

Article

Sustainable Agriculture and Its Implementation Gap—Overcoming Obstacles to Implementation

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Abstract: There are numerous studies and publications about sustainable agriculture. Many papers argue that sustainable agriculture is necessary, and analyze how this goal could be achieved. At the same time, studies question the sustainability of agriculture. Several obstacles, including theoretical, methodological, personal, and practical issues, hinder or slow down implementation, resulting in the so-called implementation gap. This study addresses potential obstacles that limit the implementation of sustainable agriculture in practice. To overcome the obstacles and to improve implementation, different solutions and actions are required. This study aims to illustrate ways of minimizing or removing obstacles and how to overcome the implementation gap. Unfortunately, the diversity of obstacles and their complexity mean there are no quick and easy solutions. A broader approach that addresses different dimensions and stakeholders is required. Areas of action include institutionalization, assessment and system development, education and capacity building, and social and political support. To realize the suggestions and recommendations and to improve implementation, transdisciplinary work and cooperation between many actors are required.

Keywords: sustainable agriculture; implementation; obstacles; barriers; practice; farm-scale; knowledge-to-action gap; extension service; agricultural policy; behavior

1. Introduction

Sustainable development has been a guiding principle for all economic and political sectors since the UN Conference on Environment and Development in Rio in 1992. There is also broad consensus that it is an essential goal for agriculture, and sustainable agriculture is seen as essential for global sustainable development [1]. The urgency of developing sustainable agricultural production systems is widely acknowledged [2].

However, the meaning behind “sustainable agriculture” is ambiguous, and sustainable agriculture is an umbrella term that encompasses many different approaches [3]. Numerous definitions indicate that sustainable agriculture means different things to different people [4]. Currently, this is regarded as a chance and necessary in order to make sustainable agriculture a reality [5]. Sustainable agriculture is not an arbitrary concept, yet we no longer need to seek the one correct, universal definition. Instead, we need to adapt the definition of sustainable agriculture to the respective context [6–9]. Within this context, it is important to distinguish “goal-prescribing” and “system-describing” concepts that reflect different understandings of sustainability [3]. This differentiation is crucial because it affects how sustainable agriculture is perceived, possible approaches for an assessment, the methods applied, indicators used, etc.

While goal-prescribing concepts interpret sustainability as an ideological or management approach, system-describing concepts understand sustainability as the ability to fulfil a diverse set of goals or as the ability to continue over time [3]. In goal-prescribing approaches, certain types of management, measures, or prescribed techniques are defined as being sustainable in general. As long as these requirements or standards are met, sustainability is assumed. Corresponding approaches are also

described as “mean oriented” [10–12]. They are typical, e.g., in the context of certification. An example is the “European Renewable Energy Directive” (Directive 2009/28/EC) and the sustainability criteria defined therein [13]. The advantage of these types of approaches is that their implementation (depending on the standards set) is more straightforward. If this definition is used, then sustainable agriculture is already being implemented in practice.

In system-describing concepts, sustainability is instead an objective property of an individual agricultural system that fulfils different goals, perhaps even conflicting goals, over time (“goal-oriented”). This understanding of sustainability is related to the “competing objectives” view of sustainability, where the focus is on “balancing social, economic, and ecological goals” [14]. Sustainable agriculture has various different goals (e.g., to satisfy human needs for food, feed and fiber, enhance environmental quality, sustain economic viability) [15]. This shows that sustainable agriculture has to simultaneously consider social, economic, and environmental issues. Besides these dimensions of sustainability, further aspects need to be considered: demands of current and future generations (time horizon of sustainability and ability to continue over time) as well as societal, entrepreneurial (farms), and individual (farmers) demands. The more goals an agricultural system can achieve, the more sustainable it will be. Thus, sustainability is not simply a certain state that has to be reached. Development towards more sustainability hence means finding a compromise that will better achieve the different goals in overall [12,15]. This sustainable development presents a dynamic understanding of sustainable agriculture. The implementation of sustainable development requires a continuous optimization process. Its implementation in practice is ambitious, difficult, and constrained by many obstacles and barriers. To establish sustainable agriculture on a broad scale, we should try to remove or reduce these obstacles and thereby close the implementation gap.

This analysis aims to start a discussion about the obstacles that are responsible for the implementation gap and that limit the implementation of sustainable agriculture in practice. Discussing strategies for solving or minimizing these issues, this paper provides a road map for the development of sustainable agriculture, focusing on key research aspects. Finally, an overview of major obstacles (mechanisms, causes) responsible for the implementation gap is given, as well as ways to overcome these hurdles. This paper gives suggestions for research adaption, provides an additional perspective on the debates about sustainable agriculture, and, importantly, highlights ideas (strategies) for its implementation in practice. This analysis is focused on Central European agricultural systems; this study does not consider all agricultural systems of the world.

2. A Look Back at Sustainable Agriculture and Research Themes

The debates about agricultural sustainability date back to the 1950s and 1960s [7]. At this time, agriculture was being changed by the green revolution. Improved crop varieties, modified management, and the use of external inputs (e.g., fertilizers, biocides) led to increases in crop yields [16] and food production [7,17]. Unfortunately, unintended side effects accompanied these developments. Natural resources were jeopardized [16], and different forms of environmental degradation became apparent (e.g., air and water pollution, soil depletion, diminishing biodiversity) [8]. In this situation, environmental concerns appeared, and alternative approaches to common agricultural practices were sought. Conventional agriculture was described by some as unsustainable [6,18,19] and, therefore, alternatives to conventional agriculture were often seen as being sustainable. This is where the understanding of sustainable agriculture as an alternative form of agriculture or ideology has its origin [3]. The debates about sustainable agriculture received additional impetus from the Brundtland report and the idea of sustainable development [20]. In principle, this new perspective has led to sustainable agriculture being understood as a system-describing concept. Since then, the meaning behind agricultural sustainability and the right methods and indicators for its assessment have been debated. This long tradition has led to various scientific analyses and many publications. Examples are:

- theoretical contributions on how sustainable agriculture should be defined and understood [3,5,6,17–19,21–24];

- conceptual frameworks [25–30];
- studies about the dimensions of sustainability, including how they are defined and what they comprise [31–33];
- methodological issues addressing assessment of sustainable agriculture, including indicator selection, aggregation, and weighting [1,4,9–11,34–43];
- descriptions of the assessment methods that have been developed [20,44–46];
- comparison or reviews of methods for sustainability assessment [2,47–49];
- case studies and examples of how methods have been applied [12,50–52].

Thus, the scientific community has worked on sustainable agriculture a lot and many issues have been looked at from different perspectives. We probably have enough knowledge and methods that allow us to implement sustainable agriculture, as well as the intention to do so. Currently, we cannot claim that agriculture is sustainable everywhere. Many examples indicate that, on a broader scale, we have not been able to develop sustainable agriculture [53–55]. This is shown by, e.g., the degradation and subsequent loss of productive agricultural land [56], adverse effects on biodiversity, ecosystem services, and the stability of ecosystems [24,57,58], increased amounts of nutrients and toxins in ground- and surface water [59], the reliance on external resources (e.g., fossil fuels) and freshwater [60], or the stagnation of the “rate of crop yield increase (. . .) in many of the world’s most productive regions” [61].

Putting the theoretical concept of sustainable agriculture into practice does not seem to be easy. It is instead a “long-term and complex process” [45]. We should find solutions that support the wide-scale implementation of sustainability in agriculture. Nevertheless, scientists and researchers in the field of sustainable agriculture should place more emphasis on how theory can be put into practice (Figure 1).

