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Rooted in Sustainability: Developing an Integrated Assessment Framework for Horticulture—The Example of Potted Plants

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Abstract: The increasing importance of sustainability in our society also affects horticulture. Ornamental plants are a multi-billion-euro business in Germany, with EUR 4.1 billion for potted plants, EUR 1.5 billion for fruit/ornamental shrubs as well as cut flowers and EUR 0.3 billion for flower bulbs, identifying potted plants as the largest stakeholder. In terms of sustainability, the potted plant branch in Germany is interesting due to its almost year-round production and cold winters. For example, a decision must be made as to whether a greenhouse should be heated all year round, possibly with fossil fuels, or whether cuttings should be imported from warm climate zones. In order to provide a farm manager with information about the degree of sustainability of their own production and to communicate sustainable production, an assessment method is necessary. As there is no comprehensive sustainability assessment system in German horticulture so far, especially in the field of potted plants, this study aims to fill this gap. This article reviews the state of the research of theoretical sustainability assessment. As the most important topics of sustainability assessment and as essential components of the framework, the system boundaries, indicators, base value, measurement level, target values, implementation, acceptance, data collection, assessment, aggregation and weighting, as well as communication and certification, are identified and discussed. An integrated framework for the assessment of sustainability in potted plant companies is developed.

Keywords: sustainability; sustainability assessment system; framework; horticulture; potted plants; floriculture production; ornamentals

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1. Introduction

The Brundtland report is the first big milestone in the international debate on sustainability [1]. Other than the definition of the term ‘sustainable development’ [2] as progress that is only sustainable if ecological, economic and social issues are taken into account simultaneously [3], it focused on inter-generational equity. Hence, the debate on sustainability started in the 1980s [4]. Nevertheless, the term sustainability is difficult to define [5]. In 2016, the United Nations developed the 17 Sustainable Development Goals (SDGs) to support sustainable development in the world [6]. SDGs 3 (good health and well-being), 6 (clean water and sanitation), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 12 (responsible consumption and production), 13 (climate action) and 15 (life on land) are particularly relevant for sustainability in horticulture. Sustainability is multidimensional, applicable in all areas of life and measurable in different ways [7]. The triple bottom line approach (TBL), with its ecological, economic and social dimensions, is the most appropriate and widely used to represent sustainability in a holistic way [8] and was described by John Elkington in 1994 [9]. The lack of a clear definition of the term ‘sustainability’ allows companies to use it strategically, which can create an impression of environmental and social responsibility that does not necessarily correspond to reality. The dimensions are visualised in the integrative sustainability triangle (Figure 1).

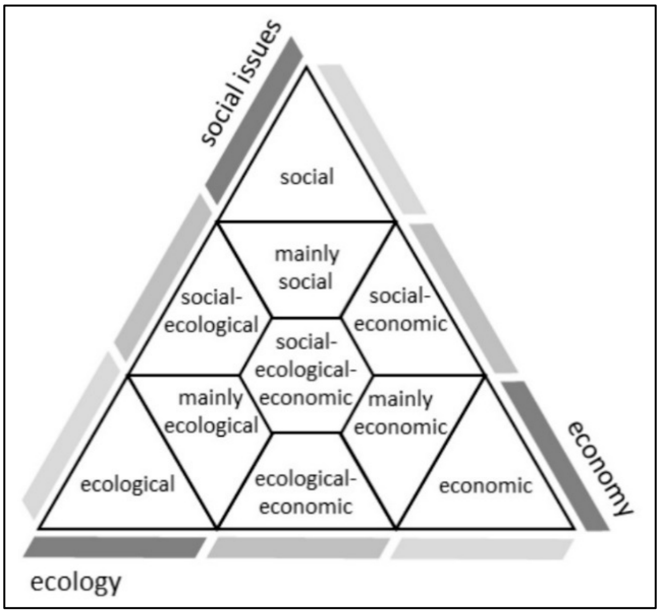

Figure 1. Integrative sustainability triangle (Bitter et al. [10]; adapted from Kleine and von Hauff [11]).

Worldwide, several hundred systems of general sustainability assessment exist and are applied [12], but most systems only focus on one dimension [13]. The first products were compared in terms of their environmental impact in the 1960s and 1970s [14]. Since the 1990s, sustainability assessment has also been used in agriculture [15], and several methods have been developed to measure sustainability in the industrial sector [16]. There are about 170 sustainability assessment frameworks, systems and tools for the topics of land use, agro–ecosystems and rural areas [17]. In historical development, companies started with economic balance sheets and successively expanded them to include ecological and social balance sheets. Sustainable production is a strategy that aims to maintain and promote agricultural productivity, economic feasibility, (energy) resources, stable communities and quality of life and to avoid environmental damage [18]. In addition, consumers are starting to pay more attention to sustainability aspects when buying (food) products [19] and sustainable farming practices are also expected to be sought by producers themselves [20]. This results in a need for a sustainability assessment system (SAS) for the horticultural industry, which is not yet existent. There are hardly any scientific studies on sustainability assessment in horticulture, but there are in agriculture. Due to the requirements for sustainability reporting in the context of the EU's taxonomy regulations, which have an impact on access to capital, the horticulture sector will also have to increasingly address the issues of sustainability and sustainability assessment in the future.

The aim of this paper is to develop a framework for the sustainability assessment of the production of potted plants in Germany.

2. Methodology

The methodology for this article primarily involved a scoping literature review to provide an overview of research on the topic of sustainability measurement and assessment. Relevant academic and non-academic sources were collected and analysed to gain broad insights into the existing body of knowledge on sustainability assessment theory. The criteria for this were appropriate scientific sources with existing keywords, such as sustainability assessment, sustainability measurement, sustainable agriculture, sustainability system or indicators. The most important aspects of sustainability assessment should be identified and the definitions found. The literature was critically analysed with regard to potted plant cultivation in Germany. The aim of the synthesis was to form a theoretical model that can be adapted to the assessment of sustainability in horticulture. This model summarises the key concepts and frameworks identified in the literature and provides a structured approach to sustainability analysis. The results from the literature review were therefore summarised in a model and the content-related links between the individual topics were marked with arrows. The process was iterative and allowed the model to be refined as new information was integrated.

