Applying and Extending the Sustainable Value Method related to Agriculture – an Overview

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Abstract— **Sustainable Value is a method to measure the contribution of an economic entity, such as a farm or the entire agricultural sector, towards the sustainability (sustainable development) of a region, a country or on a global scale. A positive sustainable value is created once resources are used more efficiently than by a benchmark. It shows the excess return that is created or lost by the use of economic, environmental and social resources by an economic entity relative to a benchmark. The purpose of this paper is to give an overview on the characteristics and requirements of the SV and to provide information on (a) possible applications and (b) extensions of the SV method related to the agricultural sector. A particular emphasis is put on the choice of sustainability indicators (resource figures, welfare figure) to be included, the generic steps of SV calculation, the meaning of weighting and aggregation in the SV, the role of the Return-to-Cost Ratio in taking farm size into consideration, and the interpretation and communication of the results of an agriculture-related SV assessment. After sketching out possible extensions and variations of the SV method, the paper closes with a summary of those aspects to keep in mind when applying the SV to agriculture.**

Keywords— **sustainability contributions, value, measurement**

I. INTRODUCTION

The purpose of this paper is to provide information on (a) possible applications and (b) extensions of the Sustainable Value (SV) method with respect to the agricultural sector. Related to applying the SV to agriculture, the goal is also to develop a step-by-step procedure for carrying out an SV assessment using the data set of the Farm Accountancy Data Network (FADN) of the European Union that includes a variety of economic as well as some environmental and social indicators.

When we speak of applying the SV in this paper, we mean SV calculations with indicators and benchmarks that are appropriate for predefined research questions to compare the sustainability contributions of agriculture on different levels of aggregation (e.g., farm, production forms, entire sector). Extending the SV refers to complementing approaches or methods that are integrated into or added to the SV assessment. Examples for extensions include: (i) applying different approaches for calculating benchmarks to be used in an SV assessment and (ii) descriptive and analytical statistical analyses (such as factor or cluster analyses) that complement SV assessments.

The paper is structured as follows: In Section II, we give an overview on the general characteristics and requirements of the SV. In particular, we highlight conceptual elements of the SV regarding the meaning of sustainability and resource and the kinds of research questions that the SV can contribute to answering. In Section III, we provide an overview of the different steps to go through when carrying out SV assessments.

Each SV assessment step is then explained in detail and specifically related to the agricultural sector (Sections IV to VII). Section IV refers to the various aspects of the scope of the SV assessment with a particular emphasis on the sustainability indicators to be used. Sections V and VI put a focus on the processes of data mining and calculating the SV. This includes two methodological aspects of the SV that we feel should be given special attention: the meaning of weighting and aggregation in the SV as well as the role of the Return-to-Cost Ratio in taking farm size into consideration. Section VII refers to interpreting and communicating the results of an SV assessment.

In Section VIII, we sketch out possible methodological extensions of the SV method, some of them being in the process of being developed at the time of writing this paper. The paper closes with a summary (Section IX).

II. CHARACTERISTICS AND REQUIREMENTS OF THE SV

The SV [1, 2, 3, 4, 5] is used to measure the contribution of an economic entity, such as a farm or the entire agricultural sector, towards making a region, a country or another entity more sustainable. The sustainability contribution or performance measured by SV consists in using resources more efficiently than an alternative use. Note that the approach is not about measuring the absolute sustainability of, for instance, that farm, i.e. the approach does not tell us, if a farm is sustainable. SV relates the resource efficiency of one entity to that of a chosen benchmark. It is therefore a relative measure, based on the concept of opportunity costs [6, 7]. SV tells us how much an entity has contributed to a higher level of sustainability of resource use through the fact that resources were used by the entity being assessed rather than by the benchmark.

According to the SV concept, a positive sustainable value is created once resources are used more efficiently than by the benchmark. Analogously, a negative sustainable value is created when the resources are used less efficiently compared to the benchmark. Usually, the sustainable value is expressed in monetary terms. However, it is also possible to express it in physical units, such as product output or tons of CO_2.

A. What research questions can be answered using the SV

All research questions related to the SV incorporate a comparison of resource use efficiencies, relative to a benchmark. For instance, we can compare how efficiently a farm uses various economic, environmental and social resources (such as water, energy, financial capital, workers, but also CO_2-emisisons, see Section IV C). Typically, the resource use is assessed and evaluated individually for each resource and for the resource bundle.

The benchmark represents the opportunity costs of the resource use. The benchmark therefore shows how much return would have been generated had the resource(s) been employed alternatively. It is crucially important that the benchmark und thus the opportunity costs represent a feasible and comparable alternative. Opportunity costs will only be meaningful, if the resources could really have been employed by the benchmark and would have produced an acceptable alternative return.

An alternative is for example not feasible when it does not exist or cannot be implemented. Assume for example that an investor cannot invest in companies outside his/her home country. Using the return that could have been created had the investment been carried through in another country does not represent a feasible alternative.

