fluctuations.

Table 2.2: Evaluation criteria of economic sustainability (KWL)

Indicator	Unit	Rating		
		1	6	10
Income	1 000 €AWU	> 50	> 25	< 10
Profit ratio	%	> 10	> 0	< -6
Profit ratio of total capital	%	> 5	> 0	< -3
Profit ratio of owner's equity	%	> 10	> 0	< -6
Remuneration of factors	%	> 130	> 90	< 75
Net debt service	%	< 33	< 100	> 100
Cash flow III	€ha UAA	> 500	> 50	< -100
Share of owner's equity	%	> 95	> 60	< 30
Change of owner's equity	€ha UAA	> 160	> 0	< -100
Change of owner's equity	1 000 €AWU	> 10	> 0	< -6
Net investment	1 000 €AWU	> 10	> 0	< -6
Farm net value added	€ha UAA	> 1 200	> 700	< 400

Source: Bachmann (2006).

³ BEVER, a calculation system with a total of 200 key financial indicators; see <http://www.tll.de/ainfo/betr0583.htm>

The system was tested based on 600 agricultural enterprises in Thuringia, and farm accounting data of approximately 10,000 farms included in the national FADN. For a sample of Thuringia farms, seven criteria were at the upper level of tolerance range (≤ 6) and the remaining criteria were slightly beyond the limits (7 and 8).

The aspect of economic performance was evaluated for a sub-sample of farms considering only four indicators (income, profitability, change of owned capital and net investment). Farms of the upper quartile are justified as economically sustainable, while farms of the lowest quartile are not. Partnership farms show better performance compared to legal entities. Applying this approach to professional farms of the German FADN lead to the conclusion that only two of four indicators were within the tolerance range.

Socially compatible farming

The system Criteria for Socially Compatible Farming (KSL) also uses the principles of KUL of TLL. Social criteria cover the areas of labour input, farm structure, employment indicators (workplace supply, age distribution, share of women, training), employment conditions (holiday, working conditions, level of income) and participation in the social life (social activities, share of owners of the enterprise). Calculation basis and threshold values for the nine indicators suggested are described by MATTES (2006).

The data required for the calculation of the criteria have to be imposed at farm level. This might be realised by additional questions in the KUL questionnaire. Only few information on this subject is available in FADN data. In the national FADN, the codes, age and professional formation for family workers is available, as well as salaries for hired workers. Data availability is further restricted in the EU-FADN data set.

The underlying criteria are oriented to 'legal entity or partnership farms' dominating in Thuringia. It cannot directly be applied to family farms, which dominate the farm structure of western Germany.

2.1.3 Conclusion with regard to the KSNL approach

So far, KUL/USL has been used in several hundred farms. This indicates that the system can be applied in practice. On the other hand, a broad application at the national level - strived for by USL - has not yet been reached. This might have different causes: Farmers have to decide if costs and labour input required for data collection are lower than returns from consultative advice. On the other hand, KUL and KWL are used in Thuringia as decision criteria for farms applying for the programme of 'Joint Agreement for the Improvement of Regional Economic Structures.' Obviously a lower number of criteria (10 of 15 in KUL) are used for this judgement.

Comparative descriptive analyses or test application in some farms came up with the following conclusions:

- KUL covers the environmental problem areas identified by the SRU, but the areas of bio-diversity, air pollution or greenhouse gas emissions are rather incomplete (ROEDENBECK 2004). Meanwhile, a criterion for bio-diversity, based on the Shannon Index as well as criterion for greenhouse gases, based on the direct and indirect energy input has been worked out.
- The different environmental indicator systems come up with different results and justifications. Comparing KUL with other methods, a test farm of the Technical University of Munich shows that results differ with regard to the environmental compatibility of single indicators (MEYER-AURICH 2002). This is due to different calculation methods for indicators (yard gate mineral balance versus area balance sheets; whole farm or plot based approaches; fixed (KUL) versus a flexible number of indicators (REPRO)) (ROEDENBECK 2004).

2.2 The system “Reproduction of Soil Fertility (REPRO)”

The system REPRO (Reproduction of Soil Fertility) has been developed by the University of Halle since 1990. The objective for the development of REPRO was to overcome some weaknesses of given indicator schemes. It is argued that in indicator models, indicators are sometimes subjectively selected, which don't cover sustainable issues of farms in a holistic way. The chosen relation often doesn't adequately illustrate the research question, and simplified algorithms are mostly applied instead of modelling oriented approaches.

REPRO is a system and process-oriented analysis and assessment instrument. REPRO should be compatible with the international indicator concepts and be suitable for practical as well as for scientific applications. Model development was accompanied by extensive test applications in agricultural farms to guarantee a sufficient validation of the model (HÜLSBERGEN, 2003). Long time series of field trials, e.g., Seehausen, are especially important for model development and evaluation of the model results.

The model REPRO was developed by the Institute of 'Arable and crop research' of the Martin-Luther University Halle-Wittenberg and the Institute for Sustainable Agriculture Halle/Saale. The Technical University Munich (TUM) is also involved. The German Agricultural Society (DLG) and the KTBL⁴ are partners in the project. The model-

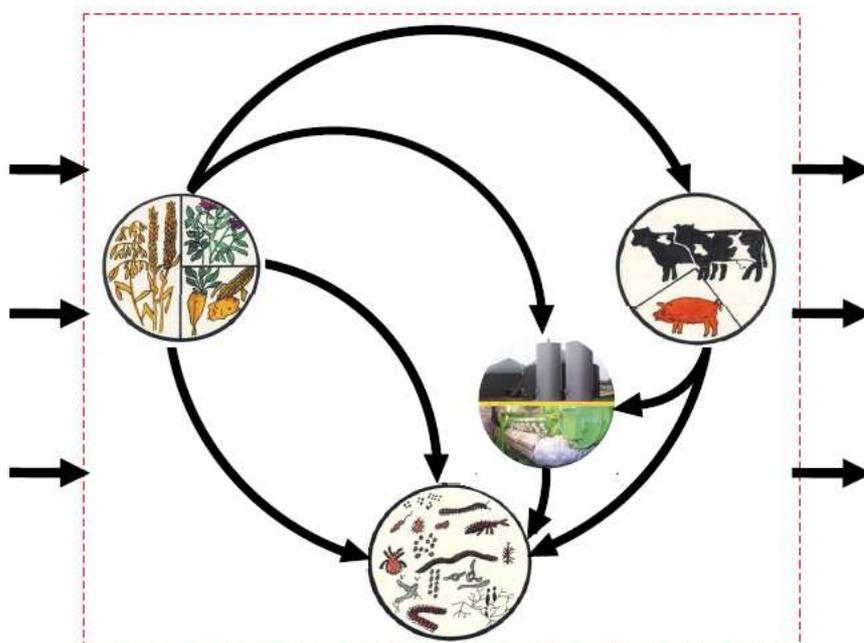
⁴ The Association for Technology and Structures in Agriculture (KTBL) is a registered association to which about 400 members belong. The KTBL is promoted by the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV). The mandated mission of KTBL is technology transfer.

development is supported by the German Foundation of Environment (DBU).⁵ Thus, PhD students of various universities are involved in research and further development of REPRO.

Methodology

The REPRO model is an indicator-model. It has analogies to the Driving Force-State-Response- Model of OECD (OECD 1997). The indicators are not used in isolation but are linked with each other. This provides the possibility of scenario runs. The model analyses the balance of organic matter and energy flows at farm level. Against balance methods like KUL, handling the farm as black box, the REPRO model is aligned to assess energy and material flows inside farms (Figure 2.3). This provides the possibility to point out differences between field plots, crop rotations and habitats (HÜLSBERGEN 2003). The environmental quality target is measured under conditions of the closure and balance of the whole system. In addition, the level of bio-diversity is used as a fourth item of environmental quality.