The Business Process Model and Notation (BPMN) methodology was used to create the theoretical model in this article. BPMN is particularly relevant for workflow management systems [21], and flow charts are one technique of the BPMN [22]. They can be used to visualise processes as a simple diagram from their beginning to their end [21,23]. The process consists of several boxes connected by arrows [23]. Generally, flow charts are very flexible [22]. In the flow charts created in this article, the arrows indicate the direction of flow. If several arrows point away from a box, this indicates alternative process sequences, with dashed arrows leading to non-essential intermediate steps.

3. Sustainability in Floriculture Production

Floriculture production includes ornamental plants, which can be divided into cut flowers, cut foliage, potted plants and bulbs [24,25]. In this article, the focus is on potted plants. Potted plants are all annual or perennial plants that are produced and sold in a pot [26]. As they are cultivated in greenhouses and/or container production in open fields—thus, in a protected environment [27]—this sector is high-input agriculture with respect to area [28] and especially in terms of energy [29], which makes topics such as the utilisation of waste heat or heating material relevant. Potted plants are high-input crops as well as high-value crops [30]. The cultivation time of potted plants varies from two to almost five months [31], and cultivation is performed in staggered batches. Despite the protected environment, production is dependent on season and weather, so the cultivation time can change [27]. The season also influences the consumption of electricity for lighting or heating; for example, as seen in Ref. [32].

The working conditions and environmental impacts of this sector could be problematic [33]. The amount of packaging and plastic as well as the substrate consumption depends on the pot size of the potted plants. Single-use plastic is prevalent in horticulture. However, the predominantly black colour of the pots can lead to problems in automated plastic sorting systems [34]. Possible solutions to the waste problem and the reduction of greenhouse gas emissions are therefore a kind of deposit for plant pots, which is paid for by the customer, and the subsequent reuse of the pots [34]. Therefore, farm managers have the opportunity to increase the sustainability of ornamental plants [35], with particular attention to the ecological dimension [33]. In general, sustainable greenhouse cultivation should be socially acceptable, environmentally friendly, competitive and resource-efficient [36]. According to Allera et al. [37], resource use must be optimised for sustainable floriculture production. Therefore, integrated pest management must be sustainable, waste management and disposal must be efficient and organic waste from agriculture should be used as a fertiliser resource. According to survey results among horticultural consultants, the reputation of the horticultural sector in society as a whole is rated ‘slightly positive’ [38]. Nevertheless, horticulture is still seen as an industry in many respects, which implies scepticism towards modern and sustainable production methods [39]. Therefore, improving the perception of horticulture in society could contribute to the competitiveness of the sector [39].

Many of the problems mentioned with regard to sustainability affect not only the potted plant branch but also other branches of horticulture. Nevertheless, due to its characteristics (high proportion of production in greenhouses, a lot of sealed surface area, large amount of packaging material), potted plant cultivation has a high potential for increasing sustainability compared to other branches.

In 2022, potted plants accounted for 46% of sales (EUR 4.1 billion) of flowers and ornamental plants in Germany, making them the largest segment ahead of flower bulbs (3%; EUR 0.3 billion), fruit and ornamental shrubs (16%; EUR 1.5 billion) and cut flowers (35%; EUR 1.5 billion) [40]. A total of 19.8% of sales in German horticulture were achieved with ornamental plants [41]. The market volume (retail prices) of ornamental plants was EUR 9.0 billion in 2022 [42]. This underlines the importance of this horticultural branch. The value chain of potted plant production is multi-layered and includes different production steps (Figure 2). Depending on whether propagation happens vegetatively or generatively, the stages of the value chain take place in different regions, which can lead to different sustainability problems. In vegetative propagation, the breeding/research and development phase is processed in Europe and the cuttings in Africa and Central America [27], where the working conditions may be poor. In 2023, Germany imported live plants, including their roots and cuttings, worth EUR 9.2 million from Kenya and EUR 2.2 million from Uganda [43,44]. In generative propagation, the breeding/research and development and seed stages are worked on worldwide [45]. The following phases, rooted cuttings/seedlings and potted plants and distribution, take place in Europe and retail in Germany [45]. All in all, there are not many scientific studies, but a few projects concerning the sustainability of ornamental or potted plants are in Germany. This is therefore still a research gap that should be closed.

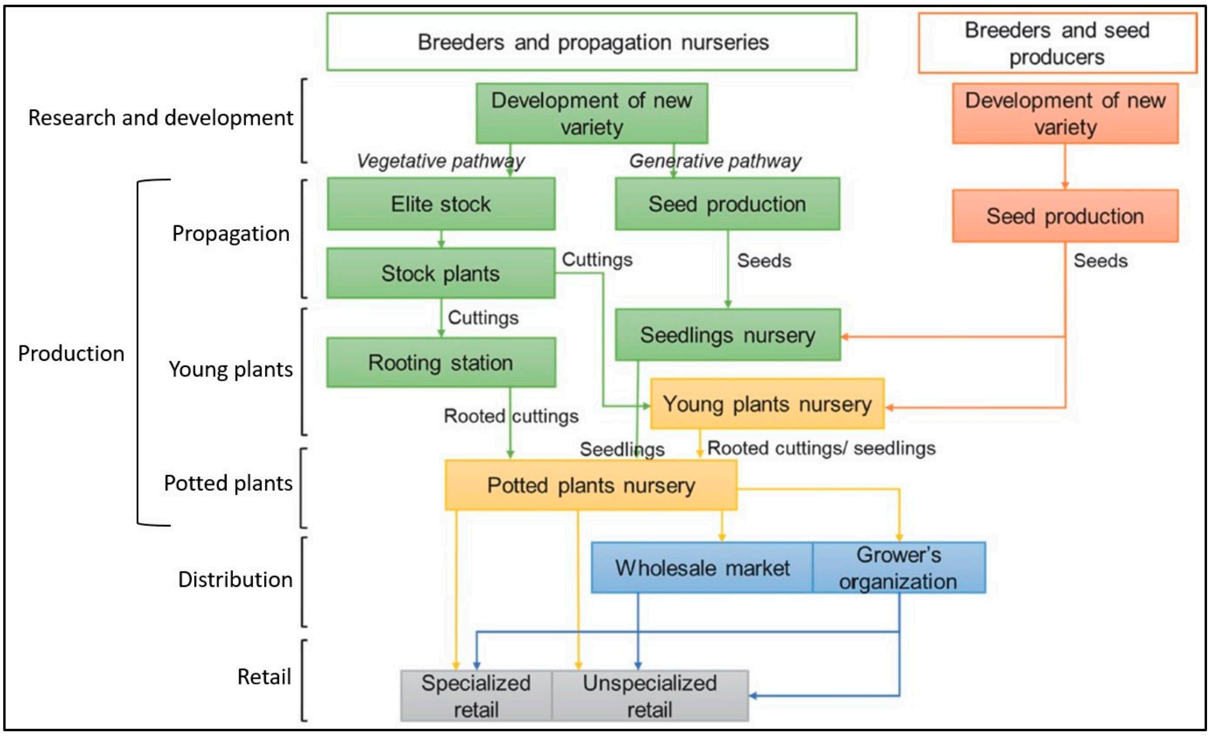

Figure 2. Value chain of potted plants (adapted from Havardi-Burger et al. [27]). Green: breeders and propagation nurseries; orange: breeders and seed producers; yellow: young plants and potted plant nurseries; blue: distribution; grey: retail.

