Sustainability **2015**, *7*, 7833-7865; doi:10.3390/su7067833

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Review

What Is Sustainable Agriculture? A Systematic Review

Sarah Velten *, Julia Leventon, Nicolas Jager and Jens Newig

Institute for Sustainability Communication, Leuphana University Lüneburg, Scharnhorststr. 1, Lüneburg 21335, Germany; E-Mails: julia.leventon@leuphana.de (J.L.); nicolas.jager@leuphana.de (N.J.); jens.newig@leuphana.de (J.N.)

***** Author to whom correspondence should be addressed; E-Mail: sarah.velten@leuphana.de; Tel.: +49-4131-677-1582.

Academic Editor: Marc A. Rosen

Received: 5 March 2015 / Accepted: 10 June 2015 / Published: 18 June 2015

Abstract: The idea of a sustainable agriculture has gained prominence since the publication of the Brundtland Report in 1987. Yet, the concept of sustainable agriculture is very vague and ambiguous in its meaning, which renders its use and implementation extremely difficult. In this systematic review paper, we aim to advance understandings of sustainable agriculture from a social science and governance perspective by identifying areas of complementarity and concern between emerging definitions of sustainable agriculture. For this purpose, we conducted a structured literature review in combination with a cluster analysis in order to (1) identify the overall ideas and aspects associated with sustainable agriculture; (2) detect patterns and differences in how these ideas and aspects are adopted or applied; (3) evaluate how the different ideas and aspects of sustainable agriculture are combined in the scientific debate, and assess whether these different conceptions match with those that have been claimed to exist in the debate. There are two valuable outcomes from this research. The first is a framework for understanding the components of sustainable agriculture. The second outcome is in highlighting ways for actors involved with sustainable agriculture to deal with the complexity and multiplicity of this concept in a constructive manner.

Keywords: sustainable agriculture; definitions; qualitative content analysis; cluster analysis; journal articles; grey literature; goals; strategies; fields of action

---

1. Introduction

An agriculture able to continually provide food and other resources to a growing world population is of crucial importance for human existence and hence for any human activity. However, there are a great number of problems that threaten this ability of agriculture to fulfill human needs now and in the future, including climate change; a high rate of biodiversity loss; land degradation through soil erosion, compaction, salinization and pollution; depletion and pollution of water resources; rising production costs; an ever decreasing number of farms and, linked with that, poverty and a decrease of the rural population [1–8]. Agriculture not only has to face these problems, but in the form it has been practiced over the last decades it also is a major cause of all of these issues [2,9].

In face of these challenges, the idea of sustainable agriculture has gained prominence since the publication of the Brundtland Report in 1987, alongside the overarching concept of sustainable development [10]. Yet, like the notion of sustainable development itself, the concept of sustainable agriculture is ambiguous in its meaning [11]. This characteristic has led to the emergence of a great variety of different discourses, views or paradigms of sustainable agriculture [10,12–18] and rendered the discussion and implementation of this idea extremely difficult. It also allows for exploitation of the concept by vested interests who use the notion for their own purposes [19]. In the hope of solving this problem and making the concept more tangible, there have been numerous attempts to define sustainable agriculture. Collections of definitions are found in [20] and [21], and include:

> Sustainable agriculture is an "integrated system of plant and animal production practices having a site specific application that will, over the long term: (a) satisfy human food and fiber needs; (b) enhance environmental quality; (c) make efficient use of non-renewable resources and on-farm resources and integrate appropriate natural biological cycles and controls; (d) sustain the economic viability of farm operations; and (e) enhance the quality of life for farmers and society as a whole." 1990 U.S. Farm Bill [22].
>
> "For a farm to be sustainable, it must produce adequate amounts of high-quality food, protect its resources and be both environmentally safe and profitable. Instead of depending on purchased materials such as fertilizers, a sustainable farm relies as much as possible on beneficial natural processes and renewable resources drawn from the farm itself." Reganold *et al.* 1990 [23].
>
> Sustainable Agriculture comprises "management procedures that work with natural processes to conserve all resources, minimize waste and environmental impact, prevent problems and promote agroecosystem resilience, self-regulation, evolution and sustained production for the nourishment and fulfillment of all." MacRae *et al.* 1989 [24].

These attempts to try and find a single all-encompassing definition were doomed to failure: Due to the complex and contested nature of the notion of sustainable agriculture, and its adaptation to context, its precise and absolute definition is impossible [25]. The emergence of variable definitions, interpretations and uses of the term could lead to complementarity between definitions, whereby all definitions can co-exist, and potentially aid each other. Alternatively, there could be negative interplay between definitions, whereby the aim of one works against the aim of another. Indeed, it is often claimed that there prevail two [12,14,15,26–28] or more [29–31] different and opposing overarching schools of

thought or paradigms of sustainable agriculture that have made the use of the term even more confusing and obscure.

In this systematic review paper, we aim to advance understandings of sustainable agriculture by identifying areas of complementarity and concern between emerging definitions of sustainable agriculture. Our main interest here is on social processes and the social reification of sustainable agriculture rather than mapping it as a technical paradigm. For this aim, we initially conduct a structured literature review with the objective of identifying the ideas and aspects associated with the concept of sustainable agriculture as well as the central aspects of the debate (objective 1). We therefore focused on papers that engaged critically with the definition of sustainable agriculture. We then seek to identify patterns and differences in how these ideas and aspects are adopted or applied (objective 2). To do so, we look at the differences in the perceptions of sustainable agriculture held by different groups. Thus, we compare the views of scientists and practitioners as well as the perspectives of scientists of different academic disciplines. Framing the different conceptions of sustainable agriculture of these different groups can improve their mutual understanding. This in turn might benefit future work as all of them are involved in the attempt to realize a sustainable agriculture, and for this purpose, their collaboration is indispensable [31–35]. We also compare how ideas have evolved over time. Finally, in objective 3, we apply a cluster analysis methodology to identify how the different ideas and aspects of sustainable agriculture are combined in the scientific debate, and explore whether these different conceptions match with those that have been claimed to exist. We explored these overlaps and differences to examine the extent to which emerging concepts are complementary. In putting these objectives together, we are able to highlight strategies for progressing our understanding and implementation of sustainable agriculture.

There are two valuable outcomes from this research. The first is a framework for understanding the components of sustainable agriculture. Such an understanding of all aspects associated with sustainable agriculture is especially important as farmers, extension professionals, policy makers and other stakeholders need to have a notion of what is meant by the term in order to put it into practice [36]. The second outcome results from highlighting the complexities and subtleties of varying definitions. We intend that actors involved in sustainable agriculture can use our understandings to consider their own definitions of sustainable agriculture, and identify how to strengthen their actions through collaboration with others. Our discussion section describes these outcomes, and highlights their applicability for future sustainable agriculture research and implementation. Prior to the discussion, the following section outlines our methodology in detail. We then present our results for each objective. Finally, at the end of the paper we sum up and draw conclusions.

2. Methods

In order to collect a sample of definitions of sustainable agriculture, we conducted a search of both academic and practitioner-oriented literature. Academic publications were searched in Scopus, a database of abstracts and citations of peer-reviewed scientific journal articles, with the search string TITLE-ABS-KEY (“sustainable agriculture” OR “agricultural sustainability”). We searched for publications in English, German, French, Spanish and Portuguese published in all years up to and including 2012 in the subject area of social sciences and humanities. This subject area was chosen

because of our focus on social science and governance aspects of sustainable agriculture. We wanted to engage with publications that critically discuss the concept of sustainable agriculture itself. In order to avoid technical research that is justified by the objective of contributing to sustainable agriculture, but does not make explicit what the researchers mean by the term, we did not actively search the physical science and engineering literature.

For the evaluation of the practitioner view on sustainable agriculture, we searched for non-peer reviewed literature, mainly those kinds of publications without ISBN or ISSN such as websites, reports or brochures. Such publications may or may not be authored by scientists but mostly they are directed less towards the scientific community and more to practitioners, decision-makers *etc*. This type of literature is referred to as "grey literature" in the remainder of this article. Grey literature publications were searched in Google with the search terms "sustainable agriculture" and "agricultural sustainability" in English, German, French, Spanish and Portuguese. The results of each query were checked until a point where no new usable publications were found. Additionally, we searched websites of organizations known to be related to agriculture or sustainability including BUND (Friends of the Earth Germany), FAO, German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Greenpeace, Monsanto, Syngenta, UNEP, Unilever, U.S. Department of Agriculture, WHO, WWF, *etc*.

Search results were narrowed down to include only those publications that were available, and that gave at least a minimal definition or explanation of what was meant by sustainable agriculture. With this search, we found 129 journal articles and 26 grey literature publications (see Table S1 in the Supplementary Information for the full list of these publications). This selection is not a complete compilation of all publications that have ever defined sustainable agriculture. Particularly, it does not contain any book chapters or conference papers. Nevertheless, it provides a broad overview of the conceptions of sustainable agriculture in use.

Objective 1 was fulfilled by subjecting the publications to content analysis supported by ATLAS.ti. We employed an inductive qualitative content analysis [37] in order to identify different topics and aspects that are related to sustainable agriculture in the examined literature. In the remainder of this article, we refer to the single aspects of sustainable agriculture as "categories" and to the overall topics as "themes" (see Tables 2–4). These categories and themes were organized into a framework which summarizes descriptions of sustainable agriculture. This framework includes both technical and non-technical issues of sustainable agriculture. However, as we focused on governance and social issues in this research, technical aspects were strongly summarized into few categories and themes while the issues of greater interest to this research are represented in more detail and in a greater number of categories and themes. In order to assess which topics are more central in the debate about sustainable agriculture, we assessed the number of examined publications—both journal articles and grey literature publications—the different themes occurred in.

Our framework served as an analytical framework for the quantitative analysis of the investigated literature in objective two. One part of this quantitative analysis consisted of the assessment of the occurrence of the different themes in journal articles and grey literature publications. Furthermore, for the journal articles we assessed differences in the occurrences of the themes and categories between different disciplines. Additionally, we assessed changes in the debate over time by focusing on the level of categories. All categories were classified according to their persistence and relevance. The persistence

is measured as the percentage of the years in which a category appears in the journal articles. To determine the relevance, the mean percentage of journal articles mentioning a category for those years in which the category appeared was calculated. The categories were classified as persistent or occasional, and as being of low, medium or high relevance. By combining both parameters, a typology of six category-types with different combinations of persistence and relevance was developed (Table 1).

