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Review

Climate-Smart Agriculture on Small-Scale Farms: A Systematic Literature Review

Tamás Mizik

Department of Agribusiness, Corvinus University of Budapest, Fővám tér 8, 1093 Budapest, Hungary; tamas.mizik@uni-corvinus.hu

Abstract: Overpopulation and climate change are among the greatest challenges the world faces. Climate-smart agriculture (CSA) provides an adequate answer by aiming for higher productivity, resilience, as well as GHG emission reduction. As small-scale farms are the cornerstone of the agricultural sector, especially in developing countries, their greater involvement in climate-related actions is essential. CSA practices seek a higher and more stable income sustainably. This systematic literature review aims to provide an overview of how CSA is realized on small-scale farms, what the major CSA practices applied are, and what factors motivate and hamper higher CSA adoption. Based on 30 selected articles, the major message of the literature is a case/site-specific approach due to the tremendous heterogeneity of small-scale farms. As agricultural production is characterized by high risks and low returns, small-scale farmers must consider the length of the payback period when they decide on any CSA practices. This is the reason smallholdings, who implement any CSA practices, must achieve economic benefits, otherwise, they need to be compensated for providing environmental benefits. Moreover, simpler methods with low labor intensity are often applied. Access to the different financial instruments and inputs, knowledge/education/information, and land use security are the critical factors of the CSA adoption. Furthermore, it is worth mentioning that, unlike off-farm activities/incomes, full-time farming is a serious commitment that positively influences CSA adoption.

Keywords: climate-smart agriculture; small-scale farms; smart technology; adoption

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1. Introduction

According to the latest available projection of the United Nations, the global population is forecasted to grow to 9.7 billion by 2050 [1]. Producing enough food seems to be the greatest challenge of the agri-food industry. As the available agricultural land is limited, this requires enormous efficiency gains. Maximizing production with scarce resources is a necessity and requires the substantial transformation of agriculture [2]. On the other hand, special attention should be paid to climate change, especially to the reduction of greenhouse gas (GHG) emissions. Its atmospheric concentration is projected to double by 2030, which causes a significant increase in global temperature [3]. This has serious implications for the agricultural sector all over the world. These initiatives interrelate in climate-smart agriculture (CSA), which, on the one hand, uses the latest technological achievements, while on the other hand, aims to mitigate climate change. The FAO defined climate-smart agriculture as "that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals" [4]. CSA has three main objectives/pillars in which site-specific efforts should be applied [5]:

1. higher agricultural productivity and income in a sustainable way;
2. higher (adapted and built) resilience to climate change;
3. efforts towards GHG reduction.

The successful implementation of these objectives accomplishes the so-called "triple win" when the implementation of the different innovative practices results in higher yields, climate change mitigation, as well as lower GHG emissions [5]. Based on reviewing the relevant literature, Siedenburg et al. [6] concluded that CSA practices seem to be able to provide a solid win-win outcome in developing countries.

It should also be noted that this is a complex system with embedded trade-offs between the 3 objectives [7,8]. Practically this means that e.g., a yield-focused measure can easily result in higher GHG emissions. Moreover, potential synergies and/or co-benefits may arise too, e.g., a climate-friendly measure contributes to the GHG emissions savings. These issues underline the importance of proper planning and careful implementation. CSA relies on a wide range of stakeholders (e.g., research and development partners, responsive governance systems, and supportive agricultural policy) and should be a long-term initiative [9]. The site-specific characteristics (innovativeness and flexibility) of the CSA result in a higher resilience and lower food security risks, which is different from the normal business-as-usual approach [10].

CSA is not a completely new production method, rather a production philosophy. This relies on the already existing tools and devices of conventional agriculture, as well as on new and novel technologies. However, those new technologies will spread within the whole of agriculture as time goes on. Therefore, CSA is narrowly interpreted as either precision agriculture or smart agriculture. The difference lies in their approaches. Precision agriculture is a management approach that ultimately aims at input optimization [11], while smart agriculture aims to optimize the entire farming system [12,13]. Moreover, smart farming relies not only on farm-level data but also on other datasets/data sources (e.g., weather or market datasets), which makes it possible for comparison [14]. CSA is part of the smart agriculture category where, due to its threefold objectives, further (environmental) efforts are made beyond the farming system optimization. Figure 1 summarizes the relationship between these systems/approaches.

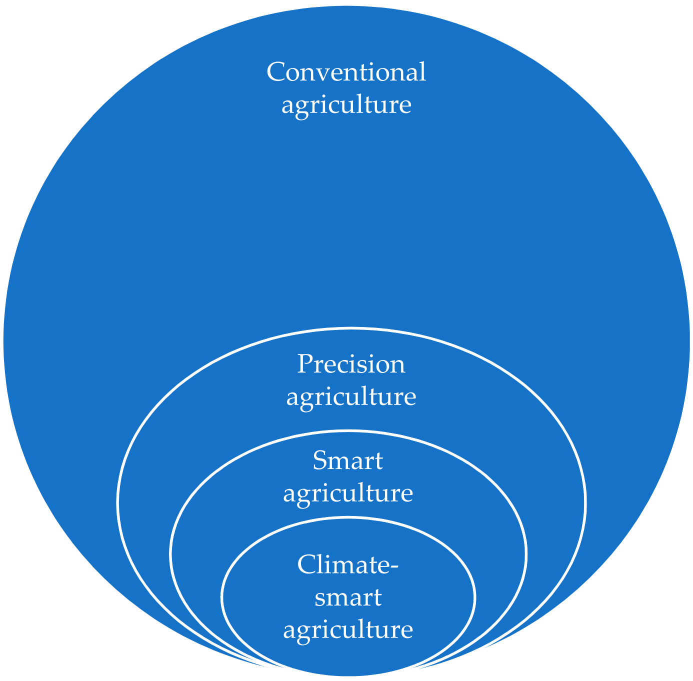

Figure 1. The simplified relationship of the different agricultural systems.

The broad definition of CSA includes the integration of different farming/agronomic practices and systems, as well as the improvement of input use, such as seeds, pesticides, water, etc. [10,15]. Due to rapidly developing technology, there are many new CSA items on the verge of commercialization related to the Internet of Things, artificial intelligence (e.g., detection), and robotics (e.g., harvesting or multi-robot systems) [16]. Novel machine learning, cloud, and big data-based computing should also be mentioned [17]. These items can further accelerate the speed and accuracy of data collecting and processing, and, therefore, provide more precise information and recommendations for the farmers. Different farming activities can also be carried out at a greater speed with high(er) accuracy, such as weeding and harvesting.

Climate change directly impacts the whole agricultural sector, which can be either positive (e.g., agricultural production zones expand) or negative (e.g., more frequent natural disasters such as heat stress). The developing countries are particularly affected due to the higher share of agriculture in their national gross domestic product. In addition, they are typically more vulnerable to such changes compared to the developed countries [18].

Smallholder farms make up the cornerstone of the global food chain by providing food and income for the majority of the world's poorest peoples [19]. The global share of small-scale farmers (<2 ha) is 84% and most of them are in developing countries [20]. Therefore, transforming them into a more productive, climate-resilient unit with reduced GHG emissions (CSA objectives) is essential. In this process, raising their climate awareness is vital as that shapes their CSA adoptions [21]. At the farm level, the short-term benefits of CSA may outweigh its long-term promises [22]. Short-term benefits are particularly important for small-scale producers because they have no financial room for any doubtful maneuvers. As agriculture provides small profit margins along with high risks, smallholders opt for CSA practices that offer immediate benefits [23]. In general, smallholdings need assurances, as well as financial support to implement any CSA practices that may affect them financially [22]. As a matter of the three pillars of CSA, this may result in a shift towards increased productivity (and income) at the expense of higher resilience and reduced GHG emissions (longer-term impacts).

