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Prioritizing climate-smart agriculture: An organizational and temporal review

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Abstract
Extant systematic literature reviews on the topic of climate smart agriculture (CSA) have mainly focused on two issues: reviewing framing of the CSA discourse in the academic and policy literature; and policy initiatives in the Global South that enhance the adoption of climate-smart agricultural practices. Yet, there is little systematic investigation into how international organizations can help smallholder farmers manage agricultural systems to respond to climate change. Analyzing these organization's priorities and highlighting their knowledge gaps are crucial for designing future pathways of CSA. We intend to use this article to identify overarching CSA themes that can guide large international organizations to focus their CSA agenda in the hope of achieving goals associated with food security and sustainable intensification. We specifically ask the following question: *How have the key CSA topics and themes emerged in the gray literature of international organizations between 2010 and 2020?* We adopted a topic modeling approach to identify how six international organizations engaged with several topics related to CSA. Following the Latent Dirichlet Allocation (LDA) approach, we identified eight topics in the documents, representing four overarching themes: gender research, weather and climate, CSA management and food security. We found that there is insufficient discussion on the issues relating to governance measures and gender mainstreaming, with a larger focus on techno-managerial measures of CSA. We conclude that research and training related to CSA must offer opportunities for marginalized and disproportionately vulnerable populations to participate and raise their voices and share innovative ideas at different levels of governance.

This article is categorized under:
Climate and Development > Social Justice and the Politics of Development
Vulnerability and Adaptation to Climate Change > Institutions for Adaptation

KEYWORDS
climate-smart agriculture, Global South, international organizations, topic modeling, triple-wins

1 | INTRODUCTION

Climate smart agriculture is defined by the Food and Agriculture Organization (FAO) of the United Nations as an approach that aims to tackle three main objectives: (a) sustainably enhance agricultural productivity and rural farm incomes; (b) enable adaptation and build resilience to climate change across different scales, from local to international; and (c) reduce and remove greenhouse gas emissions from food and agricultural activities (FAO, 2021). CSA intends to support and promote efforts across spatial scales, from the local to global levels for "sustainably using agricultural systems to achieve food security for all people at all times, integrating necessary adaptation and capturing potential mitigation" (Lipper et al., 2014, p. 1069). Thus, CSA provides an important overarching framework to achieve mitigation, adaptation, and sustainable food production across the world, particularly in least developed countries.

Extant research suggests that the effectiveness of CSA is linked to an enabling environment whereby institution and policies—that aim to increase food production and farmer livelihoods—can reorient agricultural systems vis-à-vis changing socio-climatic conditions. One policy area identified in need of urgent attention is CSA's supporting role for social equity. For instance, research suggests that most CSA approaches are gender-insensitive and their benefits are unequally realized by men, given male domination in receiving weather and climate information and extension services, as well as access to financial or other nonmonetary resources (Karlsson et al., 2018). As with numerous policies or project interventions whose *raison d'être* is responding to the climate crisis (Nightingale et al., 2020), CSA interventions' apolitical approach of facilitating triple-wins largely prioritizes technical fixes to climatic problems, thereby preserving power relations of the socio-political dimensions that animate transformations in the political economy of agriculture and mediate differentiated vulnerability to climate-related impacts (Newell & Taylor, 2018; Shilomboleni, 2018; Taylor, 2018). Without explicitly accounting for power interactions and processes within the governance arrangements (Chandra et al., 2017; Eriksen et al., 2019; Vij et al., 2019; Vij et al., 2021), CSA interventions often fall short of their mandate to facilitate "triple wins" for smallholders across its three dimensions: sustainable intensification, adaptation, and mitigation (Karlsson et al., 2018).

However, the three dimensions of CSA are unequally prioritized by nation-states and international organizations. Most organizations developing CSA initiatives in the Global South have prioritized adaptation over mitigation (Siedenburg et al., 2012). For instance, Saj et al. (2017) highlight that during the 2015 CSA conference—a flagship event for CSA practitioners—among the abstracts accepted in the conference program, there was disproportionately greater prevalence of the keyword "adaptation" over words such as "food security" and "mitigation." Even where mitigation was highlighted, it was often presented as a positive spillover of adaptation (Saj et al., 2017). With fewer indicators for monitoring progress or assessing the performance of CSA across all three dimensions, there is a risk that international organizations may be unable to help smallholder farmers fully realize CSA benefits (Cavanaugh et al., 2017; Newell et al., 2018; Taylor, 2018).

Over the last decade, systematic literature reviews on the topic of CSA have mainly focused on two issues: reviewing framing of the CSA discourse in the academic and policy literature (Chandra et al., 2018) and policy initiatives in the Global South that enhance the development and adoption of climate-smart agricultural practices (Totin et al., 2018; Zougmoré et al., 2016). Yet, there is little systematic investigation on how international organizations can help smallholder farmers manage agricultural systems to respond to climate change. Analyzing these organization's priorities and highlighting their knowledge gaps are crucial for designing future pathways of CSA that may be more sustainable and equitable. We intend to use this article to identify overarching CSA themes that can guide large international organizations to focus their CSA agenda in the hope of achieving goals associated with food security and sustainable intensification. We specifically ask the following question: *How have the key CSA topics and themes emerged in the gray literature of international organizations between 2010 and 2020?* We adopted a topic modeling approach to identify how six international organizations engaged with several topics related to CSA. Under this approach, an algorithm uses the distribution of words in all documents to identify patterns of word co-occurring that can be usefully combined into set of topics (Jacobi et al., 2016). By analyzing the documents and finding key topics, this article evaluates whether some organizations prefer topics related to CSA over others and how organizational priorities for CSA have changed since the concept emerged around the year 2010.