Table 1. Category types according to their persistence and relevance in the debate.

Category-Type	Persistence	Relevance	Interpretation
Famous topics	*persistent*: appear 51%–100% of years	*high*: appear in 50%–100% (mean) of papers in years of appearance	form mainstream debate
Key topics	*persistent*: appear 51%–100% of years	*medium*: appear in 25%–49% (mean) of papers in years of appearance	form mainstream debate
Wall-flower topics	*persistent*: appear 51%–100% of years	*low*: appear in 1%–24% (mean) of papers in years of appearance	niche topics
Buzz topics	*occasional*: appear 0%–50% of years	*high*: appear in 50%–100% (mean) of papers in years of appearance	complement mainstream
Visiting topics	*occasional*: appear 0%–50% of years	*medium*: appear in 25%–49% (mean) of papers in years of appearance	complement mainstream
Outsider topics	*occasional*: appear 0%–50% of years	*low*: appear in 1%–24% (mean) of papers in years of appearance	niche topics

For objective three, we conducted a cluster analysis of only the journal papers in order to identify overall conceptions of sustainable agriculture in the academic discourse. For this cluster analysis, we assessed which themes of our framework (Tables 2–4) were mentioned in each publication. Thus, we obtained a binary dataset containing the information of which themes of sustainable agriculture are brought up in which journal article. As it was our aim to obtain clusters of different positions regarding sustainable agriculture, a special approach had to be taken for those papers that juxtapose two or more positions regarding sustainable agriculture [10,14,16,17,38]: In order to separate these positions, these articles were divided into several sub-articles with each sub-article containing the coding data pertaining to only one of the presented positions. Those aspects which were mentioned in these articles and for which it was not clear to which of the positions they related were coded in all of the sub-articles. Each of the sub-articles was regarded as an own instance for the cluster analysis, leading to a total number of 136 instances whereas each instance contains one position regarding sustainable agriculture.

The cluster analysis was carried out in a two-step approach. In the first step, all instances were included in the analysis. We used different algorithms to calculate the clusters, but for all of them, clusters were mainly determined by the number of themes mentioned in the instances rather than by different orientations with regard to contents. To counteract this effect, in a second step we excluded all those instances that mention less than four or more than fifteen of the seventeen themes (see Table A1 in the Appendix). With that, the number of instances analyzed was reduced to 119. For the cluster analysis of these 119 instances, we specifically conducted an agglomerative hierarchical cluster analysis using Euclidean distance measures and Ward's method of agglomeration. With this method we aimed to

minimize within-group variance while simultaneously maximizing dissimilarity between groups. Based on all variables, the analysis proceeds in a bottom-up way, starting from the single units (*i.e.*, instances). It then aggregates successively the two most similar units (or aggregates of units) until only one all-encompassing cluster remains [39]. We employed Ward's method of agglomeration because it resonates well with our goal of arriving at homogenous groups and tends to produce readily interpretable and widely understood results [40].

Table 2. Themes and categories making up the goals of sustainable agriculture.

Goal Themes	**Goal Categories**	
	General	***Specific***
Overarching Goals		• ethics • multifunctionality • safety • stability & resilience
Environmental Goals: Production-Specific	*ecological soundness*	• ecosystem function conservation • natural resource conservation • productive capacity
Environmental Goals: Non-Production-Specific		• animal well-being • environment conservation & improvement • harmony with nature
Social Goals	*social responsibility*	• acceptability • cultural preservation • equity, justice, fairness • fulfillment of human needs • good working conditions • human health • nourishment • quality of life • strong communities
Economic Goals	*economic viability*	• development • livelihood • provision of products • thriving economy

Table 3. Themes and categories making up the strategies for sustainable agriculture.

Strategy Themes	Strategy Categories
Adaptive Management	• adaptation • learning & experimentation • management, integration & redesign • prevention • substitution
Co-operation	• collaboration & communication • participation
Ecology-based Strategy	• diversification • ecological principles
Economics-based Strategy	• capital asset maintenance • demand-orientation • efficiency • quality-orientation
Holistic & Complex Systems Thinking	• long-term perspective • scale-sensitivity • systemic thinking
Knowledge & Science	• innovation • modern • traditional
Subsidiarity	• decentralization • independence • local/regional

Table 4. Themes and categories making up the fields of action for sustainable agriculture.

Fields of Action Themes	Fields of Action Categories
Agrifood System	• consumption • production • supply Chain
Management & Technological Solutions	• crops & livestock • management tools • resource use • technology & practices
Social & Environmental Challenges	• emission-reduction • global trends
Social & Human Capital	• organization • knowledge, education, skills • research & development
Social, Political & Economic Environment	• accessibility • economic system • infrastructure • investment • policy & institutions • society

3. Results

3.1. Objective 1: Categories and Themes that Contribute to Sustainable Agriculture

The inductive content analysis revealed a great variety of different categories that are associated with sustainable agriculture, which can be organized into three general groups. Sustainable agriculture is often described as a set of ideal objectives which it is supposed to achieve (*Goals*). In order to achieve these goals, authors suggest or criticize different approaches and principles (*Strategies*), which should or should not be applied in different areas (*Fields of Action*). We identified altogether 17 themes that specify which are the concrete Goals, Strategies and Fields of Action of and for sustainable agriculture from a social science and governance perspective, thus forming a framework of sustainable agriculture (Figure 1). These 17 themes summarize the overall 66 more detailed categories (or aspects) of sustainable agriculture that were identified through the qualitative content analysis (Tables 2–4).

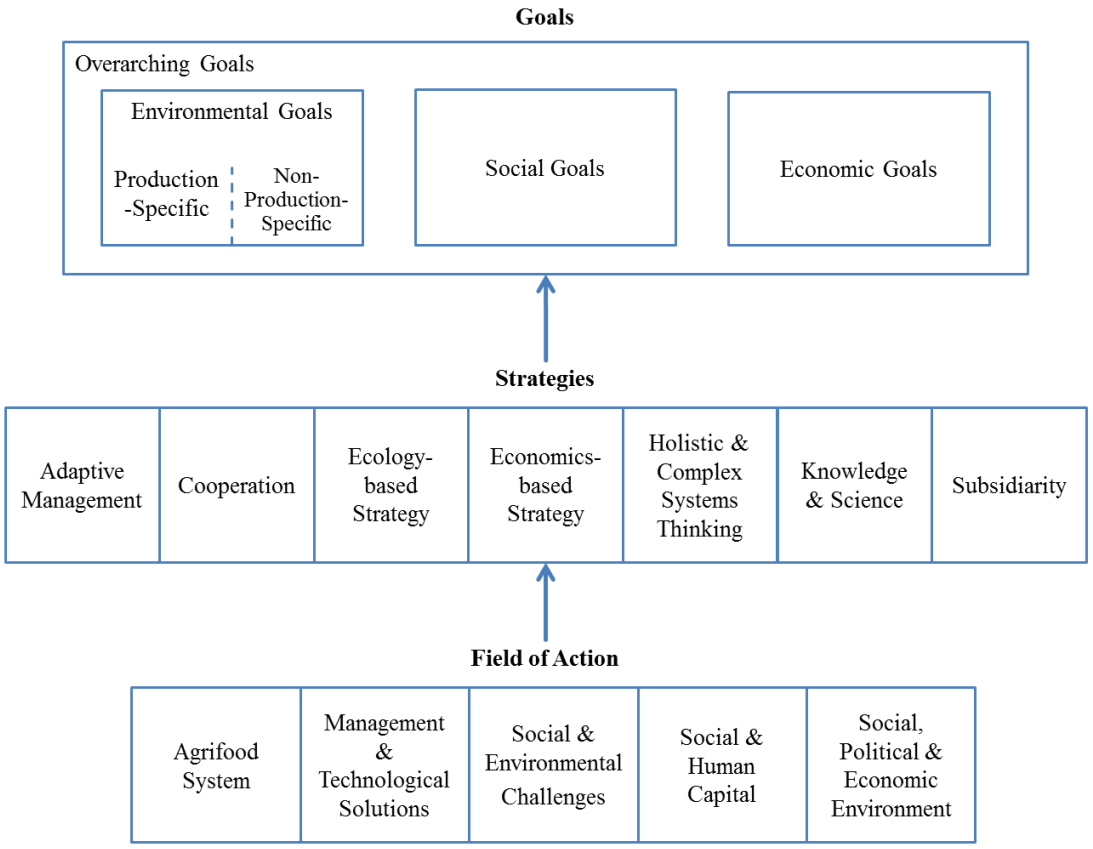

Figure 1. Groups and themes of the sustainable agriculture framework.

While the division of the groups of Strategies and Fields of Action into single themes is quite straightforward, the structure of the group of Goals is more complex: The Environmental Goals theme is subdivided into two sub-themes. Whereas the theme of Production-Specific Environmental Goals summarizes those categories that demand the protection of the environment as a basis for agricultural production, the theme of Non-Production-Specific Environmental Goals contains categories that imply environmental protection rather for its own sake and for the greater good [41,42]. Another specialty are the categories "ecological soundness", "social responsibility" and "economic viability", which represent

the general goals of sustainable agriculture in the environmental, social and economic pillars respectively. The remaining categories in each of these themes give a more detailed and concrete account of these goals and therefore operationalize the general goal categories of ecological soundness, social responsibility and economic viability. In addition to the classical sustainability triad of environment, social sphere, and economy, our framework contains Overarching Goals as a further theme. This theme comprises categories which represent goals that are not specific to any of the three areas of sustainability but rather are valid for all areas, such as "stability & resilience". Descriptions and explanations of all of the themes and categories in this framework can be found in Table S2 in the Supplementary Information of this article along with some exemplary citations for each category.

Our analysis of central (*i.e.*, most frequently used) topics highlights that the debate about sustainable agriculture seems to be focused more on anthropocentric than ecocentric values: The most mentioned and therefore most considered goals are the Production-Specific Environmental Goals, Economic Goals, and Social Goals (Figure 2). There is almost complete balance among these three dominating goals as they all appear in very similar shares of approximately 80% of the publications.