The FAO pointed out the importance of institutional and public financial support of the smallholdings in the CSA implementation as early as 2010 [4]. This reflects the fact that developing countries will be more affected where the majority of the farms are smallholders. Supporting institutions, including extension services, proved to be essential in many countries, e.g., in Ghana [24], Italy [25], India [15], Mali [26], Nepal [27], Pakistan [28], and South Africa [29]. Partly contrary to this, Emerick et al. [30] found that traditional agricultural extension (farmer field day) can have a larger impact on the diffusion process than relying solely on the sharing of farmers' knowledge. In addition to this, any successful CSA implementation should be based on the commitments of the broad local stakeholders [7]. Although their share is less than 20% of potential adopters, early adopters play a crucial role in the diffusion process [31], acting as information transmitters [32]. Regional, country-level cooperation and knowledge exchange are also important, especially in developing countries [33]. Chanda et al. [34] added more elements to this list. They argued for a broader perspective, i.e., CSA should go beyond the farm level and deal with inequality, unequal power relations, and injustice, especially in developing countries where smallholder farms dominate. Nevertheless, widespread adoption is hindered by the lack of evidence due to uncertainties, the need for model downscaling, and limited available information [10]. Some CSA practices may have unintended side effects, e.g., crop rotation itself resulted in reduced technical efficiency in Zambia, therefore, they should be combined with appropriate measures [35].

While the benefits of CSA have been well-analyzed and are obvious, one should not forget about its drawbacks. Doshi et al. [36] highlighted some important issues that farmers should be aware of. These issues can be unstable and slow Internet; potential sensor errors that may go over the whole production chain; and inadequate skills and knowledge for a smooth operation. The potential conflicts between the different CSA elements should also be mentioned, e.g., higher productivity often causes higher GHG emissions [37]. Timely access to different inputs (e.g., seeds, fertilizer, etc.) can be a problem as well [10]. When the implementation of CSA requires investments into technologies (e.g., sensors, smart devices), a lack of financial resources and/or access to them could make adoption impossible. Technology providers may create issues and difficulties for CSA adopters [18]. These issues may escalate in developing countries. However, it is worth emphasizing that there are cheap, or even free, CSA elements, such as changes in intercropping, planting dates, and/or the use of more tolerant crop varieties [4]. Moreover, Payments for Environmental Services (PES) provide an alternative solution by covering the initial costs of the implementation of CSA practices [38]. This is particularly important for the poorest farmers because they will suffer the highest economic impacts of climate change [39]. In addition to the potential financial issues, the lack of available labor can also be a problem. Many CSA elements require higher labor intensity, such as the different irrigation systems [40,41], different elements of conservation agriculture [42,43], and bench terracing [44].

CSA is often accompanied by sustainable intensification (SI). SI means a more intensive production in a more sustainable way. Campbell et al. [9] highlighted their complementarity due to their many common elements, such as diversification. They provided examples to demonstrate the importance of SI in CSA, such as banana-coffee intercropping or livestock diet intensification through agroforestry. But the same rule applies to CSA-SI than to CSA itself: spatial variation always should be taken into account and implementation should be targeted [45]. CSA has a global aim that requires local actions. Another corresponding line that is often associated with CSA is conservation agriculture (CA). This is based on three basic principles: the lowest possible soil disturbance, permanent organic cover, and crop diversification [46]. These principles highly overlap with the pillars of CSA. Therefore, one may say that CSA includes CA [43]. Figure 2 illustrates the relationship between these systems.

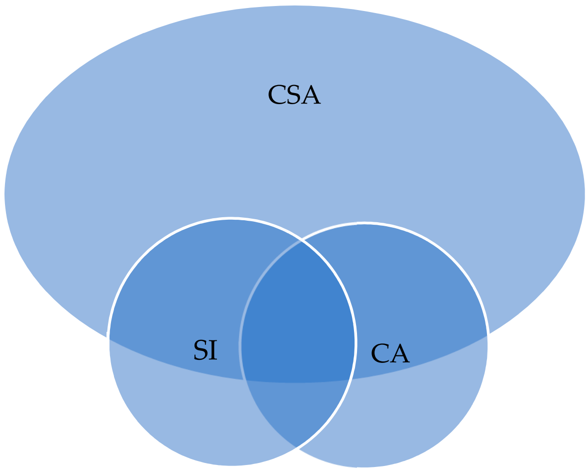

Figure 2. Relationship of the CSA, SI, and CA.

Giller et al. [47] pointed out that CA cannot be easily applied by small-scale farmers due to their limited financial resources to invest in herbicides and mechanization. In general, smallholdings have limited options. As Harris and Orr [48] illustrated, one of their potential paths from poverty is land acquisition, which is still feasible in some parts of Africa but much less in South Asia, and commercialization; otherwise they need to leave the agricultural sector. They also emphasized that the anticipated returns from technological improvements are too small to solve their poverty problems due to their small land size.

This article aims to discover how CSA can be implemented on small-scale farms, and what the benefits of this system are at the farm level. What are the motivating factors, as well as major constraints of adoption? The paper is structured in the following way. The next section describes the materials and methods used for the article selection process. The third section provides the results of the systematically reviewed articles. The final section contains a discussion and conclusions.

2. Materials and Methods

The research method applied in this article is a systematic literature review. For the article selection, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method was applied, which contains 4 stages: identification, screening, eligibility, and included [49]. Articles were searched in the following databases: ScienceDirect, Scopus, and Web of Science. Additionally, Google Scholar was searched. Climate-smart (with and without a hyphen between climate and smart) agriculture and small-scale farm were applied as keywords with the Boolean operator "AND" between them. These keywords need to have been part of the articles' title, keywords, or abstract in the case of the databases (ScienceDirect, Scopus, and Web of Science). As there is no such option in Google Scholar, items on the first 10 pages ranked by relevance were reviewed. Moreover, only English scientific and review articles were screened.

In decreasing order, 29 potential articles were identified in the Web of Science database, 16 in the Scopus database, and 7 in the ScienceDirect database. Google Scholar provided most of the related items, however, it is not possible to automatically sort scientific and review articles out of them. Therefore, a manual selection was applied to the 100 items on the first 10 pages. During this process, books, book chapters, working papers, conference proceedings, and newspaper articles were excluded. This resulted in 70 additional articles.

At the identification phase, 52 + 70 items were identified. This was followed by screening when duplications were removed. This resulted in 97 identified articles. Then the abstracts of these articles were reviewed and it was verified whether or not they dealt with the smart agriculture–small-scale farm nexus. After removing the non-relevant items, 43 articles were saved for the detailed analysis. Most of the excluded articles dealt with purely technology, methodological, and climate-smart issues. However, it should be noted that the topic of these articles partly overlapped, i.e., they analyzed more than one issue. Their common point was that the excluded articles negligibly dealt with smart agriculture–small-scale farm nexus. Finally, the systematic literature review relied on 30 articles. At the eligibility level, 123 articles were sorted out due to their different focus from the desired topic, i.e., they were experimental studies or provided a theoretical framework. Figure 3 summarizes the steps of the literature selection process.

The composition of the thoroughly analyzed articles is very diverse, the selected 30 articles were published in 25 different journals. As a matter of their publication years, the earliest was published in 2012, which can be explained by the relatively short official history of the CSA concept. The most frequent year was 2018 when one-third of the total articles were published (Figure 4).

Regarding the geographical coverage of the included articles, 4 articles have global, 10 articles have regional, and 16 articles have country-level coverage. It should be highlighted that only 1 article had a broader coverage (low- and middle-income countries), all the other regional articles analyzed some of the African countries. At the country level, 8 articles dealt with African countries, 5 with Asian countries, 2 with a South American country, and there was 1 European country among them. Although climate change and GHG emissions are global problems, developing countries, especially in Africa, are more impacted and/or have fewer financial resources to fight against them. This is reflected in their high representation. Nevertheless, it should always be kept in mind that the climate-related changes have global impacts, they do not stop at the country's borders. In addition to developing countries, Australia, the Southern part of Europe (the Mediterranean), and the Southwest part of the USA are also particularly exposed to these changes.