The topic modeling approach bridges the epistemological gap between quantitative and qualitative methodologies used in traditional systematic literature reviews and meta-analysis. We used topic modeling to extract keywords from the documents without imposing preselected categories or characteristics on the data. This deductive approach provided quantitative results in the form of keywords and phrases to highlight topics that are subsequently labeled qualitatively by the authors. We provide recommendations to the CSA implementation community by effectively combining several aspects of the CSA topics into themes that are more manageable for achieving positive outcomes for society and the environment. This analysis will further help them to understand the trend of CSA interventions and guide them to emphasize on the less-focused aspects of CSA. Our review provides a multi-country and international outlook of CSA initiatives from an organization's perspective.

The remainder of this article is organized as follows. The next section introduces the materials and methods used, by explaining the data collection process, the use of analytical methods and the limitations. This is followed by a presentation of the results, highlighting key topics identified from our data analysis. In the discussion section, we reflect on the key thematic gaps that organizations could address in the near future for implementing CSA. We highlight areas where CSA needs to take a more critical and reflexive turn by directly interrogating social power within the political economy of agrarian transformation to facilitate smallholders' empowerment in the Global South.

2 | MATERIALS AND METHODS

2.1 | Organizations included in the study

Our data collection strategy included documents from six international organizations, including the World Bank, the Food and Agriculture Organization of the United Nations (FAO), The International Fund for Agricultural Development (IFAD), Global Alliance for Climate-Smart Agriculture (GACSA), International Food Policy Research Institute (IFPRI) and the Consultative Group on International Agricultural Research (CGIAR) research program on Climate Change, Agriculture and Food Security (CCAFS). These six organizations are the global vanguard of CSA in terms of their financial support to the initiative and the geographical scope of their work that encompasses large swathes of countries in Africa, Asia, and South America. The World Bank and FAO are the pioneers of the CSA agenda. The former introduced CSA in its 2010 World Development Report: Development and Climate Change. In the same year, FAO organized a conference in the Hague, Netherlands where CSA was formally introduced to the international development community (Shilomboleni, 2020). Since 2018, the World Bank has individually pledged at least US$ 8 billion of its annual spending on agriculture to support CSA activities (Dinesh et al., 2017). The other four international organizations studied in this article also play a proactive role in the research and implementation of CSA in the Global South. In 2014, the Global Alliance for Climate Smart Agriculture (GACSA) was launched at the UN Climate Summit. GACSA has since brought together a coalition of over 450 members to support the scaling up of CSA activities around the world through knowledge exchange and learning platforms (GACSA, 2020). Similarly, CGIAR (through CCAFS), IFPRI, and IFAD continue to focus on research and practice with the goal to enhance synergies and reduce trade-offs between climate change, agriculture, rural livelihoods and food security. CSA is the newest research program of CGIAR developed to generate evidence-based approach to support adoption of climate-smart agricultural policies, practices, and services. Overall, these six international organizations together are at the forefront of CSA financing and research initiatives in the Global South.

2.2 | Data collection

The documents were collected using the search words “climate-smart agriculture” and “climate-smart” in each organization's publication and research portals (see Appendix A for the web address of each organization's publication portal). The search was conducted between March and June 2019. Only English language documents that mentioned “climate-smart agriculture” in the document title, abstract, or keywords were included in the study. A total of 382 documents were collected into a data repository, including policy documents, reports, training manuals, and books. Thirty-five (35) documents were assembled from the World Bank, 90 from FAO, 10 from GACSA, 56 from IFPRI, 28 from IFAD, and 163 from CCAFS. The data are presented in the extraction table, recording document titles, author(s) names, keywords, geographic scope, and publication year for each document (see Appendix B for the list of documents reviewed in this study).

2.3 | Analytical approach

The collection of documents was converted to text files and read into the R software package (R Core Team, 2018) to create a corpus. Then the paragraphs were tokenized, transformed to unigrams while keeping a record of the document

