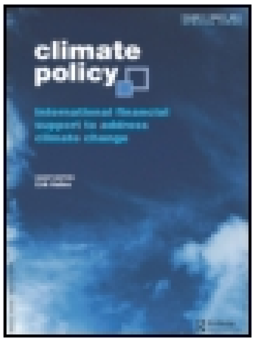


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SYNTHESIS ARTICLE

# Climate-smart agriculture: perspectives and framings

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**ABSTRACT**
This paper offers a systematic analysis of the concepts and contexts that frame the climate-smart agriculture (CSA) discourse in the academic and policy literature. Documents ($n = 113$) related to CSA and published in peer-reviewed journals, books, working papers, and scientific reports from 2004 to 2016 were reviewed. Three key trends emerged from the analysis: studies are biased towards global policy agendas; research focuses on scientific and technical issues; and the integration of mitigation, adaptation, and food security (the three pillars of CSA) is becoming a popular scholarly solution. Findings suggest that CSA is a fairly new concept used to describe a range of adaptation and mitigation practices without a specific set of criteria. Although CSA is often framed around the three pillars, the underlying issues constructing the discourse differ at global, developing, and developed country scales. Although there is increasing research on developing countries, particularly in relation to how CSA can transform smallholder agriculture, there is a paucity of research documenting the experiences from developed countries. The findings suggest that research on CSA needs to move beyond solely focussing on scientific approaches and only in certain geographical contexts. If CSA is to be applicable for farmers across the globe, then cross-disciplinary research that is underpinned by broad socio-economic and political contexts is essential to understand how differences in narratives might affect implementation on-the-ground in both developing and developed countries.

**Policy relevance**
Although policy makers are increasingly supportive of the climate-smart agriculture (CSA) approach, the rhetoric has largely been developed on the basis of scientific and technical arguments. The political implications of varying perspectives have resulted in a growing divide between how developing and developed countries frame solutions to the impacts of climate change on agriculture under the 2015 Paris Agreement. Different framings are part of the explanation for why the scope of CSA is being rethought, with the scientific community redirecting attention to seeking a separate work programme under the United Nations Framework Convention on Climate Change (UNFCCC). The current policy framing of CSA will give no new policy direction unless it grounds itself in the smallholder farmer and civil society contexts.

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**KEYWORDS**
Adaptation; climate-smart agriculture; farmer; food security; mitigation

## 1. Introduction

There is a clear signal from the scientific community that temperatures will increase globally due to climate change, and this is likely to adversely impact agricultural productivity significantly. Climate-smart is therefore being embraced globally as an approach to transform and protect the agriculture sector. Climate-smart agriculture (CSA) is defined as a strategy to address the challenges of climate change and food security by sustainably

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increasing productivity, bolstering resilience, reducing GHG emissions, and enhancing achievement of national food security and development goals (FAO, 2010). Policy imperatives for CSA include the need to increase food yields, feed a growing population of nine billion by 2050, mobilize investments to farmers and reduce GHG emissions (WB, 2010). Agriculture is the predominant economic industry in many countries, and is key to meeting basic needs and livelihoods for 70% of the world's poorest people (GCEC, 2014). Thus adaptation, mitigation, and food security (the three pillars of CSA) will have important implications for the world's poorest farmers.

In principle, CSA imperatives have much to offer beyond contributing to sustainable development goals at the local level. But numerous factors constrain the adoption and effectiveness of CSA policy. McCarthy, Lipper, and Branca (2011), for example, argue that there are institutional[1] barriers to the adoption and upscaling of CSA technologies and practices. CSA interventions are knowledge-intensive, location-specific, and require considerable capacity development (Neufeldt et al., 2013). Therefore, scholars suggest that upscaling participatory community-driven approaches to sustainable agriculture can engender equitable transformation of agriculture (Nagothu, Kolberg, & Stirling, 2016; Porter et al., 2014). Low-cost sustainable agriculture practices such as conservation agriculture, agro-ecology, ecosystem-based management, small-scale irrigation, agroforestry, soil/water conservation, and grazing land management have been implemented for decades (Lasco, Delfino, Catacutan, Simelton, & Wilson, 2014). Likewise, environmentalists are concerned about the weak participation of a broad range of actors in the global governance and knowledge co-production of CSA that currently promotes certain scientific and political ideologies (Ewbank, 2015). Overall, there are differences in how CSA is being framed, perceived, and discussed by actors at the global, developing, and developed country levels.

But how does the current literature reflect the diverse perspectives on CSA and what are the implications for framing the discourse in particular ways? Does the scientific literature offer any new solutions or does it simply rebrand existing agricultural development approaches as CSA? In this article, we aim to systematically review scientific and policy literature on CSA and report findings from three different geo-economic institutional scales: global, developing, and developed countries. More specifically, this synthesis examines the similarities, differences, and narratives that frame CSA between these three geo-economic groupings. These three scales are used to analyse CSA literature to reflect the recent globalization of agro-food systems and climate policy negotiations. This article provides a summary of key research and policy gaps, and the implications for CSA research and knowledge co-production.

## 2. Background: brief history of CSA

CSA represents a combination of practices that have historically been used in the environmental ecology, conservation, climate change, and agriculture fields. However, the relationship between agriculture and climate change is weakly understood, particularly the dual nature of the sector (i.e. agriculture systems are a major contributor to global anthropogenic GHG emissions and are simultaneously vulnerable to climate change shocks and stresses). By 2007, evidence on the dual relationship between climate change and agriculture became apparent through scientific assessments of the Intergovernmental Panel on Climate Change (IPCC) and policy reviews of development agencies. The nature and extent of the dual effect became clearer: agricultural systems are likely contributors to and are impacted by climate variability and change, with the majority of impacts being felt by developing countries. In particular, the IPCC (2007) concluded with a sense of global urgency that GHG emissions ($CH_4$ and $N_2O$) from agricultural lands were increasing and that 'there are interactions between mitigation and adaptation in the agricultural sector, which may occur simultaneously, but differ in their spatial and geographic characteristics' (p. 500). Given the limited progress made on mainstreaming climate change in the agriculture sector, the potential for integrated actions became imperative: new approaches were needed to transition to climate-resilient agricultural development.