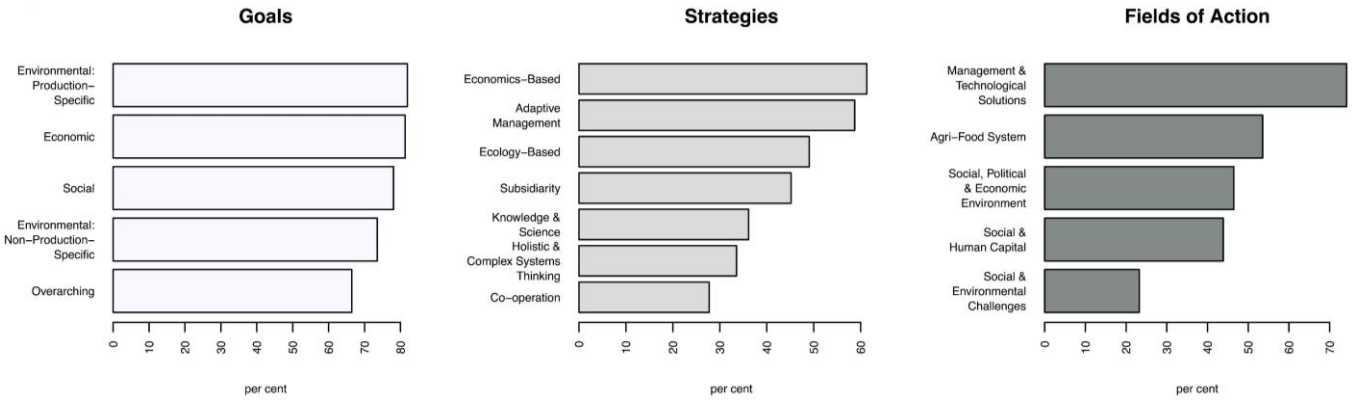

Figure 2. Total share of publications mentioning the different themes in the group of Goals, the group of Strategies, and the group of Fields of Action.

Furthermore, from the occurrences of the Strategy and Fields of Action-themes, we find that the main focus for the realization of sustainable agriculture has so far been on rather technology-centered, on-farm solutions: The most mentioned Strategies are the Economics-Based Strategy and Adaptive Management and the most suggested Field of Action is the one of the Management & Technological Solutions. Thus, there is a strategic emphasis on economic efficiency and adaptation of practices. At the same time, most action-related statements make recommendations or prescriptions about which technologies, management practices, kinds of resources, crop varieties, and livestock breeds are supposed to be used in which way if one wants to practice sustainable agriculture. The focus on measures at the farm level is also highlighted by the fact that roughly two thirds of the scientific publications only consider the level of agricultural production when writing about sustainable agriculture whereas only one third of the publications follow demands to look beyond the farm gate to solve sustainability problems in agriculture [28,43,44] (Figure 3).

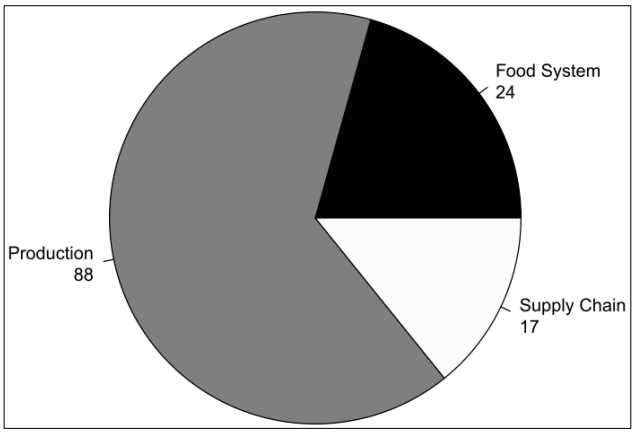

Figure 3. Breadth of focus of the journal articles. Journal articles attributed to "production" consider only the stage of agricultural production; publications with a supply chain focus take into account both production of agricultural goods and the subsequent marketing and distribution; articles considering the food system look at production, distribution and also consumption of agricultural produce.

The debate about sustainable agriculture is not solely characterized by these themes; alternative conceptions have a strong standing in the discourse. This becomes evident, on the one hand, by looking at the two remaining goal themes—Environmental Goals which are not directly related to agricultural production and Overarching Goals. They are of lesser concern in the debate than the three anthropocentric goal themes but have an occurrence in two thirds or more of the publications and are thus widely considered. Also, in the groups of Strategies and Fields of Action, there are themes that appear significantly less often than the dominant Strategies and Fields of Action, but still they are mentioned in more than one third of the publications and therefore are of relevance, too. These are all remaining Strategies except for Co-operation, and all of the remaining Fields of Action, with the exception of Social & Environmental Challenges. We evaluate the remaining themes of Co-operation and Social & Environmental Challenges, which appear in less than one third of the publications, to be niche themes: They have been relevant only to few authors and/or during some time periods.

3.2. Objective 2: Use Patterns of Ideas and Aspects of Sustainable Agriculture

3.2.1. Use Patterns of Ideas and Aspects of Sustainable Agriculture over Time

Over time, the sustainable agriculture debate has been shaped by a large number of Famous and Key topics. As described in the methodology section (Section 2, Table 1), the single categories of sustainable agriculture were classified as belonging to one of six category-types according to the persistence with which they occurred in the debate and the relevance attributed to them (see Table 5). The fact that there are no Buzz topics as well as the overall low number of categories with a low persistence and the high number of categories classified as Key topics suggest that the overall discourse about sustainable agriculture is not one which homogenously favors few topics for a short time period before it turns its attention towards other topics. Rather, it is characterized by a great, heterogeneous variety of topics that are discussed parallel to each other and remain on the agenda almost constantly, which indicates the presence of alternative, competing conceptions of sustainable agriculture.

Table 5. Classification of the categories of sustainably agriculture according to their relevance and persistence.

Persistence	**Group**	**Relevance**			
		0%–24%	***25%–49%***		***50%–100%***
51%–100%	*Goals*	**Wallflower topics** cultural preservation	**Key topics** development livelihood thriving economy ecological soundness ecosystem function conservation productive capacity ethics multifunctionality safety	Acceptability equity, justice, fairness fulfillment of human needs nourishment quality of Life social responsibility strong communities	**Famous topics** economic viability provision of products environment conservation & improvement natural resource conservation stability & resilience
	Strategies	long-term perspective systemic thinking	Adaptation management, Integration & redesign participation diversification ecological principles	demand-orientation quality-orientation innovation decentralization independence local/regional	efficiency
	Fields of Action	emission-reduction	Production supply chain crops & livestock knowledge, education, skills	economic system policy & institutions society	resource use technology & practices

Table 5. *Cont.*

Persistence	**Group**	**Relevance**		
		0%–24%	***25%–49%***	***50%–100%***
0%–50%	*Goals*	**Outsider topics** animal well-being good working conditions	**Visiting topics** harmony with nature human health	**Buzz topics**
	Strategies	learning & experimentation prevention substitution capital asset maintenance scale-sensitivity	collaboration & communication modern traditional	
	Fields of Action	Consumption organization infrastructure investment	management tools global trends research & development accessibility	

However, evaluating the significance of the categories only based on frequency and relevance measured over the whole observed time period might obscure changes in the persistence or the relevance of a category during this time. Thus, a category could be an Outsider topic in the first years and become a Key topic in later years. Overall, the category could be classified as a Visiting topic but this classification would not reflect changes in the debate in a sufficient way. Therefore, we also checked the time lines of the individual categories for such trend changes (Table 6). Only 18 of the overall 66 categories (27%) experienced such a trend change.

These findings further underline the overall constancy of the presence of manifold aspects of sustainable agriculture at the same time. Yet, some developments can be detected: After the turn of the millennium, both the Environmental Goal to conserve ecosystem functions or ecosystem services and the Overarching Goal of having agriculture fulfill a variety of different functions rather than just producing food and other products ("multifunctionality") started to be discussed in more papers and have therefore gained relevance. Therefore, the commodity-centered view that considers agriculture and the environment as providers of certain resources has been complemented by a function-centered view. In this view, the functions of the environment and of agriculture are recognized as valuable in addition to material goods because they underpin the provision of such goods and offer additional benefits to society.

Another development is the narrowing down of the debate regarding the Strategies for a sustainable agriculture, *i.e.*, fewer Strategies are now widely considered than before. This trend is most pronounced for Co-operation and the Ecology-Based Strategy. In the first half of the 2000s, both categories of the Strategy of Co-operation ("collaboration & communication" and "participation") turned from Key into almost completely neglected Outsider topics. A few years later, the Ecology-Based Strategy also started to lose weight in the debate as "ecological principles" turned from a Famous to a Key topic and "diversification" from Key to Wallflower topic. Thus, in earlier years the Ecology-Based Strategy belonged to the dominant Strategies, just like the Economics-Based Strategy and Adaptive Management (see Section 3.1), and for just a few years it has been an alternative strategy.

Table 6. Categories that experienced trend changes.