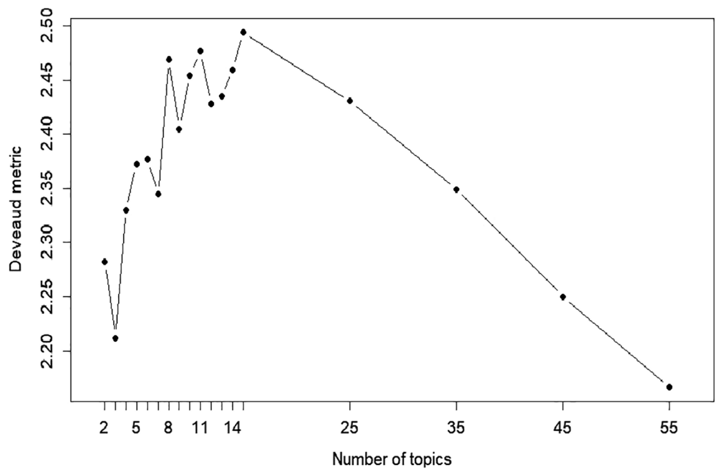

FIGURE 1 Selecting optimal number of topics

and organization's unique identifiers (IDs). Preprocessing of the data was done by converting all words to lower-case, removing stop-words, punctuation, numbers and also removing some words that are noise for our specific application such as "climate," "change," "smart," and "agriculture." To reduce the sparsity of the matrix created, we used the term's frequency-inverse document frequency (TF-IDF) method to further clean the data. The TF-IDF is a method that reflects the importance of a word in a document relative to a corpus. This numeric measure reflects how frequently the word occurs in a document, relative to its frequency in other documents within the corpus. For example, if the word occurred very frequently for a specific document (TF) but was not found in other documents (IDF), then it received a higher weight. In the same vein, if the word also occurred in other documents (IDF) then it received a lower weight. This method (TF-IDF) also helped alleviate the problem of having documents of different lengths. Using this method, we computed TF-IDF for each word in a document. Next, we computed the average TF-IDF for each organization (group). The words used by each international organization with TF-IDF values above the group average were included for further analysis, while those words that had TF-IDF less than the average were removed from the data. This process reduced the original 8834 unique words to 6789 words. Finally, words selected by TF-IDF were used for the remainder of the analysis.

To identify a set of topics in this collection of documents a probabilistic modeling approach commonly known as Latent Dirichlet Allocation (LDA) was employed. The algorithm was first proposed by Blei et al. (2003) and is used to find latent topics in the collection of documents among other applications. This model assumes that each document is a mixture of topics and a topic is a collection of words with probabilities attached to them. Therefore, the topic proportions will be specific to a document, but topics are shared by the whole collection of documents. The best fitting (optimal) number of topics in the data needs to be determined using a model selection criterion. Therefore, the LDA model was fitted with different number of topics ranging from 1 to 50, and several model selection methods were implemented in the R software package *ldatuning* (Nikita, 2016). Model selection methods, in general, try to find the best model fit and avoid overfitting. Out of the methods implemented by Nikita (2016), we used the Deveaud metric (Deveaud et al., 2014) to maximize the overall dissimilarity between topics and found the optimal number of topics by observing the point of inflection (Figure 1). The Deveaud metric was maximized somewhere between 8 and 22 topics. For ease of interpretation of the topics, we used eight as the optimal number of topics and fitted the LDA to find eight topics from the corpus. For validating our choice of selecting eight topics, we also generated keywords for models with fewer (5) and greater (10) number of topics. Appendix C shows that many important keywords were omitted from the results when five topics were selected. On the contrary, when 10 topics were generated, some topics were repeated more than once. Eight topics allowed us to create labels that were statistically robust and interpretively independent.

2.4 | Data analysis

We used LDA to classify and label the data. The model provided posterior probability distribution for topic-word and document-topic. The former was used to find the six most probable keywords in each topic and the latter was used to perform the time-trend analysis of topics by organization. Topics were labeled according to the six keywords. We used six keywords with the highest probability as they provide sufficient detail for labeling the topic without oversimplifying (with fewer keywords) or overcomplicating (with a greater number of keywords) the topic labeling process. The topic labels were finalized through an iterative process, whereby the authors deliberated over appropriate topic labels. Using the same iterative process, the eight topics were merged into four overarching themes. Based on their expertise in climate change adaptation and climate-smart agriculture, each author justified their choice of themes and ultimately reached consensus on four themes that integrated several topics.

2.5 | Limitations

There are at least five limitations associated with the methods used in this study. First, the time scale for data collected from each organization is asynchronous. For example, the time scale for IFAD ranges from 2010 to 2020, while CCAFS is from 2014 to 2020. The uneven time range is a result of some organizations (such as CCAFS) having none or a few (one or two) publications relevant to CSA in their organizational database before 2014. The temporal disparateness makes it difficult to simultaneously compare all organizations' priority topics for every year since 2010. Second, the inference made based on the LDA probabilistic model is as good as the representativeness of the data gathered. Third, the LDA is known to be affected by the length of documents in the corpus. Since the length of documents in the corpus varied, we partially mitigated this concern by using the TF-IDF method. Fourth, the labeling and merging of topics can introduce some subjectivity in this analysis. To overcome this concern, we allowed authors to freely exchange their topic labels and deliberate extensively on them to validate their preferences (Riddell, 2014). Fifth, the study only focused on primary organizations that initiated the CSA and currently have substantial investments and influence. Organizations such as UNDP are important to development initiatives but are excluded from the analysis, as these organizations are not primarily focused to achieve SDG 6 (water) and SDG13 (climate change).

3 | RESULTS

There are eight topics that we found dominant among the international organizations: soil carbon management, nutrition security for adaptation, water and irrigation, rice production, women and gender research, fisheries and adaptation, coffee and cocoa supply chains, and weather and climate. Figure 2 (below) shows the distribution frequency of the top six words in each topic. Each topic is characterized based on the keywords.