Figure 2.3: The farm as a system



Source: Betriebs- und Umweltmanagement mit dem System REPRO

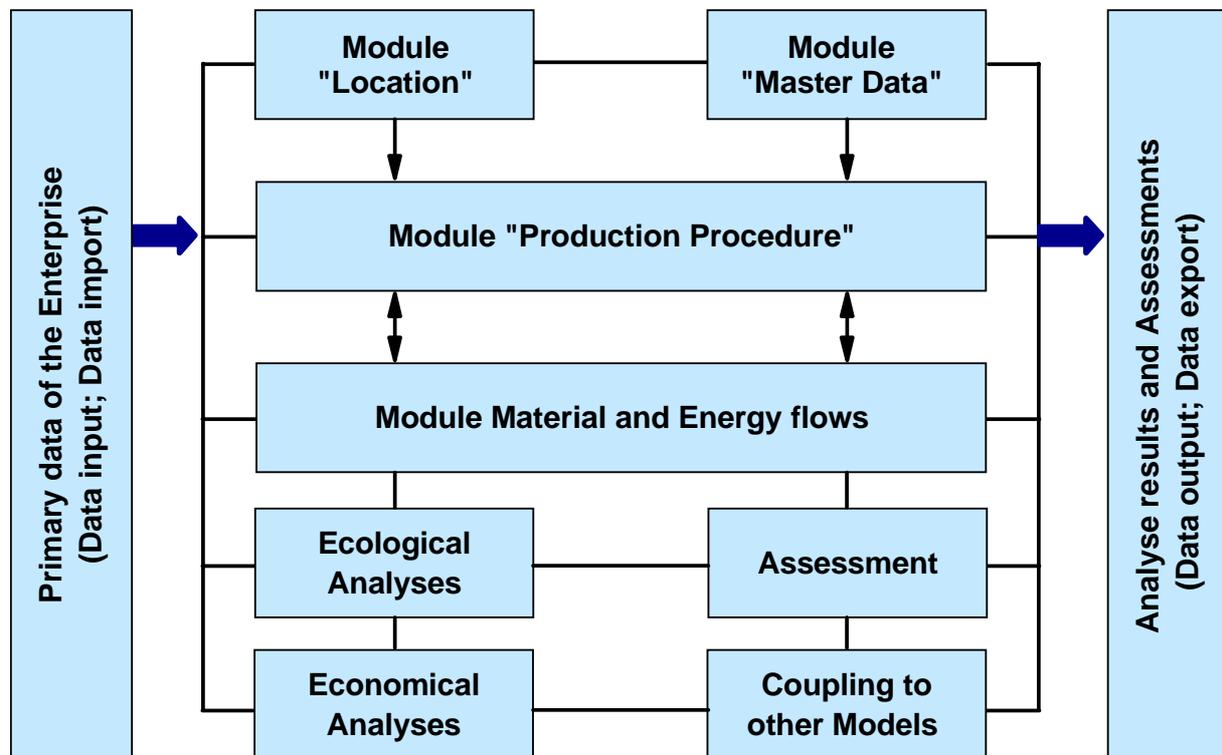
It is not possible to quantify effects of all activities of farming. To simplify the assessment, the basic principle of REPRO is that the material and energy-flows dominate the effects on environment and ecological sustainability.

⁵ The DBU is a research foundation and promotes innovative environmental projects and case studies.

Structure of the REPRO- models

The model REPRO consists of the following modules (see Figure 2.4).

- The module “**Production processes**” is the central part of the model. It contains the structure of farms, production processes and its intensities. It is necessary that all branches of farms are consistent with each other.
- The module “**Master data**” contains model parameters for the various operating systems; they can easily be extended towards other activities. In this way the model can be adapted to new production processes.
- The module “**Location**” contains a field-plot management tool linked to the Geographical Information System (GIS). If farm data are not available, soil and weather data can be taken over from the master data.
- The module “**Material and Energy flows**” calculates balances at different system levels of farms. This allows a close representation of material and energy flows inside farms. For this consideration the material flows must be coupled with each other (universal and consistent balance).
- In the module “**Ecological Assessment,**” agricultural activities are assessed with location-related indicators and target values. In addition to management indicators (structural key figures, intensity key figures, procedure parameters’), direct and indirect agro- environmental indicators are used. Beside material and energy flows, soil erosion, soil pressure, pest management and biodiversity are assessed in this module. Target values are specified for different regions and production procedures, thus special regional features can be taken into account.
- In the module “**Economic Assessment,**” gross margins (and full costs) are calculated based either on normative coefficients or farm specific data. This is linked with monetary assessments of environmental costs (e.g., nitrate pollution of waters) and achievements of management systems with regard to the preservation of soil fertility (humus reproduction, symbiotic nitrogen fixation).

Figure 2.4: Structure of REPRO

Source: <http://141.48.85.4/repro/Model1.htm>

The modules are linked with each other and illustrate the whole farm:

- Location conditions, e.g., soils and climate
- Structure of farms, e.g., cultivation structure and crop rotation, stocking rate of livestock and animal species
- Production procedures, e.g., application of inputs
- Yields, achievements and quality of products
- Costs and output of products.

REPRO has even more tools and modules dealing with specific questions, of which some are still in a developmental stage, i.e.:

- Analysis of soil compaction
- Appraisal of erosion-potential based on Geographical Information Systems (GIS)
- Relevant energy and material flows for environmental assessments of biogas plants
- Methods for the registration and assessments of biotopes in agriculture farms
- Methods for assessments of the aesthetic potential of farms

- Carbon cycles in agricultural systems.

Use and collection of data

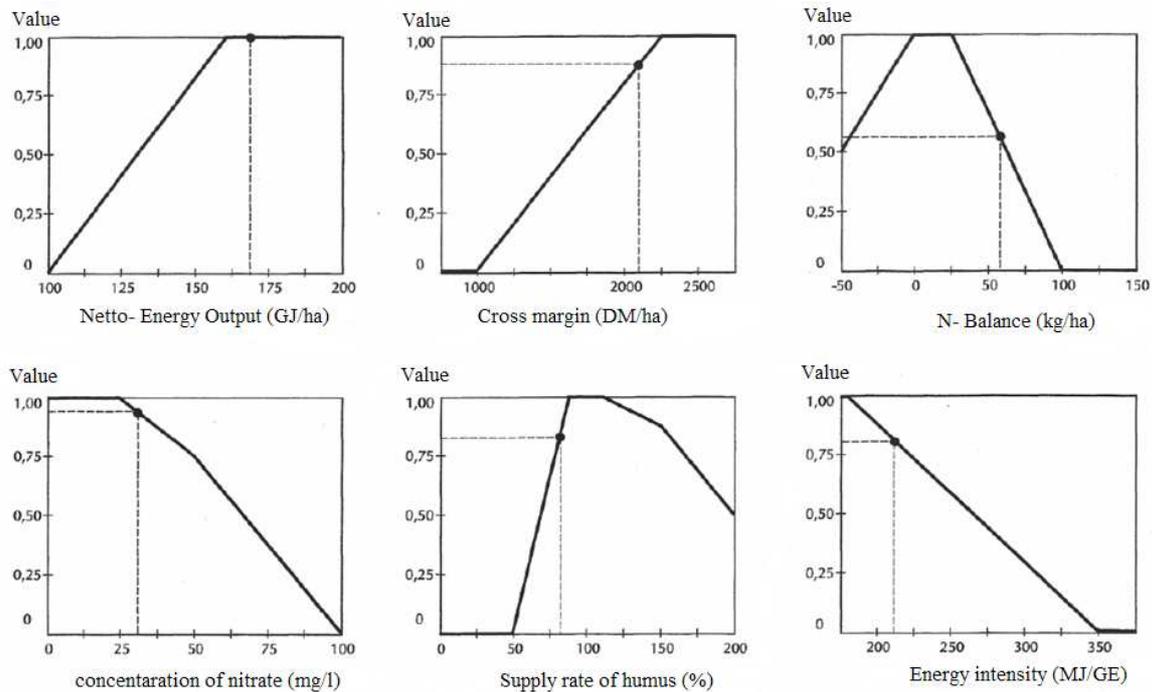
One type of data used in REPRO are master data defined by experts for various procedures. Moreover, data from the Geographical Information System (GIS) and data from the German National Meteorological Service (DWD) are included. The individual farm data are usually collected via personal interviews. Explicit data for each production procedure are necessary for the ecological and economic analysis. To limit the data treatment for cost items, interfaces were created for the data import and data export, e.g., of the field-plot-register. Procedures can be transferred to other field-plots; also master procedures can be defined and assigned for each crop.

Indicators and their assessment

REPRO uses more than 200 indicators. Not all indicators are relevant for each farm, so the indicator set has to be adjusted related to region or farm type.

Each of the available indicators are evaluated with regard to their relevance for environmental problems of concern. In a first step, the indicators were tested wrt. location conditions, reproducibility of results, data availability, model suitability and available target values. In a second step relations of indicators to the defined farming activities and environmental issues (e. g., quantity of pesticide, nitrate in groundwater) are assessed. Thus, each indicator gets a score in accordance with the different environmental issues. Score '1' means that the indicator isn't adequate, while level '5' indicates a close relationship between the indicator and the environmental issue. Based on this rating appropriate indicators are selected from the total of available indicators in REPRO. For example, the indicator "Nitrogen balance" has the score '4' with reference to nitrate in groundwater but only '1' with reference to the use of mineral fertilizer and other raw materials (HÜLSBERGEN, 2003).

For the evaluation of indicators, assessment functions are defined which show the achievement of target values on a standardised scale. If the target value of an indicator is reached, this indicator gets the highest rating (Rating 1). If the farm value lies below or above the target value, reductions are carried out (Figure 2.5).