An alternative is for example not comparable when it does not have the same characteristics as the original alternative. Assume for example that an investor invests in a risk-free investment. If we assume that our investor is risk-averse then a risky alternative would not reflect the appropriate opportunity cost.

Generally, if comparing on the farm level, those farms can be identified that (a) create the highest excess return with their environmental, social and/or economic resources (absolute SV) or (b) use a resource bundle most efficiently (return-to-cost ratios). The former shows which companies or farms contribute the most to a more sustainable development in absolute terms. The latter reflects which companies or farms use their resources most efficiently. Differences between the two are due to differences in company/farm size.

B. Sustainability concept

The sustainability concept provides the normative foundation for the selection of relevant sustainability issues to be included in the assessment. It can be described as follows:

- The overall goal is the sustainable development of a larger entity that will usually encompass the individual entity being assessed. Very often the larger entity is described in geographical terms (for example a region, country or larger geographic area).

- As there is a trade-off between the different goals such a development must be environmentally, socially and economically efficient.
- An individual farm, a farm type or the entire agricultural sector (different levels of aggregation possible) contributes to sustainable development (positively or negatively) by using certain resources more efficiently than a benchmark.
- The sustainable value approach can cover a range of economic, environmental and/or social resources. To be included in the sustainable value approach a resource must satisfy two criteria: (a) The resource must be required to create a return. (b) The resource must be scarce.

Criterion (a) reflects the anthropocentric nature of the sustainable value approach. Criterion (b) lays out the basis for the need to be efficient. In contrast to existing approaches the sustainable value approach does not consider economic, environmental and/or social resources based on their degree of harmfulness or similar. The sustainable value approach will consider any economic, environmental and/or social resource that can be considered to be scarce.

The natural, social and economic conditions and problems differ of course in the various regions and countries to be investigated. Thus, to attain an applicability of the concept in the countries and regions under investigation, the resources and issues considered must be relevant to these countries and regions.

In addition, there are some general features of the sustainable value approach arising from the sustainability concept:

- Carrying capacity constraints (absolute amounts of resources used) can be included in the benchmark for individual resources.
- The value contributions for the individual resources are aggregated to a total index number. Thus, changes in the use of several resources could cancel each other out and eventually result in the same SV again.
- The SV is about substitutability between resource users, not between resources. The assumption of the basic Sustainable Value model is that a given set of resources is exchanged between different resource users.
- The overall level of resource consumption is unchanged. The sustainable value in its basic model is therefore compatible with strong sustainability.

III. OVERVIEW OF STEPS FOR CARRYING OUT AN SV ASSESSMENT

Each SV assessment is carried out following a number of steps. These steps are outlined below and will be described in Sections IV to VII related to the agricultural sector in Europe:

1. *Defining the scope of the assessment:* (a) choice of economic entities to be assessed (example: farms, production forms, a sector in various regions) and of time span; (b) choice of benchmark (example: sector average); (c) choice and definition of resource indicators to include (examples: energy, work accidents, CO_2 emissions); (d) choice and definition of the welfare/return indicator (example: farm profits).
2. *Data mining:* (a) collection of data on farms, production forms etc.; (b) collection of benchmark data; (c) cross-checking of data quality.
3. *Calculating SV:* (a) How much return does the farm create with its resources? (b) How much return would the benchmark have created with each resource? (c) How much SV does the farm create? (d) Taking farm size into account: calculation of Return to Cost ratios.
4. *Interpreting and communicating the results:* (a) explanatory power of absolute SV; (b) explanatory power of the Return to Cost Ratio; (c) potential users and uses of the results; (d) transparency in communicating results.

IV. SCOPE OF THE ASSESSMENT

A. Choice of economic entities to be assessed and of time span

Generally, it is possible to carry out an inter-sector assessment or an intra-sector comparative assessment. In this paper, we refer only to intra-sector SV assessments within agriculture. In this case, it is possible to assess, e.g., individual farms; farm types (e.g. specialized beef, dairy, pork, poultry, and crop farms); production forms/labels (e.g., conventional, organic). While comparisons within a farm type can identify the room for improvement within a particular farm type, a key strength of assessments between farm types with the SV is that they can uncover the potential of structural change for sustainable development.

Depending on the research questions, it may be reasonable to assess the SV contributions of agricultural farms over a relatively long period of time, provided that data is available. Generally, a larger time span of the SV assessment can help identify mavericks and, consequently, improve the accuracy of the data set. Moreover, the assessment of a number of consecutive years can reveal performance trends. In addition, significant changes in the data over the years may help to identify structural changes of farms or the entire agricultural sector.

So far, the time scale for SV applications has been a maximum of 7 years (due to data availability). SV assessments are typically carried out ex-post. Yet, from these ex-post results, future developments may also be extrapolated. Provided that the agricultural SV assessments will be largely based on the FADN data sets, the following should be kept in mind with respect to the time frame. Although the FADN data set was established already in 1965, its variable names and features have been modified several times. Thus, SV time series can only be constructed in a limited way, that is, generally, for rather short periods of time.