The 2007–2008 global food crisis brought a surge of multiple issues impacting the productivity of agricultural systems in developing countries to the political level. For example, spikes in food and energy prices adversely affected low-income consumers and the poor (Beddington et al., 2012). Key food commodities such as rice, corn (maize), wheat, and soybeans experienced sharp increases, causing social and economic tensions in poor food-importing countries (Addison et al., 2011). Among market and trade barriers, internal/external drivers such as weak agricultural policies, rural development efforts, subsidies for biofuel, property rights and land tenure, crop failures from natural disasters and soil loss, were impacting the livelihoods of smallholder farmers and women in particular (UNDP, 2013). In a world of already declining food production, development agencies such as the United Nations Food and Agriculture Organization (FAO) and World Bank raised concerns that efforts to reduce poverty, especially for the rural poor were being undermined (FAO, 2010). It was also apparent from the 2007–2008 global food crisis that food security remained a volatile issue for the poorest, whereas resilience of agricultural production systems needed a new direction in developing countries to address the multiple interlinked challenges.

The need for more resilient systems, where agriculture is part of the solution to climate change, led the FAO and World Bank to formally develop CSA in 2010 (FAO, 2010) as an approach to guide the transformation of commercial and subsistence agricultural systems in developing countries – a major target group of multilateral donors. Recognizing the need to reconcile different emerging perceptions of CSA, the first global policy conference on the topic was held at The Hague, Netherlands (31 October–5 November 2010), organized by developing and developed country governments, along with the World Bank and FAO. Stakeholders representing governments, international and regional organizations, the private sector, NGOs, philanthropic foundations, and the scientific community met at this *Global Conference on Agriculture, Food Security and Climate Change* to develop a roadmap for action (Neufeldt et al., 2013). The *Roadmap for Action on Agriculture, Food Security and Climate Change*, endorsed by ministers, called for urgent actions that target the world's poor living in rural areas, particularly women farmers (WB, 2010). For the first time, the Roadmap recognized the interlinkages between agriculture, food security, and climate change at the ministerial level, and that integrated policies were needed for CSA.

To further develop the approach to, and partnership on, CSA, conferences were held in Vietnam (2012) and South Africa (2013). Successive science workshops were also held in the Netherlands (2011), USA (2013) and France (2015). In September 2014, during the UN Secretary-General's Climate Summit, the Global Alliance for CSA (GACSA) was launched with an emphasis on developing knowledge and coordinating global level collaboration (GACSA, 2015a). The global agenda on CSA has so far focussed on developing the knowledge base on what constitutes CSA and how partnering institutions could promote CSA imperatives.

The following sections of this article show the results of an analysis of the CSA discourse as perceived and practised at the global, developing and developed country levels through a review of relevant academic and policy literature.

## 3. Method

Systematic analysis is a rigorous research strategy used to investigate knowledge gaps, critical issues, and novel approaches. The method involves reviewing studies using formulated questions and explicit criteria to appraise relevant research (Nielsen & D'haen, 2014). The systematic review and qualitative analysis of data in this research was informed by methodologies for climate change literature reviews undertaken by Ford, Berrang-Ford, and Paterson (2011) and Thomas (2014). It was conducted between March 2015 and September 2016 and includes a range of relevant technical, policy and research materials covering theory and evidence on CSA. It was conducted in three stages: document selection, data analysis using Leximancer software, and manual coding of data and triangulation into narrative themes.

First, a review of existing scientific and policy literature on CSA was conducted to identify the range of peer-reviewed published academic materials available on the subject. Using information from the preliminary data, keywords and a set of inclusion and exclusion criteria were established for the selection of documents. The use of established criteria for screening the documents helped reduce bias in the selection and inclusion of studies, appraised the quality of studies, and provided an objective overview of emerging themes (Petticrew, 2001). The inclusion criteria for the selection of documents were:

- published documents that focused on answering CSA research questions, examining CSA theory, or providing evidence and policy from the developed, developing or global levels (e.g. journal articles, books (including chapters and booklets), working articles, reports);

- studies that addressed climate change or climate related impacts on smallholder agriculture (e.g. adaptation, mitigation, food security, and climate smart), and integrated options for the agriculture sector; and
- materials published between 2004 and 2016.

The exclusion criteria related to:

- documents focusing on crop production systems that are not integrated with smallholder mixed farm systems;
- unpublished materials and documents for which origins cannot be found or sourced through online databases (e.g. abstracts, presentations, conference papers);
- documents written in languages other than English; and
- documents outside the selected timeframe of publication.

The scope of studies and timeframe of published documents was necessary to understand the development of, and narratives underpinning, CSA. Documents were identified by searching online databases including ScienceDirect (Elsevier), Web of Science, Google Scholar, Springer Link, Wiley Online Library, and Climate Change, Agriculture and Food Security (CCAFS). The principle keyword search term was 'climate-smart agriculture' and five more search criteria were used to identify documents: 'smallholder', 'agriculture adaptation', 'agriculture mitigation', 'food security and climate-smart', and 'integration of mitigation and adaptation'. Only published research papers, technical reports, policy briefs and books were searched. The initial search retrieved 3754 documents, and all the publications were screened for keywords in the title, abstracts and introduction using the established criteria. The introduction of the selected publications was read to identify whether the study was a global overview or country case study. The category 'global' included documents that presented CSA data from the perspectives of a number of countries and regions (e.g. IPCC reports, world agriculture reports etc.). The category 'country case studies' included data and findings from a specific country, with the aim of providing detailed analysis of national and sub-national level CSA case studies from developing or developed countries. Documents from developing and developed countries were closely read and the final screening involved the selection of documents relevant to smallholder agriculture, focusing on mixed crop systems. For example, publications about production systems such as commercial livestock, fisheries, and large-scale forestry not integrated with smallholder farming systems were excluded. The final selection of 113 published documents was grouped into three folders: global, developing country, and developed country.