Figure 2 shows that "adaptation" is a recurring keyword across several topics (e.g., "soil management," "nutrition security," "fisheries," "weather and climate indicators") suggesting that it is an important dimension of the CSA framework for international organizations. Adaptation is also more likely to be integrated with other CSA topics, such as those pertaining to fisheries or weather and climate tools. On the contrary, the keyword "mitigation" is lacking presence in these documents. This is problematic especially because adaptation alone will not be sufficient for achieving resilience in agri-food systems. Among the six highest occurring keywords, "mitigation" is found in one of the eight topics: "soil management." Soil management practices such as reduced tillage and intercropping with cover crops, can increase soil organic carbon and at the same time reduce N_2O emissions linked to lower fertilizer use (Plaza-Bonilla et al., 2015). Therefore, these practices can increase carbon sinks and improve productivity for food production and security (McCarthy et al., 2012). The little integration of mitigation across these topics suggests that international organizations have been relating mitigation to soil management only, instead of building understanding of how mitigation can also become relevant for and through other topics, such as women and gender research.

Figure 2 also shows that organizations give more emphasis to technical and managerial CSA initiatives than to other softer or governance approaches to adaptation, mitigation, and food security. Keywords such as "seed" and "irrigation," as well as topics such as "soil management" and "weather and climate indicators," provide evidence for greater focus on technology over governance-related approaches to implementing CSA. A narrow focus on technical and managerial approaches, such as to enhance weather and climate forecasting capacity or to implement soil and water conservation practices expose individuals and communities to potential new opportunities, but also to new risks. For instance, knowledge of these services takes time to learn and can disproportionately benefit early adopters, who have more education or are younger or wealthier (Chandra et al., 2017). While IGOs and INGOs are continuously responding to ever-evolving social, political, economic, and environmental regimes, keywords and topics relevant to the

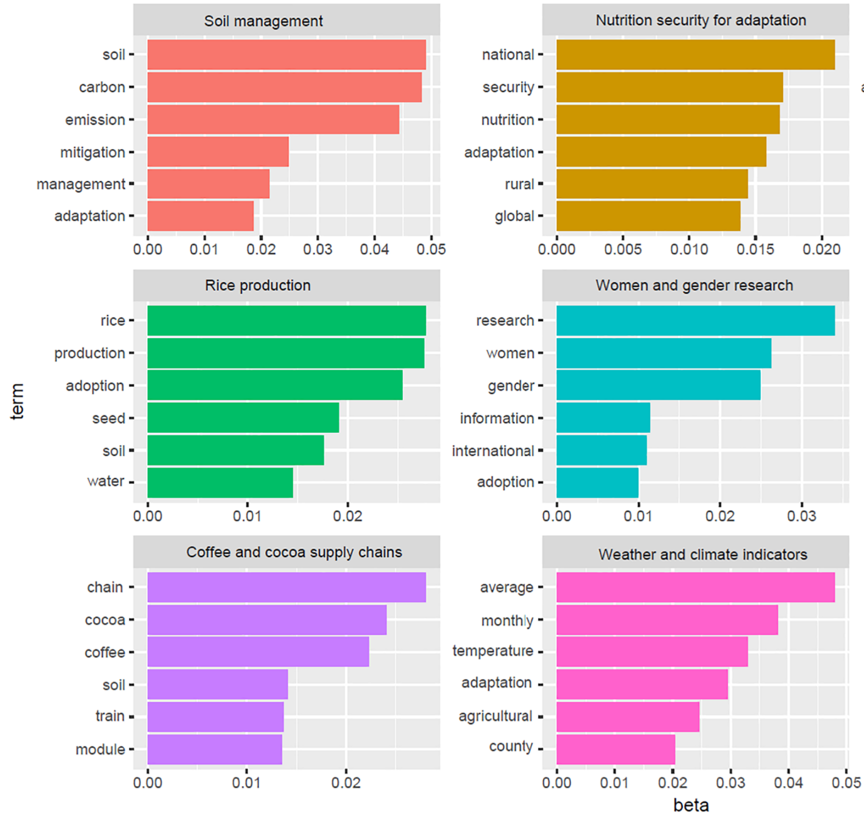

FIGURE 2 Top six words for each topic. The *x*-axis (beta) indicates the probability that a given word is assigned to a topic

role of governance arrangement and the social and political power that can perpetuate outcomes and processes of CSA among smallholder peasants are missing. The focus of the policy documents is on techno-managerial aspects of CSA, with very limited or no discussion on how to design and implement various governance arrangements for successful CSA. Moreover, results indicate that policy documents have limited emphasis on soft adaptation measures within CSA strategies. Keywords related to soft adaptation measures such as capacity building, technical training of women and small and marginal farmers are missing in the results emerging from the topic modeling (see Figure 2). The choice of keywords shows that as CSA is a relatively new topic in the domain of climate change and the focus remains on the testing of CSA technologies, little attention has been given to cultural and contextual aspects of agricultural research. On the contrary, organizations have focused on the keyword of water management and food security. This emphasis is possible due to two reasons. First, organizations such as the World Bank, FAO, and IFAD have been traditionally working on water issues and agriculture in the Global South. With investments in CSA, their previous technological advancements and financial portfolios have found a new outlet. Second, focusing on the keyword of water management and food security appeals for the 'triple wins' narrative, allowing the opportunity to reduce emissions (mitigation), enhance adaptive capacity (adaptation), and generate better income (development and food security).