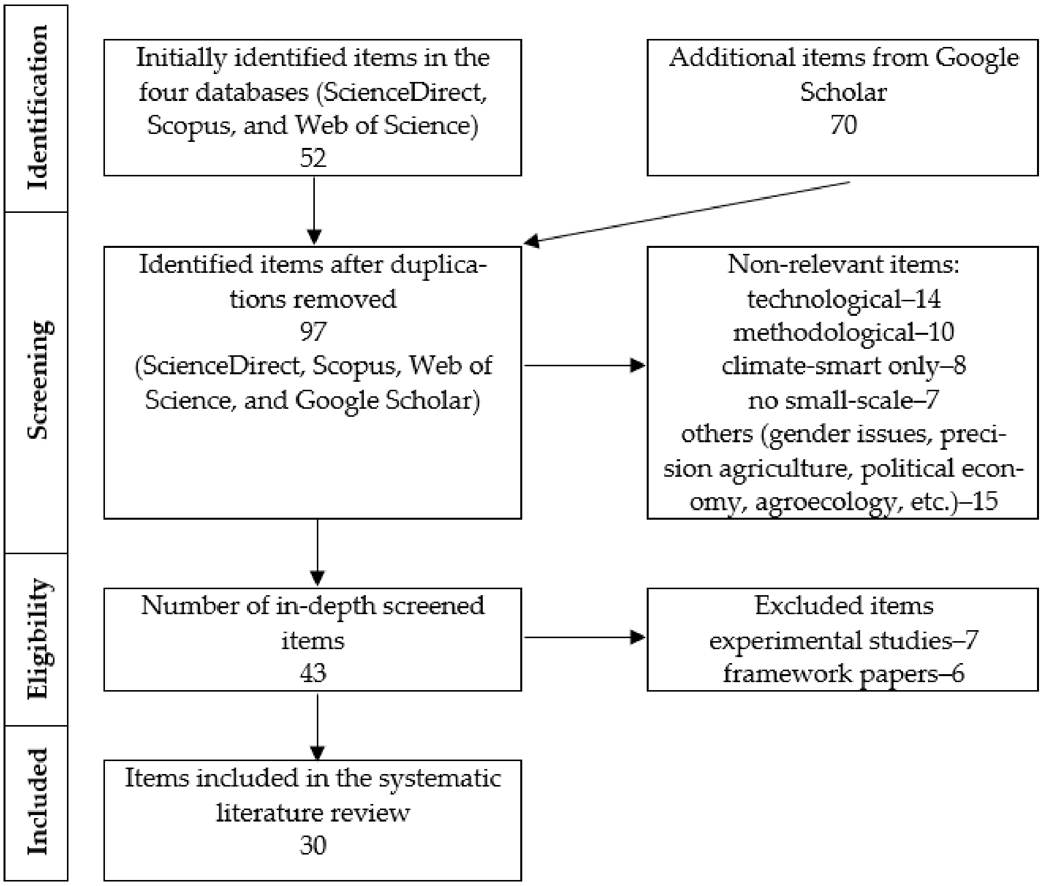

Figure 3. Flowchart of the literature selection process.

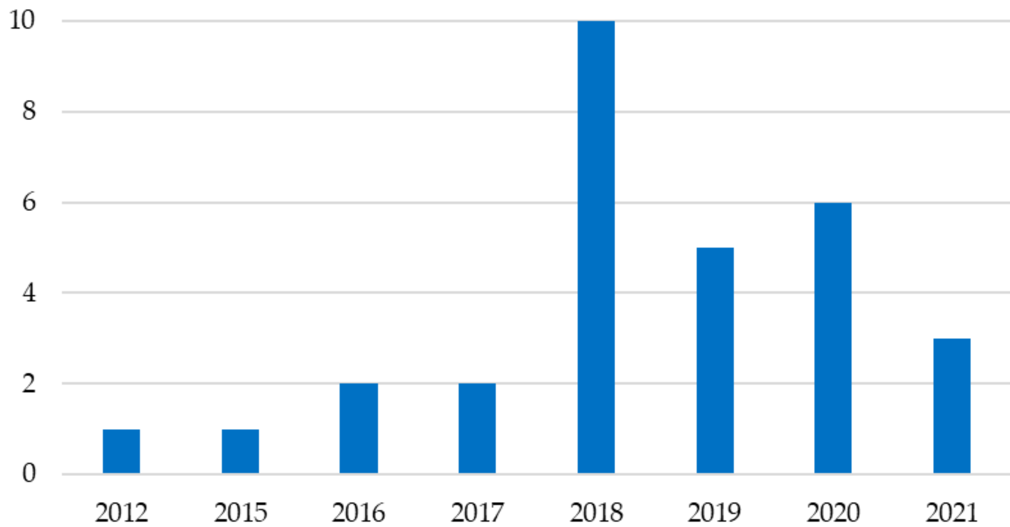

Figure 4. Yearly distribution of the included articles.

3. Results

Due to a large number of small-scale farms, even a small, climate-smart step would have an enormous global impact. Martinez-Baron et al. [50] highlighted that small-scale farmers play an important role in keeping global warming under 1.5 °C. Based on the analyzed articles, however, it becomes clear that purely environmental aims cannot be the driving factors of CSA implementation at small-scale farms. As farming is often the main, or even only, income source of the household, implemented CSA elements should contribute to their higher production and income. Therefore, different policy incentives play a crucial role in achieving a better environmental performance of the smallholdings.

The heterogeneity of the small-scale agricultural sector in Sub-Saharan Africa (SSA) was a strong theme in the analyzed studies, which can be generalized at the global level. Adhikari [27] added that even a geographically similar region requires heterogeneous adaptation measures. Therefore, any CSA implementation should start with acknowledging this [51]. This also implies a case/site-specific approach rather than a general one, and stakeholders should be aware of this [44,52,53]. Taking this into account requires targeted agricultural policies. In addition to this, it seems that the integrated and combined CSA adoption strategies provide higher benefits [43,54], therefore, agricultural policies should encourage them more.

According to its objectives, CSA is linked to higher productivity (along with technology) and better environmental performance (climate change mitigation and GHG emission reduction). From a practical point of view, the different influencing factors of CSA adoption are also important. These three themes were planned to organize the selected articles. However, environmental drivers did not show up solely in any articles. Therefore, instead of having an environmental-focused sub-section, a CSA sub-section combining economic and environmental factors was used. This contains articles with twofold (economic and environmental) objectives.

3.1. Productivity/Technology Related CSA

Zougmoré et al. [55] analyzed the opportunities of CSA in the SSA countries. They highlighted resilient cultivars, better water management, agroforestry, insurances, and climate information services. They are in accordance with Abegunde et al.'s [52] results who identified "conservation agriculture, agroforestry, integrated crop-livestock management, mulching, intercropping, crop rotation, an improvement on water management, and development on grazing" as the most commonly used practices in the region. Zougmoré et al. [56] examined the potential CSA practices in the livestock, fishery, and crop sectors of West Africa. The major problems of the region are high climate risks, e.g., droughts, bush fires, floods, and new diseases. They collected several adaptation options for each subsector. In the case of livestock systems, mixed production with crops, intensification, improved feeding methods, shift to smaller ruminants, or even moving out of agriculture could be a possible option. At the fisheries, more efficient equipment (e.g., vessel) and technologies (e.g., bulk sea freight), and more local selling are advised. Finally, there are CSA practices available for the crop sector from CA, agroforestry, different water conservation/management technologies, and higher input efficiency to more tolerant varieties. Moreover, climate information services are getting more important. It is worth mentioning that drought is the major constrain of the smallholders' production in Moldova too, but 82% of the analyzed farms do not use any CSA practices, they do not even apply crop rotation [57].

Arslan et al. [58] examined different CSA practices in Zambia. While minimum soil disturbance and crop rotation had no significant impact, legume intercropping increased maize yields. The authors emphasized that timely access to fertilizers has one of the most important positive impacts on maize yields. Therefore, any delays may result in future losses. The smallholders' access to fertilizers is generally cumbersome, which makes their situation even worse. Improving access to fertilizers should be a suggested path for the Zambian policy to achieve higher food security.