Second, the 113 documents were analysed using Leximancer$^{TM}$ Version 4. Leximancer is a data analysis tool used to extract themes, concepts, and ideas, thus relating contextual meaning and understanding to the analysis (Leximancer, 2016)). Leximancer software analyses text documents to identify the high-level concepts providing relationships of key ideas, themes, and summaries via interactive visualizations and data exports (Leximancer, 2016). The use of the software helped to reduce human bias in data coding, and analyse the CSA approach in the context of multiple factors in the literature. The software uses proximity in texts and word correlation to analyse large streams of qualitative data. The method of data analysis used in this research is further described in Thomas (2014). Clusters of texts producing a series of themes and summaries are produced in cloud visualizations of cognitive maps by the software. The cognitive map locates the proximity and relationship between the themes and concepts with similar meanings within the data sets using networks. The concepts were grouped according to their mutual relevance, with the size of the dots in the cognitive maps describing the frequency of the concept's appearance (Thomas, 2014). The software was directed to a minimum of four simulations, each time focusing separately on global, developing and developed countries data sets. Each analysis examined 20 concepts related to CSA per category: adaptation, barriers, capacity, crop, finance, food, gender, governance, institutional, integration, knowledge, market, mitigation, policy, production, resilience, security, technology, vulnerability, and yield. All the related concepts, except 'climate', 'smart', 'agriculture' and 'smallholder' (central concepts in all documents) were excluded in the mapping simulations. The three network map visualizations were 're-clustered' in the same themes ten times to ensure the software produced stable clusters of concepts (Thomas, 2014).

For the third component, the content of documents was analysed by manually coding and triangulating narrative data themes, contained in individual publications, as exemplified in the discussion of research results presented in this paper. Each of the cluster themes and their relationship to each other was explained using summaries extracted through Leximancer analysis. The Leximancer summary list provided brief characteristic text segments that illustrated the relationships between key concepts in the maps. The most important concepts (identified by number of connections, tag categories, concept profiles, and size of circle) were extracted from the summary analysis. The concepts were read alongside the respective publications to discover patterns, themes, and categories. The summaries were manually coded, synthesized, and elaborated using literature to identify themes on CSA, key ideas, patterns, and research gaps from the selected publications. Each publication was closely read and then coded, whereby sections of the document texts were manually matched with the appropriate codes. Coded text was then retrieved, evaluated, and compared with the cognitive maps to identify different narratives on and framing of CSA (Ford et al., 2011).

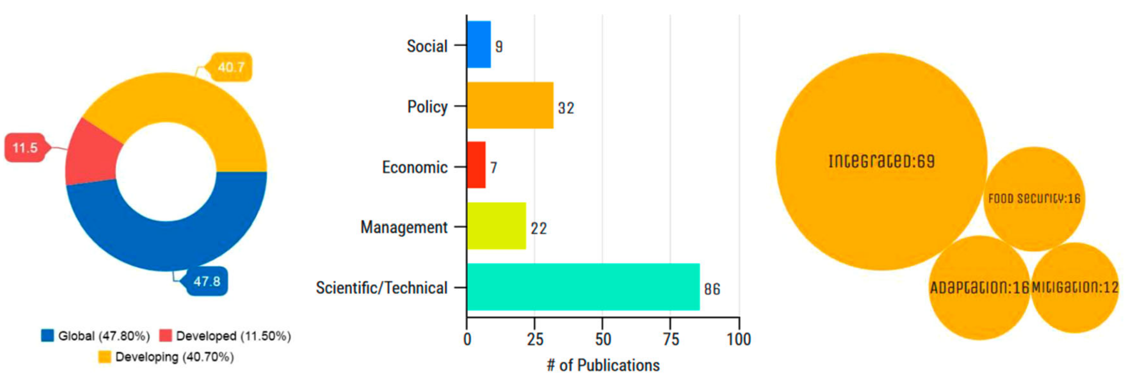
The data collection stage of the systematic review has some limitations. CSA is a broad approach and includes several sustainable agriculture practices. However, only publications making reference to CSA and the search criteria were included. The databases search was limited to only one keyword at a time, and initial screening was limited to titles and abstracts referring to CSA. Articles referring to adaptation and mitigation approaches in the agriculture sector relevant to CSA may have been overlooked.

## 4. Results and discussion

### *4.1. Overview of the CSA research agenda*

The systematic review analysed 113 documents, 54% of which ($n = 61$) were specific to CSA. Documents consisted of four types: 63 peer-reviewed papers published in academic journals, 11 books and book chapters, 21 published reports by development agencies, and 18 working papers. A summary of the publications according to the search criteria is provided in Supplementary Data D1. A full set of results and details of documents included in the data analysis grouped according to type and focus is provided in Supplementary Data D2.

Three key trends on CSA research emerge from the systematic analysis: a predominant focus on developing countries and generating global trends; a focus on scientific/technical issues; and a re-branding of sustainable agriculture practices (Figure 1(a)). First, most literature puts forward a global perspective. An increasing number of studies focuses on developing countries, recommending CSA as an alternative approach for agriculture (as discussed further in Section 4.3). 11.5% ($n = 13$) of the publications focused on developed countries (Figure 1(a)) or large-scale implementation of CSA. In many of the works, scientists have explained crop distribution and allocation, potential impact of global temperature change on crop yields and the challenges of




**1(a)** Study location **1(b)** Research focus **1(c)** CSA dimension

**Figure 1.** Systematic analysis of climate-smart agriculture literature grouped according to (a) location, (b) focus, and (c) pillar. (a) Reports percentages while (b) and (c) report actual values.

climate change integration in the developing country agriculture sector. Literature following the above-mentioned First Global Conference on Agriculture, Food Security, and Climate Change focused on establishing a global agenda for CSA. These studies originate mainly from the agriculture, development, and climate change institutions based in the northern hemisphere. For example, between 2013 and 2016, 19% ($n = 21$) of CSA specific research was published by the Consultative Group on International Agriculture Research (CGIAR)-CCAFS, based in Denmark. Within the developing country group, most studies were conducted in Africa, identifying CSA investment opportunities. Overall, studies from Latin America and Southeast Asia were limited. Where studies were conducted in Asia, most research focused on India and China.

Second, most studies focused on understanding the scientific and technical practices related to CSA (Figure 1(b)). 46% ($n = 52$) and 42% ($n = 47$) of the studies took place between 2011–2014 and 2015–2016 respectively. The short timeframe of research corresponds with key policy developments such as the launch of CSA by FAO (2010), and the UN Action on Agriculture and GACSA at the Climate Summit (2014). A focus of the Climate Summit was to encourage scientific development on CSA at global, regional, and national levels. Scientific partnerships such as CGIAR Research and Development and the Global Research Alliance on Agricultural Greenhouse Gases were launched to enhance research cooperation (UN, 2014). Few studies, however, examine the social, economic, and management dimensions of CSA. The overall lack of studies conducted by community-based and NGO programmes or available on online databases is striking. Few studies have integrated NGO perspectives; emerging NGO literature focuses on the policy implications of CSA, particularly for smallholder farmers, and the growing influence of the GACSA (e.g. Anderson, 2014; Aubert, Brun, & Treyer, 2015; GRAIN, 2015). Even fewer studies have examined the application and development of participatory tools for implementing and prioritizing CSA, the use of assessment frameworks and cost–benefit analysis of climate-smart farming practices.