"Women and gender research" is a standalone topic in the corpus of policy articles and documents published by international organizations (Figure 2). There is no keyword "gender" or "women" in other topics identified by the algorithm. This suggests that there is little evidence that policy actors including international organizations working on CSA are beginning to mainstream gender-responsive considerations into climate change adaptation and sustainable development interventions. Moreover, while climate change adaptation requires countries and international organizations to focus on gender equality by enhancing the adaptive capacity of marginalized social groups and individuals, our findings show that not all of the international organizations have discussed "gender" as part of their CSA initiatives. Figure 3 shows the frequency of topics emerging between 2010 and 2020 to determine how organizations have prioritized CSA topics. It shows that except CCAFS and IFPRI, organizations that have emphasized the interlinkages of gender and CSA have done intermittently or have started to do so only recently. For instance, IFAD's publications between 2010 and 2015 had lesser emphasis on gender, but interest in this topic has increased starting from year 2015. Sudden emphasis on gender issues in CSA can be linked to the signing of the 2015 UN Paris Agreement and discussion to

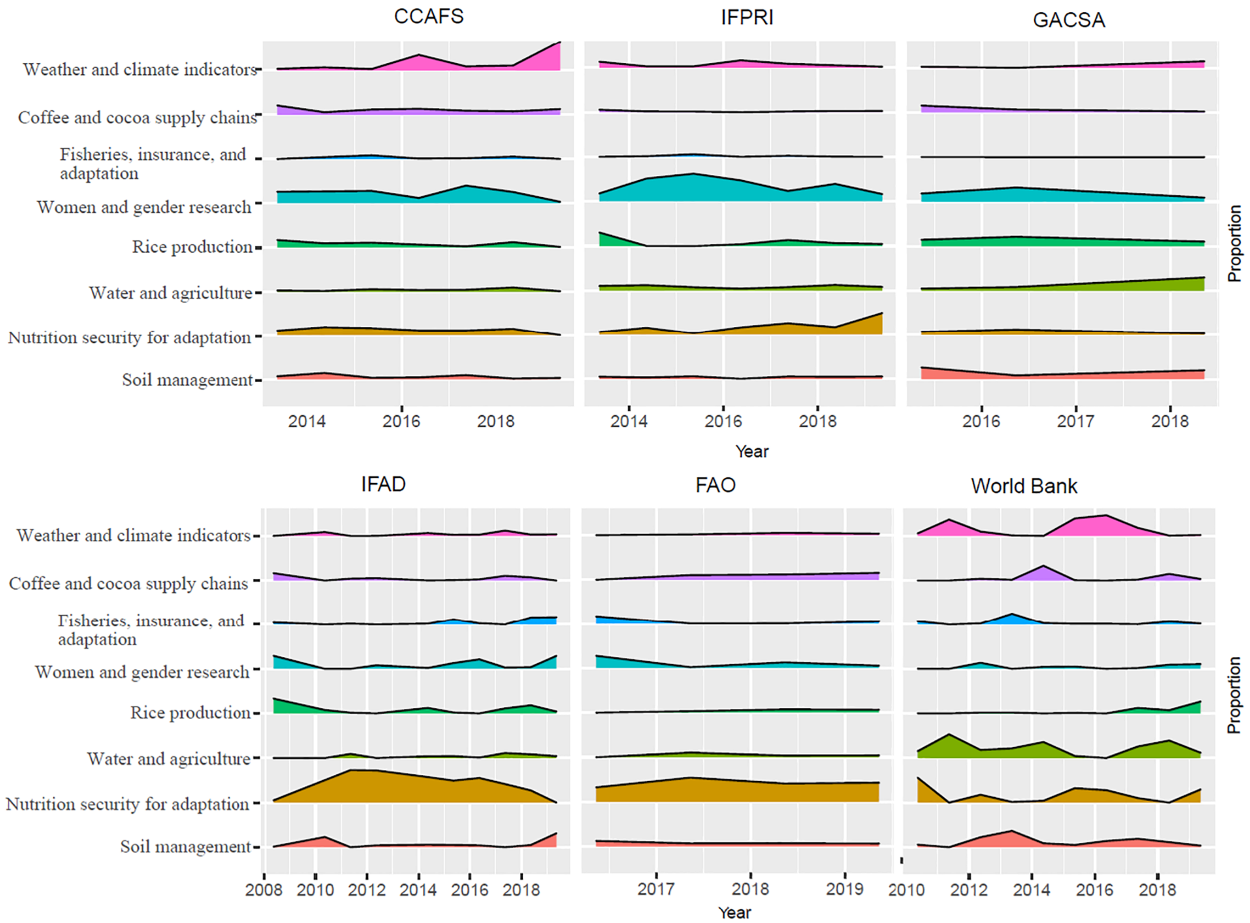

FIGURE 3 Climate smart agriculture topic time trends for six international organizations

incorporate gender issues in the forthcoming sixth assessment report of IPCC. Moreover, the UN Sustainable Development Goals have pushed the agenda of gender equality and awareness (SDG 5), especially in Asia and Africa.