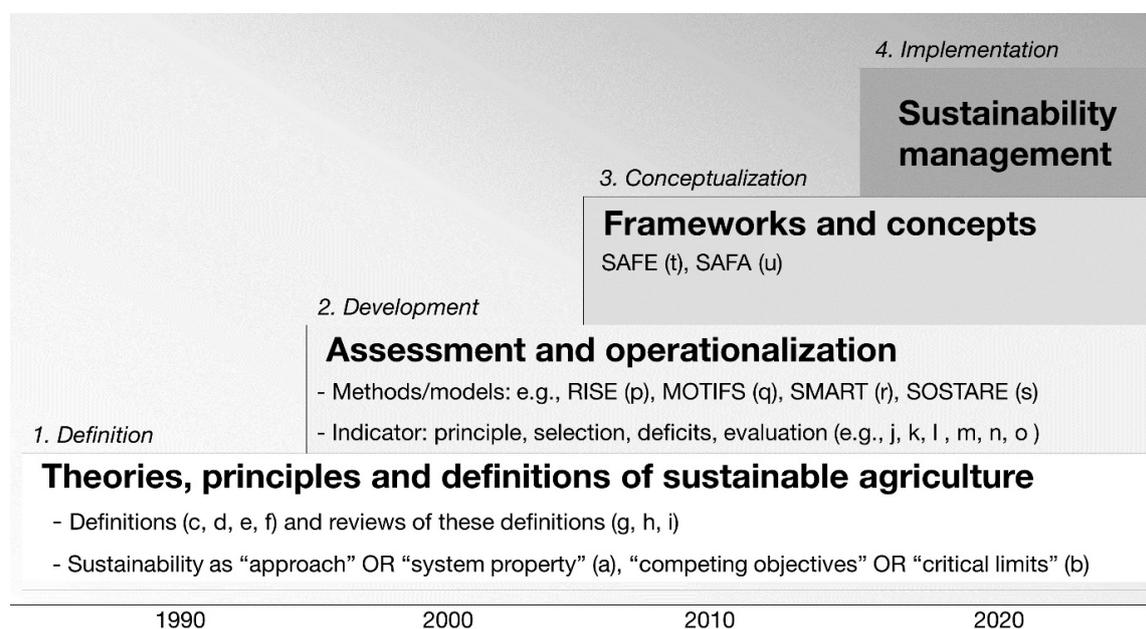


Figure 1. The four phases in science and research of sustainable agriculture; a [3], b [14], c [19], d [18], e [6], f [8], g [21], h [5], I [17], j [4], k [62], l [38], m [12], n [63], o [36], p [44], q [45.], r [46], s [20], t [27], u [29].

3. Obstacles to Implementation

Putting sustainable agriculture into practice (on a broader scale) is not limited by one explicit obstacle or a particular constraint. The limitation is more a consequence of several issues that interact and that are case-specific. In the following, an overview of potential obstacles is given (Figure 2). The obstacles are categorized into four types (no claim to completeness): (a) theoretical obstacles,

(b) methodological obstacles, (c) personal obstacles, and (d) practical obstacles. Theoretical obstacles are issues that arise from the concept of sustainable agriculture itself, its definitions, and how it is understood. Methodological obstacles are related to the assessment and the operationalization of sustainable agriculture. Personal obstacles are a result of the individual who influences the sustainability of agricultural practice (the farmer) and their characteristics. While these obstacles affect the prerequisites required for implementation (e.g., information, knowledge, and intention), practical obstacles are related to issues that limit action and adaptation to a more sustainable situation. Compared to the first three obstacles, practical obstacles relate to societal problems or barriers.

Theoretical obstacles	Methodological obstacles	Personal obstacles	Practical obstacles
Ambiguous definitions and missing adaption	Dissenting aims and suboptimal development	Missing knowledge, skills and capabilities	Uncertainties and risks (complexity, interactions)
Unclear scale for implementation	Ignoring prerequisites (tools)	Behaviour and decisions	Effort, cost, recognition
Relationship between science and practice	Low applicability (data, results, guidance)	Individual goals, perceptions, risk aversion	Lack of support and guidance

Figure 2. Overview of possible obstacles to the implementation of sustainable agriculture.

3.1. Theoretical Obstacles

3.1.1. Ambiguous Definition and Its Implications

Sustainable agriculture is, as already emphasized, not a clear and well-defined concept that is simple to apply correctly. Each actor has their own explicit or implicit understanding of sustainable agriculture. Yet, this is not a disadvantage.

Instead, after appropriate adaptation, many publications state that this is necessary and essential for successful implementation [6–9]. However, this does not mean that we no longer need to define sustainable agriculture, but instead that it should be defined more and more precisely. Of course, we have to distinguish analyses by their objectives. Methods of assessing and evaluating agricultural systems (empirical contributions) need a more detailed definition. These definitions should include the vision or understanding (mean- or goal-oriented [10–12]), the goals and objectives, selected indicators, and the methods used, including the data basis. The development of this type of definition could be guided by the SAFA (Sustainability Assessment of Food and Agriculture systems) framework [29]. Theoretical approaches do not depend on such a detailed definition. For these types of analyses sustainable agriculture could be described as follows (using our own understanding as an example): sustainable agriculture is a “system-describing” (goal-oriented) concept. Sustainable agricultural systems fulfil a diverse set of goals (multifunctional) and have to continue in time [3]. These principles and goals partly compete with each other (according to “competing objectives”, [14]). Goals include social, economic, and environmental issues, the demands of current and future generations, global and local demands, as well as societal, entrepreneurial (farms), and individual (farmers) demands. Continuity relates to the finiteness of resources, environmental degradation, and “long-term system performance” [3]. Depending on the type of resource, the following principles should be adhered to, the replenishment rates of renewable resources must be taken into consideration, and non-renewable resources should only be used sparingly, if at all. In general, the objective is good resource-use efficiency. (Agro)-ecosystems are preserved, and adverse effects are avoided as much as possible. Continuity also relates to possible disturbances, system resilience, and stability [32,58,64–66]. This means that disturbances (e.g., drought, electricity shortages, floods, pests, and diseases) to agricultural systems do not inevitably result in a collapse or a significant failure in achieving goals. The main objective of sustainable agriculture is to balance different goals and to find the best compromise between competing or conflicting goals. Sustainability is thus not an explicit goal that can be achieved and which then

no longer needs to be worked on, nor a defined mean. Sustainable agriculture is a guiding principle that is based on a development process (that allows sustainable development). The process is aimed at development where a better compromise is reached and optimization is the overall motivation. Sustainable agriculture requires a sophisticated process of sustainability management (article in preparation). Hence, it is important to note that the different goals are highly case-specific and depend on the specific context.

What does this mean for the implementation of sustainable agriculture? Using specific criteria (e.g., the SMART criteria: specific, measurable, achievable, reasonable, time-bound) when setting goals can make it more likely that the goals will be achieved. Assuming that developing sustainable agriculture is a goal, meeting these requirements is not easy. For example, “specific” by definition means that a goal must be as clear and as precise as possible. Sustainability itself is not very specific. This ambiguity means that the definition of sustainable agriculture and how it is understood is still being debated. Sustainable agriculture is still an umbrella term that encompasses many approaches [3]. This ambiguity causes confusion [67], especially when talking to farmers. They argue that even experts (academics) do not know the exact meaning of sustainable agriculture (author’s own experience). How should practitioners deal with this ambiguity? This is often an argument for continuing with business as usual (author’s own experience when talking to farmers).

Authors highlight that the understanding of sustainable agriculture should be adapted to the respective context [6–9]. Context integrates the aims, the scale, the site, and the social environment, as well as the time perspective. Thus, there is no need to generalize and standardize sustainable agriculture. It is instead necessary to understand sustainable agriculture as a concept that requires adaption and flexibility. Therefore, we need a well-defined process applicable in practice that is understandable and transparent. To avoid misunderstandings in this context, the term “practice” needs to be considered in more detail.

3.1.2. Implementation Scale—A Possible Definition for the Term “Practice”

“Practice” is a widely-used but seldom well-defined term. While agriculture is somehow general (e.g., the agricultural systems of a country), abstract, and unspecific, practice is more precise, and it includes many aspects. I understand the term practice as follows (Figure 3): practice is the level of agriculture where the actual management occurs, where procedures, processes, and intensity can be adapted, and decisions can be changed to enable sustainable development (decision unit) [63,68–71]. Practitioners and their choices are relevant to sustainable development because effects on natural resources depend on their management and decisions [38,72]. The diverse set of goals and demands also become relevant at this level. Farmers must produce agricultural goods (for society or themselves), protect the environment, consider further societal demands, etc. Only farmers can ensure that the diverse requirements of sustainable development are met and avoid unsustainable practices [40]. The relevant interactions between management, site conditions, and sustainability (social, economic, and environmental) occur at the farm scale, and a detailed assessment of sustainability performance can be carried out. Practice also refers to the organizational unit of a farm. It includes the structure of the individual production system (its identity) and possible interactions (e.g., between a cropping system and animal husbandry), the site conditions, existing facilities, available resources (e.g., labor, machines, equipment, fields), or the procedures. Practice also covers the farm as a business unit where all economic issues (e.g., various farm income streams and their interactions, products, prices, costs) come together, and which builds the “legal unit for all legislation (. . .) that receives payments for externalities as done in the EU CAP” (EU CAP = Common Agricultural Policy of the European Union) [69].