Finally, the overall evaluation of studies in the systematic review finds a trend towards the rebranding of sustainable agriculture practices as climate-smart or integrated agriculture. Almost any crop and farm management technology and practice that contributes to food productivity, low inputs, land management, resource conservation (soil, water, and biodiversity), agroforestry, or agro-ecology is considered to be climate-smart (e.g. Bedmar Villanueva et al., 2016; Deng, Chen, Feng, Chen, & Zhang, 2016; Saravanan, 2013; Thierfelder, Rusinamhodzi, Setimela, Walker, & Eash, 2015). Crop and farm management technology and practices, although not explicitly mentioning climate benefits (adaptation or mitigation), were similar to studies on sustainable agriculture (e.g. Franks, 2014; Reidsma et al., 2015; Rockström et al., 2016). The focus of the reviewed CSA practices was mostly on commercial crops such as rice, wheat, and corn; few studies examined impacts on mixed vegetable cropping systems. In comparison, 61% of the publications classified on-farm practices as 'integrated' strategies (Figure 1(c)). Integrated strategies identified how the different dimensions of the three pillars of CSA interact or directly contribute to counter climate vulnerability and change.

### 4.2. What are climate-smart practices and technologies?

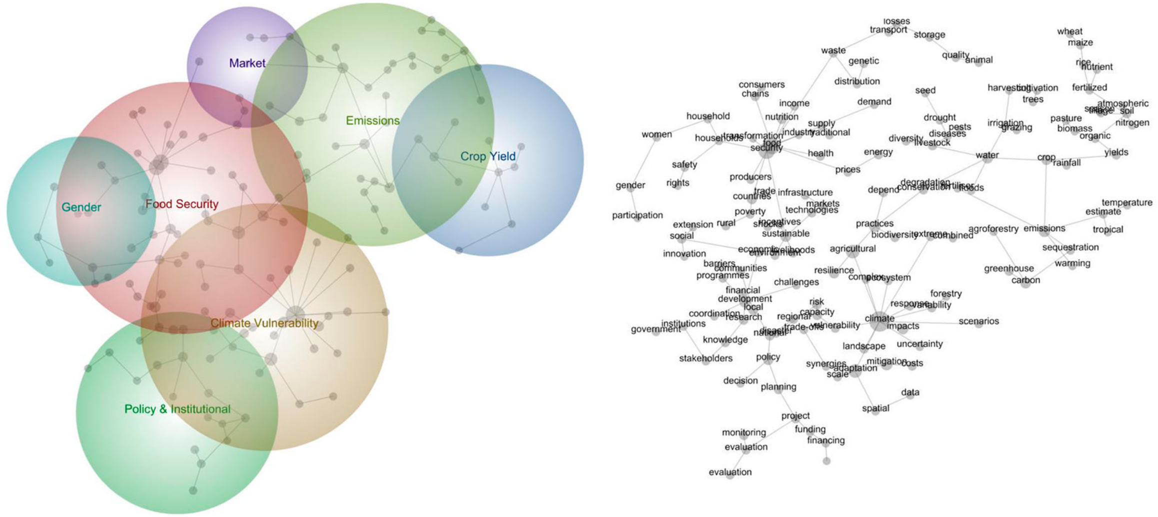
The assessed literature includes different definitions of CSA, along with different interpretations of CSA practices and integration of the three CSA pillars (see Supplementary Data D3). CSA practices described in the literature include diverse on-farm practices such as agronomy, agroforestry, livestock, forestry, land use, pastoral and grazing, water and soil management, and bioenergy (Bryan et al., 2013; Thorn, Friedman, Benz, Willis, & Petrokofsky, 2016). Similarly, the literature states that smart practices can provide policy directions for mainstreaming of climate change, health and nutritional benefits, finance, and infrastructure development (Dinesh et al., 2015; Harvey et al., 2014). In theory, CSA practices and technologies should address three core components: sustainably increasing productivity, supporting farmers' adaptation to climate change, and reducing levels of GHGs (Lipper et al., 2014). Critics point out that many agricultural practices are being 'rebranded' as climate-smart, although they may not actually be addressing climate change issues (Ewbank, 2015; GRAIN, 2015).

The early studies (2004–2010) assessed in this review indicate that 'smart' agricultural practices emphasized the adaptation dimension more than mitigation. Studies focused on the impacts of global warming on future crop yields, climate risk management (CRM), production enhancement activities and farm-level management adaptation responses. Crop modelling studies indicate adaptation benefits to major crops such as rice, wheat, and maize. They conclude that on-farm adaptation would lead to significant improvements to yield, avoiding damage for temperature increases of up to 1–2°C in temperate regions and up to 1.5–3°C in tropical regions (Howden et al., 2007). Most categories of adaptation practices are also reported to have positive impacts on mitigation by reducing GHG emissions, improving efficiency of nitrogen use, and increasing soil carbon storage (Rosenzweig & Tubiello, 2007). Several studies point to the need to include the growing emissions of the agriculture sector in GHG regulation systems (Branca, McCarthy, Lipper, & Jolejole, 2011; Camargo, Ryan, & Richard, 2013). However, mitigation options in agriculture were less likely to be profitable for smallholder farmers unless accompanied by strong economic support for adaptive capacity and demonstration (Smith & Olesen, 2010).