Among many other questions, McKune et al. [59] surveyed 71 randomly selected households in Kenya and Senegal about their CSA practices. At the country level, Kenyan smallholders adopted more CSA practices than their Senegalese counterparts. The most beneficial elements were manure management, intercropping, and crop management. According to some other studies [60,61], they have not found a significant difference between the CSA adopters and non-adopters in terms of food security. Abegunde et al. [29] found that organic manure, crop rotation, and crop diversification were the most frequently used practices in South Africa. Makate et al. [51] write that drought-tolerant maize and different elements of integrated soil fertility management were used (e.g., different conservation methods and fertilizers) in the Southern African countries. Being a feasible and cost-effective practice, crop diversification was the most common practice.

Hasan et al. [60] analyzed how CSA adoption impacts coastal farmers' food security in Bangladesh. Out of the 17 outlined practices, farmers applied 7 on average, where urea deep placement, sorjan method, pheromone trap, and seed storage techniques were the most used. They experienced low adoption of the different cultivations and mulching. The number of applied CSA practices only weakly contributed to higher food security via the increased income of the households. By using the dataset of 269 randomly selected households, Lopez-Ridaura et al. [61] examined the impacts of CSA adoption in the form of CA in India. While rice-wheat intercropping has had no significant impact on smallholdings' food security, mixed small farms benefited the most from enhanced livestock production. They found maize-livestock mixed farming a potentially promising opportunity at a small scale. Ruales et al. [62] analyzed the CSA adoption of small-scale coconut farmers in the Philippines. The most frequently used practices are early harvesting and weather forecasting. They are related to the high occurrence of different natural disasters, such as typhoons. Despite the high profitability, coconut-banana intercropping is rarely applied. The possible reasons for this include the need for an initial investment and the relatively long payback period (4 years). This applies exponentially to the higher "typhoon-tolerant" coconut varieties.

Sain et al. [23] examined the CSA adoption among the small-scale maize and beans producers in Guatemala. By applying a cost-benefit analysis, they analyzed conservation tillage with mulch, agroforestry systems with hedgerows, crop rotation (maize/bean), contour ditches, stone barriers, water reservoirs/ponds + drip irrigation, heat and water stress-tolerant maize variety, and pest- and disease-tolerant bean variety in the order of their application frequency. They calculated different profitability indicators and found that the least applied practices have a high financial return and the lowest payback period (maize and bean varieties with higher tolerance). The two most popular practices also had positive financial outcomes, but their payback period is more than 8 years long. This highlights the importance of more complex analysis, e.g., considering non-financial issues such as adoption risks, labor intensity, and ecosystem services. Hellin and Fisher [42] pointed out that sometimes off-farm activities and income could be the only option for the smallholdings in the Western Highlands in Guatemala. Regarding CSA adoption, small plots make it almost impossible to use different cross-slope soil conservation technologies (e.g., barriers or walls) because that would further limit production. Labor shortages may also result in the inclusion of certain CSA practices, e.g., field burning is easier than applying conservation agriculture.

Although the basic principles of CSA are clear, Alexander [63] raised two, CSA-related controversial issues: genetic engineering and artificial fertilizer. According to her research, the CSA approach does not regulate any of them explicitly, rather delegates the decision-making at the local level. However, CSA is often linked to (smart) technology which may be a threat to the potentially less educated and/or less skilled smallholders. Moreover, Totin et al. [64] highlighted the need for complex CSA interventions as purely technology-focused ones may not be appropriate to achieve sustainable agricultural transformation.

3.2. Combining Economic and Environmental CSA

Mutenje et al. [54] applied a cost-benefit analysis to evaluate the different CSA practices (improved maize varieties, soil and water conservation, and cereal-legume diversification) in Malawi, Mozambique, and Zambia. One of their most remarkable results was that the combination of the different CSA practices resulted in the highest economic and environmental benefits for the small-scale farms. In general, diversification provides the highest benefits from both economic and climate aspects in terms of financial returns and mitigation. Branca et al. [43] analyzed the potential benefits of CSA on the smallholdings in Malawi and Zambia. They found that minimum soil disturbance (MSD) as a CSA practice resulted in a higher income than tillage-based farming in the case of maize cropping. Although this method has higher production costs (e.g., better inputs, and higher labor intensity), the increase in revenues due to the much higher yields offset that. Combining MSD with other CSA practices has produced positive outcomes too. They also highlighted the importance of accessibility and affordability of the different inputs (herbicides, fertilizers, and seeds) for small-scale farms.

Abegunde et al. [22] examined farmers' perception of technical, economic, and environmental compatibility of CSA practices among the South African small-scale farms (farm size ≤ 5 ha). According to their combined analyses, the use of organic manure and crop rotation turned out to be the most popular CSA practices (Table 1) based on the Acceptance Level Index (ALI), which is a composite score index based on 327 farmers' responses on CSA acceptance (acceptable = 2, neutral = 1, and not acceptable = 0). The authors pointed out the conformity of these items with the farmers' cultural values or gender norms as a potential explanation. Besides, these practices are inexpensive to implement and they are part of the farmers' production routines, such as crop rotation. Regarding the least accepted CSA practices, the situation is diverse as the list of items in the different dimensions hardly overlap, only agroforestry showed up twice. These are highly correlated with the small farm sizes, as most of them make no sense or would be challenging to adopt on small plots. These findings provided relevant practical implications for shaping the CSA-supportive policies.

Table 1. Farmers' perception on the acceptance of the compatibility dimensions of the different CSA practices (Author's composition based on [22]).

	The 3 Highest Accepted CSA Practices	**The 3 Lowest Accepted CSA Practices**
Technicality	use of organic manure (545), planting of cover crops (533), crop rotation (529)	soil conservation (423), agroforestry (430), conservation agriculture (432)
Economics of use	use of organic manure (542), mulching (541), crop rotation (515)	planting of drought- and heat-tolerant crops (430), agroforestry (436), diet improvement for animals (447)
Environmental friendliness	use of organic manure (524), crop rotation (504), soil conservation (503)	efficient manure management (436), use of wetlands (445), crop diversification (462)

Note: the values of the ALI are in parentheses.

According to Nyasimi et al. [44], on-farm diversification (different crop varieties, mixed farming, etc.), especially for smallholdings, is very important not only from an economic viewpoint but also from the risk mitigation aspect. They also pointed out that adequate knowledge on climate risk management strategies is equally important with the use of CSA for the African small-scale farmers. As droughts seem to be the most severe problem in Malawi, CSA practices focus on the increased surface and sub-surface irrigation among the small-scale farms [41]. Zerssa et al. [65] listed the most commonly used CSA practices in Ethiopia: CA, integrated nutrient management, agroforestry, and water harvesting and irrigation. They provide multiple benefits such as higher productivity/income, carbon sequestration/GHG emissions savings, and increased resilience, though to a different extent.

Asia has different conditions compared to Africa; therefore, CSA is expressed in partly different ways, for example, unlike Abegunde et al. [22], Adhikari [27] found crop diversification that aims to use fewer water-demanding crops, and agroforestry practices effective among the mid-hill farmers in Nepal.

Siedenburg et al. [6] argued for sustainable land management practices that provide multiple advantages at the small-scale farming level. These practices result in higher productivity, as well as better environmental performance.

3.3. Influencing Factors of CSA Adoption

Based on a systematic literature review, Acevedo et al. [66] investigated the determinants of the adoption of climate-resilient crops in low- and middle-income countries. According to their results, these determinants vary greatly in the different regions. In East Asia and the Pacific, the focus of the related literature was equally on extension/awareness/information, experience and skills, and education. In Latin America and the Caribbean, as well as the Middle East and North Africa, education was analyzed the most. Farm inputs (seeds, fertilizer), social status of households, and education were in the center of the majority of articles dealing with South Asia, while extension/awareness/information, farm inputs, social status of households, and experience and skills dominated the studies on SSA. Regarding climate-resilient crops, modified planting activities (32%), irrigation and water management (32%), and new variety planted (24%) were the most frequent topics in the studies dealing with the potential climate mitigating options. Entirely in line with the major findings of the individual articles cited in the first section, the importance of extension programs, access to financial instruments, and community programs were the top suggestions of the 202 analyzed articles on how to improve the adoption of climate-resilient crops and crop varieties.