Group	Theme	Category	Year																					
			89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12
Goals	Environmental: Non-Production-Specific	*harmony with nature*	Outsider								Key															
	Environmental: Production-Specific	*ecosystem function conservation*	Key													Key (with higher relevance)										
	Overarching	*multifunctionality*	Wallflower																				Key			
	Social	*acceptability*	Visiting													Key						Wallflower				
		equity, justice, fairness	Key													Famous							Wallflower			
		good working conditions	Outsider																	Wallflower						
		human health	Visiting																	Key						
Strategies	Adaptive Management	*learning & experimentation*	Outsider (not mentioned)						Key										Outsider							
		prevention	Outsider												Outsider (not mentioned)					Wallflower						
	Co-operation	*collaboration & communication*	Key															Outsider								
		participation	Key																	Outsider						
	Ecology-based	*ecological principles*	Famous																	Key						
		diversification	Visiting										Key								Wallflower					
	Holistic & Complex Systems Thinking	*long-term perspective*	Key											Outsider					Wallflower							
	Knowledge & Science	*modern*	Visiting											Outsider						Wallflower						
Fields of Action	Social & Environmental Challenges	*emission-reduction*	Wallflower												Wallflower (with higher relevance)											
	Social & Human Capital	*research & development*	Outsider							Key									Outsider							
	Social, Political & Economic Environment	*economic system*	Key												Key (with higher relevance)						Wallflower					

3.2.2. Differences in the Use of Ideas and Aspects of Sustainable Agriculture between Scientists and Practitioners

Differences in the perceptions of sustainable agriculture held by scientists and practitioners indicate that in academia a more utilitarian view is dominant than in the practitioner-oriented literature. We compared the ranking of the themes for each publication type (academic and grey literature) [45] according to the frequency of mentions in the publications (Table 7). Whereas economic benefits of sustainable agriculture and the conservation of environmental assets as a basis for agricultural production are the most considered goals in journal articles, grey literature publications focus on social aspects and attribute more importance to the protection of the environment for its own sake. This can be seen by the fact that for practitioners, Social Goals and Non-Production-Specific Environmental Goals are apparently more relevant than for scientists, whereas the opposite is true for Production-Specific Environmental Goals. Also, the Fields of Action theme Human & Social Capital ranks significantly higher for grey literature publications than for journal articles.

Table 7. Shares and ranks (based on the frequency of mentions) of the different themes of the sustainable agriculture framework in journal articles and grey literature publications.

	Themes	Share		Rank	
		Journal	**Grey**	**Journal**	**Grey**
Goals	Environmental: Production-Specific	80%	92%	1	4
	Economic	78%	96%	2	2
	Social	74%	100%	3	1
	Environmental: Non-Production-Specific	69%	96%	4	2
	Overarching	64%	77%	5	5
Strategies	Economics-based	60%	69%	1	2
	Adaptive Management	56%	73%	2	1
	Ecology-based	47%	58%	3	3
	Subsidiarity	43%	54%	4	4
	Knowledge & Science	32%	39%	5	6
	Holistic & Complex Systems Thinking	32%	54%	5	4
	Co-operation	26%	35%	7	7
Fields of Action	Management & Technological Solutions	73%	81%	1	1
	Agri-Food System	51%	65%	2	3
	Social, Political & Economic Environment	45%	54%	3	4
	Social & Human Capital	39%	69%	4	2
	Social & Environmental Challenges	21%	35%	5	5

The draw towards a more socially-centered view in the perspective of the practitioners is noticeable also when looking at the categories: The issue of the need for agriculture to provide a livelihood for those working with it gains overwhelmingly more attention in grey literature than in journal articles as in grey literature more heed is paid to categories such as “good working conditions”, “safety”, “accessibility” and “infrastructure”. In return, in grey literature publications, much less attention is paid to the conservation of ecosystem functions than in journal articles.

3.2.3. Differences in the Use of Ideas and Aspects of Sustainable Agriculture between Scientists from Different Disciplines

Views of sustainable agriculture may not only differ between scientists and practitioners but also within academia itself, as evaluated by comparing the occurrence of the different themes in the journal articles from the different disciplines. The journal articles in our sample originate from six academic disciplines (Figure 4). Although the search for journal articles had been limited to social sciences and humanities, roughly one third of the articles were written either by authors with an engineering and natural sciences background or by agricultural scientists. Thus, also the more "technical" view of sustainable agriculture is represented in the sample.

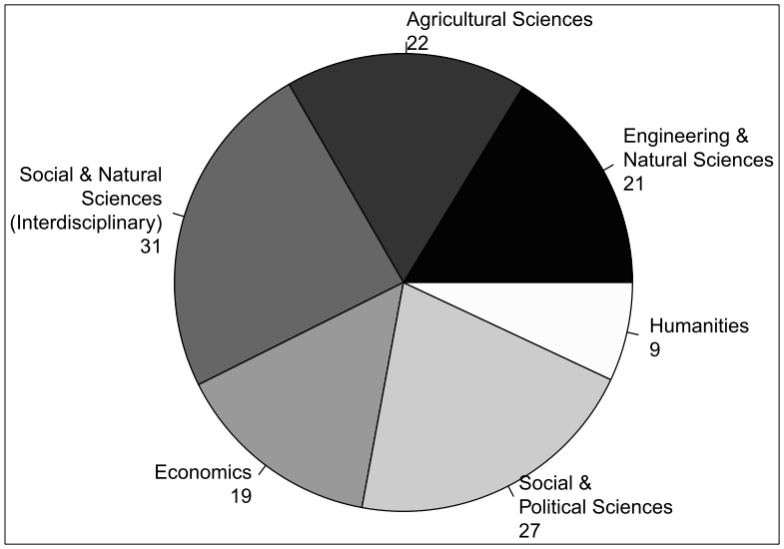

Figure 4. Distribution of the journal articles regarding the discipline they originate from. Journal articles were attributed to a discipline according to the discipline/affiliation of the first author.

Overall, among the views of sustainable agriculture in the different disciplines, we find a spectrum of perspectives ranging from more production-centered views with a concentration on fewer aspects on the one end and a consideration of a great variety of aspects accompanied by a greater regard for social and societal questions on the other end. We consider disciplines to have a more production-centered view if they put their main focus on the Production-Specific Environmental Goals together with an emphasis on the Economics-Based Strategy and Adaptive Management and an almost exclusive interest in the Field of Action of Management & Technological Solutions. At this end of the spectrum, with a focus on agricultural production and concentration on a smaller set of aspects, we find the disciplines of engineering and natural sciences as well as the agricultural sciences. However, these characteristics are more pronounced for engineering and natural sciences than for agricultural sciences (for a more detailed view of our findings, see Table A2 in the Appendix).

At the opposite end of the spectrum, we locate disciplines that consider a greater variety of aspects and attribute greater importance to aspects which are not directly related to agricultural production: In these disciplines, objectives other than the conservation of the natural production base, such as Social, Economic, and Non-Production-Specific Environmental Goals, receive more attention. Also in

these disciplines, production-oriented themes (Economics-Based Strategy, Adaptive Management, and Management & Technological Solutions) play a crucial role. However, different from the production-centered disciplines, authors from the socially-focused disciplines discuss also those Strategies and Fields of Action that point at changes in the social and societal environment in which agricultural production takes place (Strategies of Co-operation, Knowledge & Science, and Subsidiarity, Field of Action Social, Political & Economic Environment). The disciplines at this end of the spectrum are the humanities and the social and political sciences.

The two remaining groups of disciplines—interdisciplinary sciences, which work at the intersection of natural and social sciences like geography or environmental sciences, and economics—build the middle ground of the spectrum as they combine characteristics of both orientations. When writing and researching about sustainable agriculture, interdisciplinary scientists are in general interested in a maintained and improved productivity of the natural production base of agriculture—just like the production-centered disciplines. Yet, regarding Strategies and Fields of Action to achieve this goal, they do not only seek to improve agricultural production but also look at issues of societal organization. For economics, the opposite is the case: They consider a wider range of goals and the conservation of the natural production base is not their primary concern. Also, economists rather build on alternative strategies. In these respects, publications from economics are similar to the socially-focused disciplines. However, when it comes to concrete action, economists mainly focus on agricultural technologies and management practices in the same way as the production-centered disciplines.

Despite the emphases on different themes in the different disciplines, there is one area on whose importance all disciplines seem to agree: Management & Technological Solutions is the most frequent Field of Action in all disciplines.

3.3. Objective 3: Different Conceptions of Sustainable Agriculture in the Scientific Debate

Our cluster analysis revealed five specific lines of argumentation as to what constitutes sustainable agriculture. We identified six clusters based on how they reflected the themes and categories identified in objective one: cluster (1) anthropocentric goals; cluster (2) production and overarching goals-centered; cluster (3) collecting pond; cluster (4) systems thinking; cluster (5) comprehensive; and cluster (6) knowledge and science (Table 8; see Figure A1 in the annex to see which instances are contained in which clusters). Cluster 3 does not represent a specific line of argumentation or orientation but, as its name already suggests, just captures all instances that do not fit with the patterns of the other clusters. This is shown by there being no particularly strong presence of any theme in the cluster.

The other five clusters emerge as groups with themes that are strongly present within them. They can be grouped into outcome-centered, process-centered, as well as outcome and process-considering clusters. Cluster 1, the "anthropocentric goals cluster", presents an outcome-centered view of sustainable agriculture, claiming that agriculture is sustainable if defined objectives are achieved. These objectives are particularly strong in the themes of Social, Economic and Production-Specific Environmental Goals. Yet, it leaves open the question of how these objectives are supposed to be achieved. In contrast, the instances of the "systems thinking cluster" (Cluster 4) and of the "knowledge and science cluster" (Cluster 6) have a process-centered view of sustainable agriculture, claiming that agriculture becomes sustainable if specific approaches are applied and action is taken in certain areas. Here, the "systems

thinking" cluster strongly promotes Holistic & Complex Systems Thinking and also the Subsidiarity principle and focuses on action related to Management & Technological Solutions. In contrast, the instances in the "knowledge and science cluster" concentrate on the use of Knowledge & Science in combination with some other Strategies and recommend to take action in all Fields of Action but especially regarding Social & Human Capital and the Social, Political & Economic Environment. At the same time, these process-centered clusters tell little about what is supposed to be accomplished by using their recommended approaches. Only the "production and overarching goals-centered cluster" (Cluster 2) and the "comprehensive cluster" (Cluster 5) refer to both outcomes and processes and provide explanations of what means of sustainable agriculture are supposed to be applied for which ends of sustainable agriculture. However, whereas the "production and overarching goals-centered cluster" (Cluster 2) focuses on certain Goals, Strategies, and Fields of Action, the instances of the "comprehensive cluster" (Cluster 5) discuss almost all themes, yet with a special emphasis on the rather alternative Ecology-Based Strategy and Subsidiarity.

Table 8. Strength of the presence of each theme in the different clusters based on the indicator values (measure the statistical alliance of the themes to the different clusters): + stands for indicator values of 0.10 to 0.14, ++ for values of 0.15 to 0.29, and +++ for values of 0.30 and higher. A table with the individual indicator values can be found in Table S3 in the Supplementary Information.