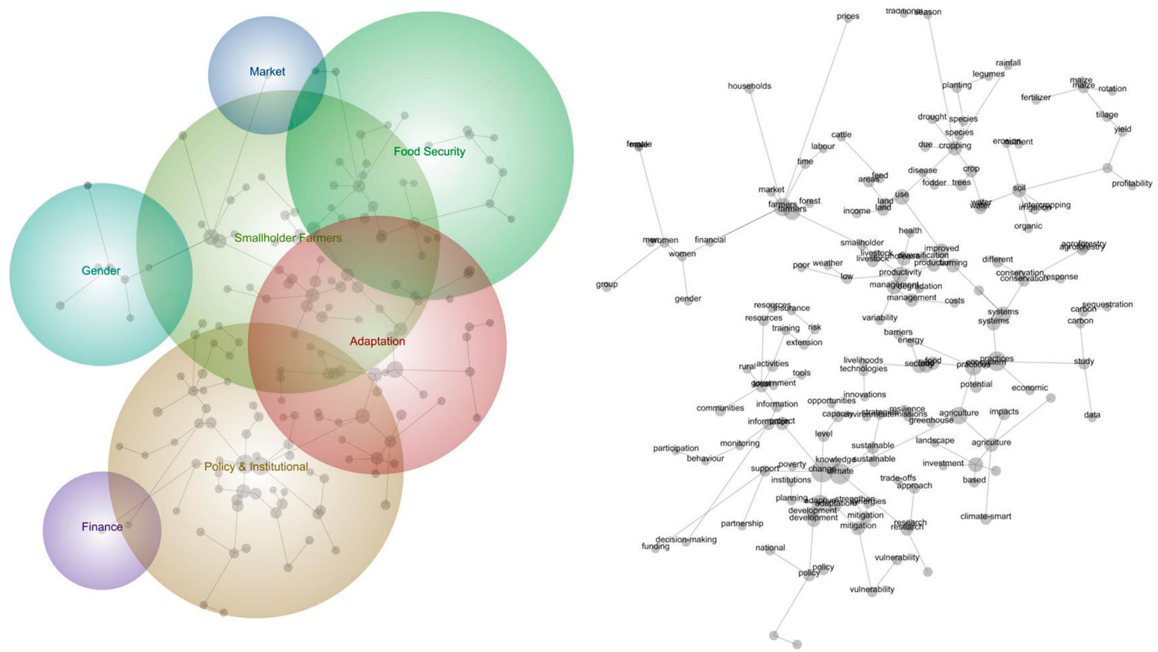
Wary of increasing GHG emissions, the integration of adaptation and mitigation practices in the agriculture sector has become a focus of scientific scrutiny. Scholars have proposed changes in farming systems to increase land-based mitigation from the agricultural sector, where soil carbon has highest returns to food security (e.g. Zanella et al., 2015). Furthermore, the IPCC assessment reports provide a discussion on important overlaps and non-linear interactions between food, water, land, and climate systems (Klein et al., 2007; Smith et al., 2007). These overlaps and inter-relationships become more apparent at landscape and farm levels (Falloon & Betts, 2010) involving potential *synergies* or *trade-offs* in the changes in production needed to meet food demand and reducing climate vulnerability and GHG emissions. Synergy is defined as 'the interaction of adaptation and mitigation so that their combined effect is greater than the sum of their effects if implemented separately' while trade-offs are 'a balancing of adaptation and mitigation when it is not possible to carry out both activities fully at the same time' (Klein et al., 2007, p. 749). Synergies between adaptation and mitigation in the agriculture sector have been studied in more detail by Smith and Olesen (2010). Synergistic adaptation and mitigation practices are the same farming practices and not necessarily a 'synergy' between different practices.

Following the IPCC recommendation of integrated strategies, CSA studies have begun an examination of synergistic practices in an attempt to increase the cost-effectiveness and efficiency of climate change actions. Studies conclude that CSA should involve an assessment of the optimal mixes of synergistic adaptation–mitigation practices (Lipper et al., 2014) that minimize negative trade-offs. Yet synergies and trade-offs between agri-food systems, climate change responses and development are interconnected and complex. Detailed knowledge of local social-ecological contexts and transformational processes (Thornton & Comberti, 2013) affecting the implementation of adaptation and mitigation practices within agrarian societies is limited. Studies emphasized that the context and scale of synergies and trade-offs affect the outcomes of CSA. Researchers recommend that the influence of spatial, temporal, and institutional contexts and scales should be further investigated in CSA implementation (Rosenzweig & Tubiello, 2007; Smith & Olesen, 2010). To date, the literature provides little empirical evidence on how different scales influence synergies and trade-offs in adaptation and mitigation farming practices.

Around the time when CSA was discussed as a means of agricultural transformation, the resilience agenda had gained resonance in the scientific community. Studies recommended that in addition to climate benefits, climate-resilient transformation pathways for agriculture should aim to integrate broader resiliency and development benefits at rural landscape levels. Suckall, Stringer, and Tompkins (2015) frame the development co-benefits of synergistic practices in the context of '*triple-win*' solutions. For example, irrigation and soil and water conservation solutions can provide improved livelihoods in addition to adaptation and mitigation in tropical and arid regions. *Co-benefits* in the context of CSA are described as additional benefits and positive side effects that can significantly increase the outcomes of CSA policies and practices (IPCC, 2007). These co-benefits can range from improved income, education, and nutrition to more diversified livelihood options (Wilbanks & Sathaye, 2007). The co-benefits approach to CSA is a multiple 'win-win' strategy and one that would require programmes to rethink agricultural landscapes within the food–water–energy nexus (Bogdanski, 2012; Rasul & Sharma, 2016; Scherr, Shames, & Friedman, 2012). Triple wins, synergies, and co-benefits of CSA, however, depend on scales and agro-ecological zones (Lipper et al., 2014). Although these concepts feature as common terms in the CSA literature, co-benefits in particular are under-recognized (Ürge-Vorsatz, Herrero, Dubash, & Lecocq, 2014) and there is limited evidence of its measurement or practical application in the agriculture sector.




