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Review

Institutional Perspectives of Climate-Smart Agriculture: A Systematic Literature Review

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Abstract: Climate-smart agriculture (CSA) is increasingly seen as a promising approach to feed the growing world population under climate change. The review explored how institutional perspectives are reflected in the CSA literature. In total, 137 publications were analyzed using institutional analysis framework, of which 55.5% make specific reference to institutional dimensions. While the CSA concept encompasses three pillars (productivity, adaptation, and mitigation), the literature has hardly addressed them in an integrated way. The development status of study sites also seems to influence which pillars are promoted. Mitigation was predominantly addressed in high-income countries, while productivity and adaptation were priorities for middle and low-income countries. Interest in institutional aspects has been gradual in the CSA literature. It has largely focused on knowledge infrastructure, market structure, and hard institutional aspects. There has been less attention to understand whether investments in physical infrastructure and actors' interaction, or how historical, political, and social context may influence the uptake of CSA options. Rethinking the approach to promoting CSA technologies by integrating technology packages and institutional enabling factors can provide potential opportunities for effective scaling of CSA options.

Keywords: climate-smart agriculture; institutions; adaptation; mitigation; systematic review

1. Introduction

Global climate change is recognized as one of the greatest threats to agricultural productivity in several regions of the world [1]. Many African countries is projected to be severely compromised by climate variability and change in agricultural production, including access to food, the length of growing seasons, and yield potential [2]. Sub-Saharan Africa (SSA) has been particularly exposed to the impact of climate variability due to the high reliance on rain-fed agriculture in this region [3]. Harvell, et al. [4] have shown that the climate change impacts on agriculture will occur along with high population growth and change of consumption patterns. The world population is projected to be about 8 and 10 billion in 2020 and 2050 respectively [5]. With such a population trend, agriculture will require a significant transformation to ensure adequate food supplies for the growing population and meet the challenge of climate change [6].

Two major scenarios are considered to increase food production for the growing world population: (a) greater land clearing to expand the production area to meet the food demand, and (b) intensification on existing crop lands with an increased use of inputs, such as fertilisers and seeds. Regarding the fast expansion of urban areas, land scarcity is now a serious issue in many parts of SSA [7]. Technically, it would be relatively easier to increase food production and close the yield gaps through the intensification on existing crop lands with available technologies [8]. Therefore, the sustainable intensification of smallholder farming is a serious option for satisfying food requirements. The Climate Change, Agriculture and Food Security (CCAFS) program, an interdisciplinary CGIAR Research Program, seeks to achieve the sustainable intensification of food production and support global demand for food through the promotion of "climate-smart agriculture" (CSA).

The concept of CSA emerged as a promising way to secure food for the growing world population under climate change conditions [9]. The Food and Agriculture Organization of the United Nations FAO [10] defines CSA as "agriculture that sustainably increases productivity, enhances resilience, reduces greenhouse gases, and enhances achievement of national food security and development goals". The concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals within the context of a changing climate and increasing food demand [11]. The CSA includes both traditional and innovative practices and technologies that promote agricultural productivity and generate income. It also boosts resilience to climate change and mitigates greenhouse gas (GHG) emissions when possible. It includes three major pillars: (a) increasing agricultural productivity; (b) increasing adaptive capacity at multiple scales (from farm to nation); and (c) reducing greenhouse gas emissions [12]. While there is a consensus on the potential of the CSA to support global food and nutritional security in less-favored conditions [11–13], CSA scholars have different perspectives to approach the scaling of CSA options.

For decades, many countries have made significant investments in agriculture through successive generations of climate adaptation projects to increase the productivity of smallholder farmers (e.g., irrigation infrastructures; dissemination of improved agricultural packages) [14,15]. However, studies suggested that these projects have not achieved much success because, among other flaws, they focused on technology development assuming that this will be sufficient to stimulate agricultural intensification. However, by doing so, they underestimated the complexity of the institutional context within which the farmers and other actors in agricultural systems operate [16,17].

Over the past few decades, efforts to enhance the food systems productivity focused on a "technology push"-approach, assuming that significant productivity growth could be easily achieved through access to technologies [18,19]. Technologies then are transferred to the end-users with limited understanding of the local context under which these users operate, thus leaving out important issues such as access to market and credit [20]. Seemingly helpful options do not always receive the expected outcomes as the quality of the technology itself may not be the only factor that determines the adoption and the scaling [21]. Therefore, some authors, including Quisumbing and Pandolfelli [22] and Hounkonnou, et al. [23] argued that effective deployment of technological interventions in complex situations calls for a more comprehensive approach to stimulate sustainable transformation.

Overall, there has been a gradual shift from a technology-oriented approach to a more systems-oriented approach that considers the complexity of farming systems. This includes the full array of policy, market, political, and other institutional aspects that shape the context in which farming takes place. Several studies conducted in the agricultural innovation domain have shown that when focusing on technologies alone, one overlooks the enabling and constraining factors that determine whether technologies are available, accessible, and are able to make a difference for farmers [23–25].