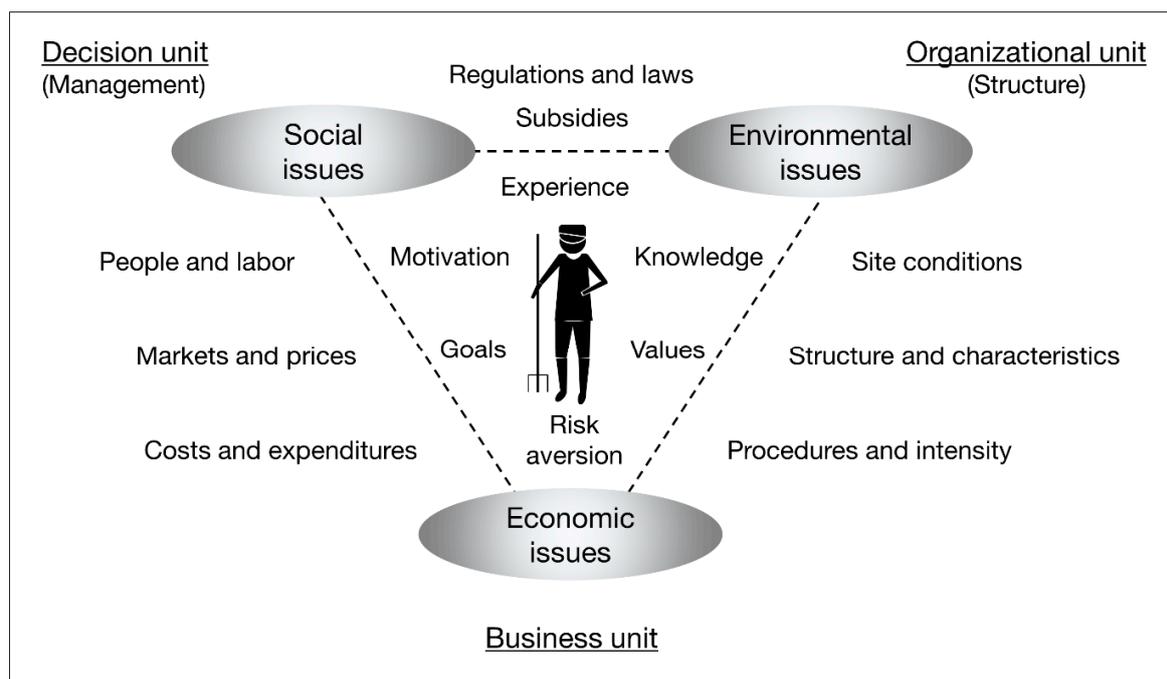


Figure 3. Practice as Socio-Economic-Environmental System—the practice units.

Farms are sophisticated socio-economic-environmental systems where all dimensions of sustainability come together and where interactions occur. When talking about practice, a complex and individual object—the farm—is addressed. This means that putting sustainable agriculture into practice is challenging because it has to address the farm scale and its complexity. Each farm is different, and we need to treat each farm individually. However, the question then arises as to whether this level, where individual analysis of farms is required, is the most suitable or interesting for scientists and researchers working in the field of sustainable agriculture.

3.1.3. The Relationship Between Theory and Practice

Scientists and researchers have different motivations for working on sustainability in agriculture, and their objectives may differ. Motivations are, e.g., to improve the theory behind sustainable agriculture and to help define and improve the understanding of sustainable agriculture, to assess sustainability performance, and to compare agricultural systems. The question is, however, if enough work has been done to achieve the goal of putting theory into practice. Some articles suggest that “theory and practice” should be connected, that “practice-oriented research” should be supported, and that the process of transformation to sustainability in agriculture should be improved [73]. Others propose that the synergies between “agricultural policy, practice, and research” should be enhanced [74] and discuss “knowledge exchange” between science and practitioners [75]. Within this context we have to discuss the relationship between science in sustainable agriculture and the process of putting theory into practice.

Publications about science and research in sustainable development mention that the required tasks for the process of implementation, e.g., the establishment of a useful knowledge system, are not that relevant in science and research [76]. Other authors call to bridge the “gap from research to practice” [77] or criticize the lack of information flow between scientists, practitioners, and policymakers, and the resulting difficulties [74]. Differentiated perspectives on the relationship between research (knowing) and practice (doing) are also present [78]. The authors distinguish between “basic research”, “use-inspired research”, and “pure applied research”, as well as “practice-oriented” and “basic research-oriented” work. This means that not all scientific contributions to sustainable agriculture need to address implementation. If we want to achieve the broad implementation of sustainable agriculture,

we should probably rethink and discuss the relationship between science, research, and practice. The task “transfer to practice”, which is often a work package in projects, is probably not as effective as intended. Even when applied research is similar to what happens in practice, it does not necessarily mean that implementation is the goal or that it is supported. The development of methods for the assessment of a farm’s sustainability, for example, is usually about evaluation, ranking, or benchmarking sustainability issues. The methods often include results in descriptive form and conclusions. Based on these results the adjustments required can be worked out independently by the user. Management adaptation to optimize and to guide sustainable development, and to find a compromise between conflicting or competing goals is not usually part of the methods. This means that the farmers are left alone with setting up sustainable systems on their farms and with the implementation of sustainable development. It is essential to analyze why the researcher should engage in transfer to practice and implementation. However, transfer to practice is neither valued nor supported in universities and the current incentive system is based on publication in journals [79]. Additionally, transfer to practice is an ambitious and sophisticated process. While implementation in practice in sustainable agricultural science has not been discussed widely, it has a long tradition in other scientific disciplines. In medical science, translation of “research findings into clinical practice (. . .)” is seen as a priority for research [80]. The authors point out that the “research landscape might be changing to support this type of work, with governments providing funding to support collaboratives to conduct research translation, implementation, and evaluation” [80].

3.2. Methodological Obstacles and Sustainability Assessments

Sustainability is a theoretical approach, and its implementation needs further action [45]. To achieve progress, manageable objectives and concrete measures are required [11,81]. Assuming a farmer wants to implement sustainable agriculture, we have to distinguish between the definitions mentioned above: (a) sustainability as a method (mean-oriented) or (b) as a system property (goal-oriented). Different courses of action are required, depending on which definition of sustainable agriculture is used.

Implementation processes:

- (a) Mean-oriented sustainability requires that the criteria (standards, measures, or rules) specifying sustainable agriculture are well defined and communicated (declaration of standards). The specifications can be adapted to a certain extent, for example, to take farm characteristics (e.g., animal husbandry yes/no) into account. Compliance with these criteria has to be checked (e.g., external audits, self-declaration, checklists, farm visits). If standards are not complied with, the farmer needs information about the necessary adjustments and modifications. Once the changes have been implemented, a new check can be performed. When all standards are met, full implementation is reached. In general, this is a relatively quick process and can be conducted in a single year.
- (b) Goal-oriented methods require more complex procedures. In principle, the different goals, resource use, potential adverse effects (e.g., to the environment) and the system’s stability have to be assessed and evaluated. An appropriate method would therefore have to record and analyze the specific system very precisely. In the next step, interactions and conflicts of interests between the different goals (e.g., improving farm income and outputs, reducing adverse environmental effects and costs, better conditions for employees) have to be identified and highlighted (synergies and trade-offs). Based on this analysis, possibilities for improvements in the system as a whole should be evaluated. The potential effects of adaptations could be modeled as scenarios during the decision-making process (by the farmer). The most suitable and most promising solution could be adopted as a goal for business development. A further assessment should be performed when all required adaptations have been realized. A comparison of the two evaluations should show better overall goal achievement. If this is the case, the farm is developing sustainably. The overall

procedure takes much longer (several years), requires more data and information, and is more demanding. This could therefore be combined in a farm development and planning process.

The implementation of sustainable agriculture in practice therefore requires sufficient information that should be provided by appropriate tools [49]. This has led to many publications, including reviews on assessing sustainable agriculture, and suggested methods and tools [2,10,40–42,47–49,72,82–86]. In order to distinguish between existing methods, criteria such as the aims, intended scale, complexity, and realization can be used. Others distinguish between “full sustainability assessment (FSA) and rapid sustainability assessment (RSA) tools” [70]. RSA tools are quick and easy, use data that are readily available, have high transparency, and user-friendliness. The accuracy of outputs is subjective and the results are more an audit. FSA are more complex, require detailed farm data, need trained users (farmer, advisers), and more time is required. The methods used are high in complexity with low transparency and the results are detailed, scientifically reliable, and more accurate. Other authors distinguish between “context-generic” and “context-specific” assessment methods [51]. Context-specific assessments are almost identical to FSA. RSA tools on their own will not suffice to achieve objectives or provide enough support to practitioners. FSAs, on the other hand, can be used for these purposes.