B. Choice of benchmark

Generally, the benchmark choice needs to follow from the overall empirical research question. It also depends on whether and how risk aspects are taken into account [8]. In addition, there may be several options for calculating a particular benchmark (e.g., weighted or non-weighted average). Since the explanatory power of the SV largely depends on the benchmark, it should be chosen with great deliberation. It is indispensable that one defines a benchmark that is appropriate and suitable with respect to the research question that is addressed by an SV application.

Each benchmark choice is associated with certain analytical goals, assumptions, and methodological consequences. For instance:

- Comparing the SV performance of the agricultural sector of a country to the entire EU 15 economy implies that the idea of structural change within a national economy is an option to be considered.
- If averages are used as benchmarks, they may either refer to a specific year or incorporate an average over several years. An average over some years may help to eliminate effects of fluctuations between years or missing data, but will not allow for taking innovation effects (technological change) into consideration. The implicit assumption is that the allocation decisions allow for a shift of the use of resources over time. A farm can for example decide to use an environmental resource in the following rather than the ongoing year.
- Comparing the sustainability contributions of individual farms in a particular region helps to identify frontrunners and laggards within the regional sector.
- Using the best existing performer as goals for the regional sector runs the risk that this one observation is an outlier or due to a wrong observation. From a development perspective, it also contains a certain static element since the performance boundaries of the analysis are limited to what has already been achieved.
- If a political performance target is used as benchmark the assessment shows the contribution of the economic entity under analysis to the achievement of such goals.

- However, it has to be kept in mind that political targets represent results of political discourse and bargaining processes that do not necessarily define a sustainable level of farm or farm sector performance from, e.g., an ecologist's perspective.
- If the goal is to investigate the evolution of farm contributions to sustainability over time (e.g., in order to investigate possible policy-induced shocks), a benchmark that is not linked to an individual year may be useful. Such a benchmark may be a performance average of several years. As pointed out above this is linked to the implicit assumption that the use of a resource can be shifted in time.

Even though the use of various different benchmarks could lead to similar results in terms of ranking the identified frontrunners and laggards, the choice of an adequate benchmark will still be very important related to policy analysis. Potentially useful benchmarks for policy analysis include political performance targets (as far as they exist) and best performance.

Overall, it should be made transparent what the benchmark stands for in the assessment and why it was chosen. Also, in order to uncover the influence of benchmark choice on the results, it is useful to carry out sensitivity analyses by testing different benchmarks and comparing them with each others with regard to the underlying assumptions and the results they generated [9].

C. Definition of resource indicators

Within the SV, a resource is defined as something that is required to generate a return in an economic activity. Examples for such resources include water, energy, materials and labour. The effect of using these resources is that their scarcity is increased. If a resource is used up (or needs to be given time to be reproduced in the case of renewable resources) it is not available for immediate further use any more and, in this way, creates a loss or burden for society. Referring to capital theory, instead of the term resource also the term capital is used related to SV [10]. However, in this paper, we use the term resource.

Generating a return may also cause environmental pollution or work accidents. Such phenomena also have got the characteristics of resources, as defined above: Without them no return could be generated and they constitute at the same time a burden for society. They can also be included in SV assessments. SV assessments can therefore include a large variety of economic, environmental and social resources.

In addition, in order to be included in SV assessments, a resource has to fulfil the following technical requirements: (a) a resource needs to be measurable in quantitative, cardinal terms, (b) it can be measurable in monetary units (Euro) or physical units (e.g., tons, number of accidents). It should be noted that the choice of a resource does not depend on the relative burden or similar of the resource. Sustainable Value reflects the extra return given a set resource base. As explained above for an indicator to be incorporated it must be necessary for the creation of a return and it must be scarce.

When choosing indicators for the SV assessment, it should be indicated which agricultural sustainability issues these indicators represent. Also, one should keep in mind that one indicator may represent more than one sustainability issue. For instance, the indicator 'Total labour input' represents both a social and economic sustainability issue.

Furthermore, it is important to avoid double counting of the same sustainability issue. For example, one should include either energy use or energy related emissions in order to represent the environmental issue of global warming due to greenhouse gas emissions. As these indicators are directly related, there would be an overlap and thus double counting of the same sustainability issue if both were taken into account.

In the following sections, we first present environmental, social and economic resource indicators with respect to the following questions: (a) Which issues do the indicators stand for? (b) In which units are they typically measured? (c) Are they part of the FADN data set of the EU? (d) Have they been used in SV assessments so far (to the knowledge of the authors at time of writing this paper)? Note that the following listings are not exhaustive. Additional resources and indicators are possible as well.