There are some certification programs for sustainability in floriculture production. Veriflora is a certification for sustainable ornamental horticulture, including cut flowers and potted plants [46]. It focuses on environmental sustainability (sustainable crop production, resource conservation, energy efficiency, ecosystem protection and integrated waste management), social and economic sustainability (fair labour practices, community benefits) and product integrity (product quality, product safety and purity) [46]. At least 60% of certified companies are from the US, 17% from Ecuador and the rest are from countries in North or South America [47]. MPS offers environmental certification (MPS-ABC) for the entire sector of floriculture production, especially in the Netherlands [48]. This certification covers the topics of crop protection agents, fertilisers, energy, water and waste [48]. It can be complemented by the social certification 'MPS—socially qualified' [49]. GlobalG.A.P. also offers a consumer label for certified floriculture production [50]. In the "Principles and Criteria for Flowers and Ornamentals" Version 6.0, there are 158 control points in this certification, which are distributed among the topics of environment (18 points), management and traceability (25 points), workers' health, safety, and welfare (18 points) and production process (97 points) [50]. In addition, the Floriculture Sustainability Initiative is an international association that has been in existence since 2012 and is based on the three pillars of responsible production and trade, responsible conduct and integrated reporting [51]. These certification programs are not sufficient for the sustainability assessment in the German potted plant industry, as the economic dimension is never considered, and the social dimension is only partially considered. In addition, the programs are aimed at certification or reporting, but there is no assessment of sustainability. In order to create a holistic approach to sustainability assessment in German horticulture, the Centre for Business Management in Horticulture and Applied Research is currently working on the development of such a system [52].

4. Results

In the scoping literature review, several studies were identified as relevant for the development of a sustainability assessment framework. Table 1 provides an overview of the studies and literature sources compiled in Section 4.

Table 1. Overview of relevant studies for the development of a sustainability assessment framework.

Author	Year	Title	Type of Study	Sector
Bell and Morse [53]	2008	Sustainability indicators. Measuring the immeasureable?	Book	Cross-sector
Breitschuh et al. [54]	2008	Kriteriensystem nachhaltige Landwirtschaft (KSNL)	Book	Agriculture
Bitsch [12]	2016	Sustainability as innovation: challenges and perspectives in measurement and implementation	Book section	Agriculture
Gallopin [55]	1997	Indicators and Their Use: Information for Decision-making	Book section	Cross-sector
Boone and Dolman [56]	2010	Monitoring sustainability of Dutch agriculture	Conference Proceedings	Agriculture
Coteur et al. [57]	2016	Benchmarking sustainability farm performance at different levels and for different purposes: elucidating the state of the art	Conference proceedings	Agriculture
Dumanski and Pieri [58]	1997	Application of the pressure-state-response framework for the land quality indicators (LQI) programme	Conference proceedings	Agriculture
Knauber et al. [59]	2023	Communication of sustainability in horticulture—what messages do consumers currently perceive and what expectations do they have regarding sustainability?	Conference proceedings	Agriculture (Horticulture)
Wustenberghs et al. [60]	2016	Discerning the stars: characterising the myriad of sustainability assessment methods	Conference Proceedings	Agriculture
Derksen and Mithöfer [61]	2018	Bemessung von Nachhaltigkeit im Gartenbau	Report	Agriculture (horticulture)
Nardo et al. [62]	2005	Tools for Composite Indicators Building	Report	Cross-sector

Table 1. *Cont.*

Author	Year	Title	Type of Study	Sector
Neumayer [63]	2012	Human Development and Sustainability	Report	Cross-sector
Russillo and Pintér [64]	2009	Linking Farm-Level Measurement Systems to Environmental Sustainability Outcomes: Challenges and Ways Forward	Report	Agriculture
UNAIDS [65]	2010	An introduction to indicators	Report	Cross-sector
DLG e.V. [66]	n.d.	(not applicable)	Reports from assessment systems	Agriculture
GRI [67]	n.d.	(not applicable)	Reports from assessment systems	Cross-sector
INL GmbH [68]	n.d.	(not applicable)	Reports from assessment systems	Agriculture
De Olde et al. [69]	2017	When experts disagree: the need to rethink indicator selection for assessing sustainability of agriculture	Research article	Agriculture
Dominguez et al. [33]	2017	Evaluation of Existing Research Concerning Sustainability in the Value Chain of Ornamental Plants	Research article	Cross-sector
Allain et al. [70]	2018	Spatial aggregation of indicators in sustainability assessments: Descriptive and normative claims	Research article	Cross-sector
Dantsis et al. [71]	2010	A methodological approach to assess and compare the sustainability level of agricultural plant production systems	Research article	Agriculture
Dong and Ng [72]	2016	A modeling framework to evaluate sustainability of building construction based on LCSA	Research article	Building construction
Farrell and Hart [73]	1998	What Does Sustainability Really Mean? The Search for Useful Indicators	Research article	Cross-sector
Gatti et al. [74]	2021	Green lies and their effect on intention to invest	Research article	Cross-sector
Grenz et al. [75]	2009	RISE—a method for assessing the sustainability of agricultural production at farm level	Research article	Agriculture
Häni et al. [76]	2003	RISE, a Tool for Holistic Sustainability Assessment at the Farm Level	Research article	Agriculture
Havardi-Burger et al. [45]	2021	Framework for sustainability assessment of the value chain of flowering potted plants for the German market	Research article	Agriculture (Horticulture)
Isaak and Lentz [77]	2020	Consumer Preferences for Sustainability in Food and Non-Food Horticulture Production	Research article	Agriculture (Horticulture)