An on-going systematic review is being conducted to evaluate the effectiveness of 73 promising farm-level technological management practices to achieve the CSA intended benefits and inform discourse on food, agriculture, and climate change [26]. This review targets CSA practices and technologies across five categories (agronomy, agroforestry, livestock, postharvest management, and energy systems) to assess their contributions to the three CSA pillars. This review focuses on the technologies, and ignores the institutional dimensions of CSA options. This paper adopts the system's perspective, and argues that institutional dimensions are paramount as they embody political agency, historical contingencies, and locally-specific dynamics of power that also play out in the adoption and the scaling of the CSA options. Therefore, the objective of this paper is to explore specifically whether and how institutional perspectives are reflected in the existing CSA literature. This study aims enlarge the scope of the previous syntheses on CSA practices conducted by Rosenstock, et al. [26] and to contribute to the broader debate about the potential role of institutions and institutional innovation in agricultural development in low- and middle-income regions. This is an issue which has only been investigated to a limited extent [27].

Following a detailed overview of the search protocol used to review the literature (Section 2), the article analyzes the thematic and geographical distribution of the available CSA literature and explores the different dimensions of the institutions reflected in the literature (Section 3). Finally, we highlight lessons emerging from this study and the major existing gaps in the literature that can inform future climate research (Section 4).

2. Materials and Methods

2.1. Data Sources and Extraction

To understand how institutional dimensions are reflected in CSA literature, we conducted the study by using the systematic review framework proposed by Berrang-Ford, et al. [28], which provides guidelines and formats for synthesizing and tracking climate change adaptation research. The framework includes, (a) the description of literature sources, (b) articulation of search terms and a detailed description of the search process, (c) the description of criteria for inclusion and exclusion, and (d) the documentation of literature included and excluded.

2.1.1. Description of Literature Source

We used web-based search engines ISI Web of Science (WoS) and Scopus for literature identification. We limited the scope of these search engines because of their ability to provide easy access to complex search terms. They also provided extensive coverage both in terms on disciplines and the quality of their publications [29]. We purposely decided not to include grey literature such as institutional reports and based the study on peer review scientific literature.

In WoS, topic search was used to identify publications that refer to CSA in title, abstract, and author keywords. It was indexed in the Science Citation Index Expanded, the Social Sciences Citation Index or the Emerging Sources Citation Index. In Scopus, the Compound Field TITLE-ABS-KEY that searches abstracts, keywords, and article titles was used to identify CSA literature. The search was narrowed down to English language publications (in both search engines). The search considered all peer-reviewed articles, reviews, book chapters, books, and editorial material available in the search engines at the time of the search (from 1945 until February 2017).

2.1.2. Articulation of Search Terms and/or Detailed Description of Search Process

To identify relevant literature associated to CSA, we combined the search terms "climat* smart*" OR "climat* friend*" with descriptors (or keywords) related to agricultural sector (see Supplementary Materials Table S1 for a complete list of search strings used for the review). For the scope of this study, we partly based our methods on the work of Rosenstock, et al. [26]. In the study, we conceptualize agriculture as referring to crops, livestock, and fisheries sectors in the broadest sense, including soil/land and water management (see Table S1).

2.1.3. Description of Criteria for Inclusion and Exclusion

The preliminary search yielded 624 documents (including 225 publications from WoS and 399 publications from Scopus), which were exported into ENDNOTE X7 [30] for initial screening. After removing the duplicates and publication types other than article, review, conference paper, book chapter, book, or editorial material, 392 publications remained. Of these, 138 publications met relevance criteria after screening titles and abstracts based on our inclusion and exclusion criteria (Table 1). We performed a full text review for the 138 relevant publications to confirm eligibility for inclusion. Of the final list, one book chapter was not accessible and was excluded. The final list contains 137 publications.

Table 1. Inclusion and exclusion criteria for literature selection.

Inclusion Criteria	Exclusion Criteria
Text in English	Text in languages other than English
Publication type is article, review, or book chapter	Publication type is other than article, review, or book chapter (e.g., note, erratum, book review, conference paper)
Focuses on the agricultural sector	Focuses on sectors other than agriculture (e.g., energy and transport sectors)
Addresses at least one of the CSA pillars (productivity, adaptation and mitigation)	Addresses none of the CSA pillars
Text includes sufficient detail to carry out data analysis	Text does not provide sufficient detail to carry out data analysis

In the next step, we studied in detail the 137 relevant CSA publications to identify (a) the CSA pillar(s) addressed; and (b) specific institutional dimensions of CSA options that are studied. The full text review targeted the publications' thematic focus, geographical scope, economic development status of the country of each publication, and CSA pillars addressed. We followed the World Bank's income-based distribution—low income, lower middle income, upper middle income, and high income [31]—to determine the development status of the countries. The income distribution is based on gross national income (GNI) per capita.

Next, we defined keywords (Table 2) to guide the analysis of institutional dimension, using an institutional analysis framework [32,33]. This framework subdivides between the following institutional dimensions: (a) 'knowledge infrastructure', relating to the way the creation and use of knowledge is organized (e.g., knowledge, research and development); (b) 'physical infrastructure', consisting principally of roads and telecommunications; (c) 'hard institution' refers to formal rules, regulations, and norms such as technical standards, labor law, and risk management rules; (d) 'soft institutions' relates to informal rules, such as social norms and values, culture and implicit rules; (e) 'interaction', calibrated by strength of connectivity, relation among actors as governments, NGOs and research institutes; and (f) 'market structures', relating to the position of and relations between market parties along the value chain. Following Schut, et al. [34], keywords were formulated progressively and examined as a proxy data source to reflect the features of institutions, recognizing that there are potential overlaps among some of the dimensions. Keywords were later clustered (for each dimension, when possible) to give more insights on how each institutional dimension was reflected in the literature.