Group	Theme	Indicator Value					
		cl. 1	**cl. 2**	**cl. 3**	**cl. 4**	**cl. 5**	**cl. 6**
Goals	Economic	++	++		+	++	+
	Environmental: Non-Production-Specific	+	+	+		++	
	Environmental: Production-Specific	++	++			++	+
	Overarching	+	++		+	++	
	Social	++	++			++	
+Strategies	Adaptive Management		++			++	++
	Co-operation					++	+
	Ecology-based		+			+++	
	Economics-based		++			++	++
	Holistic & Complex Systems Thinking				+++		
	Knowledge & Science					+	+++
	Subsidiarity				++	+++	
Fields of Action	Agri-Food System		++			++	++
	Management & Technological Solutions		+	+	++	++	++
	Social & Environmental Challenges					+	++
	Social & Human Capital				+	++	+++
	Social, Political & Economic Environment					++	+++

Table 9. Different characterizations of the positions in the debate about sustainable agriculture (all of these characterizations were proposed or made reference to in journal articles of our sample).

References	Techno-Economic Position	Agroecological-Ruralist Position
Pierce 1993 [12]	• position promoted by economists	• position promoted by ecologists
Farell & Hart 1998 [26], Tait & Morris 2000 [10]	• competing objectives	• critical limits
Johnson 2006 [27]	• life sciences integrated paradigm	• ecologically integrated paradigm
Rezaei-Moghaddam & Karami 2008 [14]	• ecological modernization	• de-modernization
Thompson & Scoones 2009 [15]	• paradigm of molecular biology and genetic engineering	• holistic stream
Robinson 2009 [28]	• technocentric approach	• Ecocentric approach
O'Riordan 1993 [46], Cobb *et al.* 1999 [47]	• very weak sustainability	• very strong sustainability • Strong sustainability
Frouws 1998 [30], Hermans *et al.* 2010 [16], Hermans *et al.* 2012 [17]	• utilitarian discourse	• agri-ruralist discourse • hedonist discourse
Marsden 2003 [29], Hermans *et al.* 2010 [16]	• agro-industrial model • post-productivist model	• rural development model
Pretty 1997 [31]	• business-as-usual optimists • industrialized world to the rescue • new modernists	• environmental pessimists • sustainable intensification

Our identification of five clear clusters contrasts with the frequently cited idea that there are two contrasting positions as to what constitutes sustainable agriculture. Many existing analyses of what constitutes sustainable agriculture claim that the debate is framed by two contrasting positions, which have been termed in different ways [12,14,15,26–28]; we term these two positions the techno-economic and the agroecological-ruralist positions. There have been arguments that the debate can be divided into three or more different positions on sustainable agriculture [16,17,29,31]. However, we argue that these additional positions result from emphasizing different aspects of the same paradigm, such that they can be organized as different framings or characteristics of the same position (Tables 9 and 10). However, our cluster analysis of positions on sustainable agriculture demonstrates that most conceptualizations of sustainable agriculture actually combine elements of both positions. Only one of the identified clusters, the "anthropocentric goals cluster" (Cluster 1), can be clearly matched with one of the two positions proposed in the literature, namely with the techno-economic position. The remaining four clusters are hybrids of the two positions as they contain elements of both the techno-economic and the agroecological-ruralist position (Table 11). Most notably, the "comprehensive cluster" (Cluster 5) integrates (almost) all themes and therefore greatly combines the aspects of both positions suggested in the literature.

Table 10. Stances of the techno-economic and the agroecological-ruralist position on different components [9,10,12,14–16,26–29,31,46].

Topic	Techno-Economic Position	Agroecological-Ruralist Position
underlying mindset	economics, belief in the effectiveness of market mechanisms	ecology
role of science and technology	belief in modern science and technologies	belief in traditional knowledge, skepticism/rejection of modernity and technology
approach to solving problems	problems can be approached and solved separately modification	problems require integrated and interdisciplinary solutions transformation/fundamental change
guiding principles of economic action and organization	competitiveness, productivity, efficiency	respect for the limited carrying capacity of ecosystems, no or minimal growth
orientation of agricultural production and the supply chain towards	globalization and export agribusiness	local autonomy/autarky regional development
management style	entrepreneurship, individual action	collective action, participation
role of the farmer	entrepreneur	custodian of nature and countryside
most reasonable form of agriculture	intensive agriculture with high use of external inputs production of standardized products in monoculture production in large scales	Organic agriculture, low use of external inputs diversified production, multifunctional agriculture Production in small scales, small/family farms
main strategy to satisfy the needs of all humans	compromise (especially with nature conservation targets) to ensure the satisfaction of all consumption needs	change of life and consumption styles
value of nature	consumption good	intrinsic value of nature
to be conserved	material capital	natural environment

Table 11. Similarities of the five clusters with clear orientations regarding sustainable agriculture to the techno-economic and the agroecological-ruralist positions.

Cluster	Similarities to the Techno-Economic Position	Similarities to the Agroecological-Ruralist Position
Cluster 1: the anthropocentric goals cluster	• strong focus on Economic Goals • higher relevance of Production-Specific Environmental Goals than of Non-Production-Specific Environmental Goals aiming • low focus on Overarching Goals	
Cluster 2: the production and overarching goals-centered cluster	• high occurrence of the anthropocentric Goals • emphasis on Economics-based Strategy • concentration on agricultural production: o strong presence of the Field of Action Agri-Food System (with "production" being the by far most mentioned category) o slight presence of Management & Technological Solutions	• Overarching Goals (include e.g., "multifunctionality") are the most present theme • Adaptive Management is often suggested • Slight presence of the Ecology-based Strategy
Cluster 4: the systems thinking cluster	• concentration on agricultural production: main Field of Action: Management & Technological Solutions	• strategic focus on Holistic & Complex Systems Thinking and Subsidiarity
Cluster 5: the comprehensive cluster	• high presence of the anthropocentric Goals • high consideration of the Economics-based Strategy • high consideration of agricultural production: o Management & Technological Solutions is the most mentioned Field of Action o strong presence of the Field of Action Agri-Food System (with "production" being the by far most mentioned category)	• high presence of Non-Production-Specific Environmental Goals and Overarching Goals • main strategic focus on Ecology-based Strategy and Subsidiarity • high presence of Adaptive Management and Co-operation • high presence of the Fields of Action Social & Human Capital and Social, Political & Economic Environment
Cluster 6: the knowledge and science cluster	• very pronounced presence of the Strategy of Knowledge & Science with a high occurrence of the categories "innovation" and "modern" • strong presence of the Economics-based Strategy • strong presence of the Field of Action Management & Technological Solutions	• very pronounced presence of the Strategy of Knowledge & Science with a high occurrence of the category "traditional" • high presence of the Strategy of Adaptive Management • very strong emphasis of the Fields of Action Social & Human Capital and Social, Political & Economic Environment • comparatively high occurrence of the categories "supply chain" and "consumption" in the Field of Action Agri-Food System

4. Discussion

The analysis of scientific and practitioner-oriented literature on the characteristics of sustainable agriculture has shown that the debate about sustainable agriculture is marked by various different conceptions of sustainable agriculture. By analyzing the way in which sustainable agriculture is defined or used in a range of publications, we identified a number of themes and categories that characterize framings of the concept. Our review structures these categories and themes into Goals, Strategies and Fields of Action. We see that there is a selection of themes that are dominant in the debate. These are anthropocentric Goals and those Strategies and Fields of Action that recommend the application of specific technologies on the level of the farms. However, there is also a strong alternative discourse which considers ecocentric and overarching values, proposes the application of alternative, less technology-oriented approaches and promotes action in arenas beyond the farm gate, *i.e.*, in the whole agri-food system and in society at large. Our cluster analysis shows that authors tend to combine Goals, Strategies and Fields of Action into specific groups, such that there are five distinct framings of sustainable agriculture.

We propose our structure of Goals, Strategies and Fields of Action (and the categories contained therein) as a framework for understanding the real difference between such conceptions; the areas of complementarity and clash with other conceptions; and therefore the implications for governance and actions towards realizing sustainable agriculture. Using our framework, we have shown that over time, different conceptions of sustainable agriculture are discussed in parallel to each other; there are a number of categories that are considered by significant numbers of publications on an almost constant basis with little overall change in the debate. However, we can see greater variation amongst disciplines and uses. Whereas in the scientific literature a more utilitarian view of sustainable agriculture is prevalent, authors of practitioner-oriented literature emphasize non-production-related issues and especially social issues concerning individuals working in and living with agriculture. Within the scientific debate itself, we identified a spectrum of views ranging from production-centered and focusing on few aspects at a time to social-centered and considering a greater number of aspects.

Our framework also helps to understand the substantive differences between the identified clusters, highlighting that most divergence in concepts happens in terms of strategies. We can see that the outcome-centered cluster (cluster 1) focuses on anthropocentric goals of sustainable agriculture. The two clusters that characterize sustainable agriculture both in terms of its desired outcomes and processes to achieve these outcomes offer complete overviews of both goals and strategies. However, these do not clash with each other–both include the same goals as that of the "anthropocentric goals cluster", and both include a focus on economics approaches. Cluster 5 (the "comprehensive cluster") only opens up the range of options by integrating non-anthropocentric Goals and adding further Strategies, having its main emphasis on an ecology-based and subsidiary approach. The two process-centered clusters focus mainly on strategies, and thus both could fit with the "anthropocentric goals cluster". However, one of these clusters (Cluster 4) has a strong focus on Complex & Holistic Systems Thinking and Subsidiarity. The theme of Complex & Holistic Systems Thinking is not well represented in other clusters and therefore presents a divergence from the debate. Yet, despite its demand for holism, this cluster concentrates only on agricultural practices for concrete action. Our framework

and analysis have clarified that there is actually a high degree of complementarity or fit between different conceptions of sustainable agriculture.