Environmental resource indicators

Environmental resource indicators of relevance for agriculture include the following (see Table 1):

Table 1 Agriculture-related environmental resource indicators suitable for SV assessments

Environmental sustainability issues (=resources)	Indicators	Units	FADN	Used in SV so far
Input-related				
Land	Total Utilised Agricultural Area (UAA)	10,000 m^2	X	X
	Rented UAA	10,000 m^2	X	-
	UAA for cereals	10,000 m^2	X	-
	UAA for other field crops	10,000 m^2	X	-
	UAA for energy crops	10,000 m^2	X	-
	Set aside	10,000 m^2	X	-
	Woodland area	10,000 m^2	X	-
	Quantity of soil compaction		-	-
Livestock	Total livestock units		X	-
	Dairy cows	# of livestock	X	-
	Other cattle	# of livestock	X	-
	Sheep and goats	# of livestock	X	-
	Pigs	# of livestock	X	-
	Poultry	# of livestock	X	-
Seeds and plants	Costs for seeds and plants	Euro	X	-
Fertilizers	Costs for fertilizers	Euro	X	-
Crop protection	Costs for plant protection products, e.g., against animals, hail, frost	Euro	X	-
Pesticides	Area under pesticide application	10,000 m^2	-	-
Feed for grazing livestock	Costs for feed for grazing livestock, e.g., rent for forage land	Euro*	X	-
Feed for pigs and poultry	Costs for feed for pigs and poultry	Euro	X	-
Energy	Costs for Motor fuels and lubricants, electricity, heating fuels	Euro	X	
	Direct energy input for production	MJ	(X)	X
	Renewable direct energy input		-	-
Water	Total water use	m^3	-	X
	Use of alternative water resources (rainwater, surface water, shallow ground water)		-	-
Output-related				
Carbon dioxide (CO_2)	Carbon dioxide emission	CO_2-eq	-	X
Methane (CH_4)	Methane emission	t	-	X
Nitrogen oxides (NO_X)	Nitrogen oxides emission	t	-	X
Water pollution by manure	Manure emissions	m^3	-	-
Waste generation	On farm produced waste (type and quantity)	t	-	-
Heavy metals	Addition of heavy metals	g	-	-
Organic carbon	Soil organic carbon input	t	-	-
Input and output-related				
Energy	Energy balance (direct & indirect energy output - direct & indirect energy input)	MJ	-	-
Nitrogen	Nitrogen surplus or balance (balance=Output-Input)	kg	(X)	X
Phosphorus	Phosphorus balance	kg	-	-
Surface water	Surface water balance	m^3	-	-

The indicators in Table 1 may be divided into three groups. The first group are those environmental indicators that are part of FADN and directly measured in physical terms. This rather small group includes land use and use of livestock and, at least for Belgium, Nitrogen surplus. In addition, milk production in physical terms (milk units) can be calculated using FADN variables. For the second group, only the farms' costs for acquiring the agricultural inputs are available within the FADN. Examples include feed, fertilizers and energy. Depending on the research question, these costs should be transformed into physical variables. The third group contains those indicators that are not part of the FADN, e.g., ammonia emissions and waste water production. Thus, data for these indicators need to be derived from additional sources.

Some environmental resources, such as fertilizers, are useful only once they are used in proper amounts: too little is unproductive, too much causes emissions into water, air or uncultivated soil that are hazardous to the environment (e.g., N, P). Instead, an optimal amount or range of resource use exists. However, it is much more likely that resources like N and P will be used in overly large amounts leading to a resource surplus (e.g., N surplus, P surplus). This is why the resource balance indicators that are typically used in this context are often called resource surplus indicators. A resource balance or surplus is calculated by subtracting resource inputs from outputs.

In the context of sustainable value this should be interpreted as follows. If there are emissions that are hazardous to the environment then there is a scarcity. In this case, the resource can be used in the sustainable value approach just like any other resource. If the emissions are not hazardous to the environment then there is no scarcity. In that case the resource should not be considered in the sustainable value approach, as there is no value in using it more efficiently.

Social resource indicators

Overall, there are relatively few social resource indicators available within the FADN data set. However, this is a common problem related to applying the SV to social sustainability issues. Generally, such issues tend to be available in quantitative terms only in a very limited way. As a result, SV assessments (just like many other quantitative sustainability measures) tend to be short of the social dimension of sustainability. Social resource indicators of relevance for agriculture include the following (see Table 2).

Table 2 Agriculture-related social resource indicators suitable for SV assessments

Social sustainability issues (=resources)	Indicators	Units	FADN	Used in SV so far
Labour				
	Total labour input	Annual work units (AWU; full-time person equivalents)	X	-
	Labour input (time worked by total labour input)	Hours	X	-
	Unpaid labour input (Family labour)	(Annual) family work units (FWU)	X	-
	Unpaid labour input (time worked by unpaid labour)	Hours	X	-
	Paid labour input	Annual work units (AWU; full-time person equivalents)	X	-
	Paid labour input (time)	Hours	X	-
	Number of jobs	No unit	X	X
	Number of work accidents	No unit	-	X

Economic resource indicators

Economic resource indicators of relevance for agriculture are presented in Table 3. Economic capital refers to all assets of a farm (both fixed and current assets). In addition to economic capital, Table 3 contains a number of resources that are also mentioned regarding other sustainability issues. These include labour, land and other resources of natural origin.