Setshedi and Modirwa [53] interviewed 170 small-scale farmers (livestock, grain, and mixed) in South Africa. Farmers were selected by a random sampling technique and information was collected by a structured questionnaire. They found that the major barrier to CSA adoption is the lack of knowledge and information. Most of the rural farmers have a poor internet connection, they are less educated, and lack sufficient financial resources, therefore, targeted incentives, CSA policy, and knowledge transfers are essential. Based on a questionnaire filled up by 327 small-scale farming households (farm size below 4.5 ha) in South Africa, Abegunde et al. [29] analyzed the determinants of the CSA uptake. By analyzing the impacts of the different variables on CSA adoption, "Perception of the effect of climate change" had the highest positive, while "The distance of farm to homestead" had the highest negative impact among the statistically significant variables. Most of the sample farms (56.6%) were medium adopters based on the number of CSA practices they applied. Unsurprisingly, off-farm incomes decreased further adoption of CSA practices.

Based on the analysis of 601 interviews in different agro-ecological zones of Malawi, Mozambique, Zambia, and Zimbabwe, Makate et al. [51] demonstrated that farm size and financial circumstances play an important role in CSA adoption. Makate [67] emphasized the importance of cooperatives in the CSA adoption of the African small-scale farms by not only providing knowledge transfer but also resource pooling. Moreover, value chain development and/or better market access can significantly help them as well. Relying on a literature review, Makate [67] summarized the major success factors of CSA adoption: material benefits for farmers, peer learning and stakeholders' support, low capital and workforce need, and access to key resources. Based on interviews with 312 randomly selected household heads, Mango et al. [40] analyzed the adoption of the small-scale irrigation system as a CSA practice. They found a strong positive connection between irrigation farming and agricultural income. This impact comes from at least two sources: higher and more stable production, and the opportunity of off-season production. Among the significant variables, having a reliable water source has the highest positive impact on their adoption in Southern Africa, followed by the awareness of conservation practices. If the household's head has off-farm income from either formal employment or small-scale business, the chances of adoption greatly decreased. It is generally accepted that full-time farming is a serious commitment that increases CSA adoption, especially because some practices, such as the use of an irrigation system, are labor-intensive. This is the case for Moldova too [57]. This may sound contradictory. In general, lack of financial resources is a significant barrier to CSA adoption; however, even an ample amount of financial resources may decrease the chances of adoption if the money comes from formal employment outside of the agricultural sector.

There are various barriers to CSA adoption in Tanzania, such as high investment costs, knowledge intensity, high labor needs, and tenure and ownership rights, which widen the gap between awareness and adoption [44]. As Murray et al. [41] highlighted, expensive and labor-intensive CSA practices are less often adopted. Moreover, the introduction of novel practices requires substantial knowledge transfer. Access to inputs and resources is key, as that may make the CSA adoption process harder even if financial resources are available. A clear gender inequality is shown, as women smallholders not only suffer even more from the different adoption constraints but also do not always have the right to decide on CSA adoption.

Zerssa et al. [65] identified many limiting factors in Ethiopia such as land scarcity exacerbated by tenure insecurity, knowledge intensity, access to credits along insufficient income generation potential. They also offered different options to increase CSA adoption: restoration of marginal lands, microfinancing, and knowledge transfer and sharing. All require strong policy support. Tsige et al. [68] identified the same constraints of CSA adoption in Ethiopia as the other analyzed studies: access to credits, lack of knowledge/information, land scarcity, and limited membership in cooperatives. Like Murray et al. [41], they also identified that these constraints are harder for the women-led small-scale farms (gender constraint).

Shahzad and Abdulai [69] surveyed 540 farm households on the impacts of CSA adoption in Pakistan. To have an unbiased sample, they randomly selected villages from the three agroecological zones, and fifteen farmers from each of them. According to their results, being informed/trained and having access to credits are the strongest indicators of potential CSA adoption. They found that CSA practices significantly reduce food insecurity and poverty. Policies that are aiming for higher CSA adoption may contribute to the same results at the country level. This requires measures such as better access to credits, education, extension services, and weather forecasts. They also highlighted that the aggregated small-scale level impacts are much higher than the same impacts on large-scale farms. As recognized by Siedenburg et al. [6], smallholders "potentially have a comparative advantage in providing" mitigation services.

According to Pilarova et al.'s [57] results, additional incomes (remittances) and soil productivity are the major levers of CSA adoption among the statistically significant variables. Its major barriers are migration (via labor unavailability), lack of financial resources, and irrigation problems. Unlike many country-level studies (e.g., in Ghana [24], Italy [25], India [15], Mali [26], Nepal [27], Pakistan [28], and South Africa [29]), they did not find a strong positive connection between the use of extension services and CSA adoption, especially in the case of minimum and no-tillage.

McKune et al. [59] stated that small-scale farmers' knowledge and experience, their information about CSA practices came mostly from personal connections, such as family or extension services. Martinez-Baron et al. [50] emphasized that social networks and key actors play a crucial role in the CSA adoption process. This also points out the direction for global, as well as local level actions. Ruales et al. [62] highlighted the importance of knowledge transfer to achieve higher CSA adoption. Hasan et al. [60] emphasized that supporting further adoption of CSA is important, but not enough as other factors have an even higher impact on food security, such as education, pond size, and cattle ownership.

Adhikari [27] highlighted that agricultural and non-agricultural adaptation are equally important. This contains financial support, off-farm income generation, mainstreaming climate adaptation, access to CSA-related information, governance and institutions, and migration. Regarding the barriers to CSA adoption, farmers face natural limits (ecological and physical) due to the special environmental endowments; knowledge, technological and financial constraints; and social barriers (cognitive, normative, and institutional).

To overcome the general barriers of CSA adoption (potentially high investment cost, lack of skills, delayed benefits, uncertainties), Siedenburg et al. [6] proposed "farmer-friendly" incentives that have sufficient value, flexible use, and production-specific timing. They consider climate finance related to adaptation and mitigation a great opportunity for small-scale farmers.

4. Discussion and Conclusions

Overpopulation and climate change are among the greatest challenges the world faces. CSA provides an adequate answer by aiming for higher productivity, resilience, as well as GHG emission reduction. The majority of the farms are smallholdings, and their share is even larger in developing countries. Therefore, the importance of higher CSA adoption of small-scale farms cannot be overemphasized. For example, irrigation development in the SSA could generate 14–22 billion USD revenues a year and provide a better life to 113–329 million rural people [70]. This is only one CSA practice applied and in only one region.

The most important message of the 30 reviewed articles is the need for a case/site-specific approach due to the tremendous heterogeneity of small-scale farms. This is not only a regional issue as these differences occur even within a smaller geographical area of a country. The same applies to the agricultural policies, i.e., they should be targeted and flexible enough to provide opportunities to these various smallholdings. Moreover, the high risks and low returns of agricultural production make the smallholdings' situation worse. Dealing with these problems, complex and integrated CSA interventions are needed [54,64].

However, we should recognize the fact that small-scale farmers will never be driven by solely environmental reasons because farming provides most, or even all, of their income. Therefore, any implemented CSA elements should either contribute to their higher incomes or be supported by different policies. Due to the high share of small-scale farms, even a small climate/GHG-related step would have a strong positive global impact.

Based on the systematically analyzed articles, major findings on the adoption factors, constraints, and potential solutions for the most frequently applied CSA practices at the small-scale level are summarized in Table 2.

Table 2. Major characteristics of CSA adoption.