It has often been argued that these different conceptions of sustainable agriculture have been competing [10,14] or even opposing [15,16,28] and rivaling [38] and the very presence of such a multitude of interpretations has made the debate about sustainable agriculture confusing [1,48,49]. Yet, we argue that the existence of different conceptions of sustainable agriculture does not necessarily cause conflict. Rather, the diverse views of sustainable agriculture may complement each other and a diversity of interpretations might be what is necessary to realize sustainable agriculture. In fact, different paradigms of sustainable agriculture have already been integrated. This is shown through our cluster analysis, where we found elements of both the techno-economic and the agroecological-ruralist paradigms in all but one cluster. Additionally, there are explicit demands in the literature that both approaches be combined for the sake of sustainable agriculture. For instance, there is a number of publications that suggest that modern and innovative knowledge and approaches (which are promoted in the techno-economic position) be combined with local and traditional knowledge and practices (which are promoted in the agroecological-ruralist position) [23,33,50–53].

Our findings lead us to support ideas that integrate approaches in ways that are appropriate to context and scale, rather than to propose a single one-size-fits-all definition. For example, Firbank *et al.* [54] suggest that in some cases an approach that focuses on increased yields alone may be appropriate, in others a low-input approach seeking to enhance ecosystem services would be more sustainable. Therefore, both approaches are necessary and contribute to a more sustainable agriculture if applied in appropriate situations. In a similar vein, Fischer *et al.* [55] conclude that an integrated farming approach that includes both land sparing (techno-economic) and wildlife-friendly (agroecology-ruralist) farming offers complementary benefits for biodiversity conservation, which in turn contributes to a more sustainable agriculture. Indeed the globalization of agricultural supply chains, (as advocated by the techno-economic position), and the localization of agricultural production, distribution, and consumption (favored by the agroecological-ruralist position) are not necessarily mutually exclusive. Sustainable food strategies should have a balance between the localization and globalization of food chains [56]. This translates into local production and consumption of (seasonal) foods and raw materials while maintaining fair supra-regional trade relations, thus ensuring sufficient supply with food and raw materials in times of bad harvests. Trade with other regions and countries also enables the provision of those foods and raw materials that are necessary for a wholesome nutrition and required economic activities that can be neither produced in the region nor substituted by regionally available products.

There already are practical examples which show that the techno-economic and the agroecological-ruralist paradigms can be combined to offer approaches for a more sustainable agriculture. For example, in farmer cooperatives, actual agricultural production happens on smaller farms with the associated benefits of small-scale production such as increased biodiversity, higher productivity in terms of total farm output, more vivid rural and even national economies [57,58]. At the same time, by acting collectively also small farmers can take advantage of economies of scale and economize on transaction costs [59,60], which are important arguments in favor of large-scale agricultural production [61–63]. Consequently, farmer organization in cooperatives is one way to integrate both the demand for production on smaller units of the agroecological-ruralist position and the demands for large-scale agriculture of the techno-economic position.

The need to integrate paradigms and conceptualizations of sustainable agriculture demands that knowledge is integrated between scientific disciplines. Indeed, such integral solutions address a range of different challenges all at once instead of seeking different isolated solutions for single aspects [64]. For the design of integral solutions, it is necessary to combine the knowledge and expertise from different scientific disciplines because each discipline delivers answers to only some of the relevant aspects. Our analysis highlights that appropriate agricultural production practices, the specialty of engineering and natural sciences as well as agricultural sciences, are at the core of a sustainable agriculture. However, "a technocratic approach to sustainable agriculture is not necessarily any more responsive to rural and urban stakeholder groups, or even to environmental concerns, than was traditional agricultural research" [65] (p. 341). For this reason, it has often been argued that looking at agricultural production alone is not sufficient [43,64,66]; that the realization of sustainable agriculture also requires looking beyond the farm gate [28]. Thus, research looking at the human-made context in which agricultural production takes place, as is conducted by the more socially-focused disciplines, is necessary and important.

However, our recommendations actually extend beyond that of interdisciplinary collaboration and into transdisciplinary research that engages with stakeholders in order to "look beyond the farm gate". The need for more exchange and cooperation between scientists and practitioners is emphasized by our findings. Social and non-production-related environmental issues are of great relevance to practitioners but do not find equivalent consideration in the scientific debate. This very clearly expresses what has already been expressed by other researchers [67–69]: Social issues of sustainable agriculture have been neglected in the scientific debate about sustainable agriculture. At the same time, these issues are of high relevance in practice and therefore research should pay greater attention to these aspects. On the other hand, the conservation of ecosystem functions is little mentioned in the practitioner-oriented literature but has been a topic of increasing importance in the scientific publications (as we have seen in Section 3.2.1). Thus, the rather new insight on the relevance of what we call the function-centered view has not found its way into the discourse of practitioners, yet. Consequently, enhanced exchange between scientists, practitioners, and other stakeholders could be fruitful to inform scientific research about real-life challenges and relevancies and to have a faster diffusion of new findings into practice of and the societal debate about sustainable agriculture.

With these findings in mind, we argue that proliferation in strategies proposed, and therefore in definitions of sustainable agriculture is beneficial to realizing the aim of achieving sustainability in agriculture. Integral solutions require the combination of different insights, kinds of expertise and strategies. For the design of integral solutions, a variety of different options needs to be at hand [25,70]. Therefore, it would be of little value to point out certain approaches and strategies to be adopted for the realization of a sustainable agriculture and neglect others as all approaches identified in our analysis have their value and merit in different situations. What is more, our observed reduction in the variety of frequently discussed strategies in recent years is worrying. With only a limited selection of strategies, the solutions designed might not be integral and comprehensive enough to foster sustainable agriculture over the variety of scales and locations discussed here. Therefore, although this might make the concept of sustainable agriculture seem confusing and fuzzy, we encourage the consideration of a broad range of approaches and possibilities for their integration when designing solutions for sustainable agriculture.

We only caution that academics and practitioners have regard for how such solutions fit together, and what goals they are working towards. For this, our framework should provide clarity.

5. Conclusions

In this review article, we aimed to advance the understanding of the concept of sustainable agriculture, especially from a social sciences and governance point of view. We pursued this aim by identifying the ideas and aspects that are associated with sustainable agriculture. We summarized these ideas and aspects in a framework of Goals, Strategies and Fields of Action of sustainable agriculture, which gives an overview of the debate. We highlighted the use of this framework in understanding differences and fit between different views on sustainable agriculture. Additionally, we pointed out the central and important alternative aspects that are frequently discussed in the debate. We evaluated different patterns in which the term sustainable agriculture has been conceived. Here, we investigated changes that occurred in the scientific debate over time, and assessed differences between scientific and practitioner-oriented publications as well as differences in the conception of sustainable agriculture between different academic disciplines. Through a cluster analysis, we identified how the different ideas and aspects of sustainable agriculture are combined in the scientific debate, and assessed whether these different conceptions match with those that have been claimed to exist in the debate.

Our findings highlight strategies to progress understanding and implementation of sustainable agriculture. Since the beginnings of the debate about sustainable agriculture, there has been a great variety of conceptions of the term. It has been claimed that this multitude of different and partially opposing definitions has made the realization of sustainable agriculture a fuzzy affair, and caused confusion by exacerbating differences in the views of different stakeholder groups. However, there is no way to streamline the concept. Thus, we recommend embracing the complexity of sustainable agriculture with its varied and seemingly contradictory aspects. For complex problems of the modern world such as sustainability challenges in agriculture, ambiguous terms may indeed be more useful than precise and supposedly unambiguous concepts. This is due to their multivalent and flexible meanings, which are better able to "[represent] the objects of interest to, and [create] bridges of common purpose and meaning across otherwise differentiated social worlds" [71] (p. 461). Furthermore, we found the different conceptions of sustainable agriculture to be not as contradicting and mutually exclusive as they have often been portrayed. There are many examples where the integration of the different paradigms has been proposed and even been practiced. Indeed, the different views of and approaches to sustainable agriculture of the different academic disciplines complement each other. Thus, their integration allows a more comprehensive picture of the situation and approach to resolving the existing issues.

Nevertheless, there remains the challenge of bringing together the different viewpoints on sustainable agriculture in practice when working on solutions for concrete problems. An important way to approach this challenge is something that has actually already been proposed in the literature on sustainable agriculture before but has been paid rather little heed: co-operation, interdisciplinary and transdisciplinary research and work. Through interdisciplinary collaboration, the different kinds of expertise and insights can be combined; through transdisciplinary cooperation, practical relevancies, theoretical considerations and technical requirements can inform each other. In general, this suggests more engagement with each other and finding links between the different conceptions in order to advance the development towards a

sustainable agriculture rather than giving up due to the supposedly unsurmountable differences, even if this might be at times a very difficult process. We highlight that our framework can help to find such links by showing similarities between ideas and concepts. Future research could further help the integration of the different approaches and paradigms by detecting and understanding the motivations that have led the different groups to conceive sustainable agriculture in the way they do. This understanding would help to discover more complementarities between the different conceptions where motivations are similar or where differences are rather superficial because they merely stem from practical requirements (such as different working focuses of the different disciplines). Where the differences are more deeply rooted and originate from diverging belief systems, an understanding of the underlying motivations could be the basis to evaluate whether these differences can be overcome without necessarily having to challenge the different belief systems.

Acknowledgments

This research was realized with financial support from the Innovation-Incubator at Leuphana University, TM 1.4 Graduate School (Sarah Velten), and from the MULTAGRI project, funded by RURAGRI ERA-NET through the German Ministry of Education and Research (Julia Leventon and Jens Newig). The authors would like to thank Lisa-Britt Fischer, Nataly Jürges, Jacqueline Loos, Katharina Moths, Nico Stelljes, and Klara Stumpf for their comments on earlier versions of concepts and the article itself as well as Jan Hanspach for the provision of ideas and code templates in R for the graphics.

Author Contributions

This research was designed, carried out and written mainly by Sarah Velten. Julia Leventon contributed conceptual thoughts and also was involved in structuring the results and findings as well as in writing the article. Nicolas Jager executed the cluster analysis and wrote the concerning part of the methods section. He also provided the figures in this article. Jens Newig contributed methodological and conceptual ideas. All authors were involved in the finalization of the submitted manuscript and in adapting the manuscript according to the reviewers' comments. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Appendix

Table A1. Instances excluded from the cluster analysis.