4 | DISCUSSION: FUTURE CSA AGENDA FOR INTERNATIONAL ORGANIZATIONS

This study assessed the key CSA topics for organizations and how these topics have evolved since 2010. These reflections emerge from four cross-cutting themes that are deduced from the topic modeling (see Table 1). The four themes are: (1) Gender research, (2) Weather and climate for CSA, (3) CSA management, and (4) Food security. Table 1 provides a rationale for combining the eight topics into four themes. The theme "gender and adaptation" highlights how CSA may offer opportunities for reducing the gender-related vulnerabilities and inequalities while building adaptive capacity for women in the Global South. "Weather and climate for CSA" highlights how successful CSA initiatives that allow farmers to adapt to climate change and mitigate GHGs from food production practices are dependent on their timely access to accurate and usable weather and climate information services, such as temperature, rainfall, humidity, as well as the integration of this data with market and profit analysis (Wassie & Pauline, 2018). The third theme "CSA management" suggests that soil and water conservation mechanisms help increase carbon sinks, enhance mitigation, but also improve productivity for food production and security for nation-states (McCarthy et al., 2012). The fourth theme, "food security," marks that within the international development community of practitioners, there has been a strong desire to achieve food security for improving farmers' livelihood and nutrition through better food production practices. Based on these four themes, the next few paragraphs will discuss the three key reflections that are significant for the future of CSA activities in the Global South.

TABLE 1 Summary and description of themes and topics

Themes	Topics	Rationale
Gender research	"Women and gender research"	"Gender research" highlights that CSA could be implemented as an instrument for empowering women and reducing gender inequality in the Global South.
Weather and climate for CSA	"Weather and climate indicators"	CSA animates the importance of integrating weather and climate information with local scale or site-specific information for helping farmers adapt and mitigate climate change.
CSA management	"Soil carbon management," "Water and agriculture," "Rice production," "Fisheries and adaptation," "Coffee and cocoa supply chains"	Indicate the concerns and opportunities related to food and water security by encouraging soil and water conservation among farmers, irrigation and water management, and enhancing supply chain management.
Food security	Nutrition security	Highlights the importance of achieving food security through the implementation of the CSA agenda.

First, organizations may be focusing on gender as a separate priority topic or only concerning climate change adaptation. Keywords, such as "gender" or "women" can be found in some, but not all topics that we generated from LDA (see Figure 2). Mainstreaming gender into CSA approaches is vital not only for improving gender equality but essential for the successful adoption of CSA practices that may be vital for food security in the Global South (Nhat Lam Duyen et al., 2020; Paudyal et al., 2019; Teklewold et al., 2019). While climate change increases the vulnerability of smallholder farmers, the disproportionate impact on women is aggravated by a lack of access to labor, credit, assets, income, and markets (Ado et al., 2019; Chandra et al., 2018; Sultana, 2014). Yet, not only in policy documents of these organizations, but also in scientific literature, the analysis of gendered aspects of vulnerability or intersectional differences in CSA approaches received less attention (Khatri-Chhetri et al., 2020). Even fewer studies have examined how gendered power relations shape CSA practices and responses to inequalities in agriculture. For example, Eriksen et al. (2019) found that the implementation of CSA in Uganda reinforced existing power relations by making women more vulnerable to the social and political dimensions of climate-related impacts. It is essential to ensure that policies and institutions are made to improve access to the rights, entitlements, and information services, which could improve participation of women farmers in various CSA initiatives (Makate et al., 2019). The inclusion of gender dimensions in policy design has the potential to ensure equitable access to improve agricultural seed, farm implements, and precision agriculture technologies (Makate et al., 2019; Paudyal et al., 2019; Vij et al., 2019). Recognizing gendered power relations will be the first step to ensure meaningful participation in the design of policymaking processes of international organizations (Few et al., 2007). Gender sensitive design and implementation of CSA solutions can be achieved by considering the intersectional social differences, the nuances of gendered power relations and inequalities, and pre-existing vulnerabilities in the social fabric of communities. This would be best accomplished by allowing representatives of marginalized groups from the community to participate in the design, decision-making and implementation of the CSA projects and by enforcing their authority over such processes. Better synergies between other CSA topics and gender should highlight both possibilities and limitations of how the development of supply chains will impact farmers differently based on their gender identity, specifically with regards to their control over land and access to markets. Interaction between more productivist topics (e.g., "rice production") and gender should highlight how new technologies often tend to disproportionately favor more powerful local actors, often perpetuating local social hierarchies between men and women (Peterman et al., 2014).

Second, there is a need for CSA to go beyond narrowly focusing on technical and managerial approaches, such as climate information. Evidence from Africa and Pakistan suggests that smallholder farmers can potentially adapt to climate change with the aid of climate information services that provide short- and long-term weather and climate forecasts (Abid et al., 2015; Daly et al., 2016; Partey et al., 20202020; Vaughan et al., 2019). However, the access to climate information services is often determined by several socio-economic facets including gender of the farmer, access to technology devices (e.g., radio, television), and wealth and income (Oyekale, 2015; Zamasiya et al., 2017). For example, access to radio significantly increases probabilities of receiving climate information in East Africa (Oyekale, 2015). Furthermore, knowledge of these services takes time to learn and experiential learning is beneficial for early adopters (Chandra et al., 2017). For instance, climate-resiliency field schools in the Philippines guided farmers to access climate information and helped them use climate-smart practices for achieving location-specific recommendations that were knowledge-intensive and technically rigorous for their production processes (Chandra et al., 2017). New farmer field schools offer opportunities for the creation of new jobs and effective ways of delivering new knowledge. Yet again, women disproportionately lack access to the knowledge from CSA extension training (Duffy et al., 2020) which reinforces our argument on considering gendered power relations and inequalities in CSA approaches. Yet we also implore international organizations to elevate the status of local ecological knowledge, specifically that of marginalized community groups, and let this knowledge inform CSA processes at the local scale and the production of CSA knowledge products for global dissemination.