Major CSA Practices	Adopting Factors/Constraints	Potential Solutions	References
Water management, including irrigation	awareness, experience/skills, information, high costs-access to finance, labor-intensity	education, extension services, farmer friendly incentives, microfinancing, sorjan method	[6,23,40,41,52,54–57,60,65,66]
improved, more tolerant varieties	awareness, experience/skills, information, input accessibility	education, extension services, secured inputs, knowledge sharing	[23,41,43,51,52,54,56,62,66]
conservation agriculture	awareness, experience/skills, information, high costs-access to finance	education, extension services, policy incentives, farmer friendly incentives, microfinancing	[22,43,51,52,56,58,59]
integrated/mixed farming (e.g., crops-livestock)	awareness, experience/skills, information,	education, extension services, knowledge sharing	[44,52,56,61]
agroforestry	awareness, experience/skills, information,	education, extension services, policy incentives	[23,27,52,55,56,65]
crop rotation and diversification	experience/skills, information	education, extension services, knowledge sharing	[22,23,27,29,44,51,52,54,58,62]
climate information services	poor Internet, awareness and climate change perception	access to weather forecasts, knowledge sharing	[29,53,55,56,62,69]

From a productivity aspect, better water management and crop rotation seem to be the most frequently used, as well as advised, CSA methods. Both can significantly reduce unforeseen weather-related problems. Connected to this, access to and the use of climate information services are becoming more important. They would also make the simplest CSA methods easier to implement, such as optimal sowing and early harvesting. Moreover, timely access to the different inputs may also have a significant impact on agricultural production. However, sometimes off-farm activities are the only income sources for small-scale farmers.

Most of the CSA methods are both economically and environmentally beneficial, especially the combination of them. On-farm diversification is one of the most frequently used methods. However, these methods should be carefully adapted to the different climatic and geographical conditions, as they may not work in the same way everywhere. Inexpensive and labor-extensive methods are more popular, although higher incomes often offset higher production costs of the other CSA elements.

The common barriers of CSA adoption at the small-scale level are similar worldwide. They include the lack of education, skills, and knowledge; potentially high investment costs and delayed benefits; and uncertainties. Most of the constraints are often harder for women. It should be mentioned that sometimes the minimum requirement for farming is missing, the officially acknowledged land rights along with tenure security. Regarding smart farming, a fundamental requirement is having a stable and fast Internet. In general, off-farm income reduces the chances of CSA adoption. The analyzed literature provided solutions to these issues, like different forms of information sharing (education, extension services, knowledge sharing), financial instruments (microfinancing, different supports, farmer-friendly incentives), and finally, climate information services.

In general, simpler methods with low labor intensity are more often applied, however, combining CSA practices provide higher benefits [43,54]. Nevertheless, the length of the payback period can be a limiting factor [23,62]. Another potential option is land acquisition and/or the restoration of marginal lands [51,65], as land scarcity is one of the smallholdings' major problems. In addition to this, tenure and/or ownership uncertainties often overshadow land-use security [44,65].

Full-time farming is a serious commitment that positively influences CSA adoption [40,57]. The potential effects of off-farm incomes/activities were also frequently analyzed. Generally, this negatively impacts CSA adoption [27,29,40]. Although off-farm incomes provide an additional financial resource, they take labor away from agricultural production. It is clear that lack of financial resources is a significant barrier to CSA adoption, but financial security based on external resources may not necessarily lead to higher CSA adoption. In contrast, remittances may help to enhance agricultural production [57], and/or sometimes off-farm income is the only way to maintain farming activities [42]. Nevertheless, leaving the agricultural sector is also an option [27,56].

The major limitations of this study include the article selection method and the characteristics of the databases/information sources used. Although the major information sources were searched (ScienceDirect, Scopus, Web of Science, and Google Scholar), the use of further datasets would enhance this analysis. This article also excludes detailed overviews of the CSA-related approaches and/or methods, as well as the deep technical details of this system such as data collecting and processing, different devices, etc.

Regarding other potential directions, analyzing the challenges that farmers face with CSA use and its adoption in the developed countries (e.g., Australia, the Southern part of Europe, and the USA) would be interesting. There are huge differences among the countries in CSA adoption, it would be useful to analyze the reasons for this. Other, CSA-related approaches and/or methods can also be analyzed (SI, CA, PES, etc.). A policy-oriented assessment would be of interest as well. Moreover, CSA adoption by large-scale farms and the various implications of this on smallholdings would also be an exciting topic.

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References

1. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects 2019: Highlights*; United Nations: New York, NY, USA, 2019
2. Ayaz, M.; Ammad-Uddin, M.; Sharif, Z.; Mansour, A.; Aggoune, E.-H.M. Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk. *IEEE Access* **2019**, *7*, 129551–129583, doi:10.1109/ACCESS.2019.2932609.
3. IPCC. *Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*; Intergovernmental Panel on Climate Change: Geneva, Switzerland, 2019.
4. FAO. *"Climate-Smart" Agriculture. Policies, Practices and Financing for Food Security, Adaptation and Mitigation*; Food and Agriculture Organisation of the United Nations: Rome, Italy, 2010.
5. FAO. *Climate-Smart Agriculture Sourcebook*; Food and Agriculture Organisation of the United Nations: Rome, Italy, 2013.
6. Siedenburg, J.; Martin, A.; McGuire, S. The power of "farmer friendly" financial incentives to deliver climate smart agriculture: A critical data gap. *J. Integr. Environ. Sci.* **2012**, *9*, 201–217, doi:10.1080/1943815X.2012.748304.
7. Andrieu, N.; Howland, F.; Acosta-Alba, I.; Le Coq, J.-F.; Osorio-Garcia, A.M.; Martinez-Baron, D.; Gamba-Trimiño, C.; Loboguerrero, A.M.; Chia, E. Co-designing Climate-Smart Farming Systems with Local Stakeholders: A Methodological Framework for Achieving Large-Scale Change. *Front. Sustain. Food Syst.* **2019**, *3*, 37, doi:10.3389/fsufs.2019.00037.
8. Chandra, A.; McNamara, K.E.; Dargusch, P. Climate-smart agriculture: Perspectives and framings. *Clim. Policy* **2018**, *18*, 526–541, doi:10.1080/14693062.2017.1316968.
9. Campbell, B.M.; Thornton, P.; Zougmoré, R.; van Asten, P.; Lipper, L. Sustainable intensification: What is its role in climate smart agriculture? *Curr. Opin. Environ. Sustain.* **2014**, *8*, 39–43, doi:10.1016/j.cosust.2014.07.002.
10. Lipper, L.; Thornton, P.; Campbell, B.M.; Baedeker, T.; Braimoh, A.; Bwalya, M.; Caron, P.; Cattaneo, A.; Garrity, D.; Henry, K.; et al. Climate-smart agriculture for food security. *Nat. Clim. Chang.* **2014**, *4*, 1068–1072, doi:10.1038/NCLIMATE2437.
11. European Parliament, Directorate-General for Internal Policies. In *Precision Agriculture: An Opportunity for EU Farmers—Potential Support with the CAP 2014–2020*; European Parliament: Brussels, Belgium, 2014; doi:10.2861/58758.
12. Budaev, D.; Lada, A.; Simonova, E.; Skobelev, P.; Travin, V.; Yalovenko, O.; Voschuk, G.; Zhilyaev, A. Conceptual design of smart farming solution for precise agriculture. *Int. J. Des. Nat. Ecodyn.* **2018**, *13*, 307–314, doi:10.2495/DNE-V13-N3-307-314.
13. Mazzetto, F.; Gallo, R.; Sacco, P. Reflections and Methodological Proposals to Treat the Concept of "Information Precision" in Smart Agriculture Practices. *Sensors* **2020**, *20*, 2847, doi:10.3390/s20102847.
14. Regan, Á. 'Smart farming'in Ireland: A risk perception study with key governance actors. *NJAS Wagening. J. Life Sci.* **2019**, *90–91*, 100292, doi:10.1016/j.njas.2019.02.003.
15. Khatri-Chhetri, A.; Pant, A.; Aggarwal, P.K.; Vasireddy, V.V.; Yadav, A. Stakeholders prioritization of climate-smart agriculture interventions: Evaluation of a framework. *Agric. Syst.* **2019**, *174*, 23–31, doi:10.1016/j.agsy.2019.03.002.
16. Charania, I.; Li, X. Smart farming: Agriculture's shift from a labor intensive to technology native industry. *Internet Things* **2020**, *9*, 100142, doi:10.1016/j.iot.2019.100142.
17. Navarro, E.; Costa, N.; Pereira, A. A Systematic Review of IoT Solutions for Smart Farming. *Sensors* **2020**, *20*, 4231, doi:10.3390/s20154231.
18. Long, T.B.; Blok, V.; Coninx, I. Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: Evidence from the Netherlands, France, Switzerland and Italy. *J. Clean. Prod.* **2016**, *112*, 9–21, doi:10.1016/j.jclepro.2015.06.044.
19. Bogdanski, A. Integrated food–energy systems for climate-smart agriculture. *Agric. Food Secur.* **2012**, *1*, 9, doi:10.1186/2048-7010-1-9.
20. FAO. *The State of Food and Agriculture 2020. Overcoming Water Challenges in Agriculture*; Food and Agriculture Organisation of the United Nations: Rome, Italy, 2020; doi:10.4060/cb1447en.
21. Ng'ombe, J.N.; Tembo, M.C.; Masasi, B. "Are They Aware, and Why?" Bayesian Analysis of Predictors of Smallholder Farmers' Awareness of Climate Change and Its Risks to Agriculture. *Agronomy* **2020**, *10*, 376, doi:10.3390/agronomy10030376.
22. Abegunde, V.O.; Sibanda, M.; Obi, A. Mainstreaming Climate-Smart Agriculture in Small-Scale Farming Systems: A Holistic Nonparametric Applicability Assessment in South Africa. *Agriculture* **2020**, *10*, 52, doi:10.3390/agriculture10030052.
23. Sain, G.; Loboguerrero, A.M.; Corner-Dolloff, C.; Lizarazo, M.; Nowak, A.; Martínez-Barón, D.; Andrieu, N. Costs and benefits of climate-smart agriculture: The case of the Dry Corridor in Guatemala. *Agric. Syst.* **2017**, *151*, 163–173, doi:10.1016/j.agsy.2016.05.004.
24. Akrofi-Atitianti, F.; Ifejika Speranza, C.; Bockel, L.; Asare, R. Assessing Climate Smart Agriculture and Its Determinants of Practice in Ghana: A Case of the Cocoa Production System. *Land* **2018**, *7*, 30, doi:10.3390/land7010030.