Table 3 Agriculture-related economic resource indicators suitable for SV assessments

Economic resource	Indicators	Unit	FADN	So far used in SV
Capital	Total assets	Euro	X	X
	Total fixed assets	Euro	X	-
	Buildings	Euro	X	-
	Machinery	Euro	X	-
	Breeding livestock	Euro	X	-
	Land, permanent crops	Euro	X	-
	Total current assets	Euro	X	-
	Non-breeding livestock	Euro	X	-
	Stock of agricultural products	Euro	X	-
	Other circulating capital	Euro	X	-
	Net worth (=total assets-liabilities)	Euro	X	-
	Average farm capital	Euro	X	X
Labour	--- See Table 2 ---			
Land	--- See Table 1 ---			
Livestock	--- See Table 1 ---			
Seeds and plants	--- See Table 1 ---			
Fertilizers	--- See Table 1 ---			
Crop protection	--- See Table 1 ---			
Feed	--- See Table 1 ---			
Energy	--- See Table 1 ---			
Water	--- See Table 1 ---			

D. Definition of the welfare/return indicator

Within the SV, different types of return figures can be used, including:

- Physical outputs of the farms (products and services),
- Farms' turnover,
- Farms' profits (= return that a farm creates for its owners/capital providers),
- Farms' personnel expenses (= return that a farm creates for employees),
- Gross (Net) Value Added (= contribution of a farm to Gross (Net) Domestic Product).

After choosing the appropriate return figure, it has to be defined how the return should be measured both for the farms and the benchmark level. In this context, it is important that the return figures on the corporate and benchmark level match.

V. DATA MINING

A. Collecting data on farms, production forms etc.

The collected data on the resources used and return created and the data sources must be well documented. Also, remember that the scope of the data on all resources has to be congruent in order to enable a meaningful SV.

B. Collecting benchmark data

Benchmark data must cover the same resources and return figure as those used at the farm (or production form) level. Depending on which benchmark has been chosen, readily available data from sources like national statistics can be used. In other cases, the benchmark has to be constructed. For instance, sector data is often not publicly available and has to be calculated or estimated. In any case it is important to properly document all data and calculations including the sources that have been used.

C. Cross-checking data quality

There are three major issues in data quality that should be addressed before calculating SV:

1. Accuracy of the collected data (one way to check the plausibility of data is to compare the efficiencies of farms with similar characteristics)
2. Scope consistency between farms regarding the resource and return indicators used.
3. Scope consistency between return figure and resource use data – or among resource use data (particularly virulent with environmental and social performance data, as such data may not be reported for all of a farm's activities). In cases where the scope of environmental data is not complete, one may extrapolate it based on farm data – or reduce the financial data to match the scope of the environmental data.

It might be preferable to use data sources like FADN where scope consistency is already given due to harmonized statistics on the European level. However, if various data sources are used (which may be necessary due do limited environmental and social data availability), scope consistency needs to be considered.

VI. CALCULATING SV

The calculation of SV is based on the notion of opportunity cost thinking. Accordingly, SV is created whenever a farm uses its bundle of resources more efficiently than a benchmark. In other words, SV is created whenever the return that a farm achieves through the use of a bundle of resources exceeds the opportunity cost of these resources. In the following the generic steps of calculating SV are described briefly. It should be noted that technically the way sustainable value is calculated in detail can differ depending on among others the production function that we assume on the benchmark level to determine the opportunity costs (see also Section VIII).

A. Generic steps of SV calculation

1. How much return does the farm create with its resources?

In the first step, the return that has been created by the farm with its resources is determined for every year under analysis. For this purpose, the return figure that has been defined earlier (see Section IV D) is being used. If different return figures are to be considered alternatively, one should conduct distinct assessment scenarios for each return figure chosen. It must be kept in mind that the return figure must relate to the same scope as the resource figures that are used in the analysis.

2. How much return would the benchmark have created with each resource?

In the second step, the opportunity costs of the resources used by the farm are determined. For this purpose, it is calculated how much return would be created if the resources were used not by the farm but by the benchmark. In this context, the choice of benchmark, including the assumptions on risk as well as the choice of production function is most influential. Depending on which benchmark has been chosen to meet the research question under analysis the opportunity costs of the resources used by the farm are determined. Note that the technical details of the calculation depend on the benchmark and the assumed production function of the benchmark.

3. How much SV does the farm create?

In the last step it is determined how much Sustainable Value the entire bundle of resources creates in a particular farm. For this purpose, the opportunity costs are deducted from the return of the farm. The difference between return and opportunity costs is defined as Sustainable Value. The SV shows how much more or less return a farm creates with a bundle of resources compared to the benchmark or – in other words – the excess return the farm achieves with its resources in comparison to the benchmark.