Figure 2.5: Relation between the dimensionless scale and the data of indicators

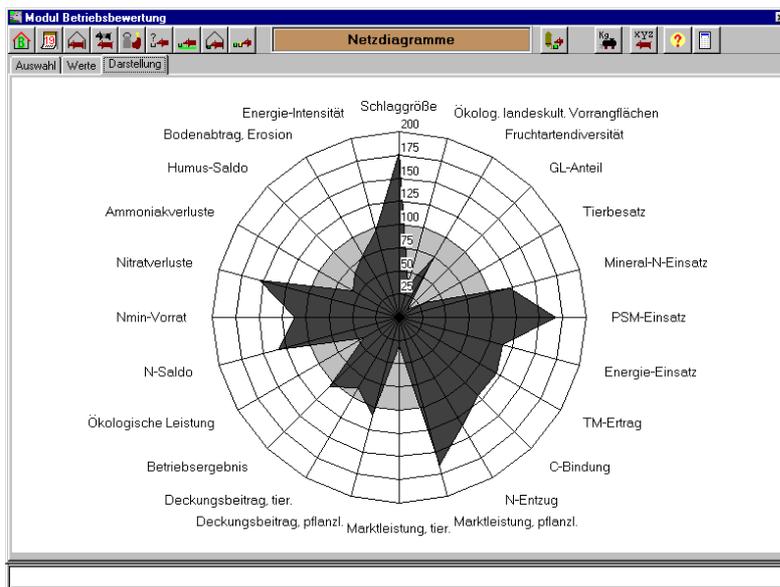
Source: Hülsergen 2003

Output of the model

In REPRO, different methods are combined to elaborate results of the ‘**Assessment module**’ (Figure 2.4). In a first step, indicators to be evaluated are selected. To simplify calculations, region-related and management-related indicator lists can be defined. Thus, different indicator sets are required for arable crop and livestock farms, respectively. The model allows horizontal or vertical comparison of farms and comparisons with regard to target values.

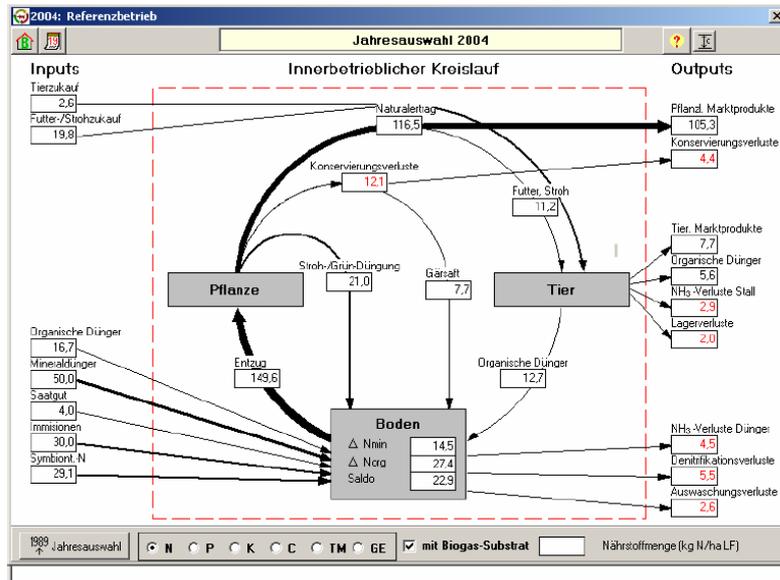
It is possible to build up thematic maps at field plot level to provide detailed information for different field plots using grip-charts (Network Diagram Technology) (Figure 2.6). Moreover it is also possible to run scenarios aiming at the optimization of farms with regard to chosen indicators. Figure 2.7 shows the nitrogen cycle of a farm and its inputs and outputs.

Figure 2.6: Demonstration of the outcomes using the web-technique



Source: (Hülsbergen, 2000)

Figure 2.7: Nitrogen cycle inside a farm



Source: (Küstermann et al. 2007)

Possible applications

Detailed tests were realised in the "Klostergut Scheyern," an experimental farm of the Technical University of Munich, and in the experimental station "Seehausen" near Leipzig, belonging to the University of Halle. In Seehausen, long-term-field tests with regard to fertilizer use and crop rotations exist, providing information for the determination and calibration of model parameters.

In Sachsen-Anhalt, the REPRO methodology is used for the evaluation of agri-environmental measures. Thus REPRO was used on more than 20,000 hectares.

Parts of the REPRO-model are used for the calculation of indicators for the *Nachhaltigkeitszertifikat* (Sustainability certificate) of DLG (see Chapter 4).

Strengths and weaknesses of REPRO

The model REPRO was compared and assessed in different studies (BOCKSTALLER 2006 ; ROEDENBECK 2004). The integration of main production procedures, accessibility of data, energy and material balances and aggregation on field plots and stables level are pointed out as strengths of REPRO. Weaknesses are seen in the huge efforts for data collection and the lack of target values for some indicators. ROEDENBECK (2004) compares and judges the model REPRO with regard to six environmental problems defined by SRU (1985). Recommendations are, that environmental issues are extensively covered, but there is a lack of indicator sets for dust and smell emissions, greenhouse effects and pesticide emissions. Most of these gaps have been solved and filled in the meantime.

2.3 The "DLG-Sustainability certificate"

This certification system is aiming at the integrated evaluation of sustainable performance of farms.

In 2003, the working group "Sustainable Agriculture" was established by the DLG⁶. Aim of the DLG-certificate is to give a clear definition for sustainable agriculture based on scientific methods. Many instruments deal with partial approaches, but there is no integrated instrument to analyze "sustainable performance" of agricultural enterprises. (SCHAFFNER et al. 2007a)

⁶ The DLG (German Agricultural Society) was founded in 1885 by Max Eyth. Today, with more than 18,000 members, it is one of four top organisations of the German farming and food economy. The DLG sees itself as a neutral, open forum for the exchange of knowledge and education. About 200 full-time employees and more than 3,000 experts compile solutions for special problems (DLG 2007).

The DLG defines the following areas of action for a sustainable management in agriculture:

- Optimisation of production processes in view of efficient application of inputs and the economic efficiency of production
- Risk management in areas of product and environmental liability
- Quality assurance and food security of products
- Minimisation of negative impacts of agricultural production on the natural environment
- Communication with stakeholders, e.g., customers, authorities and the society in general
- Assuring that products are produced in accordance with legislation.

Several quality performance systems exist and a lot of farms in Germany already apply quality certification. However, these are purely descriptive approaches aiming to quantify management effects of production systems and their impacts on environment and resource use. The DLG certification system should become a tool which can be used by farmers as operational management scheme integrating economic, ecological and social concerns (DLG, 2007).

The DLG co-operates with organisations involved in the development of REPRO: The Technical University of Munich, the Martin Luther University of Halle and the Institute for Sustainability in Halle. The project started in 2005 and is supported by the German Environment Foundation (DBU).

Structure of the assessment system

The DLG-certificate uses some of the indicators and methods from the REPRO system, especially in the ecological part. The core methodology is an indicator-system, where each indicator has a target value. The sustainable-profile of farms is determined by comparisons between target values and real values of indicators. Thereby, ecological, economical and social sustainability are weighted equally.

For the evaluation of sustainability, assessment functions are defined which show the sustainable achievement on a standardised scale. Calculations of assessment functions are equal to the REPRO System (Figure 2.5). Thereby an indicator is considered to be sustainable if the rating is between 0.75 and 1.

For the whole assessment, the average of all indicator values within each of the single areas (ecological economic, social) are calculated, resulting in an index of sustainable

achievement of the farm in three areas of sustainability concerns. The minimum requirement in each of the three areas is 0.75.

Ultimately, one sustainability score is calculated as an average value of the three single areas, which shows the sustainable status of farms. Moreover farms have to fulfil standards of a quality certification system. If such a certification doesn't exist yet, farms have to fulfil criteria of another checklist. The audit takes place every three years.

Indicators and indicator selection

About 25 indicators are chosen for the assessment system, which are described in the following. The composition of indicators, as well as the assignment of target values is defined by a DLG working group⁷. The basis for economic and social indicators are mainly described in (BACHMANN 2006; HEIBENHUBER 2000; MATTHES 2006).

Ecological indicators

- *Nitrogen Balance*: Total nitrogen loss potential and pollution of surface water
- *Phosphate Balance*: Total phosphate loss potential
- *Humus balance*: Change in the humus content of soil
- *Agro biodiversity*: Consists of farm structure, crop diversity, level of fertilizer and pesticides use
- *Landscape conservation*: Measures positive contributions to biodiversity. The definition of the measures is linked to definitions of environment programs
- *Energy intensity*: Use of non-renewable energy resources. It includes the use of direct energy (diesel and fuels) and indirect energy input. Production systems are assessed with the help of energy intensity and input-output relations
- *Pesticide management intensity*: Handling of pesticides, level of pesticides used and probable negative environmental effects are assessed
- *Soil compaction*: Soil compactions of the different soil cultivation procedures are assessed
- *Water erosion*: Soil erosions of the cultivation system are quantified
- *Greenhouse gas and climate effects*: CO₂, CH₄, N₂O emissions of cultivation systems are quantified (direct and indirect emissions)

⁷ A detailed description of calculation method of considered indicators are not yet published. Further information is provided by DLG (2008).