25. Caffaro, F.; Cavallo, E. The Effects of Individual Variables, Farming System Characteristics and Perceived Barriers on Actual Use of Smart Farming Technologies: Evidence from the Piedmont Region, Northwestern Italy. *Agriculture* **2019**, *9*, 111, doi:10.3390/agriculture9050111.
26. Andrieu, N.; Sogoba, B.; Zougmore, R.; Howland, F.; Samake, O.; Bonilla-Findji, O.; Lizarazo, M.; Nowak, A.; Dembele, C.; Corner-Dolloff, C. Prioritizing investments for climate-smart agriculture: Lessons learned from Mali. *Agric. Syst.* **2017**, *154*, 13–24, doi:10.1016/j.agsy.2017.02.008.
27. Adhikari, S. Drought Impact and Adaptation Strategies in the Mid-Hill Farming System of Western Nepal. *Environments* **2018**, *5*, 101, doi:10.3390/environments5090101.
28. Imran, M.A.; Ali, A.; Ashfaq, M.; Hassan, S.; Culas, R.; Ma, C. Impact of Climate Smart Agriculture (CSA) Practices on Cotton Production and Livelihood of Farmers in Punjab, Pakistan. *Sustainability* **2018**, *10*, 2101, doi:10.3390/su10062101.
29. Abegunde, V.O.; Sibanda, M.; Obi, A. Determinants of the Adoption of Climate-Smart Agricultural Practices by Small-Scale Farming Households in King Cetshwayo District Municipality, South Africa. *Sustainability* **2020**, *12*, 195, doi:10.3390/su12010195.
30. Emerick, K.; de Janvry, A.; Sadoulet, E.; Dar, M. *Identifying Early Adopters, Enhancing Learning, and the Diffusion of Agricultural Technology*; Public Documents; World Bank: Washington, DC, USA, 2016.
31. Dedehayir, O.; Ortt, R.J.; Riverola, C.; Miralles, F. Innovators and early adopters in the diffusion of innovations: A literature review. *Digit. Disruptive Innov.* **2020**, *36*, 85–115, doi:10.1142/S1363919617400102.
32. Frattini, F.; Bianchi, M.; De Massis, A.; Sikimic, U. The role of early adopters in the diffusion of new products: Differences between platform and nonplatform innovations. *J. Prod. Innov. Manag.* **2013**, *31*, 466–488, doi:10.1111/jpim.12108.
33. Dinesh, D.; Aggarwal, P.; Khatri-Chhetri, A.; Rodríguez, A.M.L.; Mungai, C.; Sebastian, L.; Zougmore, R. The rise in Climate-Smart Agriculture strategies, policies, partnerships and investments across the globe. *Agric. Dev.* **2017**, *30*, 4–9.
34. Chandra, A.; McNamara, K.E.; Dargusch, P. The relevance of political ecology perspectives for smallholder Climate-Smart Agriculture: A review. *J. Political Ecol.* **2017**, *24*, 821–842, doi:10.2458/v24i1.20969.
35. Mzyece, A.; Ng'ombe, J.N. Does Crop Diversification Involve a Trade-Off Between Technical Efficiency and Income Stability for Rural Farmers? Evidence from Zambia. *Agronomy* **2020**, *10*, 1875, doi:10.3390/agronomy10121875.
36. Doshi, J.; Patel, T.; Bharti, S.K. Smart Farming using IoT, a solution for optimally monitoring farming conditions. *Procedia Comput. Sci.* **2019**, *160*, 746–751, doi:10.1016/j.procs.2019.11.016.
37. Pivoto, D.; Waquil, P.D.; Talamini, E.; Finocchio, C.P.S.; Dalla Corte, V.F.; de Vargas Mores, G. Scientific development of smart farming technologies and their application in Brazil. *Inf. Process. Agric.* **2018**, *5*, 21–32, doi:10.1016/j.inpa.2017.12.002.
38. Engel, S.; Muller, A. Payments for environmental services to promote "climate-smart agriculture"? Potential and challenges. *Agric. Econ.* **2016**, *47*, 173–184, doi:10.1111/agec.12307.
39. Fernández, F.J.; Blanco, M.; Ponce, R.D.; Vásquez-Lavín, F.; Roco, L. Implications of climate change for semi-arid dualistic agriculture: A case study in Central Chile. *Reg. Environ. Chang.* **2018**, *19*, 89–100, doi:10.1007/s10113-018-1380-0.
40. Mango, N.; Makate, C.; Tamene, L.; Mponela, P.; Ndengu, G. Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. *Land* **2018**, *7*, 49, doi:10.3390/land7020049.
41. Murray, U.; Gebremedhin, Z.; Brychkova, G.; Spillane, C. Smallholder farmers and climate smart agriculture: Technology and labor-productivity constraints amongst women smallholders in Malawi. *Gender Technol. Dev.* **2016**, *20*, 117–148, doi:10.1177/0971852416640639.
42. Hellin, J.; Fisher, E. Climate-smart agriculture and non-agricultural livelihood transformation. *Climate* **2019**, *7*, 48, doi:10.3390/cli7040048.
43. Branca, G.; Arslan, A.; Paolantonio, A.; Grewer, U.; Cattaneo, A.; Cavatassi, R.; Lipper, L.; Hillier, J.; Vetter, S. Assessing the economic and mitigation benefits of climate-smart agriculture and its implications for political economy: A case study in Southern Africa. *J. Clean. Prod.* **2021**, *285*, 125161, doi:10.1016/j.jclepro.2020.125161.
44. Nyasimi, M.; Kimeli, P.; Sayula, G.; Radeny, M.; Kinyangi, J.; Mungai, C. Adoption and Dissemination Pathways for Climate-Smart Agriculture Technologies and Practices for Climate-Resilient Livelihoods in Lushoto, Northeast Tanzania. *Climate* **2017**, *5*, 63, doi:10.3390/cli5030063.
45. Prestele, R.; Verburg, P.H. The overlooked spatial dimension of climate-smart agriculture. *Glob. Chang. Biol.* **2019**, *26*, 1045–1054, doi:10.1111/gcb.14940.
46. FAO. *Conservation Agriculture*; Food and Agriculture Organisation of the United Nations: Rome, Italy, 2015.
47. Giller, K.E.; Andersson, J.A.; Corbeels, M.; Kirkegaard, J.; Mortensen, D.; Erenstein, O.; Vanlauwe, B. Beyond conservation agriculture. *Front. Plant Sci.* **2015**, *6*, 870, doi:10.3389/fpls.2015.00870.
48. Harris, D.; Orr, A. Is rainfed agriculture really a pathway from poverty? *Agric. Syst.* **2014**, *123*, 84–96, doi:10.1016/j.agsy.2013.09.005.
49. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med.* **2009**, *6*, e1000097, doi:10.1371/journal.pmed1000097.
50. Martinez-Baron, D.; Orjuela, G.; Renzoni, G.; Rodríguez, A.M.L.; Prager, S.D. Small-scale farmers in a 1.5 C future: The importance of local social dynamics as an enabling factor for implementation and scaling of climate-smart agriculture. *Curr. Opin. Environ. Sustain.* **2018**, *31*, 112–119, doi:10.1016/j.cosust.2018.02.013.
51. Makate, C.; Makate, M.; Mango, N. Farm household typology and adoption of climate-smart agriculture practices in smallholder farming systems of southern Africa. *Afr. J. Sci. Technol. Innov. Dev.* **2018**, *10*, 421–439, doi:10.1080/20421338.2018.1471027.