B. Weighting and aggregation

Weights are determined by the opportunity costs

The weights of the different resources are determined by the relative efficiency on the benchmark level. The weight of the resources thus differs according to how much they contribute to creating a return on the benchmark level. For example, if on the benchmark level the resource energy provides 3 times more return per unit than one unit of water then the relative weight of energy to water is three times. The relative value-based weight of energy and water is thus 3 to 1. Thus, there is an implicit weighting already in the SV arising from the different resource efficiencies on the benchmark level. In other words, the choice of the benchmark determines the weighting of the different resources for a specific sustainable value assessment.

This holds analogously if alternative production functions are chosen on the benchmark level to determine the opportunity costs and aggregate different resources: The weight of the different resources follows from the weighting on the benchmark level. Note that with some benchmarks (e.g. efficiency frontier or data envelopment analysis) the weights of the resources will be different for each farm under analysis. This has to be taken into account in the interpretation of the results.

The implicit weighting effect also becomes clear if, for instance, an emission target is used for the resource of CO_2 emissions. In such a case the weights will automatically increase once the target is raised. Note that this kind of weighting is different from explicitly assigning normative weights to indicator components (sustainability issues), e.g., based on their perceived societal importance for regional sustainable development.

Aggregation

Typically, the individual resources that make up SV are aggregated to one final number. The aggregate SV figure is used to evaluate the overall sustainability performance of a farm. In addition to the aggregate SV figure, one can also evaluate each resource separately regarding its efficiency and value contribution. Results on individual resources may be used to identify value drivers, i.e., resources that most strongly contribute to a positive SV. Note that the underlying logic of the aggregation and the weights will differ depending on the benchmark and underlying production function chosen.

C. Taking farm size into consideration with the Return to Cost Ratio

When comparing farms, a size effect gets in the way. Usually, large farms are expected to have large profit, sales or cash flow figures. The same applies to SV figures. One should therefore take farm size into account when comparing different farms. This is typically done using the Return to Cost Ratio (RCR). The RCR compares the return of a farm to the return the benchmark would have created with the resources of the farm. An RCR larger (smaller) than 1 indicates that a farm yields more (less) return per unit of resource, i.e., the farm uses its resource bundle more (less) efficiently than the benchmark.

The RCR is calculated by dividing the return of the farm by the opportunity costs. If a farm has a positive SV (farm return exceeds opportunity costs), this translates into an RCR above unity. A farm that is twice as efficiently as the benchmark will have an RCR of 2:1. If a farm has a negative SV (opportunity costs exceed farm return), the RCR is below unity. In order to express the RCR as a ratio with one number being equal to 1 and the other being larger than 1 one can use the reciprocal value of the result of the ratio between return and opportunity costs. For a farm that is only half as efficient as the benchmark, i.e., where the return is only half as high as the opportunity costs, this translates into an RCR of 1:2.

VII. INTERPRETING AND COMMUNICATING THE RESULTS

A. Explanatory power of absolute SV

The absolute SV answers the following question: What is the value that has been created or lost because a farm has used some resources as opposed to the resources being used by the benchmark? In other words, a positive (negative) SV shows if a farm has covered the opportunity costs of its economic, environmental and social resources (or not). In this way, the absolute SV also shows the value that could be gained, if resources were shifted from farms on the benchmark level to the assessed farms. The explanatory power of the absolute SV is thus comparable to economic value added figures – but not only with respect to economic capital but also to environmental and social resources farms are using.

SV takes into account the absolute amount of resources farms are using. This is particularly relevant from the viewpoint of environmental protection and sustainable development. Using SV, it is generally assumed that the overall amount of resources remains constant. Yet, if reduction targets are used as the benchmark, SV can also take into account the need to reduce the use of environmental and social resources on the benchmark level.

In addition to the aggregate SV figure, looking at the value contributions of the individual resources may help to identify strengths and weaknesses of an agricultural sustainability performance. They show which resources constitute a source of value creation - and which resource use should be improved in terms of their efficiency in order to generate a positive value contribution.

B. Explanatory power of the RCR

The RCR is an indicator of the efficiency with which a farm uses its economic, environmental and social resources – in brief: it measures the sustainability efficiency of farms. It is typically used to compare farms of different sizes. In addition, it may be used to determine the performance spread within the agricultural sector by comparing the RCR of the sector leader with the performance of the sector laggard. Also, one may look at the development of the RCR of a farm over time. RCR can also be calculated for each resource separately.

C. Potential uses of the results

In the context of farm performance monitoring, the identification of out- and underperformers (frontrunner and laggard farms, relative to the benchmark), value drivers (resources) with the SV is particularly relevant. If performance targets are used as the benchmark, the results can be used as early warning signals for particular relevant environmental and social problems in the future as well as to identify the vulnerability of the farm to tighter regulations or future societal or market demands. In addition, one may also identify performance trends of individual farms or the entire agricultural sector.