Social indicators

- *Remuneration of workers*: Salary in comparison to a reference wage, e.g., labour tariffs
- *Working load*: Average working load per worker
- *Working security*: Quantifies claims of insurance associations and target levels (standards)
- *Education and advanced training*: Gives information about qualifications of employees
- *Holidays*: Days of realised holidays
- *Public relations*: Involvements in local communication networks, engagement in NGO's etc.
- *Workers participation*: Support of activities among employees and their participation on farm development
- *Quality certification*: Shows whether farms are involved in a quality certification systems

Economic indicators

- *Farm income*: Achieved value added of farms, which is available for the remuneration of used production factors.
- *Relative factor remuneration*: Based on the share of use and remuneration of fixed factors.
- *Relation to the dept service limit*: Share of credits is economically acceptable.
- *Change of equity*: Development of owned capital. It indicates the share of profit that can be used for investments and private consumption.
- *Net investment*: Long term investment capability.
- *Profit rate*: Shows the stability of farms, especially with regard to activities influenced by high price fluctuations.

Data base

Beside location information, data of the last three financial years are used, e.g., amount of fertilizers and plant protection agents. Data on social aspects and partial economic aspects have to be supplied by farmers who have to fill in different forms. Farm accountancy data is also used for economic assessments.

Results and use of outcomes

Farmers receive a detailed summary of the indicator analysis. The main points of the sustainable profile of farms are determined, further optimisation potentials in production are described. Moreover, farmers receive a rating of sustainability of their farm compared to others. Results can be used for negotiations with stakeholders, property owners or banks.

The certification method should be applicable for each type⁸ of farm and production method (i.e., conventional or organic farming). There is no political pressure forcing farmers to reach standards of sustainability. Participating farms – by the certificates - may have positive effects through the sale of products or as collateral for credits. A main objective of the system is to include the whole food chain. Examples are two flour mills in Bavaria, which prefer products from certified farms, so that they can advertise with sustainable products. Also the certificated farms can use a sustainability label, developed by the DLG.

In the meantime the certificate and the assessment functions were further developed and published. Further information is provided on the homepage www.nachhaltige-landwirtschaft.info

2.4 Sustainable Value Approach

The Sustainable Value approach is value based; the main objective is to measure farm sustainability by comparing value added of farms related to their bundles of resources with those of a benchmark. The benchmark can be defined as opportunity costs of considered resources. A positive Sustainable Value indicates that a farm generates Sustainable Value, whereas a negative Sustainable Value indicates that other farms (benchmark) would provide higher values by using the same resources (FIGGE, HAHN 2004).

Calculation of the Sustainable Value

The Sustainable Value (SV) is calculated as described in Formula 1 and 2:

$$SV_{ir} = \left(\frac{y_i}{x_{ir}} - \frac{Y^*}{X_r^*} \right) * x_{ir} \quad (1)$$

⁸ Until now the system was applied especially on arable farms

$$SV_i = \frac{1}{R} \sum_{r=1}^R SV_{ir} \quad (2)$$

SV being the Sustainable Value, y stands for the Value Added of the farm i or the benchmark (*) and x for the amount of the used resources r of the farm i or the benchmark (*). In this calculation seven resources r are considered. In a first step the Sustainable Value SV_{ir} of each resource r is calculated. The value contribution of resource r of the benchmark * is subtracted from the value contribution of farm i of resource r . The total value contribution of resource r is calculated by multiplying total amounts of used resources with the value spread of the resource r . In a second step total Sustainable Value SV_i of each farm is calculated by summing up all SV_{ir} and dividing the total by the number of included resources R . This step is necessary to avoid double counting of value creation (VAN PASSEL, 2007). FIGGE and HAHN state that the weighting of the considered resources depend on their importance for value generation (FIGGE, HAHN, 2005).

In Germany the size of the farms is very different and thus the level of the FNVA, too. The return-to-cost ratio takes the farm size into account and is calculated as described in Formula 3.

$$return_to_cost_i = \frac{y_i}{y_i - SV_i} \quad (3)$$

A return-to-cost ratio greater than one shows, that a farm is more productive than the benchmark (HAHN et al., 2007). In general, benchmarks can be determined by e.g. a) value of best practice farms, b) the average of all farms or c) the values of the national economy. In this study the weighted average⁹ of all included farms is taken for benchmark calculation. One main outcome of the Sustainable Value should be a ranking of farms or different production systems wrt efficient resource use.

2.5 Data Envelopment Analysis

To compare the results of the Sustainable Value Approach, the relative efficiency is calculated with Data Envelopment Analysis (DEA) (CHARNES et al., 1994). DEA is based on a Linear Programming approach and evaluates relative efficiencies of individual farms in comparison to the efficient farms on the frontier. DEA is a non-parametric approach,

⁹ For benchmark calculation all farms are weighted with the individual weighting factor and thus represent most parts of the German dairy sector (about 90,000 farms)

thus it is not necessary to specify a functional relationship between inputs and outputs. For this calculation, an input-oriented DEA model is used (DYCKHOFF, ALLEN, 1997) as follows.

$$\min_{\lambda} \theta^0 \quad (4)$$

$$\sum_{i=1}^{\pi} \lambda^i y^i \geq y^0 \quad (5)$$

$$\sum_{i=1}^{\pi} \lambda^i x_r^i \leq x_r^0 \theta^0 \quad \forall r = (1 \dots m) \quad (6)$$

$$\sum_{i=1}^{\pi} \lambda^i = 1 \quad (7)$$

For $\lambda^i \geq 0 \quad \forall i = (1 \dots \pi)$

For the farm under consideration (Farm 0) the minimum input combination, expressed in efficiency score θ^0 , is derived. Therefore, the outputs y of all farms ($i = 1 \dots \pi$) should be at least as high as the output of the farm under consideration y^0 , where λ^i represents the level of each farm i and the sum of all λ^i must be one. Moreover, the total of inputs r of reference farms (x^i) must be less or equal to inputs r of the farm under consideration (x^0) multiplied by the farms' efficiency factor θ^0 . A farm is determined as efficient if θ^0 achieves the value one, which means that no other farm can reach the output more efficiently than the farm under consideration (farm 0). The farms which achieve the value $\theta^0 = 1$ form the efficient frontier and are used for the other farms to measure their relative inefficiency. In the DEA analysis the same resources and same output as in the SV-calculations are included. In DEA and SV approach a ranking of farms is possible: a) with DEA based on the relative efficiency, b) with SV based on sustainable value contribution and the return-to-cost ratio. A comparison of different rankings will be shown later on.

3 Comparison of selected measurement concepts for farm sustainability, a case study using FADN data

In the first phase of the SVAPPAS project, a test and comparison of different measurement concepts is realised. It covers the application of the SV approach, to be seen as the core concept of the project, but also the use of indicator methods and DEA (Data Envelopment Analysis). The indicator concept is derived from KSNL, where chosen indicators and ranking is adjusted to the data availability in FADN. The method DEA is used because it allows the simultaneous handling of monetary / physical indicators. It results in a relative efficiency measure, where the most efficient farms (benchmark) are endogenously determined.

Outcomes of mentioned methods will be shown and assessed by groups of dairy farms of different size classes, intensities and other farm characteristics. Some extensions of the Sustainable Value approach, which are necessary for the adoption to the agriculture sector, will be shown.

3.1 Data and methods

Data

Farm accounting data of farms included in the German Farm Accountancy Network (FADN) were used. For calculations, data of 4093 dairy farms from the financial year 2004/2005 were used¹⁰. Results are projected by using weighting factors to achieve estimation for the total German dairy sector. In the calculations, almost none of the farms have missing values for the resources included in farm accounts. Farms with missing values for labour, UAA, capital or energy are excluded.

Description of included resources and output for SV and DEA calculation

Resources: For the calculations, physical inputs of seven resources were used:

- Total labour
- Energy
- Nutrients (Nitrogen, Phosphorus, Potash)
- Agricultural area (UAA)
- Capital

¹⁰ The test and comparison of methods is based on data of only one economic year. Wrt to long term aspects of sustainability the analysis will be extended to long term analysis (ex-post and ex-ante) in the second phase of the project.

As some of the resources are only available in FADN as monetary accounts, physical inputs are calculated in using the farm group model FARMIS¹¹

Adjusted Farm Net Value Added is used as output. In a first step, profits are corrected by expenses and gains from other accounting periods (DLG, 2006). Subsequently, the FNVA of farms is calculated. Within FNVA, the costs for the expenditures of fertilizers and energy are already subtracted, whilst the costs for labour, UAA and the interest are not taken into account. In adjusted-FNVA, the amount of costs related to the included resources and accounted in the FNVA are added (expenditures for fertilizer and energy). A harmonised sample of farms is constructed, which is necessary for the comparison of methods.

Considered indicators

In this application, indicators which can be derived from FADN data were used. Ecological and economic indicators are calculated with the same sample of farms used by the other methods. Thereby the objective is not to describe each of the single indicators but to compare indicator approaches with DEA and SV.