Excluded Instances Mentioning Three or Less Different Themes	Excluded Instances Mentioning Sixteen or More Different Themes
Aikanathan *et al.* 2011	Beus, Dunlap 1990
Christianson, Tyndall 2011	Bowler 2002
Dubey *et al.* 2010	Chiappe, Butler Flora 1998
Erenstein *et al.* 2012	Dillon *et al.* 2010
Goodland 1997	Koohafkan *et al.* 2012
Goodwin 1991	Pierce 1993
López-Aguilar *et al.* 2012	
Manuel-Navarrete, Gallopín 2012	
Paoletti, Pimentel 1995	
Ramakrishnan 2007	
Tilak *et al.* 2005	

Table A2. Ranks of the themes that are mentioned frequently in the publications of the different disciplines (rankings are based on the frequency of mentions of the themes). Goal themes are considered to occur frequently if they are mentioned in at least 70% of the publications of a discipline. Strategy and Field of Action themes have to be mentioned in at least 45% of the publications of a discipline to be considered as frequently occurring. Different thresholds are applied because the Goal themes are generally mentioned more frequently than Strategy and Field of Action themes.

	Themes	Ranks of the Frequently Occurring Themes					
		Engineering & Natural Sciences	***Agricultural Sciences***	***Interdisciplinary Sciences***	***Economics***	***Humanities***	***Social & Political Sciences***
Goals	Environmental: Production-Specific	1	1	1	2	2	-
	Economic	-	2	2	1	2	1
	Social	-	2	-	3	1	2
	Environmental: Non-Production-Specific	-	4	-	3	2	3
	Overarching	-	-	-	-	-	-
Strategies	Economics-based	1	1	1	-	1	2
	Adaptive Management	2	2	2	2	-	1
	Holistic & Complex Systems Thinking	-	3	-	3	-	-
	Subsidiarity	-	-	3	-	2	3
	Ecology-based	-	-	4	1	2	-
	Knowledge & Science	-	-	-	-	-	4
	Co-operation	-	-	-	-	-	5
Fields of Action	Management & Technological Solutions	1	1	1	1	1	1
	Agri-Food System	-	2	2	-	-	2
	Social, Political & Economic Environment	-	-	3	-	2	3
	Social & Human Capital	-	-	4	-	-	4
	Social & Environmental Challenges	-	-	-	-	-	-
	Ø occurrence of all themes	42%	52%	53%	51%	57%	60%

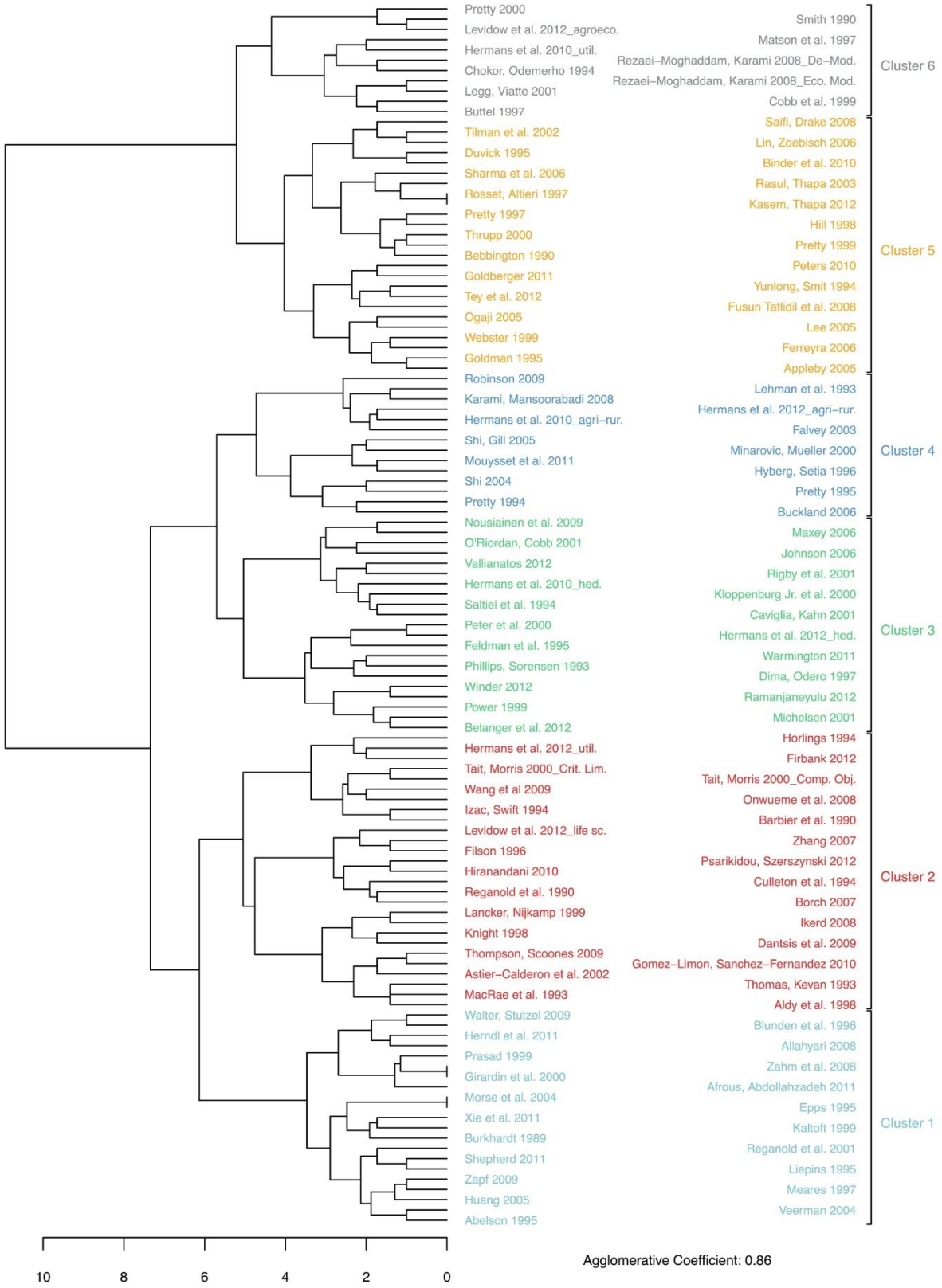

Figure A1. Dendrogram showing the six clusters and the instances belonging to each cluster.

References

1. Beus, C.E.; Dunlap, R.E. Conventional Versus Alternative Agriculture: The Paradigmatic Roots of the Debate. *Rural Sociol.* **1990**, *55*, 590–616.
2. Goodland, R. Environmental sustainability in agriculture: Diet matters. *Ecol. Econom.* **1997**, *23*, 189–200.
3. Rosset, P.M.; Altieri, M.A. Agroecology *vs.* input substitution: A fundamental contradiction of sustainable agriculture. *Soc. Natl. Resour.* **1997**, *10*, 283–295.
4. Thrupp, L.A. Linking Agricultural Biodiversity and Food Security: The Valuable Role of Sustainable Agriculture. *Int. Aff.* **2000**, *76*, 265–281.
5. Ogaji, J. Sustainable Agriculture in the UK. *Environ. Dev. Sustain.* **2005**, *7*, 253–270.
6. Peters, K.A. Creating a sustainable urban agriculture revolution. *J. Environ. Law Litig.* **2010**, *25*, 203–247.
7. Lemke, H. *Politik des Essens: Wovon die Welt von Morgen Lebt*; Transcript: Bielefeld, Germany, 2012.
8. Rivera-Ferre, M.; Ortega-Cerdà, M.; Baumgärtner, J. Rethinking Study and Management of Agricultural Systems for Policy Design. *Sustainability* **2013**, *5*, 3858–3875.
9. Koohafkan, P.; Altieri, M.A.; Gimenez, E.H. Green Agriculture: Foundations for biodiverse, resilient and productive agricultural systems. *Int. J. Agric. Sustain.* **2012**, *10*, 61–75.
10. Tait, J.; Morris, D. Sustainable development of agricultural systems: Competing objectives and critical limits. *Futures* **2000**, *32*, 247–260.
11. Culleton, N.; Tunney, H.; Coulter, B. Sustainability in Irish agriculture. *Irish Geogr.* **1994**, *27*, 36–47.
12. Pierce, J.T. Agriculture, sustainability and the imperatives of policy reform. *Geoforum* **1993**, *24*, 381–396.
13. Fairweather, J.R.; Campbell, H.R. Environmental beliefs and farm practices of New Zealand farmers: Contrasting pathways to sustainability. *Agric. Hum. Values* **2003**, *20*, 287–300.
14. Rezaei-Moghaddam, K.; Karami, E. A multiple criteria evaluation of sustainable agricultural development models using AHP. *Environ. Dev. Sustain.* **2008**, *10*, 407–426.
15. Thompson, J.; Scoones, I. Addressing the dynamics of agri-food systems: An emerging agenda for social science research. *Environ. Sci. Policy* **2009**, *12*, 386–397.
16. Hermans, F.; Horlings, I.; Beers, P.J.; Mommaas, H. The Contested Redefinition of a Sustainable Countryside: Revisiting Frouws' Rurality Discourses. *Sociol. Rural.* **2010**, *50*, 46–63.
17. Hermans, F.; Kok, K.; Beers, P.J.; Veldkamp, T. Assessing Sustainability Perspectives in Rural Innovation Projects Using Q-Methodology. *Sociol. Rural.* **2012**, *52*, 70–91.
18. Hildén, M.; Jokinen, P.; Aakkula, J. The Sustainability of Agriculture in a Northern Industrialized Country—From Controlling Nature to Rural Development. *Sustainability* **2012**, *4*, 3387–3403.
19. Constance, D.H. Sustainable Agriculture in the United States: A Critical Examination of a Contested Process. *Sustainability* **2010**, *2*, 48–72.
20. Goldman, A. Threats to sustainability in African agriculture: Searching for appropriate paradigms. *Hum. Ecol.* **1995**, *23*, 291–334.
21. Hansen, J. Is agricultural sustainability a useful concept? *Agric. Syst.* **1996**, *50*, 117–143.