Policy makers may use the results to identify those farms, production forms, etc. that are most critical for implementing economic, environmental and social policies. In general, one should keep in mind that the explanatory power and the usefulness of the results in a specific decision making situation depend on an adequate choice of the benchmark.

D. Transparency in communicating the results

As pointed out throughout this paper, the quality of the SV results will strongly depend on the quality of the data used and the appropriateness of the decisions on the design of the assessment (e.g. use of appropriate benchmark). The choice of the benchmark as well as the choice and definition of indicators are highly sensitive issues that need to be handled with great deliberation.

Given these properties of SV, it is essential to be as transparent as possible in all steps of the assessment. The data sources and all calculations should be well documented, and therefore enable the reader to understand the underlying assumptions. This also applies to cases in which data has been extrapolated, estimated or calculated. Furthermore, all communication of the results of SV should explicitly mention the indicators and the benchmark that have been chosen. It can be expected that the more transparent the result of SV are the higher the acceptance of the results with different stakeholder groups.

VIII. METHODOLOGICAL EXTENSIONS AND VARIATIONS OF THE SV

The basic concept of Sustainable Value centres around the idea that sustainability performance of economic entities such as farms are assessed by applying opportunity cost thinking to the use of a bundle of economic, environmental and social resources. Any assessment that determines sustainability performance by deducting opportunity costs of one or more resource(s) from the return of an economic activity is based on and compatible with the SV approach. However, the SV approach can be extended methodologically with regard to different aspects. In this Section, we briefly discuss the most relevant possible extensions of SV in the context of agricultural sustainability assessments and show how these extensions relate to the generic methodology described in this paper.

Extension to the SV may, on the one hand, be directly embedded in the SV calculation process. This mainly refers to the assumptions (and their variations) in choosing a benchmark and calculating the opportunity costs, which also determines the weight and aggregation of the different aspects taken into consideration. On the other hand, analytical tools that generate additional information and insights based on the results of SV assessments can extend the SV. For example, regression, factor or cluster analysis can be used to relate SV results to additional variables or gain a better understanding of the SV results. Further possible methodological extensions refer to the scope of SV assessments, i.e. its extension to value chains and product life cycles.

A. Extensions in the calculation of opportunity costs

As mentioned above, an important area of methodological extensions of the SV approach refers to the calculation of the opportunity cost and the choice and definition of the benchmark. In this context, two issues are of major importance: risk and the production function that is assumed.

In financial analysis, opportunity costs are adjusted for risk. This is based on the idea that generally, future returns on investment cannot be predicted with certainty but rather are exposed to risk. When the benchmark and the opportunity costs are defined one must make an assumption on if and - if so - how risk aspects should be taken into account. Depending on the assumptions on the role of risk, an appropriate benchmark should be chosen. The implications of these assumptions of risk should also be taken into account in the interpretation of the SV results.

It should be noted that the basic approach to SV assessments as described in this paper is based on the assumption that (1) there is risk and (2) the return created through each resource by each farm is subject to the same risk. If one chooses other assumptions on risk, we suggest that conceptually risk should be considered analogously to the way in which it is included in the assessment of economic capital in financial market assessments (based on Modern Portfolio Theory and the Capital Asset Pricing Model). However, since there is no market for some environmental and social resources, the rationale of financial markets can only be applied by making several assumptions. Taking risk into account results in a risk-adjusted opportunity cost for every farm and every resource considered. Risk-adjusted opportunity costs represent the return that the benchmark would achieve with the resources of the company at a comparable level of risk [11].

Another issue in the definition of the benchmark and the calculation of the opportunity costs refers to the assumptions on the underlying production function in SV assessments. Recall that the opportunity cost logic in general, and the SV approach in particular, are based on the notion that scarce resources can be exchanged amongst different users and that eventually resources should be devoted to their most efficient use. The basic SV assessment as described above in this paper is either based on the assumption that there are linear production functions on the farm and the benchmark level for all resources or that there is a quasi infinite number of farms with a quasi infinite number of possible combinations of different sets of resources. If one wants to deviate from such an assumption, alternative production functions may be used to determine the benchmark and the opportunity costs. However, it has to be kept in mind that changing the benchmark may have implications on the way risk is treated as well as on the explanatory power of the results. Furthermore, any benchmark that is chosen for a SV assessment must respect the two major preconditions defined above (see Section IV B), i.e., it must represent a feasible and comparable alternative to the use of the resources on the farm level.

When alternative production functions are used to determine the opportunity cost [12], one needs to be explicit about one's assumptions and implications for risk. Most importantly, the production function must be appropriate for the research question behind the SV assessment. In this context, it has been proposed to calculate the benchmark employing a hybrid method labelled StoNED [13], combining elements of data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Rather than from a universal benchmark, the opportunity cost would be derived from a modelled production frontier line that represents a farms-specific efficiency optimum.