Ecological indicators

In KUL a modification factor for each indicator is included to adjust the assessment function to special features of locations (Table 2.1). These modification factors are not taken into account by using FADN data. Following ecological indicators are considered:

- Nutrient balances ((Nitrogen, Phosphorus, Potash)
- Humus balance
- Intensity of pesticides use
- Crop diversity

Further information about the indicators is given in Table 2.1.

Economic indicators

To analyse the interaction between the Sustainable Value, DEA and economic indicators, eight indicators are calculated (DLG, 2006; TLL, 2006a):

- Income
- Profit ratio

¹¹ For further information about FARMIS or methodological issues wrt to calculation of inputs and output, please contact the authors.

- Remuneration of factors
- Net debt service
- Change in owner's equity (€/ha UAA and 1000€/AWU)
- Net investment
- Farm net value added

The target values are based on criteria for economically sustainable farming (Table 2.2) (BACHMANN, 2006). The assessment in this case study shows whether farm individual indicator values are within a specific tolerance range or not. The percentage part of economic indicators inside the tolerance range can be calculated.

3.2 Results

Sustainable performance of the German dairy sector is described in the following. We focus on the comparative evaluation of various approaches. In a first step, the results of the SV calculation, the DEA and the indicator approaches are shown. Subsequently the different approaches and their impacts will be compared.

3.2.1 Results of Sustainable Value Approach

A positive SV figure indicates that the return of resource use of a farm exceeds a specific benchmark (opportunity costs) whilst a negative figure states that farms use their resources less efficiently than the benchmark. As described above, the weighted average of all farms serves as benchmark. From this follows, that in calculating weighted mean or in summing up SVs of all farms, the total becomes zero. While Sustainable Value presents an absolute figure, the return-to-cost ratio (SV_rc) is a relative measure. The return-to-cost ratio calculated with the weighted average SV of Germany is one. In the following, results are described for different aggregates of dairy farms.

SV by size class and intensity

Table 3.1 shows absolute SV's as well as return-to-cost ratios. Return-to-cost ratios of farms with more than 100 dairy cows are higher than for farms with fewer dairy cows. Also, farms with milk yield exceeding 10,000 kg/cow/year have a return-to-cost ratio of 1.32, which is almost twice as high as of farms with a milk yield lower than 4000 kg/cow/year.

SV by LFA/ non LFA regions and organic/conventional production systems, respectively

The results of the Sustainable Value calculation indicate that the performance of organic farms is higher (return-to-cost ratio of 1.11) compared to conventional farms (return-to-cost ratio of 0.995). Farms which are located in less favoured areas show a lower return-to-cost ratio than farms outside LFA regions (see Table 3.2).

Table 3.1: Results of the SV, DEA and indicator concepts by size classes and intensities

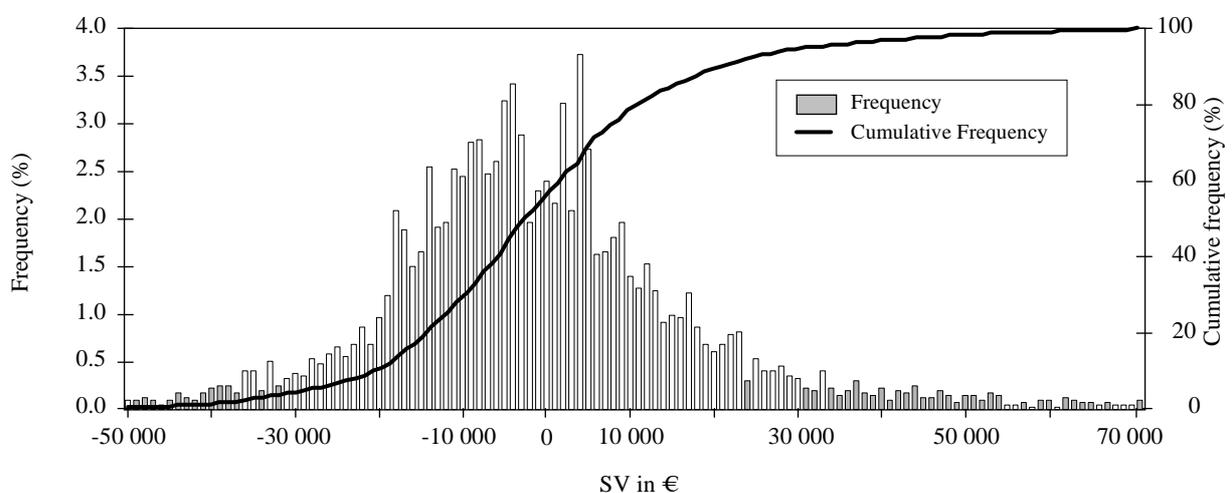
	SV €	SV_rc	DEA rel. eff.	Ecol_KUL ¹⁾ rating	Econ_Crit ²⁾ %
<=25 Cows	-4,200	0.86	0.61	4.62	29
>25-50 Cows	-1,358	0.97	0.50	5.12	41
>50-100 Cows	6,918	1.08	0.54	5.67	56
>100-200 Cows	26,456	1.17	0.62	5.94	66
>200 Cows	65,860	1.10	0.75	5.27	69
<hr/>					
<=4 t/cow	-10,216	0.68	0.60	4.72	23
>4-6 t/cow	-4,722	0.89	0.56	4.66	32
>6-8 t/cow	2,082	1.03	0.55	5.18	44
>8-10 t/cow	12,773	1.14	0.58	5.93	56
>10 t/cow	58,043	1.32	0.72	6.90	79
<hr/>					
< 25 ha UAA	-1,790	0.93	0.68	4.79	30
25-<50 ha UAA	-2,063	0.95	0.52	4.95	36
50-<100 ha UAA	2,165	1.03	0.51	5.35	49
100-<150 ha UAA	6,358	1.05	0.53	5.38	57
150-<500 ha UAA	10,316	1.06	0.58	5.33	55
>=500 ha UAA	85,080	1.09	0.84	4.44	68

1) Rating with the assessment function of KUL; a low value describes a better performance.

2) Percent of criteria values inside the tolerance range; a higher value describes a better performance.

Source: Own calculations

Figure 3.1: Frequency (%) and cumulative frequency (%) of Sustainable Value



Source: Own calculations

Frequency of Sustainable Value

In Figure 3.1 the weighted frequency distribution of the Sustainable Value is shown. The 4093 dairy farms represent about 89,933 farms in Germany. The lowest SV is -327,703 € and the highest value is 987,575 €. The median is negative (-2,188), which shows that the majority of farms have a Sustainable Value lower than zero. The frequencies of Sustainable Values are calculated in classes with a range of 1,000 €. We can observe that 79 % of farms have a SV between -20,000 € and 20,000 €, and about 49 % of the farms are within the range between -10,000 € and 10,000 €.

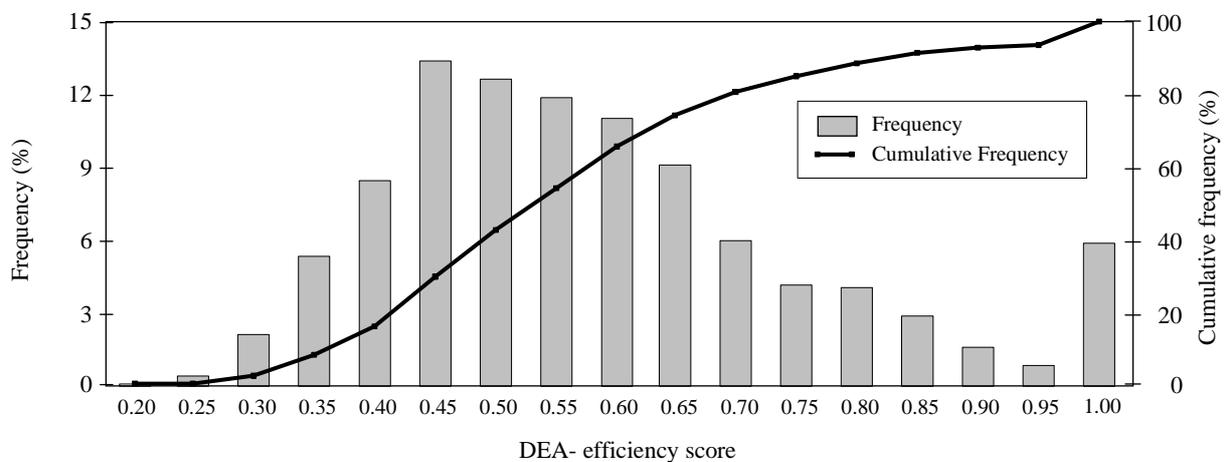
3.2.2 Results of the Data Envelopment Analysis

In the following results of the input oriented DEA model are shown. The calculation was done with all farms, included in the other approaches and the results were grouped later. The weighted average DEA efficiency of all included farms is 0.56.