22. U.S. Congress. Food, Agriculture, Conservation, and Trade Act of 1990. Public Law 101–624: U.S. Farm Bill, 28 November 1990.
23. Reganold, J.P.; Papendick, R.I.; Parr, J.F. Sustainable Agriculture. *Sci. Am.* **1990**, *262*, 112–120.
24. MacRae, R.J.; Hill, S.B.; Henning, J.; Mehuys, G.R. Agricultural Science and Sustainable Agriculture: A Review of the Existing Scientific Barriers to Sustainable Food Production and Potential Solutions. *Biol. Agric. Hortic.* **1989**, *6*, 173–219.
25. Pretty, J.N. Participatory learning for sustainable agriculture. *World Dev.* **1995**, *23*, 1247–1263.
26. Farrell, A.; Hart, M. What Does Sustainability Really Mean? The Search for Useful Indicators. *Environ. Sci. Policy Sustain. Dev.* **1998**, *40*, 4–31.
27. Johnson, R.B. Sustainable agriculture: Competing visions and policy avenue. *Int. J. Sustain. Dev. World Ecol.* **2006**, *13*, 469–480.
28. Robinson, G.M. Towards Sustainable Agriculture: Current Debates. *Geogr. Compass* **2009**, *3*, 1757–1773.
29. Marsden, T.K. *The Condition of Rural Sustainability*; Royal van Gorcum: Assen, The Netherlands, 2003.
30. Frouws, J. The Contested Redefinition of the Countryside. An Analysis of Rural Discourses in the Netherlands. *Soc. Rural.* **1998**, *38*, 54–68.
31. Pretty, J.N. Sustainable agriculture, people and the resource base: Impacts on food production. *Forum Dev. Stud.* **1997**, *1*, 7–32.
32. Giovanucci, D.; Scherr, S.; Nierenberg, D.; Hebebrand, C.; Shapiro, J.; Milder, J.; Wheeler, K. Food and Agriculture: The future of sustainability. In *A Strategic Input to the Sustainable Development in the 21st Century (SD21) Project*; United Nations: New York, NY, USA, 2012. Available online: http://www.un.org/esa/dsd/dsd_sd21st/21_pdf/agriculture_and_food_the_future_of_sustainability_web.pdf (accessed on 25 July 2012).
33. Matson, P.A.; Parton, W.J.; Power, A.G.; Swift, M.J. Agricultural Intensification and Ecosystem Properties. *Science* **1997**, *277*, 504–509.
34. Shi, T.; Gill, R. Developing effective policies for the sustainable development of ecological agriculture in China: The case study of Jinshan County with a systems dynamics model. *Ecol. Econom.* **2005**, *53*, 223–246.
35. Tilman, D.; Cassman, K.G.; Matson, P.A.; Naylor, R.; Polasky, S. Agricultural sustainability and intensive production practices. *Nature* **2002**, *418*, 671–677.
36. Allen, P.; van Dusen, D.; Lundy, J.; Gliessman, S.R. Integrating social, environmental, and economic issues in sustainable agriculture. *Am. J. Altern. Agric.* **1991**, *6*, 34–39.
37. Mayring, P. *Qualitative Inhaltsanalyse: Grundlagen und Techniken*, 9th ed.; Beltz: Weinheim, Germany, 2007.
38. Levidow, L.; Birch, K.; Papaioannou, T. EU agri-innovation policy: Two contending visions of the bio-economy. *Crit. Policy Stud.* **2012**, *6*, 40–65.
39. Everitt, B.S.; Landau, S.; Leese, M. *Cluster Analysis*, 4th ed.; Arnold: London, UK, 2001.
40. Backhaus, K.; Erichson, B.; Plinke, W.; Weiber, R. *Backhaus-Erichson-Plinke-Weiber. Multivariate Analysemethoden: Eine Anwendungsorientierte Einführung*, 13th ed.; Springer: Berlin, Germany, 2011.
41. Leopold, A. *Sand County Almanac*; Oxford University Press: New York, NY, USA, 1949.

42. James, H.S. Sustainable agriculture and free market economics: Finding common ground in Adam Smith. *Agric. Hum. Values* **2006**, *23*, 427–438.
43. Ferreyra, C. Emergy analysis of one century of agricultural production in the Rolling Pampas of Argentina. *Int. J. Agric. Resour. Gov. Ecol.* **2006**, *5*, 185–205.
44. Mills, J.; Gibbon, D.; Ingram, J.; Reed, M.; Short, C.; Dwyer, J. Organising Collective Action for Effective Environmental Management and Social Learning in Wales. *J. Agric. Educ. Ext.* **2011**, *17*, 69–83.
45. Dunlap, R.E.; Beus, C.E.; Howell, R.E.; Waud, J. What is Sustainable Agriculture? An Empirical Examination of Faculty and Farmer Definitions. *J. Sustain. Agric.* **1993**, *3*, 5–41.
46. O'Riordan, T. *Towards a Sustainable Agriculture in the UK*; The Fertilizer Society: Peterborough, UK, 1993.
47. Cobb, D.; Dolman, P.; O'Riordan, T. Interpretations of sustainable agriculture in the UK. *Progress Hum. Geogr.* **1999**, *23*, 209–235.
48. Hyberg, B.; Setia, P. Economic and environmental tradeoffs in agricultural sustainability: A Perspective. *Int. Adv. Econ. Res.* **1996**, *2*, 41–46.
49. Smith, C.S.; McDonald, G.T. Assessing the sustainability of agriculture at the planning stage. *J. Environ. Manag.* **1998**, *52*, 15–37.
50. Smith, N.J.H. Strategies for Sustainable Agriculture in the Tropics. *Ecol. Econ.* **1990**, *2*, 311–323.
51. Saifi, B.; Drake, L. A coevolutionary model for promoting agricultural sustainability. *Ecol. Econ.* **2008**, *65*, 24–34.
52. Zhen, L.; Zoebisch, M.A. *Resource Use and Agricultural Sustainability: Risks and Consequences of Intensive Cropping in China*; Supplement no. 86 to Journal of Agriculture and Rural Development in the Tropics and Subtropics; Kassel University Press GmbH: Kassel, Germany, 2006. Available online: http://www.uni-kassel.de/upress/online/frei/978-3-89958-221-5.volltext.frei.pdf (accessed on 15 June 2015).
53. Vallianatos, E. The democratic and sacred nature of agriculture. *Environ. Dev. Sustain.* **2012**, *14*, 335–346.
54. Firbank, L.G. Commentary: Pathways to global sustainable agriculture. *Int. J. Agric. Sustain.* **2012**, *10*, 1–4.
55. Fischer, J.; Brosi, B.; Daily, G.C.; Ehrlich, P.R.; Goldman, R.; Goldstein, J.; Lindenmayer, D.B.; Manning, A.D.; Mooney, H.A.; Pejchar, L.; *et al*. Should agricultural policies encourage land sparing or wildlife-friendly farming? *Front. Ecol. Environ.* **2008**, *6*, 380–385.
56. Morgan, K.; Sonnino, R. The urban foodscape: World cities and the new food equation. *Camb. J. Reg. Econ. Soc.* **2010**, *3*, 209–224.
57. Rosset, P.M. *The Multiple Functions and Benefits of Small Farm Agriculture in the Context of Global Trade Negotiations*; Food First and Transnational Institute: Oakland, CA, USA, 1999. Available online: http://foodfirst.org/wp-content/uploads/2013/12/PB4-The-Multiple-Functions-and-Benefits-of-Small-Farm-Agriculture_Rosset.pdf (accessed on 5 February 2014).
58. D'Souza, G.; Ikerd, J.I. Small Farms and Sustainable Development: Is Small More Sustainable? *J. Agric. Appl. Econ.* **1996**, *28*, 73–83.
59. Valentinov, V. Why are cooperatives important in agriculture? An organizational economics perspective. *J. Instit. Econ.* **2007**, *3*, 55–69.

60. Holloway, G.; Nicholson, C.; Delgado, C. *Agroindustrialization through Institutional Innovation: Transaction Costs, Cooperatives and Milk-Market Development in the Ethiopian Highlands*; International Food Policy Research Institute: Washington, DC, USA, 1999. Available online: http://www.ifpri.org/sites/default/files/publications/pubs_divs_mtid_dp_papers_dp35.pdf (accessed on 15 June 2015).
61. Johnson, N.L.; Ruttan, V.W. Why are farms so small? *World Dev.* **1994**, *22*, 691–706.
62. MacRae, R.J.; Henning, J.; Hill, S.B. Strategies to overcome barriers to the development of sustainable agriculture in Canada: The role of agribusiness. *J. Agric. Environ. Ethics* **1993**, *6*, 21–51.
63. Sharma, T.; Carmichael, J.; Klinkenberg, B. Integrated modeling for exploring sustainable agriculture futures. *Futures* **2006**, *38*, 93–113.
64. Elzen, B.; Barbier, M.; Cerf, M.; Grin, J. Stimulating transitions towards sustainable farming systems. In *Farming Systems Research into the 21st Century: The New Dynamic*; Darnhofer, I., Gibbon, D., Dedieu, B., Eds.; Springer: Dordrecht, The Netherlands, 2012; pp. 431–455.
65. Buttel, F.H. The politics and policies of sustainable agriculture: Some concluding remarks. *Soc. Natl. Resour.* **1997**, *10*, 341–344.
66. Dale, V.H.; Kline, K.L.; Kaffka, S.R.; Langeveld, J.W.A. A landscape perspective on sustainability of agricultural systems. *Landsc. Ecol.* **2013**, *28*, 1111–1112.
67. Psarikidou, K.; Szerszynski, B. Growing the social: Alternative agrofood networks and social sustainability in the urban ethical foodscape. *Sustain. Sci. Pract. Policy* **2012**, *8*, 30–39.
68. Pilgeram, R. "The Only Thing That Isn't Sustainable … Is the Farmer": Social Sustainability and the Politics of Class among Pacific Northwest Farmers Engaged in Sustainable Farming. *Rural Sociol.* **2011**, *76*, 375–393.
69. Shreck, A.; Getz, C.; Feenstra, G. Social sustainability, farm labor, and organic agriculture: Findings from an exploratory analysis. *Agric. Hum. Values* **2006**, *23*, 439–449.
70. Pretty, J.N. Alternative systems of inquiry for a sustainable agriculture. *IDS Bull.* **1994**, *25*, 37–48.
71. Wynne, B. Risk and Environment as Legitimatory Discourses of Technology: Reflexivity Inside Out? *Curr. Sociol.* **2002**, *50*, 459–477.