Table 2. Analytical framework and keywords used for institutional dimension analysis.

Dimensions	Keywords	Cluster
Knowledge infrastructure	Extension system/advisory service	Agricultural extension system
	Capacity building/training Education Empowerment	Capacity strengthening
	Knowledge/experience Information (access and/or sharing)/communication	Knowledge and communication
Physical infrastructure	Infrastructure Roads Transport facility(ies)/asset (s)	Infrastructure
Hard institutional	Land or resource tenure/agreements/ownership Property right Traditional rights systems	Resource tenure system
	Policy (ies)/program (s)/rule/regulation/law Subsidy (ies)/incentive (s)/financial Compensation/support mechanisms/investment	Policy
	Decision support system/planning/governance system	Governance
Soft institutional	Custom/tradition Norm (cultural)/cultural factors/trust Value/concern/attitude/belief	Socio-cultural dimensions
	Gender	Gender
Interaction	Network/relationship/interconnection Membership/association/cooperative	Networking
	Stakeholders engagement/partnership (public–private, formal-informal, multi-stakeholders)/collective (or social) learning/collective actions/mutual agreement Multi-stakeholder platforms	Collaboration and partnership
Market structure	Inputs and technology (access/availability) Labor Insurance Credit/financial support (access/availability)/capital Entrepreneurship	Inputs and support
	Market (access/availability/orientation/demand Market information/competition/price/marketing Supply/value chain/distributional channel Contractual arrangement	Market and value chain

2.1.4. Documentation of Literature Included and Excluded

All the CSA publications found in the preliminary search were exported in a database, which contains information on authors, publication year, publication title, source title, publication type, authors' name, authors' keywords, and subject areas of each document. A database was also created for relevant publications containing additional information including CSA pillars addressed, thematic focus, and element/aspect of institutional dimension addressed. The list of included and excluded criteria are presented in Table 1.

2.2. Data Analysis

Descriptive statistics were used to present quantitative trends on CSA options in the literature and geographical distribution patterns. To test the associations between CSA pillars (e.g., productivity, adaptation, and mitigation) addressed and economic development status of publications' country, the Fisher exact test was performed, with significance reported at 95.0%. Thematic content analysis was performed to examine how institutional dimensions was reflected in the relevant CSA publications. The institutional dimension analysis was guided by keywords (see Table 2) and performed electronically using Adobe Acrobat. Appearance of each institutional dimension keyword in the title, abstract, keywords and main body of the text (excluding figures, tables, captions, acknowledgement, and references) was quantified. Thus, the frequencies served as proxies to the level of importance attached to a particular institutional dimension. During the analysis, the meaning and use of each keyword was verified since specific keywords can have different meaning depending on the context in which it is being used [34]. All statistical analyses were performed using R software version 3.3.2 [35].

3. Results

3.1. Distribution

The initial 392 publications selected after the first screening included research articles (72.7%, n = 285), book chapters (9.2%, n = 36), conference papers (7.6%, n = 30), reviews (7.4%, n = 29), editorial materials (1.8%, n = 7), and books (1.3%, n = 5). The publications' years ranged from 1991 to 2017. While the average number of publications per year was 18, about 89.0% (n = 349) of the documents were published after 2008, which was the period where the CSA concept emerged in the literature (Table 3). The top-five publication sources included agricultural systems (3.1%, n = 12), agriculture and food security (2.5%, n = 10), energy policy (2.3%, n = 9), climate policy (1.3%, n = 5), and land use policy (1.3%, n = 5).

Table 3. Composition of climate-smart agriculture and institutional-oriented climate-smart agriculture publications.

	All Publications (Climate Smart/Friendly Literature)	**CSA Relevant (Agriculture) Publications**	**CSA-Institutional-Oriented Publications**
Number of publications	100.0% (n = 392)	35.0% (n = 137)	19.4% (n = 76)
Range of publication years	1991–2017	2008–2017	2011–2017
Average publication per year	18.67	15.22	10.85
Top-5 publication sources (% of total)	Agricultural systems (3.1%) Agriculture and food security (2.5%) Energy policy (2.3%) Climate policy (1.3%) Land use policy (1.3%)	*Agriculture and Food Security* (7.3%) *Agricultural Systems* (6.6%) *Journal of Cleaner Production* (2.9%) *Regional Environmental Change* (2.9%) *Nutrient Cycling in Agro Ecosystems* (2.2%)	*Agriculture and Food Security* (11.8%) *Agricultural Systems* (9.2%) *Regional Environmental Change* (5.3%) *Food Security* (2.6%) *Gender, Technology, and Development* (2.6%)

Main subject areas covered in the 392 publications were respectively environmental science (45.2%, n = 177); agricultural and biological sciences (34.4%, n = 135); social sciences (25.0%, n = 98); energy (15.6%, n = 61); engineering (11.7%, n = 46); and economics, econometrics, and finance (11.2%, n = 44) (see Supplementary Materials Figure S1 for the overall subject areas covered by the CSA publications).