Table 1. *Cont.*

Author	Year	Title	Type of Study	Sector
Lewandowski et al. [78]	1999	Sustainable Crop Production: Definition and Methodological Approach for Assessing and Implementing Sustainability	Research article	Agriculture
Rasmussen et al. [79]	2017	Bridging the practitioner-researcher divide: Indicators to track environmental, economic, and sociocultural sustainability of agricultural commodity production	Research article	Agriculture
Roesch et al. [80]	2016	Umfassende Beurteilung der Nachhaltigkeit von Landwirtschaftsbetrieben	Research article	Agriculture
Roesch et al. [81]	2017	Comprehensive Farm Sustainability Assessment	Research article	Agriculture
Roesch et al. [82]	2021	Sustainability assessment of farms using SALCAsustain methodology	Research article	Agriculture
Saisana and Saltelli [83]	2011	Rankings and Ratings: Instructions for Use	Research article	Cross-sector
Sala et al. [84]	2015	A systemic framework for sustainability assessment	Research article	Cross-sector
Schader [85]	2016	Nachhaltigkeit messen und bewerten	Research article	Agriculture
Schader et al. [86]	2014	Scope and precision of sustainability assessment approaches to food systems	Research article	Agriculture
Schader et al. [87]	2019	Accounting for uncertainty in multi-criteria sustainability assessments at the farm level: Improving the robustness of the SMART-Farm Tool	Research article	Agriculture
Speelman et al. [88]	2007	Ten years of sustainability evaluation using the MESMIS framework: Lessons learned from its application in 28 Latin American case studies	Research article	Agriculture
Talukder et al. [89]	2017	Developing Composite Indicators for Agricultural Sustainability Assessment: Effect of Normalization and Aggregation Techniques	Research article	Agriculture
Van Cauwenbergh et al. [90]	2007	SAFE—A hierarchical framework for assessing the sustainability of agricultural systems	Research article	Agriculture
Weaver and Rotmans [91]	2006	Integrated sustainability assessment: what is it, why do it and how?	Research article	Cross-sector
Wolf [92]	2013	Improving the Sustainable Development of Firms: The Role of Employees	Research article	Cross-sector

Table 1. *Cont.*

Author	Year	Title	Type of Study	Sector
Acosta-Alba and Van der Werf [8]	2011	The Use of Reference Values in Indicator-Based Methods for the Environmental Assessment of Agricultural Systems	Review	Agriculture
Chopin et al. [93]	2021	Avenues for improving farming sustainability assessment with upgraded tools, sustainability framing and indicators. A review	Review	Agriculture
Ehrmann and Kleinhanss [16]	2008	Review of concepts for the evaluation of sustainable agriculture in Germany and comparison of measurement schemes for farm sustainability	Review	Agriculture
Gan et al. [94]	2017	When to use what: Methods for weighting and aggregating sustainability indicators	Review	Cross-sector
Lebacq et al. [95]	2013	Sustainability indicators for livestock farming. A review	Review	Agriculture (livestock)
Nadaraja et al. [96]	2021	The Sustainability Assessment of Plantation Agriculture—A Systematic Review of Sustainability Indicators	Review	Agriculture
Pavraudeau and van der Werf [97]	2005	Environmental impact assessment for a farming region: a review of methods	Review	Agriculture
Schindler et al. [98]	2015	Methods to assess farming sustainability in developing countries. A review	Review	Agriculture
Becker [99]	1997	Sustainability Assessment: A Review of Values, Concepts, and Methodological Approaches	Review	Agriculture
Christinck et al. [100]	2017	Stand und Perspektiven der Nachhaltigkeitsbewertung landwirtschaftlicher Systeme und des Agrarsektors	Unpublished report	Agriculture
Christen et al. [101]	2013	Sustainable arable farming. Boosting efficiency, maintaining the image, conserving resources	Working paper	Agriculture
Dillon et al. [102]	2010	Assessing the Sustainability of Irish Agriculture	Working paper	Agriculture
Huffman [103]	1990	Indicators and assessment of agricultural sustainability	Working paper	Agriculture
Norman et al. [104]	1997	Defining and implementing sustainable agriculture	Working paper	Agriculture

First, the general goal of a sustainability assessment is to draw a sufficiently realistic picture of how sustainable a company or a product is. To do this, one must define what is sustainable and then determine what is to be measured. All relevant aspects and parts of the system being assessed must be included in order for an assessment to be called a sustainability assessment [91]. Second, all relevant aspects must be measurable in practice; i.e., it must be clarified how they are to be measured. So, a balance has to be found to cover these aspects on the one hand, but on the other hand, the practical application should not overburden the companies [78]. Furthermore, there is no broad consensus among experts on how sustainability should be measured [69]. The objectives of a sustainability assessment may include certification, communication, reporting to policy makers and operational development or research [57]. Figure 3 provides an overview of the development of a sustainability assessment as a business process model and is explained in detail in the following.