However, the adoption of existing methods or tools in practice has, to date, only been successful to a limited extent [2,87]. A framework for evaluating these methods is available, which identifies the success factors, as well as those factors hindering application [87]. Applying this framework shows that, if stakeholder expectations are ignored or objectives are not defined, these tools only have limited application [87]. Further obstacles are discussed in the literature (Table 1).

Table 1. Potential obstacles in assessment

Term Used	Issues Mentioned	Reference
Problems	Multi-functionality, scale, selected indicators, linkage of indicators, application of results	Silva et al. [11]
Limitations	Neglected impacts (e.g., biodiversity, soil quality, economic, and social effects), applicability to farm scale, transparency of methods	Schader et al. [42]
Shortcomings	Missing multi-functionality, no balance between the sustainability dimensions, missing focus on usability/implementation, neglecting interactions and conflicting goals	Binder et al. [10]
Shortcomings	Missing multi-functionality, not suitable for all forms of farming (e.g., organic)	Trabelsi et al. [1]
Factors (hindering tool adoption)	The complexity of sustainability, development process (integrated factors that influence the tools)	Triste et al. [87]

Considering the different obstacles, the most relevant are (1) conflicting assessment aims, (2) the assessment development process, (3) the related requirements and expected functionalities, and (4) obstacles that occur when assessment methods are applied.

3.2.1. Conflicting Aims of Assessment Methods

Assessment encompasses a diversity of definitions with different aims. In this analysis, the term assessment describes any process or method that provides decision-makers (farmers) with information to assist them in implementation of sustainable agriculture. An assessment should provide detailed information (e.g., strengths and weaknesses, deficits and their causes, improvement suggestions) to the farmer that can be used in farm management and for guiding decisions (as described above). It is crucial to keep in mind that not each method has these objectives. With regard to aims, for example, in existing assessment methods these range from the evaluation of methods and tools, to the benchmarking of production systems, from political consulting to scientific application [20,70]. Some methods are designed to “inform agricultural stakeholders in their decision-making”, to “provide standardized sets of data to certification and assurance programs” [88], “to support farmers for a better management”,

or to support policymakers in analyzing policy impacts [20]. Even if some methods are aimed at supporting farmers in their management, the effectiveness and acceptance of these methods are questionable. Methods often do not provide adequate information about farm management and the farmer is not able to use the new information [89]. Some authors even criticize that tools are often just for “marketing purposes” and not for the “transformation of production” [9].

3.2.2. Suboptimal Method Development Process

A key element for the success of an assessment method is the alignment of the expectations and needs of the intended user (farmer) with the capabilities of the available method. This is difficult because farmers, their goals, and their farms are highly individual. The challenge in developing assessment methods is to capture this diversity and the underlying requirements and expectations accordingly. Additionally, important assumptions and values are set during the development process [90]. The developers make decisions about, e.g., what sustainable agriculture is, the relevant content (dimensions, themes, and subthemes), how to assess (methods), and which indicators are appropriate [9]. If the user is not involved in the development process, these definitions may or may not fit the end user. In most cases, the end user has no influence over this process and may reject it. This is why the integration of farmers and their expectations into the development process is important [72], but also challenging.

3.2.3. Requirements and Functionalities that Have Not yet Been Taken into Account

There are numerous requirements that tools for sustainability assessment may have to fulfil [70,87]. Considering tools that should support the implementation of goal-oriented approaches, some requirements are highly relevant but have not yet been taken into account sufficiently.

Adaptability of Assessment Methods

Adaptability includes, firstly, how well the assessment method can be adapted to represent the farm (system) under consideration. The aims necessitate that the farm and its individuality are depicted as accurately as possible. It is important to farmers that assessment methods are specific to their particular context and that “their context and their practice” are taken into account [2,9,51]. Context includes, in addition to common criteria such as farm size and structure, site conditions, yields or outputs, the different goals of the farmer that influence all making management decisions. A farm near a city, for example, will probably have to consider recreational issues, while other farms do not have to take these issues into account. From my own experience, I can report that farmers would like that the representation of their farming system is as close to reality as possible. If not, they argue “that is not my farm” and are sceptical about the results. Adaptability here means that the farm, its properties, management procedures, and characteristics are captured in detail. The possible effects of adaptations or measures can only be analyzed when this is the case. Existing tools mostly consider just one part of the farm (e.g., the cropping system, animal husbandry) and downplay or ignore other parts (e.g., a biogas plant) and further sustainability effects [91]. In digitalization, the term “digital twin” is sometimes used [92]. This could serve as an example of what farmers would like from an assessment.

Secondly, sustainability and its definition form a framework within which the themes, subthemes, and issues that should be analyzed need to be identified [29]. An issue is any fact or process to be mapped, captured, or analyzed using a certain method. Issues represent the different goals of the competing objectives (e.g., social, economic, or environmental) and the ability to continue in time. In this context, the different sustainability factors need adaptation to the agricultural systems under consideration [7]. Sustainable agriculture is dynamic and site- or region-specific. This means that potential risks and returns depend on the location of the farm and the landscape context [6,8,93,94]. Site-specific includes the physical environment (landscape, soil, climate) as well as the “social or economic context” [8]. Methods need to be flexible so that the assessment can be modified by the user according to the context [95]. It could be assumed that this contradicts the demand for

more standardized and harmonized tools [46,49]. In general, standardization and harmonization are most often requested in assessments where the objectives are benchmarking and certification. Here, standardization is necessary to guarantee comparability. Harmonization addresses more the methodological (analytical) level and input data or coefficients. Different methods can define the same issues (e.g., soil compaction, greenhouse gas emissions, animal welfare, economic performance) but probably use different information, methods, and indicators. This will lead to different results and limit comparability [42]. Even when the methods are, in principle, comparable, the data used (that define, e.g., standard values for crops, machines, pesticides) may vary and cause discrepancies. Thus, harmonization of the methods and data used, in general, should be an essential goal for the further development of assessment methods.

Complexity and System Approach in the Assessment

Most would probably agree that sustainable agriculture is a highly complex concept that encompasses many issues [96]. This complexity challenge is not caused solely by the number of different issues that need to be considered. It is also a question of interactions and relationships (trade-offs) between the issues (e.g., yields and yield levels, usage of external inputs and reliance on inputs with potential climate gas emissions, or economic performance). For each issue, different expectations and goals (often conflicting) exist (farmers' goals) and to achieve these, various options and measures are available. An action to improve one issue can affect others. These relationships can be neutral (no interaction), positive (actions to improve one issue will improve another), or negative (actions to improve one issue lead to another issue worsening). Balancing between the different issues and actions, as well as finding the most suitable compromise (in the sense of overall optimization) is the challenge here. This is a highly sophisticated task that farmers have to master. Digital systems could provide support. Thus, the complexity challenge in assessment has different facets. The assessment system should be capable of analyzing and describing conflicts of interest with as much detail as possible so that the farmer will recognize and consider them. Farmers need the capabilities to manage these adequately. We should recognize that farmers are increasingly having to manage large amounts of information [97]. This is a complex and labor-intensive process that is very demanding, even without the holistic perspective of sustainability. The increasing quantity of information farmers need to manage is one reason why new ways of supporting farmers are needed [98]. This is where smart systems really could support farmers.

Complexity also has practical implications. The conflicts of interest found during the assessment could require adaptations or specific actions. A farmer would implement these when the benefits and the potential risks are acceptable, and the adaptations fit their management philosophy. Farmers take trade-offs into consideration when making decisions. Which trade-offs they take into consideration depends on their interests, aims, knowledge, and experience, and available information and data. Some of the trade-offs necessary may be readily apparent, others are not (e.g., the effects of management decisions on biodiversity or soil fertility). Reasons for this can be, e.g., that the methods for analyzing the issues are not available, uncertainty about whether a conflict of interest exists, or that the trade-offs only take effect in the long term.

Other authors also address the problem of insufficient consideration of complexity and interactions. To handle the "multiple connections between the various dimensions of a decision" modeling is seen as an "essential tool" [28]. Assessment methods should thus include complexity and interactions [40,48,99]. Existing assessment systems are frequently judged to be inefficient and lacking the capacity to take these conflicts of interest into account [39,100].