3.2. Climate-Smart Agriculture Focused Literature

Of the 137 CSA focused publications, 80.3% (n = 110) were research article, while review and book chapter covered respectively 11.7% (n = 16) and 8.0% (n = 11). Although, on average around 15 CSA focused publications were made per year, and about 92.7% (n = 127) of CSA publications were published after 2012. The top-five publication sources were *Agriculture and Food Security* (7.3%, n = 10), *Agricultural Systems* (6.6%, n = 9), *Journal of Cleaner Production* (2.9%, n = 4), *Regional Environmental Change* (2.9%, n = 4), and *Nutrient Cycling in Agroecosystems* (2.2%, n = 3).

In terms of geographic coverage, India was the most represented country in the CSA literature, with 13 publications [36–41], followed by Tanzania (n = 10) [42–45], Germany (n = 8) [46–48] and Malawi (n = 7) [49–51] (see Figure S2 for the distribution of the CSA related publication across countries). Some publications however, did not make specific reference to a country or region (n = 21) and provided generic conceptual development [11,52,53].

Overall, Africa was the most targeted continent in the CSA literature with about 46 out of the 137 publications that met the inclusion criteria for selection, followed by Asia (n = 32), Europe (n = 27), and America (n = 16). Within the African continent, the sub-regions of Eastern Africa and Western Africa were the most targeted with 40 and 10 publications, respectively. The CSA publications obtained in Southern Asia and South-Eastern Asia sub-regions were 19 and 6, respectively. In Europe, Northern Europe, and Western Europe were the most represented sub-regions, with 16 and 10 publications respectively. In the Americas, South, Central, and Northern America were fairly equally represented with respectively seven, six, and five publications.

Regarding the specific agricultural related focus, the review shows that the climate perspective is reflected in the CSA literature from different angles, ranging from farm-scale agricultural practices [54–56] to food supply chains and food systems [57,58].

Based on the CSA pillars addressed, about 32.1% (n = 44) of the publications addressed simultaneously the three CSA pillars—productivity, adaptation, and mitigation [12,59–61]. About 26.3% (n = 36) emphasized on mitigation only [47,48,62], while 21.9% (n = 30) on both productivity and adaptation issues [42,63,64]. A relatively limited number of the publications combined productivity and mitigation pillars (6.6%, n = 9) [49,65,66]; adaptation and mitigation (2.9%, n = 4) [67–70]; and in adaptation alone (6.6%, n = 9) [71–73].

A cross analysis of the pillars addressed and the economic development status of the country in which the study has been conducted indicated that publications addressing either adaptation or productivity pillars were more likely to come from low income and lower middle income countries, while publications reporting on mitigation were more likely to come from high income countries ($p < 0.0001$, Fisher's exact test, Figure 1). Sixty-six percent (66.7%, n = 24) of publications solely addressing mitigation were from high income countries compared with 2.8% (n = 1), 11.1% (n = 4) and 16.7% (n = 6) from low, lower-middle, and upper-middle income countries, respectively. Publications addressing specifically productivity dimension were equally (40%, n = 2) from low and lower-middle income countries compared with 20% (n = 1) from high income countries. Regarding adaptation pillar, 22% (22.2%, n = 2) of adaptation publications were from high income countries, while 33.3% (n = 3), 55.5% (n = 5) and 11.1% (n = 1) from low, lower-middle, and upper-middle income countries, respectively.

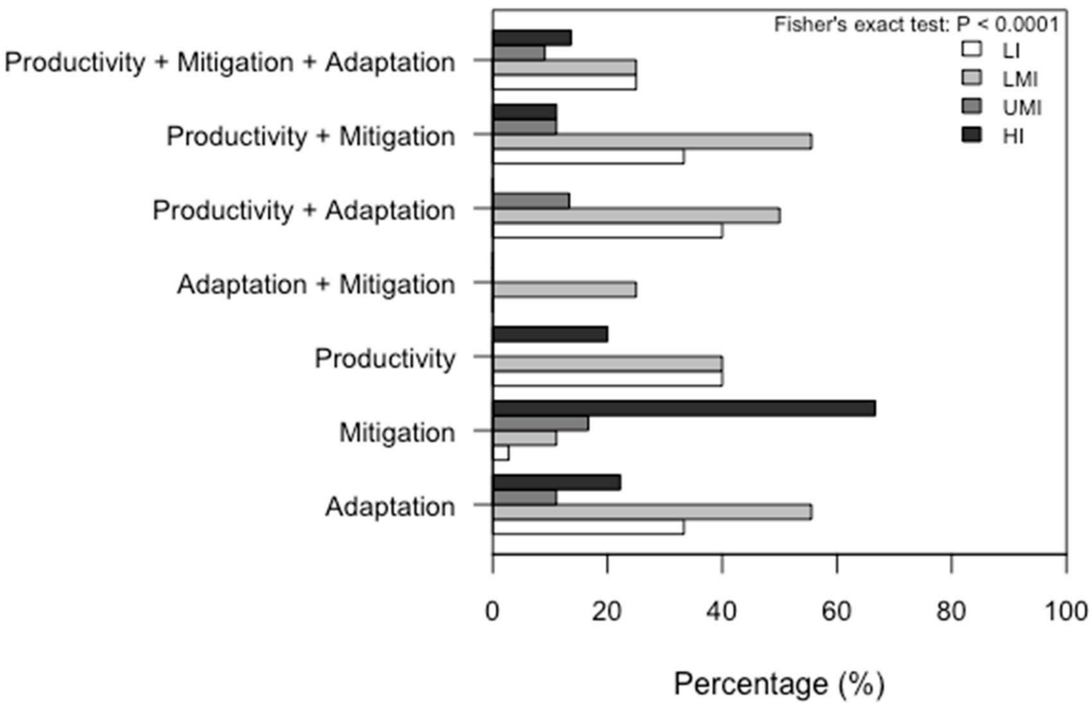

Figure 1. Correlation of CSA pillars addressed and the economic development status of the country (LI = low income; LMI = lower-middle income; UMI = upper-middle income; HI = High income).