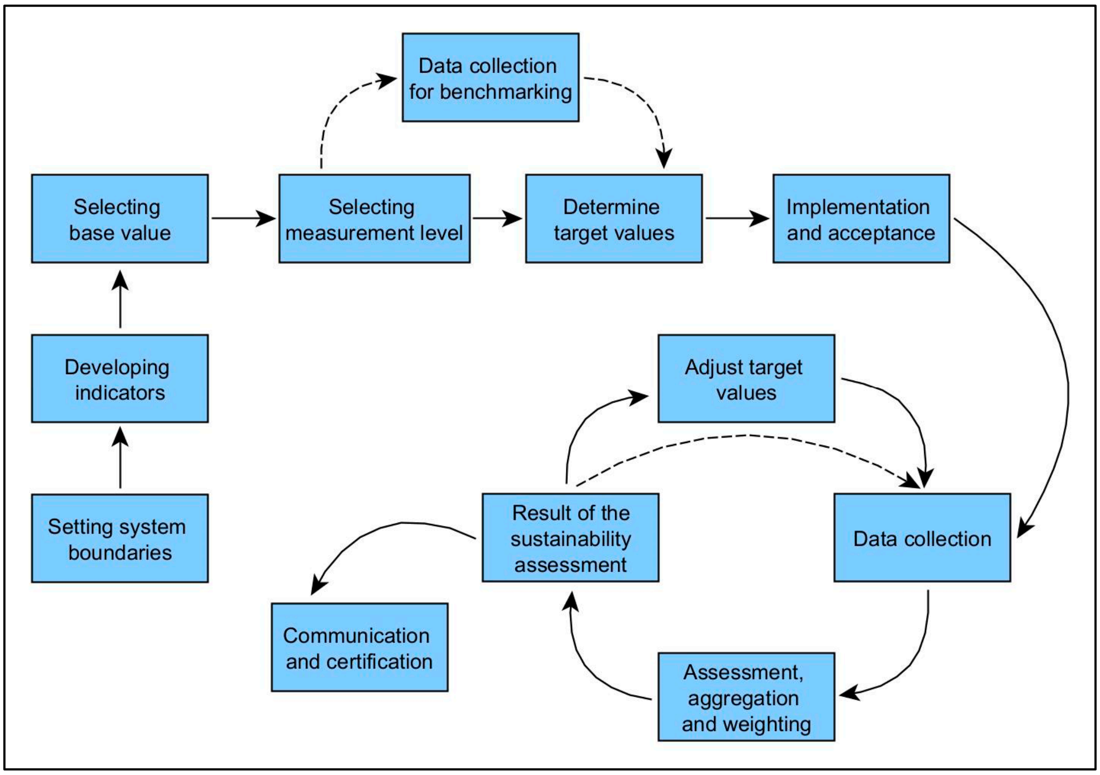

Figure 3. Simplified business process model for the development of a sustainability assessment (own figure).

System boundaries: When creating a SAS, it is important to define the system boundaries [56], as the production and subsequent use of a product is influenced over a long period of time and by several different but interconnected systems. The system boundaries need to be defined individually for the different dimensions, and it is not possible to use one system boundary for all dimensions without restrictions [81]. When considering the entire product life cycle, there are tools such as life cycle assessment, life cycle cost and social life cycle assessment that can be combined into the life cycle sustainability assessment [72]. The TBL only represents the production of a product without purchased products and further life cycles (supply chains) [105], which could be detrimental to a holistic assessment if large quantities are bought in addition [100]. A SAS including all three dimensions, like the TBL, is called an integrated system [60].

Indicators: When assessing sustainability, in some SAS, the user has the opportunity to choose which standards [67] or indicators [16] should be analysed. Indicators are signs [55] that represent complex things in a simple way [53] and describe situations [70]. They enable a comparison of sustainability performance [45], also over a period of time [12]. Indicators can include observable variables, which can be measured directly, or latent variables, which can be determined by several different measurements. Furthermore, indicators can be classified differently; there are the parameters or indicators for driving forces (internal system pressure) and for the current state (present situation), where the level of sustainability is the difference between state and driving force [53,75]. It is also possible to distinguish between means-based and effect-based indicators [97]. Means-based indicators refer to the technical inputs used in a system, while effect-based indicators include emission indicators (contribution of polluting emissions) and impact indicators (effect of polluting emissions) [97]. The more generally the indicators are described, the more difficult it is to directly understand what this indicator entails. Therefore, care should be taken to define the indicators in a compact and clear manner [99]. Generally, a catalogue of indicators should adequately represent the entire system [73], so a considerable scope of indicators is required [103]. However, the number of indicators should be limited in order to maintain practicability, as the system becomes too complicated if there are too many indicators [80]. A holistic representation of a system can be achieved by a large number of indicators and a reductionist representation can be realised by a small number of indicators [57]. Also, it is possible that there are correlations between the individual indicators [16]. Additionally, different stakeholders, e.g., society, researchers, policy makers, consumers or horticulturists, should be involved in the process of selecting appropriate indicators [12,96]. Generally, care should be taken that the indicators are relevant, practicable, have a benefit for the end user, are comparable and are adaptable [12,79,95]. According to Havardi-Burger et al. [45], a hierarchical approach should be taken to develop an indicator. First, a sustainability goal should be formulated for each of the three dimensions [45]. Then, the sustainability challenges and themes should be identified and defined [45]. In addition, the goals and sub-themes for each sustainability theme need to be defined [45]. The last step is to select and develop indicators to measure the sub-theme [45].

A central problem in the selection of indicators is measurability and, in particular, the consideration of what is measurable and what level of effort is acceptable for measurement [104]. Basically, indicators have to be cost-effective regarding their measurement [79] and regarding the time required for measurement [12]. Sometimes, there are no data to capture an indicator, so alternative indicators have to be found. It is also possible that the effort required to collect the necessary data is too high for a SAS to be affordable and feasible. Moreover, indicators can be captured by a different number of aspects and measurements, which affects the representativeness of the indicator. For example, work–life balance cannot be represented only by the number of days of leave, as other factors such as the hours worked per week also have an impact on the topic. Mostly, measuring an indicator is just a snap-reading method, so the error-proneness can be high [90].

Base value: When collecting data for an indicator, there must also be a base value to put the data in relation and to be able to interpret them because indicators are context-specific [65]. Without a base value, the measured or collected value would be without any context. Possible base values in the horticultural context, especially for the ecological dimension, would be product quantity, product quality, percentage values or area [54,68]. Added value is also a possible base value, especially for indicators related to resource use. Then, it can be seen whether an increasing input of resources also leads to an increasing output in the form of added value. Each base value treats the system differently, so the results may vary depending on the base value.

Measurement level: When thinking about the measurement level, there are the options of sustainability assessment at the product, crop batch, crop or farm levels (Figure 4). Not every measurement level is possible for every dimension because of the calculation. At the product level, almost only ecological indicators can be captured, as most social and economic indicators relate to the whole company. However, an attempt can be made to break down the assessment to the measurement level of the crop or crop batch (e.g., hydrangea or geranium), as the production factors (economic and social) are usually similar but differ between the individual production types. The product should be used as the measurement level for the ecological dimension, as it is assumed that consumers pay attention primarily to the environmental impact of an individual product. For the social and economic dimensions, the crop batch level should be used. This allows for a more accurate measurement of sustainability than if the entire farm is chosen as a basis. It should be noted that every basis and every measurement value have disadvantages and only approximate objectivity is possible.