Organizations must explore CSA approaches that can blend knowledge of local users and weather and climate forecasts to help enhance ecosystem resiliency and social empowerment (Das & Ansari, 2021; Eakin, 1999; Folke et al., 2002; Makate, 2019). As an example, analyzing the ratio of correct and false forecasts, Gbangou et al. (2021) found that more than three local forecast knowledge indicators (e.g., wind, halo, and animal behavior) can even provide better forecast than scientific forecast systems. Farmers at the local level have often found seasonal climate forecasts (SCFs) to be too coarse to be relevant for decision-making (Masinde & Bagula, 2011; Nyadzi et al., 2019). Also, in remote locations, access to forecast-related information is limited (Mapfumo et al., 2016). Therefore, farmers often rely on traditional knowledge and local understandings of weather and climate (Birkenholtz, 2014). To this day, some but not sufficient efforts have been made to integrate traditional and local knowledge into SCFs (Gbangou et al., 2021; Nyadzi et al., 2021; Speranza et al., 2010). Furthermore, acknowledging the significance of local knowledge, some organizations have attempted to coalesce this expertise with forecast science to ensure resilience and adaptation (Dube et al., 2016; Kniveton et al., 2015; Patt et al., 2005). For instance, in Kenya, the Kenyan Meteorological Agency and indigenous communities formed strategic groups to blend traditional knowledge of "rainmakers" with western scientific knowledge on weather and climate forecasts. Both groups worked in tandem to validate and calibrate their forecasts and examined how efficacious their models were to respond to climate change impacts on agricultural productivity (Denton et al., 2014; Ziervogel & Opere, 2010). Lately, CGIAR is attempting a new approach-participatory integrated climate services for agriculture (PICSA) in several African countries. PICSA makes use of historical climate records, participatory decision-making tools and forecasts to help farmers identify and better plan livelihood options that are suited to local climate features and farmers' own circumstances. This approach has been widely found useful by the farmers (Dayamba et al., 2018). Despite these progresses, for IGOs and INGOs, it is important to increase the efficiencies of the integration of local knowledge into SCFs and identify and address the barriers and limitations of current practices.

It is known that the adaptive capacity of countries and communities to reduce vulnerability to climate change is dependent on structural inequalities and available assets and entitlements that are disproportionately distributed across axes of social difference (Brooks et al., 2005; Lemos et al., 2013; Ribot, 2014; Sultana, 2014; Taylor, 2015). Not every CSA response is consistent with food security and sustainable development and some actions may have unintended negative consequences on the well-being of certain members of communities. For example, in Vietnam, state-run programs that increased the likelihood of farmers to use irrigated rice agriculture reduced poor households' capacity to diversify their income portfolio for long-term adaptation (Beckman, 2011). Also, in Uganda, CSA activities risk reinforcing asymmetric power relations (i.e., elite capture) by selectively involving farmers with greater access to information (Eriksen et al., 2019). Lest CSA interventions reproduce social power relations that result in local injustices, it becomes important to explore how these organizations can more fully respond to changing structural vulnerability considered to be influenced by social, biophysical, economic, political, and technological context and processes (Dewulf, 2013). Centering the knowledge, expertise, and authority of these groups in the design, decision-making, and implementation of CSA projects may circumvent the elite capture that often plagues development interventions. Valorizing their work through remuneration, authority, co-authorship or co-ownership over project deliverables will be a necessary step toward a larger redistribution of power and resources.

Several researchers have examined the consequences of the development and use of CSA technologies and practices for local governments, communities, and peasants (e.g., Azadi et al., 2021, Chandra et al., 2017, Karlsson et al., 2018, Taylor, 2018). These concerns have ranged from lack of consideration of smallholder-related issues, gender, equity, and justice issues, including corporate greenwashing of CSA to the use of carbon markets to serve the interest of the privileged corporate sector actors (GRAIN, 2015). The most vocal critics of CSA include the NGOs and community-based actors, a few have even organized social movements to prevent various interest groups from joining the GACSA based on the concerns that it may represent interests and ideals of big agriculture corporations and underrepresented governments from the Global South (Nagothu et al., 2016). With regards to the production of knowledge, there are power asymmetries that are biased in favor of large international and transdisciplinary networks of large agricultural research institutions, such as the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). For example, local peasants' knowledge of agro-ecological cultivation methods now considered "climate-smart" is often sidelined or subsumed under the knowledge production processes of IGOs or INGOs whose "expert" authority is unquestioned (Daly & Dilling, 2019; Nightingale et al., 2020; Taylor, 2018; Vij et al., 2019). As discussed above, international organizations need to center and elevate local ecological knowledge and place equity at the heart of all CSA projects and processes.