Obviously, in developed countries (e.g., Europe and North America), most of the literature on the climate change and global warming inevitably turns to the responsibility industrialized countries bear for having contributed to temperature change by the burning of fossil fuels [48,62]. The literature, particularly focuses on climate change mitigation and puts emphasize on the obligations of industrialized states to reduce their emissions of greenhouse gases mainly carbon dioxide produced and to help poor countries do likewise [47,74]. They often argue that global warming is a matter of international justice, fairness, and equity [75,76]. In the developing countries, however (e.g., Sub-Saharan African and South America), where climate change and variability are among the major challenges to the food systems, the literature mainly focuses on the improvement of farming practices and access to resources to increase the productivity of agriculture and to secure food for the growing population [71,73,77]. In general, the development status of a country or a region seems to influence the way the country approaches the climate change issues, either through mitigation (mostly for the developed countries) or adaption and productivity increased perspectives, which are the priorities for developing countries [53].

3.3. Institutional Perspective in CSA Literature

The in-depth analysis of the CSA literature shows that about 55.5% (n = 76) of the publications make specific reference to the institutional dimensions, albeit from diverse perspectives including knowledge and physical infrastructures, market structure, soft and hard institutions, and interactions as illustrated by Figure 2 (see Table S2 for complete overview of CSA publications according to the institutional dimension addressed). Articles were written from 2011 onwards, with on average 10 publications per year and about 85.5% (n = 65) that have been published after 2013. The top-five institutional-focused publication sources included, *Agriculture and Food Security* (11.8%, n = 9); *Agricultural Systems* (9.2%, n = 7); *Regional Environmental Change* (5.3%, n = 4); *Food Security* (2.6%, n = 2); and *Gender, Technology, and Development* (2.6%, n = 2). In this section, we analyze the specific institutional aspects reflected in the existing CSA literature based on institutional analysis framework [32].

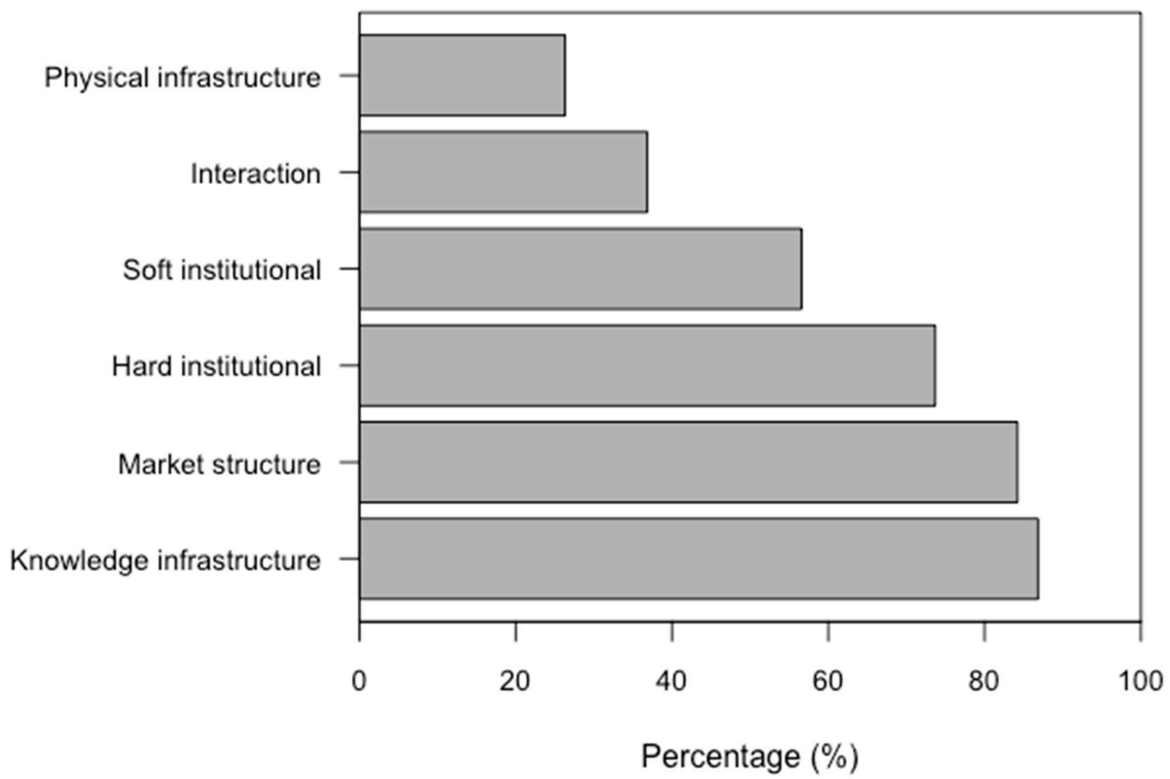

Figure 2. Institutional dimension reflected in the CSA literature.