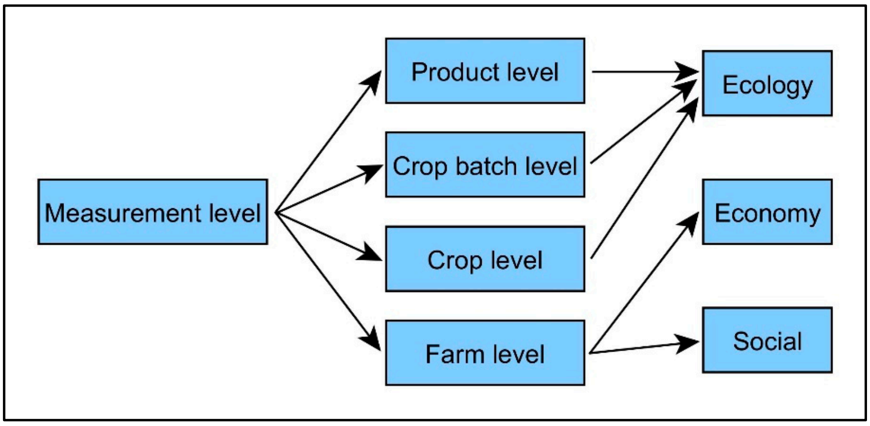

Figure 4. Measurement level (own figure).

Target value: Target values are needed for the interpretation of data collection and quantifying sustainable objectives [8]. The target value is defined as the degree of sustainability required for each indicator individually [90], and they can be divided into normative and relative target values (Figure 5) [8]. When considering normative target values, a distinction is made between science-based and policy-based [8]. Relative target values, on the other hand, take into account either the current situation or the time trend. A horizontal intercompany comparison, also called benchmarking, is used—for example, by Dillon et al. [102]—and involves improving one's own sustainability performance by comparing with a standard or the performance of other companies and learning from this [57]. Benchmarking can be performed anonymously within a sector or within a group for the exchange of knowledge. Not only should target values be achieved but also communication between companies is essential for this concept. A vertical comparison of operations is a comparison of internal data over a certain period of time, so the focus is on temporal development. No external target values are needed for this, but only the company's own internal information is processed. The target value individually chosen for the indicators can have a strong influence on the assessment of the degree of sustainability [85]. Therefore, care should be taken to select an acceptable target value for each indicator in order not to distort the result. This means that target values should not be set too high, but also not too low. To prevent this, there are a number of data sources for setting target values: scientific literature, expert opinions, community averages, modelling results or policy targets [8,84]. Also, target values should be site-specific, as the location has an influence on the measurement of sustainability due to different ecological, geographic, climatic, social and economic conditions and standards [71]. Target values should be constantly adjusted based on new research and evidence, as indicators get closer to being increasingly ambitious, and sustainability is improved over time. However, thresholds and targets for horticulture are hardly found in the literature so far.

Implementation and acceptance: For a SAS to be viable, the value of the information generated must compensate the effort of the person collecting the data [64]. Regardless of the size of the company, the implementation of a SAS and, in particular, the data collection incur costs in the form of labour hours or costs for external auditors. To improve the sustainability of a company, it is important to involve employees [92] to ensure their support and commitment. In general, stakeholder involvement is necessary to increase the acceptance and practical benefits of SAS [98]. SAS implementation is more likely if they have multiple objectives and background information is transparently available [60].

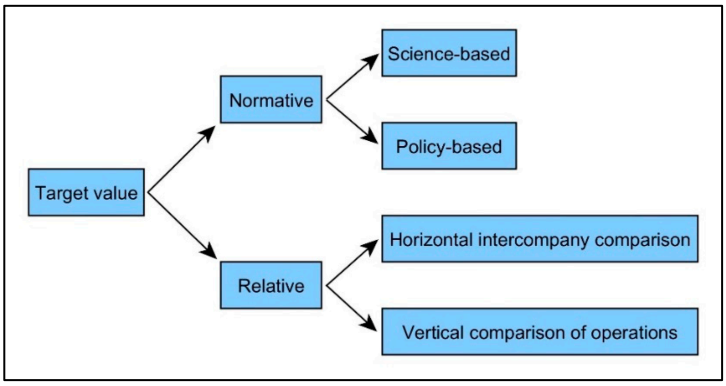

Figure 5. Target values (based on Acosta-Alba and Van der Werf [8]).

Data collection: There are several possible collection methods to obtain relevant data for the sustainability assessment (Figure 6). Annual financial statements and questionnaires (such as surveys or personal interviews) are common data collection methods [106,107]. These methods can be complemented by site inspections [76,101]. In addition to that, data collection can be performed through direct field measurements, literature reviews and simulation models [88]. Also, shop floor data collection can be used. When collecting data via interviews or similar methods, it can be problematic that respondents provide false or subjective information. Sometimes the company has to collect the required data itself [67]; for example, using Excel data entry forms [82]. Once the data have been collected by the farm manager, monitoring should be conducted [80] by self-reporting or external inspectors, who could perform the inspection announced or unannounced. Self-inspection carries the risk of deception and external inspectors have to be organised and paid.

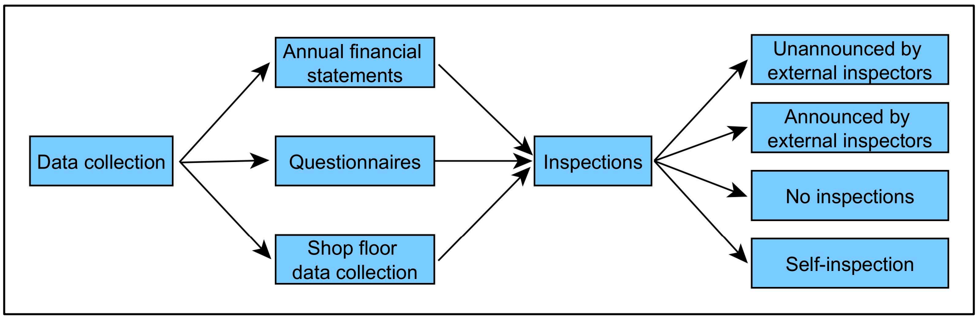

Figure 6. Data collection (own figure).

Aggregation, weighting and assessment: When discussing methods of aggregation, weighting and assessment of SAS, it should be noted that these are human-made constructs that underlie, therefore, the subjective point of view [100]. A sustainability assessment can be goal-oriented or action-oriented [66]. In a goal orientation, predefined goals are to be achieved, whereby the measures necessary for this are not specified. In the case of an action orientation, the measures to be carried out are defined. Bitsch [12] recommends a goal-oriented system. Often, detailed information about the assessment is not published; among other things, this is due to copyrights [100]. A distinction can be made between aggregation and weighting of indicators or dimensions.

- Indicators: Individual indicators can be aggregated to create a sustainability index [58,94]. Methods can be additive (equally weighted addition of the individual indicators to an overall result), linear, geometric/multiplicative (multiplication of the individual indicators to an overall result) or non-compensatory [89,94]. Aggregation should reflect the individual relevance of indicators in the measured system [83]. Although equal weighting of indicators [108] is the simplest way, it is usually not recommended.