Simplification

Each assessment follows the same basic principles: information is gathered (e.g., the use of antibiotics in animal husbandry, the number of seasonal workers, or the usage and intensity of pesticides) and interpreted or analyzed for one (or several) issue(s) (e.g., animal health, risk of

unintended effects of pesticides). These analyses are performed using different methods (e.g., measurements, expert judgments, modeling). The output or results are often described as indicators that represent, in a simplified manner, complex issues or processes. Each sustainability assessment simplifies complex realities and relies on multiple assumptions [88].

Keeping an assessment simple and easy is a requirement and success factor for tools [90]. If an assessment method is too complex and too demanding, its applicability and usability are reduced, and the assessment will not be effective [63]. However, there is the risk of oversimplification when trying to make the assessment methods easier for farmers to use or understand, so that the “representations (. . .) are divorced from reality” [28]. This is the case when an issue is analyzed using a certain method where the farmer knows that the reality is much more complicated and that further information and inputs need to be considered. There are assessment methods available that analyze, e.g., the risk of soil compaction using an evaluation of the crop rotation and the crops grown. The farmer will know that certain crops have a higher risk of compaction. However, to estimate the compaction risk correctly, the equipment (machines, tyres, tyre pressures), the soil and associated soil conditions, the timing of harvesting or movements over the field have to be considered. If the assessment method is too simple, the farmer will get worthless results and nothing will change. Ideally, the farmer should get information about which deficits exist, what the underlying causes are, what the options for improvement are and which effects and conflicts of interest can be expected from putting improvement measures into place. Ideally, the assessment has to be “problem-specific” [28]. The method should represent the management unit that is relevant to the specific problem and address where innovation or adaptations are necessary. The challenge is finding the right balance between complexity and simplification in the assessment.

3.2.4. Difficulties in Applying Assessment Methods and Their Recommendations

Even if the preceding issues have not caused problems or these have been solved, obstacles can still exist when assessment methods are applied. Reasons could be missing data, the complexity of methods, missing skills for the application and interpretation of results, low user-friendliness, or the time and money required to use the system [72,87]. Besides these aspects, problems can occur when variation with time is not considered and assessments are only carried out over a short time period, for example, a single year. The performance of agricultural systems varies from year to year because they depend on factors such as weather and climate conditions, and the availability of resources. Assessing only shorter periods (e.g., one-year data) carries the risk that this period may not be representative of long-term performance. Consequently, recommended adaptations to farm management will probably not be implemented because of the short time period. Therefore, the assessments should be based on longer periods [52] and must be seen as a “long-term exercise” [100].

Data and Data Requests

Each assessment is data-driven and requires information. Data can be, e.g., field observations, data from a questionnaire, estimates from experts, or bookkeeping data. In addition to farm management data (e.g., crops grown, nutrients applied, pesticides used, animal feeding system), further information can be relevant (e.g., site-specific information on climate, soil, topography, equipment and procedures used, information about animal housing, employees and their characteristics, prices of products sold and resources). Which data, and in which spatial and temporal resolution these data are required, depends on the individual assessment method. In practice, the availability of relevant data is inconsistent. Even if farmers increasingly need to document their management (by law) and the availability of open-access data is increasing, this does not necessarily lead to better data usability. Reasons are, e.g., that documentation of farm management may not be available in digital form (e.g., handwritten in a calendar) and data from digital systems may not be accessible or compatible. Digitalization in agriculture is currently a hot topic, but the lack of availability of adequate data remains a challenge. This is a common problem, e.g., in modeling [101]. Even on farms with modern technology

and software systems for documentation and management purposes, limitations exist. Several (digital) commercial and free information or documentation systems are available. Their compatibility tends to be low and data exchange is usually not easy. Additionally, a farm with different income streams will commonly use different systems for each type of production (e.g., a system for animal husbandry with feed and ration calculations, the cropping system, or a biogas system). Links and interfaces between these different systems are uncommon. This situation will probably improve in the future as digitalization progresses and promising Big Data methods are increasingly used [102].

Assessment Results and Convenience

Methods often do not provide adequate information to farm management [89], and the translation of the assessment results into decision-making is a shortcoming [99]. This is one explanation for the low relevance of sustainability assessment tools for farm management [88]. Results can be too complex, too simple, or may not address issues that the farmer can change. Considering that the assessment is to aid the decisions of farmers, the assessment method should enable issues to be identified that need improvement [103]. If the results are too complex and too comprehensive, the farmer may need assistance to be able to understand and interpret the results, as well as education and training for these systems. Skilled agricultural advisers or farmer groups, where farmers can discuss their results, can help in this regard [38]. In general, farmers appreciate assistance for such tasks [70].

3.3. Personal Obstacles

People do not necessarily act as expected or in their own best interests. In general, the discrepancy between knowledge, available knowledge or findings not being used, and not putting knowledge into practice is widely recognized. In the following, this phenomenon is described as the implementation gap. In the literature the terms research-to-practice gap, knowledge-to-action gap, research translation pipeline, or know-do-gap are also used. These issues are studied in the fields of implementation science, translation research, or transition science. These phrases all have slightly different definitions, which have been clarified [104–106]. In the following the most relevant definitions are presented. “Implementation research is the scientific inquiry into questions concerning implementation—the act of carrying an intention into effect, which in [in the cited publication health] research can be policies, programmes, or individual practices (...).” [106]. While implementation is more about realization and action, the term “translation” is conceptual and about making declarative knowledge available for implementation. The term “transition” is more fundamental and describes a general adaption or change of a system or principle. In the following, the focus is on implementation because it best addresses the issue of putting theory into practice as defined above and is closest to implementation sustainability.

Implementation science is most present in medical research and has been studied for more than 30 years [105]. A Scopus search (TITLE-ABS-KEY ("translation science" OR "translation research" OR "transition science" OR "transition research" OR "implementation science" OR "implementation research"; date: 15 December 2019) resulted in 5880 publications. The most common fields were medicine (41%), social science (13%), and psychology and nursing (13%). In the field of agricultural and biological sciences, 104 publications were found (<2%). The main question in implementation science is how new knowledge (procedures or findings) can be applied in practice [80,105,107–109]. Where is the link between implementation science and personal obstacles? The underlying assumption is that implementation requires knowledge. The potential actor (here the farmer) first needs to understand which issues and concepts may need changing, and what technology is needed to implement these changes. The question remains as to how the assessment results or most relevant points can be delivered to the farmer so that they can use this knowledge. Knowledge (including different forms) is thus central to implementation.

3.3.1. Knowledge and Its Role in Implementation

Knowledge can encompass all types and ways of knowing [104]. It can be created in different ways and by different actors, and also farmers can be useful and valuable sources for knowledge creation [75]. Knowledge can be grouped into declarative and procedural knowledge [108]. Declarative knowledge is common factual knowledge and can include, e.g., formal information. This knowledge is "(...) transformed with experience to a more implicit procedural form" [108]. Action or adaptations caused by knowledge will occur when knowledge is present in the procedural form. Here, a fundamental challenge exists because of the influence of the individual. Authors explain this with an image of knowledge moving through a funnel and becoming "more distilled and refined and presumably more useful to stakeholders" [104]. The implications for sustainable agriculture are as follows: sustainable agriculture is a concept and cannot be equated with knowledge. Knowing could mean that farmers understand sustainable agriculture and its complexity. For acting (in the sense of making decisions towards more sustainable production) procedural knowledge is required. This means that a farmer should know how to implement sustainable agriculture or which decisions and adaptation will lead to sustainable production. The development of sustainable production systems is a knowledge-intensive, complicated process where knowledge is often a bottleneck [53]. To achieve sustainable agricultural production farmers and land users need information, knowledge, and assessment results in order to change farm management and planning processes [89]. Is knowledge accessible and available to users, can users apply this knowledge?

This question is addressed by the "knowledge-to-action framework" (KTA) [104]. In this framework, the processes of knowledge creation, knowledge translation, and action are first differentiated. Knowledge translation (KT) is the "process of getting knowledge used by stakeholders" [104]. Adapted to sustainable agriculture, this could mean: KT should ensure that farmers are aware of science and research, as well as new knowledge and outcomes, and use this information to make their farming more sustainable. In medical science and education, knowledge translation is related to the "3Ts approach" [107,108]. This three-step process is designed to enable knowledge translation (Figure 4). In the first step (T1), basic science is translated to (clinical) efficacy (T1). Step two (T2) goes from efficacy to (clinical) effectiveness, and in step 3, from effectiveness to action (in the example healthcare delivery) [105]. Based on work in skill learning, three developmental stages are suggested [108]: In the declarative stage, new information (declarative knowledge) is mainly stored in a memory. The procedural stage is where declarative knowledge is transformed into action rules (if X > Y). When the action rules have been established, they have to be applied and tested (stage 3). This autonomous stage requires practice (training, skills) in using knowledge. We should try to use these insights to improve the options for implementing sustainability in practice. In particular, the last phase (including exercise, training, and skills development) should be looked at in more detail in the future and appropriate offers for sustainable agriculture developed.