3.3.1. Knowledge Infrastructure

The knowledge infrastructure dimension was addressed in 86.8% (n = 66) of the publications. Some of these publications (40.8%, n = 31) targeted the factors that create enabling condition for scaling CSA technologies. A set of articles conclude that despite the technical feasibility and the biophysical performances of CSA technologies, their uptake can remain low if the users, for example smallholder farmers, do not perceive the direct benefits they can gain from the technology. For farmers, the first goal of adopting CSA technologies is about the profits they can have from using the technologies, rather than the positive environmental benefits [38,78,79]. Such reward schemes represent a big boost for the farmer livelihoods and provide incentives for them to make decisions in favor of the CSA technologies [60]. This is similar to what happens at the decision stage of adoption processes as described by Rogers [80] which involves the weighing of benefits, disadvantages, and trade-offs to inform the decision of adoption or rejection of a proposed technology. Clearly, the environmental impact is not always the target of technology users, but mainly how the externalities generated from the use of CSA technologies contribute to household needs—both food security and household incomes. Likewise, Alem, et al. [42] presented the system of rice intensification (SRI), which is widely used in low-rainfall areas. The increased use of SRI is not related to the climate smart label of the technology, but people adopt the technology because it generates significant benefits for users. On average, participation in SRI increases yield per acre by about 58% and it requires less water [42]. This also results in a substantial reduction in the amount of methane emitted to the atmosphere, which is the embedded climate impact [81]. Kpadonou, et al. [13] also makes a similar conclusion, estimating that the availability of labor, security over land tenure, and capacity building are the major drivers of farmers' decisions to adopt CSA technology. Again, the positive environmental outcome of the CSA technology alone is not enough to stimulate its uptake.

Another category of publications (81.6%, n = 62) provided a more comprehensive understanding of challenges surrounding the adoption of CSA practices and emphasized the need for additional support, such as enabling policy to facilitate their uptake [13,82,83]. Along the same lines, Dougill, et al. [51] and Pulkkinen, et al. [57] highlighted the role that knowledge, communication, and capacity building all play in stimulating and enhancing the adoption of CSA options.

3.3.2. Hard Infrastructure

Regulation and policy featured in approximately 73.7% (n = 56) of the publications. The articles referred to the resource tenure [12,49], the policy [61,84], and governance [85,86]. They mapped the differences of priority setting between developed and developing countries and discuss how climate is mainstreamed in agriculture policies, negotiations, and strategies developed to achieve more sustainable outcomes [87]. For the effective implementation of the CSA options at a larger scale to meet the projected rise in global food demand, scholars also emphasized the need for a comprehensive regulatory framework to incentivize the agricultural sector to convert from conventional to more climate smart practices [61,88,89].

3.3.3. Market Structure

Almost 84.2% of the CSA literature (n = 64) addressed market related issues. These publications show that building resilient food systems for vulnerable farmers should focus not only on improving yields and on use of drought tolerant varieties, but also on creating enabling conditions for access to production inputs (e.g., seed, fertilizer, labor), post-harvest facilities [90], and market outlets [42,91]. Uncertain markets and variable prices very often determine the users' decision to adopt or not a given CSA technology. Alem, et al. [42] examines the influence of the rice market price and concluded that, even SRI indeed improves yield in rain-dependent areas, its profitability hinges on the market price farmers. Harvey, et al. [91] assert the important role of enabling institutions—the market—when exploring plausible options to strengthen the adaptive capacity of smallholder farmers. They concluded that although farmers use a variety of risk-coping strategies, these are insufficient to prevent them from food insecurity. This is a result of poor articulation of their adaptive strategies with the wider institutional setting, such as a reliable financing system and market facilities.

Some of the publications, including works of Douxchamps, et al. [64] and Fischer, et al. [36] show that the increased use of the CSA options could improve the food security status of rural households and reduced their vulnerability resulting in a more stable cash flow. These publications often point to the availability of remunerative market outlets and access to inputs as pre-conditions for the increased use of the CSA options [51,64,89,92]. The CSA related market publications also examined the major economic barriers that hinders the adoption and diffusion of CSA innovations such as the poor access to financial support [51]. The high cost of some of the CSA technologies is a major barrier, as smallholder farmers can hardly afford them. Other publications, including [93], studied the willingness of the consumers to pay more for products resulting from the climate smart farming.

3.3.4. Soft Institutions

Soft institutions are reflected in about 55.3% (n = 42) of the publications, focusing on gender [94–97] and other socio-cultural dimensions [86,89]. For instance, Njeru, et al. [86] assessed the effect of various traditional water harvesting practices and integrated soil fertility management technologies for enhanced sorghum productivity in lower and drier parts of Central Kenya. Much of these publications also analyzed locally developed strategies to cope with changing climate conditions [59,98]. Even though Nordic countries are self-sufficient in meat production, Aby, et al. [59] established that there is a high need for more local initiatives and innovative climate-smart agriculture to accommodate human population growth and climate change challenges.

Approximately 32.9% of the publications (n = 25) reflected on how the diversity of the local context within which CSA options are promoted can affect the direction and magnitude of potential outcomes generated [94,99,100]. They recommend considering a critical background analysis of social, historical, and cultural conditions when promoting the CSA options. A number of these publications also show that the CSA diffusion initiatives cannot work in isolation and should be part of wider institutional interventions (e.g., government and large scale programs) to capture additional and supportive opportunities [96,101].