B. Extensions of the scope of SV assessments

As has been stressed above, it is of crucial importance that the system boundaries of a SV assessment are clearly and consistently defined. So far, SV assessments have been applied to the production stage, i.e. both the return and the resource use that are taken into account refer to the production activities of an economic entity such as a farm. In the context of agriculture it may of interest to extend the scope of SV assessments to previous or subsequent stages in the value chain, by including for instance products or the production of fertilizers.

In principle, calculating the SV for agricultural products or previous value chain stages follows the same principals as of SV calculation for farms. However, it should be kept in mind that both the return figures and the data on resources used have to match the new extended scope. This imposes additional requirements on data collection and data quality as value chain data is often not easily available. In addition, extending the system boundaries has far reaching implications on the explanatory power of the results: A farm-based SV assessment is based on the idea that different resources could be reallocated between farms and the benchmark. Thus, some farms may grow while others may even shut down in order to achieve an improved overall sustainability performance of the agricultural sector. Analogously, in a SV assessment on the product level resources will be reallocated between products. Consequently, as an implication, some products should be produced in larger amounts while others perhaps not at all any more.

If SV assessments are to incorporate the sustainability contributions of the different value chain stages and members that participate in the production and/or consumption of a product, one may use transfer pricing techniques to obtain a measure for the return and resource use per chain member, which can then be entered into the SV calculation.

C. Subsequent statistical analysis

As a subsequent step, the results of SV assessments can be further analysed using analytical statistics, e.g., regression, factor, or cluster analysis as well as test statistics. Statistical analyses can for instance provide a better understanding of the SV results, take into account additional variables that could not be integrated in the SV assessment itself, and/or show statistically significant differences between farm types based on their SV performance.

As an example, FADN indicators can be used to carry out a statistical analysis in order to find out about relationships between sustainability performance and structural characteristics of agricultural farms/sectors include age of manager, solvency, size unit, subsidies interest, subsidies revenues, and subsidies, share of income [14].

Conceptually and methodologically, SV results should be treated in statistical analyses as any other variables used in such analyses and according to standard statistical methods.

IX. SUMMARY

In this paper we have outlined the requirements, procedures and potential extensions of the Sustainable Value approach for its application to the assessment of sustainability performance in agriculture. In summary, the following aspects should be kept in mind when applying the SV approach to agriculture:

- The SV is a relative measure, based on the concept of opportunity costs that compares the resource efficiency of one economic entity to that of a chosen benchmark.
- The explanatory power of SV is comparable to economic value added figures. However, it exceeds them by including not only economic, but also environmental and social resources. When applied to the farm level, those farms can be identified that (a) create most monetary value (in absolute terms) using a given amount of certain

resources or (b) use a resource bundle most efficiently (return-to-cost ratios).

- In order to carry out an SV assessment, choices need to be made on the economic entities to be compared, the benchmark, the resources to be included, the welfare/return figure, and the time span. In this context, assumptions on the role of risk as well as on the exchangeability of resources need to be made explicit.
- SV assessments are performed in four steps, including a calculation of (1) the resource efficiency for each resource, (2) the opportunity costs for each resource, (3) the value contribution for each resource, and (4) the sustainable value as an average of all value contributions. Both the individual value contributions and the aggregate figure of SV are useful outcomes of the SV method. The Return to Cost Ratio is an indicator of the efficiency with which a farm uses its economic, environmental and social resources (sustainability efficiency).
- The choice of sustainability issues to be included in the SV assessment will depend on (a) their relevance for sustainable development, (b) the possibility to interpret these issues as resources and to represent them with a quantitative, cardinally-scaled indicator, as well as (c) data availability for the indicators.
- A resource is anything that is required to generate a return (e.g. income, profit, value added) for an economic entity and, at the same time, causes a burden for society. It needs to be measurable in quantitative, cardinal terms. There are environmental, social, and economic resources. Environmental resources also include the assimilative capacity of the natural environment, e.g., for CO_2 emissions.
- Environmental and social issues are represented in the FADN data set only in a limited way so far – which may be a general drawback due to the method's indicator requirements and data availability. Regarding environmental issues, an option seems to be to calculate physical resource indicators based on respective monetary variables that are available within the FADN data set. Due to the limited availability of environmental and social indicators, there also seems to be a need to rely on additional data sources. For them, the scope of the data on all resources, on the return figure, and between the economic entities has to be congruent in order to enable a meaningful SV.
- The adequate benchmark needs to be chosen according to the empirical research question. Potentially useful benchmarks for policy analysis include political performance targets and best performance. There is an implicit weighting of each resource in the SV, based on the chosen benchmark for the assessment.
- Promising methodological extensions and research questions refer to the definition of the benchmark and the opportunity costs and include (a) ways of including risk aspects based on portfolio theory and the capital asset pricing model and (b) applying different production functions, data envelopment analysis and/or stochastic frontier analysis to determine opportunity costs.
- Policy makers may use the SV results to identify those farms, production forms, etc. that are most critical for implementing economic, environmental and social policy targets. Combining SV with analytical statistics (e.g., by performing cluster analysis) may also support policy-related farm assessments.

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