By applying this framework, it becomes clear that different formats and methods of knowledge communication are necessary. We should try to improve knowledge communication from science to practitioners. This is, of course, nothing new, but maybe we should consider developments from medical science: previous strategies for knowledge translation in medicine were not always successful [110]. In particular, the commonly used "one-way communication of research syntheses or summaries" (where research findings are provided for potential users, e.g., in a handbook) is a possible cause for inadequate knowledge transfer [110]. Some authors describe this as the "knowledge transfer paradigm" [79], which is based on a hierarchical and linear model of knowledge creation. This also could be valid for the field of sustainable agriculture and should be considered in the future. One aspect missing in the KTA framework is the fact that the processes of knowledge transfer and action are usually performed by different actors at different times. The scientist is not necessarily responsible for knowledge transfer (e.g., provided by teachers, instructors, or lecturers) and the transfer will happen with a time delay. KTA is an exchange of knowledge between different stakeholders that ideally results in action and to "achieve this, appropriate relationships must be cultivated" [104]. It is questionable

whether the situation is similar for the field of sustainable agriculture, where relevant stakeholders (scientists, researchers, teachers, instructors, lecturers, farmers, and advisors) need to build appropriate relationships and interact as required for successful knowledge transfer. For Germany, I would estimate that such relationships occur only occasionally (e.g., within projects and for a handful of farms over the years). The importance of relationships and personal interaction for more sustainable practices is not new [111], but has not been sufficiently considered.

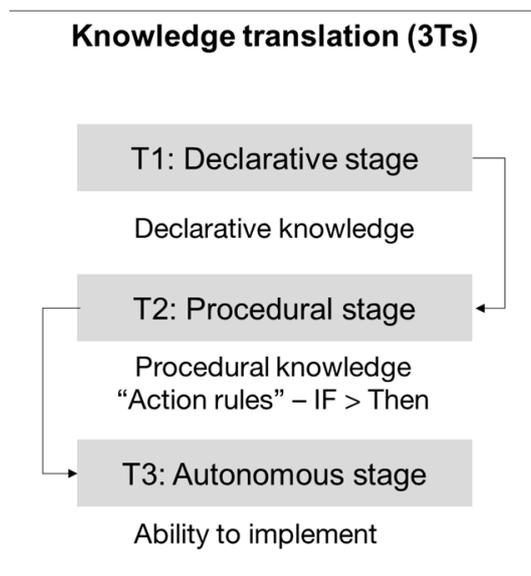


Figure 4. The knowledge translation process (based on references [107] and [108]).

New knowledge also needs to be adapted to individual situations. Knowledge “(. . .) is seldom taken directly off the shelf and applied without some vetting or tailoring to the local context” [104]. In agriculture, in particular, new knowledge cannot be applied in a one-size-fits-all manner. It always has to be adapted to individual situations (of the farms). This adaptation is particularly challenging because of possible consequences that require consideration. Experience in medical implementation research shows that people (e.g., clinicians) who need to apply new knowledge “actively seek assistance to apply the evidence in clinical practice” [80]. We can assume that, in Germany, a farmer who seeks assistance in becoming more sustainable (as an overall concept, including the different dimensions of sustainability) will get hardly any support. Agricultural consultancy is more sectoral and covers mostly single issues of sustainability (e.g., nutrients and fertilization, animal welfare, soil protection).

However, even when the necessary knowledge is available, this will not necessarily lead to action, or to changes in actions or decisions [108]. There are many reasons for this. Potential barriers should therefore be identified that limit implementation [104]. Barriers are, e.g., dependent on the individual (e.g., knowledge, attitudes, skills, habits, or the like) or on the organization of service delivery (e.g., missing structures or equipment) [104]. Because it is not possible to provide an exhaustive overview, in the following, issues which we think are relevant for sustainable development in agriculture are discussed. In medical science it is described that the implementation of new knowledge can be limited because of overloaded and demanding situations [108]. This could also be valid for agriculture, because farmers are being confronted with increasingly complex rules and regulations and rising standards. Farmers also need a lot of time to monitor field operations, and face difficulties in managing finances and when applying for subsidies [97]. In principle, we have already looked at this issue in the section about methodological obstacles. This shows that sustainability needs to be looked at from several different perspectives and that different approaches are required to improve sustainability (e.g., methodological and technical solutions, skills).

3.3.2. Behavior and Decisions—The Farmer as the Central Actor in Decision-Making

Even if all of these factors do not limit implementation, the farmer may nonetheless choose not to make any changes and stick to business as usual. The farmer is the central actor in agriculture, and a decision for or against action depends on the farmer's goals and values (farmer's perceptions, preferences, and risk aversion), as well as potential obstacles [64]. Farmers' awareness, their education level, their attitudes to risk, or farm size are relevant matters that affect sustainability [112]. The management and all decisions depend on the farmer's strategy and reflect their personality [113]. Some authors summarize this influence as the "farmer's managerial profile" [114].

Translation science analyzes changes in behaviors and looks at possible ways of improving behaviors [115]. The central question is what affects behavior. The COM-B system is a framework for describing behavior and its relevant influencing factors [115]. Within this framework, behavior (B) is dependent on the interaction of capability (C), motivation (M), and opportunity (O). Capability reflects the individual's psychological and physical capacity (including knowledge and skills). Motivation combines all brain processes that affect behavior (intention, goals, habitual processes, emotions, as well as analytical decision-making). Factors that enable the behavior or prompt it are defined as opportunity. The components are then divided further: capability is divided into physical and psychological capabilities. Psychological capabilities describe the (mental) capacity to engage in the necessary thought processes (this is where overload can have an effect). There are two types of opportunities: physical and social opportunities. While the environment provides physical opportunities, social opportunities are mainly the cultural milieu that influences the way we think about things. Motivation processes are categorized as reflective (evaluations and plans) or automatic (emotions and impulses) [115]. Based on the COM-B system, three factors are essential prerequisites for performing a specified behavior: the availability of required skills and knowledge, the intention or motivation to perform the behavior, and the absence of constraints that hinder the behavior. While skills include knowledge and education, both of which have been extensively analyzed in the literature, motivation and emotions require closer examination.

In general, farmers have the right to manage their property as they see fit [22] (private ownership assumed). Within this situation of freedom of choice, reactance can occur under certain circumstances. Reactance is a concept from the social sciences and can be understood as "unpleasant motivational arousal that emerges when people experience a threat to or loss of their free behaviors" [116]. If a farmer is, e.g., advised to adapt farm management so that it is more sustainable, the person doing the advising and the manner in which they are advising the farmer is important. If the farmer feels they are being patronized, reactance could occur ("you have to adapt your management in this way", top down). The farmer feels uncomfortable, hostile, aggressive, and their behavior is affected [116]. People who are affected by reactance will behave differently, e.g., exhibit restricted behaviors, perform a related action, or behave in a hostile and aggressive way [116]. This means that motivation to move in the direction of more sustainability becomes more unlikely when reactance happens.

A study that describes sustainability as an "abstract social norm" that is often viewed as a "moral obligation" [117] also needs to be considered. If a social norm is not part of a personal norm, it will not affect an individual's behavior. When a social norm becomes valid for an individual, we can presume that this norm has been activated. According to the "norm-activation theory", this requires that the individual is aware of the conditions or causes that have negative (unsustainable) effects and that the individual feels capable of averting the effect [117]. This means, e.g., that a farmer has to recognize that deficits, in the sense of unsustainable conditions or situations, exist and needs to know how to remedy these. Ideally, this would occur during decision-making and daily farm management. The literature highlights that "farmers have personal norms of sustainability but these do not impact on behavior, presumably because they are not activated." [117]. A potential reason is that "farmers may feel incapable of averting adverse consequences of their management" [117]. This again has implications for assessment tools. If a farmer could get tips or nudges related to sustainability effects

during the management or decision-making process (on the fly), they would have the chance to think about decisions and possible alternatives. Such functionalities require sophisticated and powerful tools.