52. Abegunde, V.O.; Sibanda, M.; Obi, A. The dynamics of climate change adaptation in Sub-Saharan Africa: A review of climate-smart agriculture among small-scale farmers. *Climate* **2019**, *7*, 132, doi:10.3390/cli7110132.
53. Setshedi, K.; Modirwa, S. Socio-economic characteristics influencing small-scale farmers' level of knowledge on climate-smart agriculture in mahikeng local municipality, North West province, South Africa. *S. Afr. J. Agric. Ext.* **2020**, *48*, 139–152, doi:10.17159/2413-3221/2020/v48n2a544.
54. Mutenje, M.J.; Farnworth, C.R.; Stirling, C.; Thierfelder, C.; Mupangwa, W.; Nyagumbo, I. A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecol. Econ.* **2019**, *163*, 126–137, doi:10.1016/j.ecolecon.2019.05.013.
55. Zougmoré, R.B.; Partey, S.T.; Ouédraogo, M.; Torquebiau, E.; Campbell, B.M. Facing climate variability in sub-Saharan Africa: Analysis of climate-smart agriculture opportunities to manage climate-related risks. *Cah. Agric.* **2018**, *27*, 34001, doi:10.1051/cagri/2018019.
56. Zougmoré, R.; Partey, S.; Ouédraogo, M.; Omitoyin, B.; Thomas, T.; Ayantunde, A.; Ericksen, P.; Said, M.; Jalloh, A. Toward climate-smart agriculture in West Africa: A review of climate change impacts, adaptation strategies and policy developments for the livestock, fishery and crop production sectors. *Agric. Food Secur.* **2016**, *5*, 1–16, doi:10.1186/s40066-016-0075-3.
57. Pilarova, T.; Bavorova, M.; Kandakov, A. Do farmer, household and farm characteristics influence the adoption of sustainable practices? The evidence from the Republic of Moldova. *Int. J. Agric. Sustain.* **2018**, *16*, 367–384, doi:10.1080/14735903.2018.1499244.
58. Arslan, A.; McCarthy, N.; Lipper, L.; Asfaw, S.; Cattaneo, A.; Kokwe, M. Climate smart agriculture? Assessing the adaptation implications in Zambia. *J. Agric. Econ.* **2015**, *66*, 753–780, doi:10.1111/1477-9552.12107.
59. McKune, S.; Poulsen, L.; Russo, S.; Devereux, T.; Faas, S.; McOmber, C.; Ryley, T. Reaching the end goal: Do interventions to improve climate information services lead to greater food security? *Clim. Risk Manag.* **2018**, *22*, 22–41, doi:10.1016/j.crm.2018.08.002.
60. Hasan, M.K.; Desiere, S.; D'Haese, M.; Kumar, L. Impact of climate-smart agriculture adoption on the food security of coastal farmers in Bangladesh. *Food Secur.* **2018**, *10*, 1073–1088, doi:10.1007/s12571-018-0824-1.
61. Lopez-Ridaura, S.; Frelat, R.; van Wijk, M.T.; Valbuena, D.; Krupnik, T.J.; Jat, M. Climate smart agriculture, farm household typologies and food security: An ex-ante assessment from Eastern India. *Agric. Syst.* **2018**, *159*, 57–68, doi:10.1016/j.agsy.2017.09.007.
62. Ruales, J.H.; Serino, M.N.V.; Ratilla, T.C.; Cuizon, J.G.; Enerlan, W.C. Investment appraisal of selected climate smart agricultural (CSA) practices among small scale coconut farmers in Leyte, Philippines. *Sci. Pap. Ser. Manag. Econ. Eng. Agric. Rural Dev.* **2020**, *20*, 499–506.
63. Alexander, S. What climate-smart agriculture means to members of the Global Alliance for climate-smart agriculture. *Future Food J. Food Agric. Soc.* **2019**, *7*, 21–30, doi:10.17170/kobra-2018122073.
64. Totin, E.; Segnon, A.C.; Schut, M.; Affognon, H.; Zougmoré, R.B.; Rosenstock, T.; Thornton, P.K. Institutional Perspectives of Climate-Smart Agriculture: A Systematic Literature Review. *Sustainability* **2018**, *10*, 1990, doi:10.3390/su10061990.
65. Zerssa, G.; Feyssa, D.; Kim, D.-G.; Eichler-Löbermann, B. Challenges of Smallholder Farming in Ethiopia and Opportunities by Adopting Climate-Smart Agriculture. *Agriculture* **2021**, *11*, 192, doi:10.3390/agriculture11030192.
66. Acevedo, M.; Pixley, K.; Zinyengere, N.; Meng, S.S.; Tufan, H.; Cichy, K.; Bizikova, L.; Isaacs, K.; Ghezzi-Kopel, K.; Porciello, J. A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. *Nat. Plants* **2020**, *6*, 1231–1241, doi:10.1038/s41477-020-00783-z.
67. Makate, C. Effective scaling of climate smart agriculture innovations in African smallholder agriculture: A review of approaches, policy and institutional strategy needs. *Environ. Sci. Policy* **2019**, *96*, 37–51, doi:10.1016/j.envsci.2019.01.014.
68. Tsige, M.; Synnevåg, G.; Aune, J.B. Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers. *Sci. Afr.* 2020, *7*, e00250, doi:10.1016/j.sciaf.2019.e00250.
69. Shahzad, M.F.; Abdulai, A. The heterogeneous effects of adoption of climate-smart agriculture on household welfare in Pakistan. *Appl. Econ.* **2021**, *53*, 1013–1038, doi:10.1080/00036846.2020.1820445.
70. Xie, H.; You, L.; Wielgosz, B.; Ringler, C. Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. *Agric. Water Manag.* **2014**, *131*, 183–193, doi:10.1016/j.agwat.2013.08.011.