3.3.5. Interactions

About 36.8% of the publications (n = 28) made reference to interaction through networking (18.4%, n = 14) [102] and partnership (30.2%, n = 23) [44,103]. The publications explored how the growing pool of investment in climate change offers an opportunity for the local communities to build their capacities and develop innovative partnership with government organizations [44,102]. An illustrative case of win–win public–private collaboration was formed between farmers, private-milk-processing enterprises and a public research institution in Tanzania to improve the standard of the locally produced milk. It also guarantees a remunerative market outlet of the surplus milk to larger and more distant markets Msalya, et al. [44]. The development of innovative market opportunities around the CSA options can stimulate smallholder farmers to engage in strategic partnership with key stakeholders such as universities and research centers. These partnerships can lead to the creation of new activities; for example, the establishment of climate-smart goat's milk processing and dairy goat maintenance in Tanzania as the outcome of joint collaboration between Universities, research entities, and farmers' organization [44]. Likewise, regarding the plausible impacts of global warming and continued uncontrolled release of greenhouse gasses and their implications for the livestock industry, no single organization (or entity) can perform the needed research and the implementation thereof on its own. Scholtz, et al. [98] recommended collective innovations and joint actions of relevant stakeholders with the objective to share research expertise and information, build capacity, and conduct research and development studies, should be a priority. This option is similar to what Pomeroy, et al. [104] have also recommended, stressing on collective and more integrated actions and the capacity building of fishery members to enhance their resilience to climate change. In general, this category of publications examined the potential role of private sector and partnership in the diffusion of CSA to small-scale farmers.

3.3.6. Physical Infrastructure

There are relatively limited CSA publications (26.3%, n = 20) that reflected on issues linked to physical infrastructure. The publications that address physical infrastructure make reference to roads and post-harvest facilities [60,61,71,97]. These publications highlight the impacts that climate change manifestations have on infrastructure for post-harvest storage and processing, and subsequent transport networks. For most of these publications, modern infrastructure facilities reflect the growing concern over climate change by adopting engineering principles and guidelines for greater adaptation to emerging environmental challenges.

4. Discussion

Research and development scholars establish that technology-oriented interventions alone may not be sufficient to sustainably address the challenges of agriculture and climate change [21–23,105]. Many agrarian systems are still suffering from the extreme climate events, despite the extensive research on climate-coping options, including existing sophisticated agricultural modelling that predicts plausible future pathways. It elucidates the uncertain characteristic of climate events and the limitation of the technology-oriented approach to address complex issues as climate change. It is clear that setting sustainable solutions in reducing risks to food security will require coordinated and systematic responses of many actors across levels [106]. Below are the main lessons and knowledge gaps identified from the CSA review.

4.1. Emerging Lessons

The review shows that the interest in the institutional dimension of the CSA options started in 2011 and focused on knowledge distribution, market, and policy aspects [48,60,84]. This interest has expanded gradually to address new perspectives such as gender and social differentiation in adoption of climate-smart agricultural practices [97]. The asymmetric access to extension officers, agricultural services, and information remains a major barrier that hinders the effective use of the CSA options. Part of the literature elucidates how the diversity of the local context can orient the scale and the amplitude of interventions [94]. New perspectives reflected in the literature also include the emergence of partnerships with a wide diversity of stakeholders, which offers an opportunity for the local communities to capture resources and build their capacity [102].

Regarding the institutional analysis, about 55.5% (n = 76) of the CSA publications studied in this review used the systems approach by including institutional perspective in their analysis. Market structure and knowledge infrastructure aspects were the most frequent institutional dimensions reflected in the literature. They specifically discussed the key role that the availability of market opportunities can play in the uptake of the CSA technologies and practices. Scholars demonstrate that creating enabling market conditions will contribute to reducing the risk for potential users to invest in the CSA options [36,60]. For example, the existence of remunerative market opportunities could stimulate farmers to use the promoted CSA technologies as they may be guaranteed that the resulting product will be sold at a relatively good price. This analysis confirms Drucker and Noel [107] perspective according to which technology is seen as a kind of 'artefact', and it is among the market mechanism that the technology is transformed into innovation. It implies that, on its own, a technology is not sufficient. It helps to create value only when it meets an enabling market opportunity [108].

The CSA concept aims at increasing productivity and resilience, reducing/removing GHGs, and enhancing the achievement of food security and development goals. While theoretically the CSA concept is defined with these three objectives, in practice however, it is not always addressed as such. Some climate scholars assert that actions related to either mitigation, adaptation, or increase of crop productivity have potential overlaps [109,110]. The gap between what CSA theoretically is and how it is implemented in practice could be linked to methodological challenges. As the boundary among the three pillars intersect in many ways, it may be necessary to assess the potential of a given practice by pointing simultaneously to the three pillars. To deepen the understanding of climate priorities and options, further works may be needed to design a methodological framework that allows a systematic assessment of the three pillars for CSA options. Thus, offering a more conducive context for implementation.

The review shows that in developed countries, much of the research and development actions emphasized on the reduction of greenhouse gas emissions with less commitment in adaptation actions. In the developing countries, however, interventions mainly focused on setting an enabling condition for increased crop productivity to ensure resilience to climate change [50,51,111]. In general, the development status of a country seems to influence the way that climate change challenges are addressed, either through mitigation (mostly for the developed countries) or adaptation and productivity-increase lenses [53].