3.4. Practical Obstacles

If we look at a successful farm (in a good economic and socially satisfactory situation), the question arises as to why the farmer should make changes or adaptations. Authors highlight that changes are usually made when these “will increase profitability or sustainability of the farm” [19]. However, what benefits does a farmer expect when she/he improves the sustainability of the farm, why should they be motivated to do this and what opportunities will influence decisions and behavior?

In farm management, economic and financial issues are key drivers for management decisions and are essential for sustainability [60,118]. “Production systems cannot be sustained in the long term if they are not profitable” [19]. Simultaneously, economic issues and interests can act as a barrier to sustainability in agriculture [8]. Farmers develop more sustainable production systems when current systems are no longer economically viable or when they receive financial inducements, and this applies to farming systems worldwide [119]. Examples exist that demonstrate that farmers prefer to optimize their income situation (in the example, high-value cash crops were grown) rather than to produce, e.g., more rice for food consumption and to improve the food supply [120]. Adaptions that are required to make production more sustainable can also influence the economic situation of a farm in different ways: firstly, the adaption (the required measures) itself can create costs. For example, to protect soil and to change a tillage system requires investment in new technology or changes to established procedures (e.g., from a conventional soil tillage system with ploughing to direct seeding). A no-till system can additionally affect the yield level (yields may decrease during the adaption phase). Developing or implementing new technologies or the adaption of existing technology always incurs transition costs that have to be considered [7]. On the other hand, adverse effects that arise from unsustainable management and their associated costs are not considered by the farmer. The hidden costs of modern industrialized farming that arise, e.g., from the contamination of ground and surface waters (costs for removing contaminants, etc.) were noted as long ago as 1993 [121]. Other authors also mention this and highlight that the person responsible for adverse effects “do(es) not pay the external resource costs” [122]. This is the cause of much criticism and needs to be taken into account [7,51,55,123]. However, if we take the negative effects into account, we also have to consider positive externalities: agriculture provides commodities (e.g., food, fiber) but also provides further outputs and services to society (e.g., recreation, regulation) [124]. These positive externalities also do not have any value in the market economy [125]. There are, of course, different ways in which these external effects can be internalized [63].

When discussing the implementation of sustainable agriculture in practice, potential economic effects and risks have to be considered. Nevertheless, we should keep in mind that farmers do not necessarily have control over prices and are dependent on the market [17]. In food production, sustainability is becoming more popular and customers expect products to meet higher standards [126,127]. This has forced companies to improve their engagement in sustainability over the entire value chain, including agricultural production. In general, this is an ambitious goal with many challenges and has led to different solutions [126,128,129]. For companies, this development is demanding and results in higher supply chain costs and lower flexibility [129]. Unfortunately, a price mark-up for products does not compensate for these higher costs and is why the additional financial outlay is transferred to the value chain [129]. Even when the final product is sold at a higher price, this does not necessarily mean more income for the farmer. This demonstrates that there are also obstacles associated with markets, consumers, and the price level of products. In the Nielsen Study over 30,000 participants from several countries were asked about their buying behavior [130]. One result was that price and quality issues are the main reasons consumers choose a particular product. Confidence in the brand, sustainability, and the work in this area by manufacturers and producers are less relevant.

Besides these economic issues, we should keep the saying “if it ain’t broke don’t fix it” in mind, which addresses possible risks when something is modified. When a farmer thinks about modifications and adaptations, they will consider profits but also the risk that something might go wrong [131]. Here, the farmer is again highly relevant because farmers differ in their risk aversion [64]. The issue of risk is probably becoming more critical because of an expected increase in uncertainties in the future [32]. Examples include extreme weather events or increases in pests that endanger production. The growing number of publications that address risk and vulnerability in the context of sustainable agriculture supports this [33,65,132].

All these aspects lead to the question of what motivates farmers to change their farming towards increased sustainability. It is unclear what would happen if they change their management. They will probably not receive significant economic benefit or general appreciation. Scientists and policymakers can initiate different programs and initiatives, but the ultimate shift to sustainable agriculture requires corresponding decisions by individual farmers [8]. The farmers must themselves be interested in improving their sustainability. Maybe we should rethink recent attempts at implementation and try to establish positive and solution-oriented development. It has been highlighted that some of the debates about sustainable agriculture can be understood as “personal criticism, or an attack, on conventional agriculture” and that this can lead to a situation where farmers may become defensive [17]. This is not the ideal situation for sustainable development.

4. Suggestions for Overcoming Obstacles and Recommendations

Several obstacles have been discussed that hinder the implementation of sustainable agriculture. To overcome these and to promote wide-scale implementation of sustainable agriculture, a broader approach that addresses different dimensions and stakeholders is required. Within this process, several issues and work packages have to be processed. To realize the suggestions and recommendations and to improve implementation, transdisciplinary work and cooperation between many actors are required. A holistic and all-encompassing project with a long-term strategy for implementation would offer the ideal conditions for this (Figure 5).

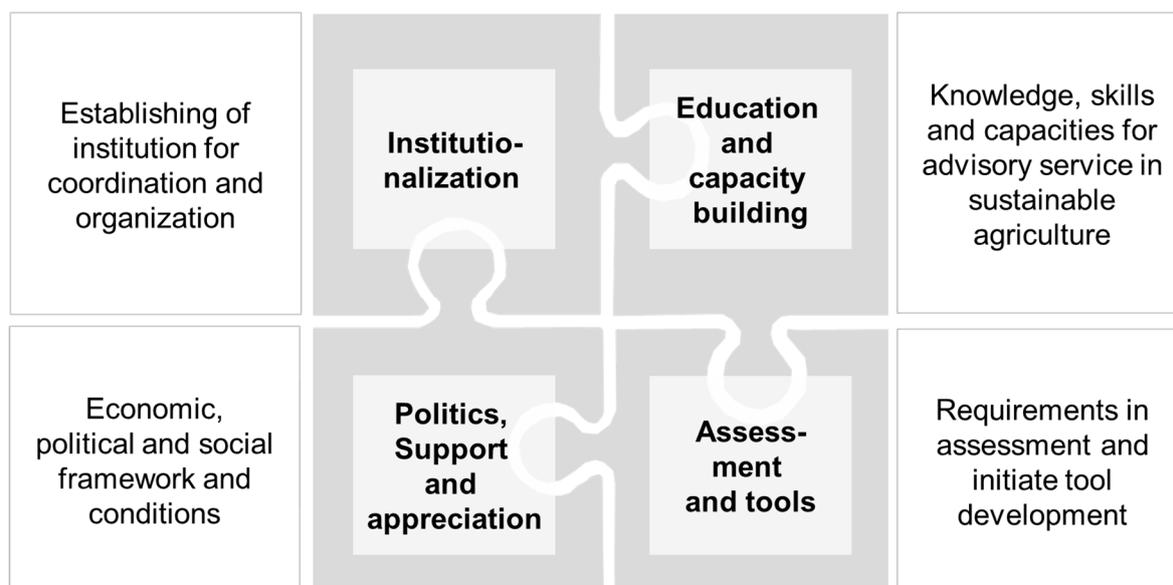


Figure 5. Suggested ways of removing or minimizing obstacles to implementation.

4.1. Institutionalization (Creating Structures, Organizations, or Facilities)

The first step is to establish an appropriate institution that takes responsibility, leads, and coordinates further development. This institute should provide the framework or organization

(association) for all stakeholders and players with a common objective. Goals could be the transformation of agricultural practice, to develop agriculture sustainably and to implement sustainable agriculture in practice. These goals include specific tasks, like the identification of further obstacles and finding ways of overcoming these obstacles. In this context, it would be worth considering limiting the process to a certain geographic area (e.g., Central Europe); otherwise, the requirements, problems, and also agricultural systems that are included would be too diverse. There are several institutions whose descriptions suggest that they are working on these objectives. However, these usually have a specific geographical focus (e.g., the “Centers for Sustainable Agriculture” (CSA) Secunderabad, India; or the “National Sustainable Agriculture Coalition” (NSAC, Washington, USA), or are working on other objectives, rather than implementation (e.g., the “Sustainable Agriculture Initiative Platform”; SAI Platform, Brussels, Belgium). It would be useful to review existing organizations and evaluate if they could also work on implementation (e.g., the Sustainability Transitions Research Network; STRN for sustainable agriculture).