Frequency of DEA results

In Figure 3.2, the weighted frequency of the DEA results, calculated with a range of 0.05, is shown. About 50 % of the farms show efficiencies between 0.4 and 0.6. About 57 % achieve an efficiency greater than 0.5, and 11 % show a relative efficiency greater than 0.8. On total, 85 of 4093 included farms are determined with an efficiency score of “1”. As shown in Figure 2.2, these farms represent 5.9 %¹² of German dairy farms. On average, efficient farms use 299 ha of UAA, whilst less efficient farms use 71 ha. Also the efficient farms keep more dairy cows and achieve higher milk yields. The return per hectare of the efficient farms is lower than the average of all farms because they employ more workers. However, the group of efficient farms shows the highest adjusted-FNVA per ha as well as per AWU.

¹² 2.1 % of farms show an efficiency of “1” without weighting farms with the aggregation factor.

Figure 3.2: Frequency (%) and cumulative frequency (%) of Data Envelopment

Source; Own calculations

Efficiency score by size class

According to DEA results, the biggest farms achieve the highest efficiency, but small farms show better results than farms of median size classes (Table 3.1). One reason is, that farms with less than 25 hectares need a lower amount of nutrients and land per 1,000 € of output than medium size farms, while the small farms use more resources capital and labour.¹³

Efficiency score by LFA/ non LFA regions and organic/ conventional production systems

The DEA results record that organic farms show an efficiency of 0.66 which is higher in comparison to the conventional farms with an efficiency of 0.56 (Table 3.2). One reason is that organic farms use a lower amount of nutrients per 1,000 € FNVA. The DEA results don't differ much between LFA and non LFA regions and thus indicate that the farms in LFA regions have the same efficiency than farms in non LFA regions with regard to the considered inputs.

3.2.3 Results of the indicator concept

Economic (Econ_Crit) and ecological (Ecol_KUL) indicators are calculated to compare the results of the two approaches discussed before. Only six ecological indicators were calculated, and therefore not every ecological issue is taken properly into account.

¹³ For further information about DEA results and characteristics of efficient and less efficient farms contact the author.

Nevertheless the relative differences between the farms can be described with the indicators.¹⁴ To compare the results of DEA and SV, the percent share of economic indicators inside the tolerance range is given.

Ranking by size class and intensity

The economic performance of size classes is similar; farms with more than 200 cows reach the target values for almost 70 % of indicators. The opposite effect can be observed for ecological indicators where farms with less than 25 cows show the best rating with an average score of 4.62 and 79 % of these farms are inside the tolerance range (Table 3.1).

Table 3.2: Results of SV, DEA and indicator concepts for different shares of LFA and organic and conventional production systems

	SV €	SV_rc	DEA rel. eff.	Ecol_KUL ¹⁾ rating	Econ_Crit ²⁾ %
Conventional farms	-274	0.995	0.56	5.13	39
Convert to organic	2,971	1.06	0.60	4.26	36
Organic farms	4,194	1.11	0.66	3.76	37
0 % LFA	5,116	1.08	0.57	5.78	45
0-50 % LFA	3,040	1.05	0.57	5.23	44
50-99 % LFA	-1,135	0.98	0.54	4.85	39
100 % LFA	-2,770	0.94	0.56	4.70	35

1) Rating with the assessment function of KUL; a low value describes a better performance.

2) Percent of criteria values inside the tolerance range; a higher value describes a better performance.

Source: Own calculations

Farms with more than 500 hectares show the best rating for ecological indicators (Rating 4.4) and achieve the tolerance ranges for about 68 % of economic indicators. The second best rating of ecological indicators can be observed in farms with less than 25 hectares, but these farms achieve the tolerance range for only 30 % of ecological indicators. The most intensive farms with the highest milk yields per cow show a high economic performance, but also the worst ecological rating, whereas farms with low milk yields show an inverse picture.

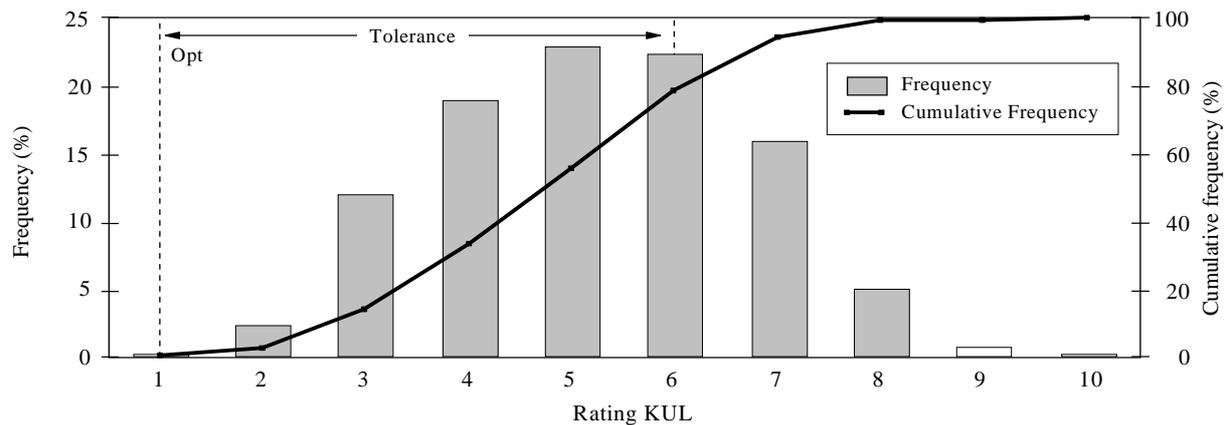
Ranking by LFA/non LFA regions and organic/conventional production systems

Ecological indicators indicate that organic farms have a higher performance. The conventional farms achieve the tolerance range for 39 % of the economic criteria, but the organic farms also achieve 37 % of economic target values (Table 3.2). Farms in less

¹⁴ The level of the rating might not be correct, e.g nutrient use in this calculation is lower than described by BMELV, 2006.

favoured areas show an ecological rating of 4.7, which is better than the farms in non LFA regions. On the other hand, a lower share of economic targets reached can be observed in these regions, too.

Figure 3.3: Frequency (%) and cumulative frequency (%) of ecological indicators (KUL)



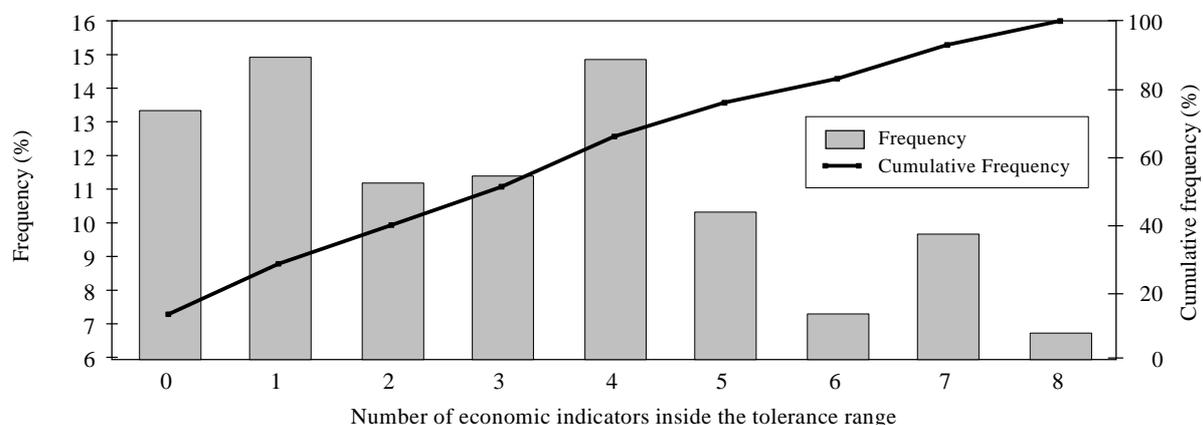
Source: Own calculations

Frequency of indicator approaches

In Figure 3.3 the frequency of the farms and their (KUL) classification is given. 68 % of farms are inside the tolerance range.

In Figure 3.4 the frequency of economic indicators inside the tolerance range is given. It is conspicuous that about 13 % of the farms don't reach the target values of at least one economic indicator. On the other hand, almost 7 % of farms are able to reach the requirements of each economic indicator.

Figure 3.4: Frequency (%) and cumulative frequency (%) of the number of economic indicators inside tolerance ranges



Source: Own calculations

3.3 Comparison of the selected approaches

In the following it will be analysed if the measurement concepts will result in comparable or different classifications of farm sustainability. Conclusions will be drawn based on the results.

3.3.1 Differences between the selected approaches

Differences by farm size and intensity

Results of SV-calculation and economic indicators with regard to size classes are similar (Table 3.1); farms with 100 to 200 cows show a return-to-cost ratio of 1.17 and in farms with more than 200 cows, target values in almost 70 % of economic indicators are reached. The opposite picture can be observed for ecological indicators where farms with less than 25 cows show the best rating with an average of 4.62, and 79 % of these farms achieve the tolerance range. The DEA doesn't give a clear picture; the biggest farms have the highest value but small farms achieve almost the same result as farms with 100 to 200 cows. The results of the SV-calculation, the DEA and economic indicators show that farms with a higher milk yield per cow have a higher performance. The ecological indicators give an inverse picture: with an average rating of 6.9, the intensive farms are outside the tolerance range.