This discussion identified several areas that need urgent attention and highlighted some ways in which the organizations can refocus priorities when implementing CSA. The findings from this study can advance our understanding of how a holistic understanding can lead to greater appreciation, understanding, and self-reflection at the organizational level about how climate change adaptation, mitigation, and food security could be concurrently prioritized and achieved to move beyond mere technical and managerial fixes and facilitate triple-wins for both farmer and nation-states. Overall, the three key insights suggest that research and training related to CSA must offer opportunities for marginalized and disproportionately vulnerable populations to participate and represent their perspectives and knowledge at the local level. It is important to ensure that knowledge flows two-way (i.e., agricultural scientist to farmer and farmer to agricultural scientist). The farmers' perspective and knowledge should not just be extracted, instead they should be integrated and CSA initiatives should be co-produced (Klenk et al., 2017). However, caution should be maintained during co-production because it can reinforce unequal power relations rather than mitigate it (Turnhout et al., 2020; Wyborn et al., 2019). All sound CSA interventions must be based on scientific data, integrating local knowledge, and should be sensitive to the local social milieu. We encourage IGOs and INGOs to continue research on the social and political dimensions of CSA to provide target populations with information or other kinds of services that are specific to their social advantage and disadvantage. Likewise, international organizations should be willing to receive and learn from information, techniques, and wisdom from local actors, especially those disproportionately vulnerable to climate-related impacts. Hence, international organizations must continue to research the relationships between mitigation, adaptation, and food security as they interact with CSA initiatives at the local level, albeit collaboratively with local actors. As opposed to universal theories of CSA design and standardized solutions, organizations should take an idiographic approach that goes "beyond technical fixes" (Nightingale et al., 2020, Vij et al., 2019). Priorities for research for IGOs and INGOs should include improving understandings of risks and benefits, trade-offs and synergies, and limitations of specific mitigation and adaptation options, along with issues of equity and ethics in achieving food security to facilitate CSA.

5 | CONCLUSIONS

This study examines how international organizations can help smallholder farmers manage agricultural systems to respond to climate change. Identifying these organization's priorities and highlighting their knowledge gaps in relation to CSA, enable us to recommend pathways for reorienting agricultural systems under changing socio-climatic conditions. Utilizing a topic modeling approach, we collected 382 of these organizations' documents from the years 2010–2020 and mined them for keywords by using term's frequency and its inverse document frequency method. We then distilled these keywords into topics for each organization through the LDA probabilistic modeling approach. Once topics were identified, we aggregated all topics into four overarching themes, including: (1) Gender research, (2) Weather and climate for CSA, (3) CSA management, and (4) Food security. These themes reflect trends of CSA globally and the priorities of organizations working to implement CSA interventions.

This review highlights several important findings. First, by revealing topic dynamics or shifts in topic over time, we were able to highlight three trends that are symptomatic of the organizations' changing and/or static priorities: (1) Not all international organizations have discussed "gender" in the context of their CSA initiatives; (2) most organizations have focused more on CSA management and food security as these have traditionally been part of their investment portfolios and research agendas, and (3) the focus of these organizations remain on the testing of CSA technologies, with scant attention to social and cultural aspects of agricultural research and practice. Second, by identifying themes based on their own documented inquiries and initiatives, this article presents organizations with an opportunity to reflect upon the priorities demonstrated by their knowledge products and initiated projects. It allows them to refocus priorities to begin addressing the sociopolitical inequalities and power asymmetries that presently undermine the pursuit of the triple-wins (adaptation, mitigation, and food security) in many CSA interventions. Facilitating triple-wins necessitates reflexivity and an iterative approach to CSA interventions aided by local knowledge. Knowledge is indeed power but let not the politics of knowledge in CSA reproduce asymmetrical social power. International development organizations must design power-sensitive approaches to climate-smart agriculture. Future research should examine CSA reports that are published by national and sub-national governments and nonprofit organizations in the Global South. Such cross-sectoral and cross-organizational comparison would be useful to contribute to CSA's theoretical and empirical debates that are sensitive to local socio-political and cultural contexts in the countries and regions under study.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Maaz Gardezi: Conceptualization (lead); data curation (supporting); formal analysis (equal); investigation (lead); methodology (lead); project administration (lead); supervision (lead); validation (supporting); visualization (supporting); writing – original draft (lead); writing – review and editing (lead). **Semhar Michael:** Data curation (equal); formal analysis (equal); investigation (supporting); methodology (supporting); validation (lead); visualization (lead); writing – review and editing (supporting). **Ryan Stock:** Conceptualization (equal); formal analysis (supporting); investigation (equal); methodology (supporting); writing – original draft (equal); writing – review and editing (equal). **Sumit Vij:** Conceptualization (equal); formal analysis (supporting); investigation (supporting); methodology (equal); writing – original draft (supporting); writing – review and editing (equal). **Ayorinde Ogunyiola:** Data curation (lead); investigation (supporting); methodology (equal); writing – original draft (supporting); writing – review and editing (supporting). **Asif Ishtiaque:** Conceptualization (supporting); investigation (supporting); methodology (supporting); writing – original draft (supporting); writing – review and editing (supporting).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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