**2(a)** Global level

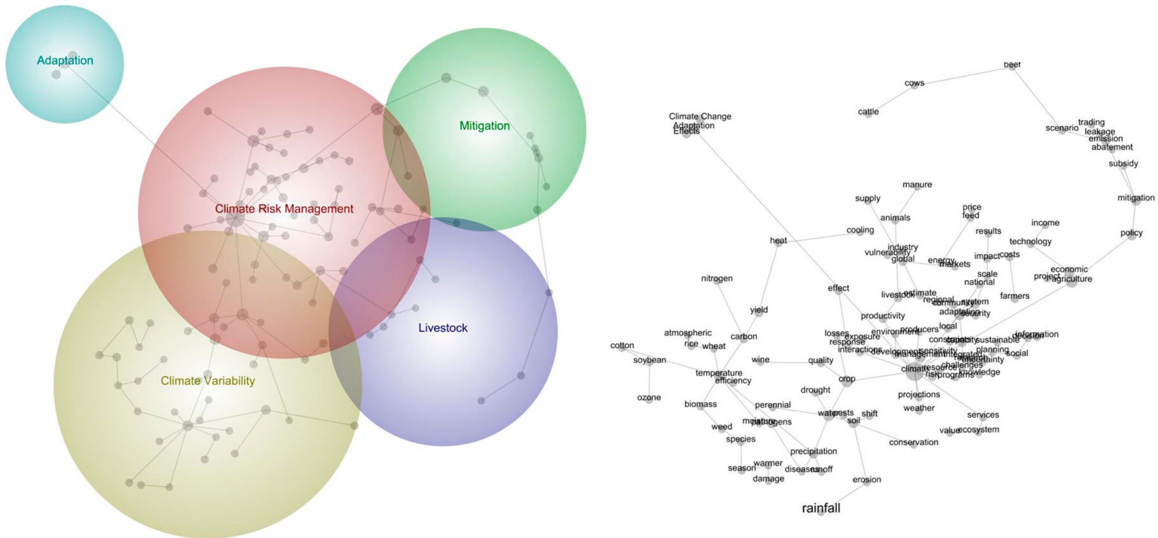



**2(b)** Developing countries

**Figure 2.** Leximancer analysis results showing cognitive maps on framings of CSA by (a) global agencies, and (b) developing and (c) developed countries. The figures on the left show the key concept of the framings and the one on the right shows their corresponding detailed network contents.

## 4.3. Similarities and differences in framing of CSA

Agro-food systems are strongly embedded within multiple scales (global–regional–national–local) and the interaction of contexts and scales can better inform the CSA concept. Cognitive maps in Figure 2 show how CSA is framed differently at the global, developing, and developed country scales. The circles represent the primary




2(c) Developed countries

**Figure 2.** *Continued.*

themes, while the concepts are represented by the dots. In this research, the cognitive maps are useful visual representations of the CSA discourse across the geo-economic institutional scales, that is, the global, developing and developed country contexts. The interconnected relationships between the themes and concepts show how agriculture will transition in the coming decades as a result of this non-linear web of factors underpinning the food-energy-climate change trilemma (see Harvey, 2014).

Two dominant themes underpin the CSA discourse: 'food security' and 'climate vulnerability'. In general, concepts that appeared similar to food security and climate vulnerability clustered together with emissions and crop yield themes. In relation to clustering, the resultant concept map also revealed some distinct thematic clusters conjoined by a common context at the global and developing country level: 'gender', 'market', and 'policy and institutional'. These three concepts are also poorly developed within the CSA literature, with most authors citing these areas as challenges to the discourse. Gender was commonly associated to 'rights', 'participation', 'women', 'finance', and 'women's group'. CSA factors relating to market changes included how transport influenced agricultural production (storage, quality, losses), how economic choices (supply, demand, consumer chains) influence CSA options, and how such decisions influence climate effects on the consumer chains. With respect to positioning of the agricultural sector for mitigation efforts, the cognitive maps revealed that the challenge is how 'market systems' can be used to achieve further reductions in GHG emissions without excessively burdening the smallholder farmers (developing) or compromising the economic competitiveness of agriculture trade (developed) whilst meeting the growing global food demand. This can be explained by 'market systems' closely associated with data-oriented concepts on agricultural mitigation financing: sequestration, technologies, farmers, energy, price, trading, income, labour, feed, demand, transport, and distribution.

The concepts and issues underpinning CSA mean a variety of things in the literature. There is a comprehensive difference in how CSA is interpreted depending on the context and the variation in the relative importance of mitigation, adaptation and food production. At the global scale, the analysis showed that CSA is framed around food security issues. Key underlying priority themes include 'climate vulnerability', 'increasing emissions', 'policy and institutional' and 'crop yield' (Figure 2(a)). For international development agencies, these are the core areas for funding, technical support, and capacity building. Climate impacts were closely related to 'uncertainties', 'complex system', 'risk', and 'vulnerability'. Uncertainties in climate projections are especially significant for how variability and change will affect commercial crop yields at the regional and (sub) national levels. Although yield reductions for most crops are likely under different climate scenarios, more recent scientific evidence suggests significant reductions in production under policy-relevant limits of 1.5°C and 2°C (Schleussner et al., 2016). Analysis also suggests that CSA research at the global level has largely focused on developing countries (about 47.8% of the sample documents, see Figure 1(a)) and the CSA concept post-2010 has largely been promoted as a research and action agenda for smallholder farmers, low-income agricultural producers and consumers.

Within the developing country cognitive map (Figure 2(b)), CSA is framed in the context of agricultural adaptation for smallholder farmers. Two issues favouring CSA are significant (Figure 2(b)). First, noting the relative sizes of the circles and concept dots, the map provides for the inductively generated conclusions that CSA priorities mostly relate to 'smallholder farmers', 'adaptation', 'food security', 'policy and institutional', 'gender', and to a lesser extent 'market' and 'finance' ramifications. 'Adaptation' (with the prospect of funding) as opposed to 'mitigation' has a role to play in helping the most vulnerable smallholder farmers in developing countries protect their farms and production systems from the negative effects of climate change. Second, financing for CSA in the world's poorest countries is closely associated with 'policy and institutional' factors, which include 'decision-making', 'partnership', 'participation', 'funding mechanisms', and 'national agenda'. A complex web of multiple institutional and decision-making arrangements generates different policy agenda and planning cycles, which are poorly coordinated to support integrated CSA strategies. A recurring issue in the literature and a likely key barrier to CSA funding, is the growing division between mitigation and adaptation strategies in national climate change policies.

In contrast, with the developed country cognitive map (Figure 2(c)) CSA is framed as CRM in the agriculture sector. Significant underlying concepts include 'climate variability', 'mitigation', and 'livestock'. The close proximity of CRM on the map represents its attachment and relationship to other themes and underlying concepts. Concepts underlying CRM included 'sensitivity', 'knowledge', 'research', 'programs', 'weather projections', and 'energy markets'. CRM is reflective of the advanced capacities of developed countries to plan and implement strategic approaches (e.g. scientific advances on climate projections, energy markets integrated with security issues). While there is an unbalanced emphasis on 'mitigation' of climate change in the agriculture sector in developed countries and at the global level, we find evidence of increasing climate impacts for the agriculture and water sectors. For example, 'crops' (e.g. rice, wheat, cotton, and soybean) were closely associated with 'drought', 'heat', 'water', 'pests', 'warmer season', 'weed', and even increasing 'losses'. Equally important to CRM, was the emphasis on 'emissions' (carbon and nitrogen) in the 'livestock' sector relating to 'manure' and 'cattle' (enteric fermentation). Distant to all other themes was the concept of 'adaptation' suggesting that mitigation remains a key priority policy in developed countries.