4.2. Knowledge Gaps

While the market and knowledge dimensions are well documented in the existing CSA literature, there are a number of gaps that still exist: (a) limited attention to contextual and cultural factors; (b) relatively poor public–private partnership to support the scaling of the CSA options; and (c) a gap in physical infrastructure analysis. These institutional dimensions have not been given adequate attention in the CSA literature.

There has been little research to understand the role of local rules, historical legacies, cultural influences, social identities, and political competition in the uptake of CSA technologies. Many scholars argue that the institutional context in which a given technology is promoted is inevitably a component that shapes the uptake process [23,112,113]. For example, in their analysis of the drivers of technology transfer, Kedia and Bhagat [114] acknowledge that better understanding of the cultural constraints is important to design technologies that meet users' expectations and values. Also, many government interventions fail in their attempt to replicate the Asian Green Revolution in Sub-Saharan Africa, among others, because these initiatives have underestimated the potential of social, political, cultural, and historical contexts [115]. The success of the Green Revolution in Asia was possible due to structurally-, historically-, and socially-constructed enabling environment that lead to crop productivity growth [116]. The recognition of the institutional dynamics and relations that link technologies to the broader context in which they are operating is important to catalyze their effective use. This contextual analysis has not been given adequate attention in the current CSA literature.

The review highlights the little interest of existing literature to the "interaction", between private sector and public government. This is an important gap, specifically in the context of Sub-Saharan Africa, where most governments reduced their public expenditures in agriculture based on the new orientation after the structural adjustment reforms [117]. These reforms happened along with global food and financial crises, changing market structure, and climate challenges [118]. In such a dynamic context, stimulating the interaction among key players to attract more investment flows, from the private sector may be an opportunity to fill public investment gaps. It also has the potential to channel capital needed for agricultural and rural development [119]. This in turn will accelerate the replication of climate-resilient technologies and services in core development sectors [119]. Unfortunately, in SSA, private sector supports to agricultural development in general and CSA technologies are weak and often seen as a negative business practice. However, strong public–private partnerships appear to be a promising alternative to create business opportunities for upscaling CSA technologies. A recent innovative public–private experiment is being constructed with Manobi ©, a private company that offers a portfolio of integrated agricultural-climate services to the most vulnerable communities to cope with climate challenges [87]. Evidence of the value of public–private interaction has not been captured much in the CSA literature. Few publications related to public–private connection exist [44,57,103], but there is still limited understanding of how this kind of cooperation adds value to the upscaling of the CSA options.

The review demonstrates a relatively poor articulation of physical infrastructure in CSA literature, which overlooks an important portion of this discourse. Many research findings, including the work of Platteau [120] highlighted the significant role that physical infrastructures such as roads and rural communication play in agricultural development. Overall, about 26.3% (n = 20) of the selected literature made specific reference to the physical infrastructure (e.g., roads and post-harvest facilities) [60,61,71,97]. Haggblade, et al. [121] observed that investments in rural infrastructure, such as roads, can stimulate the reduction of transportation costs, increase farmers' access to markets and lead to substantial agricultural expansion. Even though it is recognized that infrastructure investment has a strong impact on rural incomes [121], major infrastructural issues are not addressed yet in the CSA literature.

The works of Rinaldi, et al. [122] indicated that irrigation is one of the critical components that affects the agricultural productivity and helps to mitigate the effect of climate variability in a significant manner. Irrigation has great potential to support adaptation to climate variability and change in cropping systems. Upscaling irrigation-based CSA options will likely result in simultaneously adaptation and productivity benefits. However, there are currently limited empirical studies on the irrigation system to support crop productivity [73,123,124]. There is also limited information to policy decision-making on adaptation and food security in this challenging climate context.

5. Conclusions

The concept of CSA is becoming a booming topic in agricultural development and climate change communities. It emerges as a promising package to secure food for the growing world population exposed to climate uncertainty and increasing food demand. Many of the CSA interventions continue to focus on the development and diffusion of technological packages to increase the productivity of smallholder farmers. A growing body of literature suggested that technology-oriented interventions alone may not be enough to achieve sustainable agricultural transformation. This is due to the complexity of the institutional context within which actors in agricultural systems operate. Using the innovation system framework, the study analyzed 137 peer review CSA publications, and shows that interest in institutional perspectives of CSA technologies has gradually grown over the years. Although the existing literature acknowledges the importance of some institutions in the uptake of CSA technologies (e.g., market), other perspectives such as the engagement of private sector in agricultural development have received less attention. Another major gap in the current literature relates to the documentation of the synergies and tradeoffs among the three pillars of CSA and the poor attention on the role of the contextual factors—historical legacies, cultural influences, and political competition—in the scaling of CSA options. The review concludes that more attention is needed for the institutional and political dimensions of CSA technologies. Rethinking this approach to promote CSA technologies by building both on technology packages and institutional enabling context can provide potential opportunities for effective scaling of CSA options. Such knowledge is critical to improving the design of CSA research and supportive policy.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/10/6/1990/s1, Figure S1. Subject areas covered by the CSA agricultural oriented publications analyzed title; Figure S2. Geographic distribution of the CSA related publications; Table S1. Description of search strings used for CSA literature identification; Table S2. Categorization of CSA publications according to institutional dimensions.

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