Some indicators are more important than others because their topic poses a higher potential risk to nature, people and company, which should be taken into account in their weighting. The weighting could be performed by an expert or stakeholder groups [87,109].

- Dimensions: In terms of bringing the dimensions together, there are two key concepts: strong sustainability and weak sustainability. Weak sustainability describes the situation when natural and manufactured capital are replaceable and only the entire capital stock needs to be maintained [63]. In contrast, strong sustainability describes the situation where natural capital is not replaceable and the loss of natural capital cannot be compensated by manufactured capital [63]. Following the TBL, these definitions mean that substitution between the three dimensions corresponds to weak sustainability, but for strong sustainability, there must be no compensation between the three dimensions [100]. So, good results from the social dimension cannot compensate for bad results from the environmental dimension. Thus, when producing an overall outcome that includes all dimensions, substitution between the dimensions may occur. An overall result including all dimensions is not advisable [81], as equal weighting of the dimensions would lead to a higher consideration of the dimension that contains the most indicators [62]. An unequal weighting of the dimensions, on the other hand, would also lead to unequal treatment [110]. In the formation of an overall result, an equal weighting of the dimensions would offer the possibility of compensating poor results of one dimension with good results of another dimension. However, this problem also occurs when forming a result within a dimension [110], as in such a case that the indicators can compensate for each other. Therefore, it is essential to look at each indicator and its outcome. If the dimensions are treated separately, if they are not compared with each other and if the indicators of one dimension are not summed up, the individual problem areas for the company become recognisable and substitutions are prevented. In essence, different tools follow different strategies in dividing sustainability into dimensions and indicators [93].

Communication and certification: The result of a sustainability assessment can be made available as a calculated sustainability level or as a report. This result can be used both internally and externally. With regard to external use, sustainability communication should be improved so that the existing sustainability of horticultural businesses is also recognised by consumers [59]. When companies communicate about sustainability, there is a conflict between simple, low-threshold communication and a problem-oriented, complex presentation. Some SAS are combined with a certification, which is important for the producer to be able to sell its products better and remain competitive [77]. This is becoming increasingly important when selling on a global scale as competition increases [33]. The indicators and also the whole assessment should be easy to understand for consumers of company products, but this also carries the risk of greenwashing, especially when using certification. Greenwashing means that companies use marketing strategies to insidiously create a green image for themselves [74]. To prevent this, a sustainability assessment and certification should be communicated transparently, and also to enable a verbal exchange about the quality of the indicators, their collection and weighting. Direct methods must therefore be developed to communicate efficiently and transparently [86]. It can be assumed that participation in SAS would be higher if certification can be achieved. Meul et al. [108] found that graphical diagrams can improve the quality of communication about sustainability. Roesch et al. [82] also confirm that the visualisation of results is preferred by farmers. However, it strongly depends on the type of presentation, as simple numbers or a traffic light system are easy to understand for the consumer and would create competition. The disadvantage is that individual poor results are not recognisable to the consumer. In contrast, a spider web system (Figure 7) would show each individual result to the consumer but would be difficult to interpret. So, it is not easy to judge whether a visual presentation is more likely to have positive or negative effects.

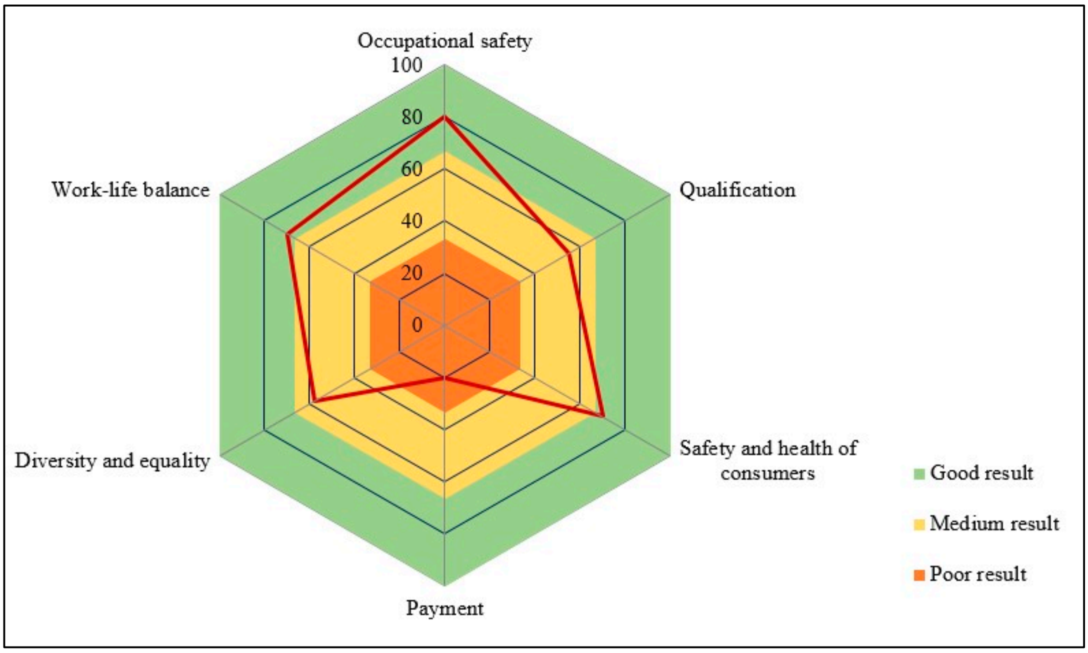

Figure 7. Example of a potential visualisation of sustainability results in a polygon for the social dimension (based on Derksen and Mithöfer [61]). The red line connects the results of the individual indicators and thus visualises the differences.

Coming to the whole concept of measuring and assessing sustainability, Figure 8 shows the entire overview. The business process model includes all the aspects mentioned before and clarifies the process of the development of a sustainability assessment. The dark blue boxes symbolise the basic steps of the business process model, while the light blue boxes represent the various options for developing a sustainability assessment system.