Differences by LFA/ non LFA regions and organic/ conventional production systems

The return-to-cost ratio, the DEA scores and the ecological indicators indicate that organic farms have a higher performance than conventional farms (Table 3.2). The conventional farms achieve the tolerance range - with 39 % of the economic indicators - and thus show a better performance than the organic farms. The organic farms also achieve 37 % of economic target values. Farms entirely located in less favoured areas show the lowest return-to-cost ratio and farms in non-LFA areas have the highest value. The DEA results indicate that farms between 50 and 99 % LFA have the worst performance. However, the DEA results don't differ much between LFA and non LFA regions with ranges between 0.54 and 0.57 (Table 3.2). Farms in less favoured areas show an ecological rating of 4.7, which is better than the farms in non LFA regions. Especially the Shannon Index¹⁵, the humus balance, and the pesticide use are responsible for the better rating. The economic indicators show a clear ranking where farms in non-LFA areas range at first place and farms with 100 % LFA at fourth place.

¹⁵ Measurement figure for biodiversity

The different approaches come out with different scores for the underlying farm aggregations (see Table 3.3):

- SV: Farms with 100 to 200 cows show the highest return-to-cost ratio; intensive farms with a high milk yield per cow, too. Also the SV indicates that organic farms and farms in non-LFA regions have a better performance than conventional farms or farms in LFA regions.
- DEA: The DEA results show that big farms are efficient but also farms with less than 25 cows are seen as more efficient than farms with 50 to 100 cows. Intensive farms as well as organic farms show a high efficiency whereas only a small difference between LFA and non LFA regions can be observed.
- Economic and ecological indicators: The ecological and economic indicators point in an opposite direction wrt regional and farm characteristics. The analysis by size class and intensity shows that a high intensity and large size is linked to a high economic performance. Organic farms and farms in LFA regions are seen as more ecologically compatible, but the conventional farms and farms in non-LFA regions reach the target values for more economic indicators.

Table 3.3 shows, that the methods SV, DEA and economic indicators came to almost comparable rankings wrt best and lowest performance of farms of different size of dairy cow stock. However the ranking wrt ecological indicators is inverse. As sustainability targets are not implicitly included in SV and DEA, the ranking derived from the indicator method seems to be more appropriate.

Table 3.3: Ranking of SV, DEA and indicator concepts by size classes

	Return-to-cost ratio		DEA		Ecological criteria		Economic criteria	
	RCR	Ranking	Score	Ranking	Rating	Ranking	%	Ranking
<=25 cows	0.86	5	0.61	3	4.6	1	29	5
>25-50 cows	0.97	4	0.50	5	5.1	2	41	4
>50-100 cows	1.08	3	0.54	4	5.7	4	56	3
>100-200 cows	1.17	1	0.62	2	5.9	5	66	2
>200 cows	1.10	2	0.75	1	5.3	3	69	1

Source: Own calculations

3.3.2 Correlations between sustainability concepts

Relationships between the above mentioned measurement concepts are analysed on the basis of Spearman¹⁶ correlations (see Table 3.4). To understand the correlations, it is necessary to take into account that a lower rating of ecological indicators indicates a better performance compared to the other approaches, where higher values for economic indicators are attached to a better performance. Therefore, if the correlation with ecological indicators is negative, the results show a similar direction. The correlation of the DEA with the Sustainable Value is 0.789¹⁷. Also the correlation of DEA and SV with economic indicators is greater than 0.5¹⁸. Correlations of all approaches with ecological indicators (Ecol_KUL) are lower than 0.15, which indicates that almost no significant relationship between SV and DEA exist. The return-to-cost ratio and the absolute Sustainable Value show a high correlation (0.946) and thus correlations of return-to-cost ratio with other approaches are similar to SV (Table 3.4).

Table 3.4: Spearman correlation between SV, return-to-cost ratio, DEA, economic and ecological indicators

	SV_tot	SV_rc	DEA	Ecol_KUL ¹⁾	Econ_Crit ²⁾
SV_tot	1	0,946 ***	0,789 ***	0,012	0,656 ***
SV_rc		1	0,762 ***	0,008	0,658 ***
DEA			1	-0,049 ***	0,520 ***
Ecol_KUL ¹⁾				1	0,130 ***
Econ_Crit ²⁾					1

* significant at 10 %; ** significant at 5 %; *** significant at 1 %

1) Rating with the assessment function of KUL; a low value describes a better performance.

2) Percentage of criteria values inside the tolerance range; a higher value describes a better performance.

Source: Own calculations

¹⁶ The Spearman correlation takes the ranking of the farms into account.

¹⁷ The Pearson correlations of DEA with SV is 0.551 and with return-to-cost ratio 0.734

¹⁸ Note that the ranking of economic indicators is limited by the number of indicators inside the tolerance range.

4 Summary and conclusions

Measurement concepts developed and applied so far in Germany are mainly based on indicator systems, taking ecological, economic and (sometimes) social indicators into account. Within the EU research project SVAPPAS, a method of sustainability measurement based on principles of financial markets, will be tested wrt sustainability issues in agriculture, and further developed. In a first phase this method will be compared with methods already available. This analysis is oriented to farm level approach based on FADN data. Simplifications wrt number and determination of indicators is required, as part of them are to be derived from monetary accounts without regarding local circumstances (due to lacking information).

The study goes in two directions; first, measurement concepts available in German are reviewed, and second, the different methods are applied to a sample of dairy farms selected from the national FADN.

The calculations undertaken don't reflect all dimensions of sustainability properly; therefore the results of the approaches are limited by the included resources. The value based assessment is a new approach and needs further research and development wrt the agriculture sector. The question of the appropriate benchmark can not be answered in this paper and depends on the individual research question. In addition to aggregated figures it is important to take the different resource SVs into account.

The efficiency approach wrt assessment of sustainability issues is useful but efficiency is only one part of sustainable development, which doesn't take all dimensions properly into account. The DEA result also gives one single indicator per farm and thus the identification of "problem areas" is difficult.

The results of the indicator approaches depend on the chosen indicator set which was limited by data. Also the definition of the assessment function and the tolerance range has an important effect on the results. In comparison to the other approaches, which assess relative performance of farms, defined target values on sustainability are included.

The results of DEA, Sustainable Value and economic indicators lead to similar conclusions in most assessments. In contrast to the high correlation between Sustainable Value and DEA, a rather low correlation with the ecological indicators can be observed. Moreover, results of SV and economic indicators are generally contrary to ecological indicators. In each case it seems to be reasonable to use more than one approach for the assessment, to get a more detailed and comprehensive picture of the individual dimensions and issues of sustainability.

Therefore, we can conclude that the different measurement concepts result in different rankings. Further work is necessary to prove the reliability application of the methods for sustainable evaluation of farms.

5 References

- BACHMANN D (2006) Ökonomische Nachhaltigkeit. Kriterien, Toleranzbereiche und Ergebnisse. TLL-Schriftenreihe Landwirtschaft und Landschaftspflege in Thüringen", Jena. Heft 8: 49-62
- BARBIER EB (1987) The concept of sustainable economic development. Environmental conservation: An international Journal of environmental science 14:101-110
- BMELV (2006) Statistisches Jahrbuch für Ernährung Landwirtschaft und Forsten. Münster
- BMELV (2008) Nachhaltige Land- Forst- und Fischereiwirtschaft.
http://www.bmelv.de/cIn_044/nn_749972/sid_21A8570A9B054D66904311B99C9BD5CF/DE/11-Forschung/Nachhaltigkeit/Nachhaltigkeit.html__nnn=true
- BOCKSTALLER C, REINSCH M, FREIERMUTH KNUCHEL R, BRAUNER R, UNTERSEHER E, GAILLARD G, BAUMGARTNER D (2006) Betriebliches Umweltmanagement in der Landwirtschaft: Vergleich der Methoden INDIGO, KUL/USL, REPRO und SALCA. Association pour la Relance Agronomique en Alsace, Schiltigheim
- BREITSCHUH G, ECKERT H, KUHHAUPT H et al (2000) Erarbeitung von Beurteilungskriterien und Messparametern für nutzungsbezogene Bodenqualitätsziele. Umweltbundesamt Texte 50/00, Berlin
- BRUNDTLAND KOMMISSION (1987) Unsere gemeinsame Zukunft. Eggenkamp Verlag, Greven
- CHARNES A, COOPER WW, LEVIN AY, SEIFORD LM (1994) Data Envelopment Analysis: Theory, Methodology, and Application. AH Dordrecht
- CHRISTEN O, O'HALLORAN-WIETHOLTZ Z (2002) Indikatoren für eine nachhaltige Landwirtschaft. ILU Bonn
- DLG (2006) Effiziente Jahresabschlussanalyse: Einheitliche Erfolgskennzahlen für landwirtschaftliche Betriebe aller Rechtsformen. 2. vollständig überarbeitete Neuauflage. Arbeiten der DLG, Band 194. DLG-Verlag, Frankfurt am Main
- DLG (2007) <http://www.dlg.org/de/ueberuns/index.html>
- DLG (2008) www.nachhaltige-landwirtschaft.info
- DYCKHOFF H, ALLEN K (1997) Produktions- und entscheidungstheoretische Begründung der Effizienzmessung mittels Data Envelopment Analysis (DEA). Aachen
- ECKERT H, BREITSCHUH G, SAUERBECK D (1999) Kriterien umweltverträglicher Landbewirtschaftung (KUL) - ein verfahren zur ökologischen Bewertung von Landwirtschaftsbetrieben. http://www.tll.de/ainfo/pdf/kul_0299.pdf