The primary mission of the new institution should be solution-oriented work on different issues to minimize or remove obstacles. During the initial phase of the institution, different stakeholders (e.g., scientists, farmers, advisers, teachers, politicians) need to be identified and motivated to join. In this phase, common goals (letter of intention) and basic terminology should be defined. Next, relevant work packages and work groups need to be set up. Work packages could be associated with the obstacles mentioned and consider theoretical, methodological, personal, and practical obstacles. In relation to the practical obstacles, for example, ways of supporting farmers with their development strategy have to be developed. These could include the Common Agricultural Policy (CAP) and associated subsidies, companies that are involved in sustainable agriculture in the context of their value chains or even the consumer (e.g., product prices).

4.2. Education, Capacity Building, and Sustainability Consulting

Most farmers are interested in new developments and trends (new knowledge) and therefore read, e.g., agricultural magazines, relevant reports, or news about specific issues. However, probably only a few farmers read scientific contributions in the sense of peer-reviewed papers about sustainable agriculture. There could be many reasons, e.g., that these publications are not relevant to daily decision-making, a lack of interest, low general accessibility of these types of publications to farmers, the language, and just the complexity. Even farmers who do read scientific publications have to interpret the paper’s findings and the implications for their farming by themselves without any assistance.

As long ago as 1993 it was recognized that “diversified farmers” are needed, that they “must be more knowledgeable, more creative, and more skilled”, in order to manage the sustainability challenge [6]. Other authors address the importance of the knowledge, skills, and capabilities of farmers because they must increasingly address new requirements in management [133]. This could be one reason why authors highlight the relevance of increasing farmers’ knowledge and education level [60]. There are different forms of education, e.g., vocational training for farmers, training for farm advisers, or university education for students. “Sustainability education is imperative”, but sustainability teaching is a challenge [55]. Preparing students to think scientifically about sustainability is not easy [134]. Nevertheless, we should intensify our efforts in sustainability education. This also includes attempts to involve practitioners in scientific debates and developments.

Within the context of knowledge and education, we also have to take consulting and advisory services into account. Consulting is more than just helping with problem-solving. It also includes networking, moderation, and education [135]. EU member states have been obliged since 1997 to offer a “comprehensive farm advisory system” [136]. The main objectives are to ensure compliance with existing regulations, maintenance of the agricultural area, or to promote entrepreneurship [136]. This has led to a diversity of approaches with different actors (private advisory service providers, official government advice, farmer associations) and advice subjects and issues [135]. The availability and utilization of advisory services does not necessarily guarantee improvements. Changing farm

management and implementing suggestions also depends on the relationship between farmer and advisor [111]. In the worst case, advisors' suggestions for improvements are ignored and the farmer continues with business as usual. Authors, therefore, have called for professional and cooperative relationships within advisory services [137]. This is also highlighted in implementation science as an essential prerequisite for the implementation of new knowledge and principles (Section 3.3). This can mean that results of analyses are regarded as a starting point for the dialogue between farmers and consultants on further farm development [9]. Farmers need and appreciate consultancy services and advisers, particularly in the context of sustainable agriculture and its assessment [38,70]. Yet, how effective are these methods at promoting sustainable agriculture? Results demonstrate that "the number of contacts with advisory service is positively related to the adoption of innovations", but a clear relationship to environmental sustainability was not found [138].

To identify possible deficits and to develop improvement measures, a systematic evaluation of existing educational programs, initiatives, and educational options, as well as existing advisory services in sustainable agriculture with the focus on implementation in practice, is needed. A quick evaluation of the options for further education for farmers in Germany (Bavaria) revealed that numerous options (153) and education courses are available (e.g., by the Bavarian Ministry of Food, Agriculture and Forests). However, these cover one-day and multi-day events with themes like animal husbandry, fodder production, farm management, plant protection. A course about sustainable agriculture is missing!

A note: The increasing interest in sustainability and sustainable development has forced different businesses to address different sustainability issues and to take sustainability into account in their management [139], i.e., corporate social responsibility (CSR). In this environment, the development of a new service sector with specialized advisory agencies, CSR departments, company networks, degree programs, and institutes has occurred. We probably need something similar for the agricultural sector.

4.3. Assessment of Sustainable Agriculture and Tools

Challenges related to sustainability assessment and deficits in tools have been discussed above. Methodological issues for the development of new, appropriate tools will be presented in a separate paper. However, in general there is no tool available that can be used to support implementation in practice and that provides all the required capabilities and functions. An appropriate tool would need to perform complex functions (e.g., data recording, analysis, evaluation of interactions, simulation, and scenario capabilities). The development of these systems is therefore a comprehensive task that needs the cooperation of different people or groups with many competencies. We cannot expect that any commercial suppliers or software companies will develop such a system, since it is likely to be a complex and high-cost job. At the same time, the willingness of potential customers (farmers) to pay for this application will be rather low. Most probably, the tool will also never be finalized, as it will more or less need to be continuously adjusted and new content will need to be integrated. This needs to be taken into account. This means system development is a permanent task. Therefore, a system like this will probably only become reality if public support and government funding (probably in combination with the EU) is available. Therefore, ways of enabling and supporting developments and application need to be identified. Digitalization in agriculture should also include these types of developments and existing funds should be used accordingly. In addition, companies from different value chains that include sustainable agriculture may like to participate in corresponding developments and applications; this needs to be verified.

4.4. Politics, Support, and Appreciation

Society and consumers can demand sustainable agriculture but ultimately, farmers have to implement it. This implies that farmers need to have the intrinsic motivation to do so. The conditions for implementation have to be suitable and farmers need to be motivated. Adaptions to ensure more

sustainable farming are not without risk and unintended effects can occur. Adjustments can be costly or reduce potential returns and profits. There are three ways implementation could be supported: firstly, the future of the EU Common Agricultural Policy (CAP) is currently being discussed. In the proposal for new regulations, the European Commission states that “a modernized Common Agricultural Policy will need to support the transition towards a fully sustainable agricultural sector” [136]. This is true, but considering the obstacles mentioned in this paper, the adaptations are probably not far-reaching enough and should be expanded. The following issues also need to be included in the development of the new regulations:

- Establishment and promotion of comprehensive farm sustainability advisory services and the promotion of the development and operation of appropriate advisory tools (for sustainability assessment);
- Training and qualification of sustainability advisors, improving the education of farmers, and improving university courses and other training programs;
- Supporting programs, funding, and subsidies for individualized methods (appropriate for each farm) to help farms become more sustainable and put in place the required changes;
- Funding and support for the establishment of an appropriate institution.

Secondly, the market and companies that are part of agricultural value chains should also be considered. Currently, each company selects, develops, and uses its own methods (mostly mean-oriented approaches). However, it might make more sense, from an actual implementation point of view, for companies to cooperate. This would have the advantage that comprehensive and more effective approaches could be developed and applied. One idea would be to establish a brand or label (similar to organic products) that is not geared towards compliance with standards but instead demonstrates the process of sustainable development that farms have embarked upon. Thirdly, consumers still expect food to be produced sustainably. Unfortunately, this does not mean that they are willing to pay higher prices. However, this is probably necessary to improve the situation and to support agriculture and farmers in improving their sustainability.

To reach real progress in the implementation of sustainable agriculture in practice, all stakeholders probably have to cooperate and joint efforts and activities are necessary. Undoubtedly, this is an ambitious project that requires patience, and detailed ideas and proposals are mandatory.

5. Conclusions

Debates about sustainable agriculture are not new and many parties agree that it is still important for agriculture to become more sustainable. At the same time, there are indications that agriculture is currently not sustainable.

This study analyzed the potential obstacles that could hinder the implementation of sustainable agriculture in practice and which options exist to overcome or minimize these obstacles. I suggest differentiating between theoretical, methodological, personal, and practical obstacles. Theoretical obstacles address science and research and definitional aspects, how to transfer new scientific knowledge to practitioners, and the implementation scale. Methodological obstacles refer to assessing sustainable agriculture with tools or systems and related challenges. Personal obstacles are found at the individual scale with the farmer, who mainly affects sustainability through management decisions and behavior. Practical obstacles are related to issues that limit implementation in practice even when there are no other critical issues. These include issues that constitute the economic, political, and social framework and influence conditions that hinder changes to more sustainable production.

The diversity of the obstacles described means that improvements will be neither quick nor easy. Instead, changes need to be comprehensive so that improvement is achieved in the medium and long term. Areas in which developments are recommended are institutionalization, assessment, and system development, education and capacity-building, and social and political support. Hopefully, this article will contribute to initiating developments that help to implement sustainable agriculture in practice.

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