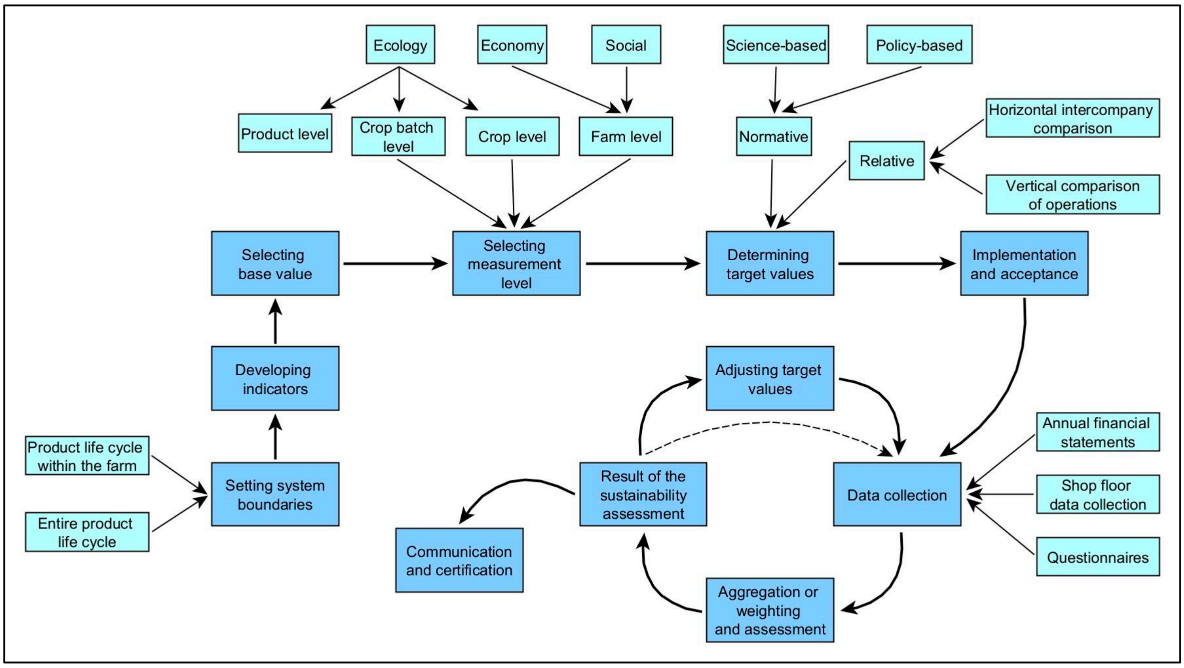

Figure 8. Comprehensive business process model for the development of a sustainability assessment (own figure). The dark blue boxes symbolise the basic steps of the business process model, while the light blue boxes represent the various options for developing a sustainability assessment system.

5. Discussion

When considering what a SAS should look like for horticulture and especially for potted plant companies, the structural differences between agriculture and horticulture must be taken into account, as this justifies a different framework. The SAS should have clearly defined system boundaries to avoid misunderstandings in the collection of relevant data. A company does not have an unrestricted overview of the product life cycle. Thus, the upstream and downstream areas of production outside the company's own operations can only be influenced to a limited extent; for example, through the conscious selection of suppliers and customers. Therefore, a SAS for potted plant companies should currently exclusively cover aspects that are within the decision-making scope of the farm manager. It is consequently an assessment at the farm level. Horticultural branches are heterogeneous [38], so it would be difficult to formulate a universal catalogue of indicators that would be applicable to, e.g., fruit-growing and potted plant cultivation. Hence, a catalogue of indicators specifically adapted to German potted plant cultivation must be developed in future research. It must also be considered whether and how possible relevant indicators can be measured. The participation of the employees and the personal conviction of the farm manager are essential for the implementation and acceptance of a sustainability assessment but may become an issue of less importance as soon as sustainability certification or assessment becomes mandatory. With the aim of reducing the capture of only a snapshot of an indicator, an average could be taken over several crop batches. However, the risk of a distorted impression due to snapshots is relatively low, especially in protected cultivation, as the fluctuations are lower than in open-field production; for example, due to the controlled production factors.

In order to give farm managers the opportunity to identify the reason for any poor sustainability assessment results, the lowest possible measurement level should be selected for the indicators. This means that product level for ecological indicators and farm level for social and economic indicators are selected. Since some target values depend on regional circumstances, for example, because some regions are more affected by water scarcity than others, it is not possible to provide precise information within this article.

Data collection should consist of different sources, especially those that provide a lot of data with little effort. Site inspections by inspectors can verify the statements. Regarding aggregation, the result of each indicator should be visible, so the aggregation of indicators within dimensions is not recommended. In addition, however, it is possible, for illustrating the sustainability levels of the dimensions, to perform a dimension-based aggregation.

After the sustainability assessment, a certificate could be awarded that enables sustainability communication between the producer and the consumer. This could be particularly useful for retail nurseries that have direct contact with end consumers. In the case of the use of a sustainability certificate, the end consumer in particular should have the possibility to inform himself about the conditions for obtaining such a certificate. Regarding base values, percentage values are particularly suitable for the data collection of social indicators. The measurements for ecological indicators can partly also be given with percentage values, and otherwise, added value can be used. Added value seems to be a favourable base value due to the comparability of different crops and also comparability at different production depths. Further, it is aimed to ensure that the consumption of resources or the pollution caused is offset by the greatest possible benefit. Various aspects need further research; target values for the individual indicators should be determined and compiled according to site-specificity. In addition, when developing a sustainability certificate, it should be ensured that the data collection and assessment are comprehensible and transparent as well as being best accepted and understood by both producers and consumers.

6. Conclusions

SAS can represent the priorities of current society. Not only are they highly geographically dependent, so a SAS from developing countries must look different from a SAS from an industrialised nation, but the importance of individual indicators also shifts over time.

For example, the intensity of water use in Europe is becoming more important due to climate change and the increasing number of hot days. Additionally, people's demands are rising, and awareness of social and ecological aspects is increasing. Generally, the process of developing a SAS is influenced by numerous stakeholders. SAS cannot be rigid constructs because of what is defined as sustainable changes depending on society, financial resources, ecological circumstances and other influencing factors. Moreover, the process is influenced by stakeholders and their interests. The approach of this article is a starting point and should therefore be discussed and further developed or adapted by the respective experts. Finally, it should be noted that the evaluation method developed here has not yet been tested in practice. However, the central contents of this approach are being incorporated into an ongoing project (sustainability analysis and evaluation in horticulture: development and testing of an assessment system) of the Centre for Business Management in Horticulture. As part of this project, the application aspects and transferability of the model are being further analysed and reflected upon.

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