### *4.4. Dominant narratives informing CSA*

The CSA approach itself is not yet certain enough to convince policy makers and practitioners that mainstreaming of both adaptation and mitigation is prudent in the agriculture sector. A large part of this uncertainty stems from how the concept is being framed and perceived by different geo-economic scales and stakeholders. There are also other political reasons for inaction such as sensitivities relating to trade. While a number of transformations are discussed in the literature (e.g. green growth, sustainable development, resilient pathways, ecological modernization, low-emissions agriculture), content analysis indicates that the narrative 'sustainable intensification' has been used to describe a variety of practices, high-yielding technologies and socio-environmental outcomes, which have largely informed the CSA discourse (e.g. see Campbell et al., 2014; Lipper et al., 2014; Rockström et al., 2016). Sustainable intensification in agriculture has been stimulated by a sense of urgency or the 'doomsday' attitude to address the food security challenge under business-as-usual climate change scenarios (Steenwerth et al., 2014). Challenges such as growth in human population, modernization of agriculture that could 'feed the world' by 2050, food and financial crises (2007-mid-2008), and rising energy prices are cited as key motivations for transforming agriculture (Holt-Giménez & Altieri, 2013; Jordan & Davis, 2015; Tittonell, 2014). Although these crises have different underlying causes, they have become intertwined in complex ways with implications for the agriculture sector and the poor.

The CSA concept differentiates itself from sustainable intensification by focusing on the more efficient use of resources via a climate change lens (Lipper et al., 2014). CSA also presents itself as a renewed way to address the complex challenges associated with global climate change policies. For example, the concept was linked to increasing political momentum on agricultural adaptation and mitigation within negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) (Beddington et al., 2012; Dinesh et al., 2016). Finally, CSA is also described in the literature as going beyond sustainable intensification by encapsulating national development and sustainability agendas. For example, it has been persuasively argued by Campbell et al. (2014) that CSA can mobilize strong government interventions and public support for sustainable production patterns and food distribution systems.

### 4.5. Governance and knowledge co-production

In this section, we discuss underlying narratives critiquing the CSA concept, and identify shortcomings within its governance. There is a growing divide within the CSA discourse, as can be seen from the opposition to the approach from some NGOs. While scientific/technical scholarship appears to support the CSA concept, NGO policy-specific publications are critical and strongly oppose the approach. Of the reviewed documents, 7% ($n$ = 8) (all published by NGOs and community-based actors) are critical of CSA. Concerns include absence of performance criteria to distinguish CSA models from unsustainable ones, weak recognition of nutrition, justice and equality issues, lack of consideration of smallholder-specific issues, and lack of accountability of GACSA members to smallholders (CIDSE, 2015; Ewbank, 2015; GRAIN, 2015).[2] In developing countries, these concerns may be fuelled by the fact that mitigation burdens and costs may fall on small-scale and poorest farmers as a result of CSA (Neufeldt et al., 2013). Furthermore, Nagothu et al. (2016) argue that carbon markets generated due to CSA may serve the interests of the corporate sector while marginalizing smallholder farmers.

There is a specific lack of guidance on the attributes and performance criteria of CSA practices and models for small-scale farmers. Practices promoted by CSA such as agro-ecology, conservation agriculture, and ecosystem management are common in the agriculture literature. These are already practiced by smallholders, indigenous farmers, and community-based organizations and implemented as part of development programmes (Andersson & D'Souza, 2014). In the absence of 'smart' characteristics and tools, CSA does not provide an alternative scientific agenda to sustainable intensification. Without such clarity, unsustainable models of agriculture may likely be reinforced, justified, and re-branded as CSA. This risk is being expressed in the literature with reference to green-washing, new injections to commercial/industrial agriculture, capitalist intensive livestock, high value cropping systems, genetically-modified production systems, and biotechnology-infused farming (Aubert et al., 2015; Nagothu et al., 2016).

Furthermore, another critique of CSA is the lack of transparency and accountability in the governance of GACSA, especially how new institutional arrangements account for pre-existing agriculture practices and policy agreements (CIDSE, 2015). Lying at the heart of this concern is the argument that GACSA governance is highly unbalanced, mainly run by the large global agencies, and presumably excluding NGOs and smallholders. The GACSA, for instance, lacks a clear governance structure, thus favouring the engagement of 'wealthy governments', global actors, multilateral regimes, and international organizations over developing countries and national NGOs (Anderson, 2014). A broad coalition of global level institutions, including the FAO, World Bank, CGIAR, research centres, and multilateral agencies are currently supporting scientific research and policy on CSA for smallholder farmers in developing countries (GACSA, 2015b). Together these agencies form the GACSA, hosted by the FAO. The GACSA is fairly new, evolving, and has been further criticized for its lack of transparency and social and environmental safeguards (Aubert et al., 2015). As a result, as many as 360 NGOs and academic groups expressed concerns about the legitimacy of power within the GACSA and refused to take part in the GACSA when it was launched in September 2014 (Caron & Treyer, 2016). NGOs followed, with calls for decision makers to reject discussion of CSA within the UN processes relating to climate change and agriculture.

Interlinked with the previous argument is that knowledge produced on CSA is highly politicized and fails to sufficiently engage different NGOs and community-based organizations (Neufeldt et al., 2013). The GACSA has resulted in the formation of international knowledge networks consisting of global scientific bodies, coalitions and mandates. Examples include the Knowledge Action Group of the GACSA, and CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) supported by 15 Agricultural Research Centres (e.g. World Agroforestry Centre). The Knowledge Action Group of the Knowledge Action Group is convened by CCAFS, FAO and French Agricultural Research Centre for International Development or CIRAD. Powerful international agriculture research institutions exercise significant influence over scientific knowledge produced in these policy spaces that flow through trans-scalar networks of CSA affiliation present in the tropical belts of developing countries. These partnerships aim to advance global research agendas on CSA and can limit the degree to which NGOs can influence CSA research and policies.

Finally, narratives informing the CSA discourse are shaped by the geopolitical relations and power imbalances within its governance structure. Power relations between different geo-economic groups, combined with policy and advocacy work of the CGIAR consortium partners (e.g. Dinesh et al., 2016) transform scientific knowledge into institutionalized strategies, which ultimately influence how mitigation and adaptation actions are integrated across scales. While not diminishing the value of scientific knowledge being produced for improved technology and practices to sustainably transform agriculture, governance entities tasked with CSA need to re-think the 'participatory' nature and transparency in producing scientific knowledge. Issues such as characteristics of CSA practices, access to scientific knowledge, engagement of the private sector in the GACSA and lack of integration of smallholder concerns remain unresolved with the discourse.