- EUROPÄISCHE KOMMISSION (2000) Mitteilung der Kommission an den Rat und das Europäische Parlament: Indikatoren für die Integration von Umweltbelangen in die Gemeinsame Agrarpolitik, KOM(2000)20. Brüssel
- FIGGE F, HAHN T (2004) Sustainable value added - measuring corporate contributions to sustainability beyond eco-efficiency. *Ecological Economics* 48(2), 173-187
- FIGGE F, HAHN T (2005) The Cost of Sustainability Capital and the Creation of Sustainable Value by Companies. *Journal of industrial ecology* 9:47-58
- GOODLASS GF, HALBERG N, VERSCHUUR G (2001) Study on input/output accounting systems on EU agricultural holdings. Centre for Agriculture and Environment, Utrecht
- HAHN T, LIESEN A, FIGGE F, BARKEMEYER R (2007) Nachhaltig erfolgreich Wirtschaften Eine Untersuchung der Nachhaltigkeitsleistung deutscher Unternehmen mit dem Sustainable-Value-Ansatz. Berlin.
<http://www.new-projekt.de/downloads/newstudiekurzfassung.pdf>
- HEGE U, BRENNER M (2004) Kriterien umweltverträglicher Landbewirtschaftung (KUL). Schriftenreihe der Bayerischen Landesanstalt für Landwirtschaft, Heft 9.
<http://www.lfl.bayern.de/iab/duengung/umwelt/14345/index.php>
- HEIBENHUBER A (2000) Nachhaltige Landbewirtschaftung - Anforderungen und Kriterien aus wirtschaftlicher Sicht. VDLUFA-Schriftenreihe 55 (Kongressband Stuttgart-Hohenheim), S.72-82
<http://www.tll.de/ainfo/pdf/nach0606.pdf>
- HÜLSBERGEN KJ (2003) Entwicklung und Anwendung eines Bilanzierungsmodells zur Bewertung der Nachhaltigkeit landwirtschaftlicher Systeme. Shaker Verlag, Aachen
- HÜLSBERGEN KJ, ROST D, DIEPENBROCK W (2000) Analyse und Bewertung von Umweltwirkungen im Landwirtschaftsbetrieb – Das Hallesche Konzept –. Landwirtschaftliche Fakultät der Martin-Luther-Universität Halle-Wittenberg [Hrsg.] Die Agrarwissenschaften im Übergang zum 21.Jahrhundert – Herausforderungen und Perspektiven. 8. Hochschultagung am 28.04.2000 in Halle/Saale.Tagungsband
- KÜSTERMANN B, SCHMID H, WENSKE K, HÜLSBERGEN KJ (2007) Betriebs- und Umweltmanagement mit dem System REPRO. Lehrstuhl für Ökologischen Landbau, kuestermann@wzw.tum.de
- MATTHES I (2006) Sozialverträglichkeit - Kriterien, Toleranzbereiche und Ergebnisse. TLL-Schriftenreihe Landwirtschaft und Landschaftspflege in Thüringen, Jena.Heft 8: 49-62

- MEYER-AURICH A (2003) Agrarumweltindikatoren auf betrieblicher Ebene - Vergleich verschiedener Ansätze zur Bewertung der Umweltleistungen landwirtschaftlicher Betriebe. Vortrag auf der Jahrestagung des Dachverband Agrarforschung 2002 in Braunschweig. Veröffentlicht in Agrarspectrum 36, 51-62
- OECD (1997) Environmental indicators for agriculture. Paris: OECD
- ROEDENBECK I AE (2004) Bewertungskonzepte für eine nachhaltige und umweltverträgliche Landwirtschaft. Fünf Verfahren im Vergleich. Biogum Universität Hamburg
- SCHAFFNER A, HÖVELMANN L (2007a) Der DLG-Nachhaltigkeitsstandard „Nachhaltige Landwirtschaft–zukunftsfähig“. DLG Frankfurt
- SCHAFFNER A, HÖVELMANN L (2007b) Kurzbeschreibung DLG-Nachhaltigkeitsindikatoren. DLG Frankfurt. Download:
http://www.nachhaltige-landwirtschaft.info/uploads/media/DLG-Nachhaltigkeitsstandard_06-07.pdf
- SRU – RAT VON SACHVERSTÄNDIGEN FÜR UMWELTFRAGEN (1985) Sondergutachten Umweltprobleme der Landwirtschaft. Verlag Kohlhammer, Stuttgart und Mainz
- TLL (2006a) Kriterien einer Wirtschaftsverträglichen Landwirtschaft.
<http://www.tll.de/ainfo/ksnl/kwl10606.pdf>
- TLL (2006b) Umwelt-Testbetriebsnetz Thüringen 3. und 4. Auswertejahr (2003/04) Ergebnisse und Schlussfolgerungen. USL-Projektstelle des VDLUFA beim Verband für Agrarforschung und -bildung (VAFB) Jena
- VAN PASSEL S (2007) Assessing sustainability performance of farms: an efficiency approach. Ghent University, Ghent, Belgium
- VDLUFA (1998) Standpunkt – Kriterien umweltverträglicher Landbewirtschaftung
<http://www.vdlufa.de/info/kul.pdf>
- VDLUFA (2002) Umweltverträglichkeitsanalyse - Anliegen und Durchführung der Umweltverträglichkeitsanalyse im USL. http://www.tll.de/kul:old/usl_02.htm

Arbeitsberichte aus der vTI-Agrarökonomie

- Nr. 01/2008 Margarian A:
Sind die Pachten im Osten zu niedrig oder im Westen zu hoch?
- Nr. 02/2008 Lassen B, Friedrich C, Prübe H:
Statistische Analysen zur Milchproduktion in Deutschland –
Geografische Darstellung (Stand: Januar 2008)
- Nr. 03/2008 Nitsch H, Osterburg B, von Buttlar Ch, von Buttlar HB:
Aspekte des Gewässerschutzes und der Gewässernutzung beim Anbau
von Energiepflanzen
- Nr. 04/2008 Haxsen G:
Calculating Costs of Pig Production with the InterPIG Network
- Nr. 05/2008 Efken J:
Online-Befragung von Erhalterinnen seltener Nutztiere oder
Nutzpflanzen zu Ihren Aktivitäten und Einstellungen
- Nr. 06/2008 Rudow K, Pitsch M:
Fallstudie zur Wirkung der Ausgleichszulage im Landkreis Oberallgäu
(Bayern)
- Nr. 07/2008 Daub R:
Fallstudie zur Wirkung der Ausgleichszulage im Landkreis Vogelsberg
(Hessen)
- Nr. 08/2008 Haxsen G:
Interregionale und internationale Verflechtung der Ferkelversorgung in
Deutschland – Berechnung regionaler Versorgungsbilanzen und Kalkula-
tionen der Produktionskosten für Ferkel im interregionalen sowie inter-
nationalen Vergleich
- Nr. 09/2008 Lassen B, Isermeyer F, Friedrich C:
Milchproduktion im Übergang – eine Analyse von regionalen Potenzialen
und Gestaltungsspielräumen
- Nr. 10/2008 Gasmi S:
Fallstudie zur Wirkung der Ausgleichszulage im Landkreis St. Wendel
(Saarland)

Die *Arbeitsberichte aus der vTI-Agrarökonomie* können unter
http://www.vti.bund.de/de/institute/bw/publikationen/bereich/ab_14_2008_de.pdf
kostenfrei heruntergeladen werden.

- Nr. 11/2008 Pohl C:
Fallstudie zur Wirkung der Ausgleichszulage im Altmarkkreis Salzwedel (Sachsen-Anhalt)
- Nr. 12/2008 Gömann H, Heiden M, Kleinhanß W, Kreins P, von Ledebur EO, Offermann F, Osterburg B, Salamon P:
Health Check der EU-Agrarpolitik – Auswirkungen der Legislativvorschläge
- Nr. 13/2008 von Ledebur EO, Ehrmann M, Offermann F, Kleinhanß W:
Analyse von Handlungsoptionen in der EU-Getreidemarktpolitik
- Nr. 14/2008 Ehrmann M, Kleinhanß W:
Review of concepts for the evaluation of sustainable agriculture in Germany and comparison of measurement schemes for farm sustainability.