### *4.6. Research and knowledge gaps*

The results of the analysis suggest that the CSA literature focuses on establishing the scientific and technical credibility of the discourse globally, and focuses to a lesser extent on research related to the social, policy, economic, and management domains. Ten broad priorities for future research emerge from our review, which are summarized in Supplementary Data D4. Future research needs to be localized to the scale of smallholder farms and community-based programmes. While this review analysed narratives informing CSA from the global, developing and developed country scales, research on concerns and priorities from a local scale or smallholder perspective is limited. The CSA discourse could benefit from including local narratives and the priorities of marginalized smallholder farmers (the ultimate beneficiaries of CSA). Key questions remain: how is CSA framed and practiced at the local level? What are the emerging concerns and narratives? How do smallholder farmers frame their priorities on CSA? How does that stack up with institutional decision making? Research on the local level can help differentiate the global narratives from the on-the-ground realities and experiences.

There is a smaller but growing literature on adaptation in smallholder landscapes (e.g. Lasco, Espaldon, & Habito, 2016; Simelton et al., 2013). However, many of the reviewed smallholder farmer case studies focus on 'on-farm' technical practices. Few studies have evaluated 'off-farm' activities (e.g. institutional arrangements, financial instruments, policies and knowledge), as well as the socio-economic dynamics of smallholder farmer resilience (e.g. Simelton, Fraser, Termansen, Forster, & Dougill, 2009). While there is a substantial body of work on what needs to happen for CSA to be useful to smallholder farmers, there is limited uptake of scientific evidence from existing experiences and successful examples from local scales. Empirical case studies on CSA and the practical application of integrated practices demonstrating triple-win benefits would be useful (Suckall et al., 2015). Key knowledge gaps include the synergies and trade-offs between adaptation, mitigation, and food security that are generated via smallholder and mixed-farm agriculture systems (Branca et al., 2011; FAO, 2010). Of importance is an investigation of the optimal mix of 'on-farm' practices and 'off-farm' adaptation and mitigation measures (Klein, Schipper, & Dessaid, 2005) that can support synergistic smallholder agriculture transformations.

## 5. Conclusion

Research on the relationships between climate change and agriculture has evolved into four multi-disciplinary agendas: science, management, economics, and policy. This systematic literature review has illustrated that while CSA is promoted as a multidisciplinary concept, on-going biases towards scientific and technical issues continue to affect how scholars position CSA at the global level. Much of the scientific attention is on farming practices, crop-based modelling, land management practices, and how farming practices can integrate the three pillars of CSA (i.e. adaptation, mitigation, and food security). Although there is sufficient scientific evidence and technical guidance to identify CSA options, social, management, and economic issues are poorly developed in the literature. In particular, research on gender, markets, broader landscape elements, and decision making to promote greater coherence, coordination, and integration of the CSA pillars is lacking.

The three CSA pillars operate at different geo-economic, institutional, and spatial scales. CSA is perceived differently by actors according to their political ideologies, and influenced by diverse funding arrangements, decision-making structures, and market and trade barriers. The relative importance of the CSA pillars varies depending on local narratives. The diversity of adaptation and mitigation approaches across different scales in the agriculture sector highlights the existing divide in the interpretation of CSA. Context, scale, and political ideologies all affect the outcomes of CSA, and a universal definition is therefore unlikely. Our argument is that if CSA is to achieve climate resilience and food security, it needs to integrate emerging narratives rather than operate around them (i.e. there is a no 'one size fits all' and CSA requires flexibility). The different narratives and political ideologies surrounding CSA need to be carefully understood and evaluated. In practice, this may be translated into adaptation-oriented, mitigation-oriented, gender-specific, and market-oriented CSA projects cutting across political scales. Another lesson is that there needs to more communication about what various communities of practice mean by CSA.

Despite the different narratives and orientations, there are important synergies and conflicts between the different CSA pillars. Pursuing different orientations would also involve trade-offs, which can favour one CSA pillar over another. Such trade-offs may result in budget re-allocations, diversion of resources, policy mandates, and organizational restructures that may support or constrain upscaling of CSA practices. In conclusion, projects introducing CSA to farmers as an alternative approach would need to closely consider the synergies, trade-offs, and co-benefits of livelihood and environmental outcomes. Optimal mixes of adaptation and mitigation interventions can ensure maximum socio-economic development co-benefits for smallholder farmers. With limited resources and competing food security priorities, creating an optimal mix of interventions can maximize synergies between the CSA components, while avoiding conflicting policies and negative trade-offs.

The governance of, and knowledge co-production on, CSA is underpinned by scalar relations, networks of power and affiliation of institutions framed by western ideologies of science and technology. CSA debates have been greatly influenced by development agencies like the World Bank and FAO given the weight of their influence. This has resulted in different interpretations of climate-smart practices with the aim of mobilizing new sources of climate finance in the agriculture sector. Knowledge co-production and a transformative CSA agenda, however, should aim to empower the most vulnerable and farmer networks first, rather than leading elite institutional agendas. Conventional top-down and scientific-led research should be complemented with the inclusion of non-experts and community-based organizations.

This review recommends that future research addresses the issue of scale, and account for differences in CSA narratives by supporting broad social participation. This obvious science-policy gap can be addressed through cross-disciplinary research agendas. The global scientific research agenda requires a re-direction of investments towards smallholder 'on-farm' and 'off-farm' realities. This includes the re-thinking of political and institutional dimensions of the CSA discourse, and can be achieved in part by strengthening the interface of the social, management, and economic dimensions of research through cross-disciplinary studies. Doing so would entail reforming existing patterns of knowledge production within CSA knowledge networks by involving farmer-led organizations, NGOs, and actors beyond elite development and research agencies.

## Notes

1. Institutions in this research are defined as the systems in place that give rise to rules, decision-making procedures, social and cultural practices, and the interactions among the formal and informal organizations of the relevant roles (Naess, Bang, Eriksen, & Vevatne, 2005).
2. The letter of concerns and reaction to CSA issued by more than 350 civil society organisations is available at: http://www.climatesmartagconcerns.info/

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