



A Changing Climate for Knowledge Generation in Agriculture: Lessons to Institutionalize Science-Policy Engagement

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Effective science-policy engagement efforts are crucial to accelerate climate action. Such efforts should be underpinned by high-quality knowledge generation that enhances salience, credibility and legitimacy of research results. This is particularly important for the agricultural sector. Agriculture has been identified as a priority for climate action. The sector also constitutes well-established institutions set up to help achieve food and nutrition security. Institutionalizing high quality knowledge generation for climate change adaptation within these institutions presents a major opportunity to catalyze climate action within the sector. To contribute to insights about this institutionalization, we draw on and develop Cash et al.'s 2002 success conditions for enhancing salience, credibility and legitimacy: (1) increased accountability, (2) use of boundary objects, (3) participation across the boundary, (4) mediation and a selectively permeable boundary, (5) translation, and (6) coordination and complementary expertise. We examine how these success conditions apply in a major global case of agricultural research for development under climate change: the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). We explore these success conditions in the wider context of CGIAR reform and response to climate change as the international system for Agricultural Research for Development (AR4D). Our results specify and confirm the practical relevance of the six success conditions for institutional design and reform, but also point to the need to complement these with two inductively-derived success conditions: effective leadership and presence of incentives. To institutionalize these success conditions among AR4D institutions, there is an urgent need to create a conducive environment that enables the development of context-specific science-policy engagement strategies, along with leadership development and efforts to break traditional disciplinary silos which constrain user-oriented knowledge production.

Keywords: science-policy interfaces, climate change, institutions, knowledge generation, research management, climate change adaptation, agricultural research for development

INTRODUCTION

In its special report on Climate Change and Land, the Intergovernmental Panel on Climate Change (IPCC) has said that food security has been affected adversely by climate change and future food security is at risk from a warming climate (IPCC, 2019). Meanwhile, the report also highlights the opportunities for land-based actions to combat climate change and the need to accelerate knowledge transfer (IPCC, 2019). In 2015, countries submitted their Nationally Determined Contributions (NDCs), which form the basis of the Paris Climate Agreement intended to keep global warming to <2 degree Celsius. These NDCs overwhelmingly prioritize agriculture as a sector for adaptation and mitigation actions (Richards et al., 2016; Strohmaier et al., 2016). One hundred and thirty-one countries have indicated adaptation in the agriculture sector to be a priority (Strohmaier et al., 2016). Among developing countries, this priority is all the more distinct, with 93% of developing countries prioritizing adaptation in the agricultural sector (Strohmaier et al., 2016). These priorities include actions pertaining to crops, livestock, fisheries and aquaculture, irrigation, water, knowledge transfer, diversification, soils, early warning systems, agroforestry, indigenous knowledge, financial mechanisms etc. (Richards et al., 2015), indicating that virtually all agricultural activities are at risk due to climate change.

In the context of climate change, many agree that new models of knowledge production with an emphasis on generation of societal outcomes are needed (Cash et al., 2003; Sayer and Cassman, 2013; Kläy et al., 2015; Popa et al., 2015; Van Der Hel, 2016; Dinesh et al., 2018). Such models will be crucial for adaptation in the agricultural sector, to enable countries to translate priorities set out in their NDCs into tangible actions which benefit rural communities. However, efforts to facilitate adoption of such actions at scale are affected by a number of factors. These include the enabling policy environment, institutional coordination and capacity, engagement among different stakeholders, research and development systems, and market development (Lybbert and Sumner, 2012; Biagini et al., 2014; Long et al., 2016; IPCC, 2019). Therefore, new models of knowledge production need to be developed, not only at the level of individual researchers or research projects, but also to be institutionalized to effectively address systemic limitations. In global environmental governance, the development of new institutions as well as the redesigning of existing institutions is a prominent need (Biermann, 2007; Young et al., 2008). Within the agricultural sector, experts have called for efforts to significantly change the approach to Agricultural Research for Development (AR4D) and to design transdisciplinary innovation ecosystems (Meinke et al., 2006; Barrett et al., 2020; Herrero et al., 2020; Steiner et al., 2020).

Global investment in agricultural research for development is significant. The World Bank has estimated that around USD 56 billion was spent on agricultural research and development in 2011 (Fuglie et al., 2020). Collectively over almost 50 years (1962–2011), it is estimated that over USD 1.1 trillion has been spent on public agricultural research and development alone (Fuglie, 2017). Ensuring that the significant public resources

devoted to AR4D enable climate action in the sector therefore provides an opportunity to deliver enhanced societal outcomes from these investments. Among institutions developed for agricultural research and development, the CGIAR, originally the Consultative Group for International Agriculture Research (CGIAR), is a key player as the network of international agriculture research centers (Pingali and Kelley, 2007; Ozgediz, 2012), which invested USD 824 million in agricultural research and development in 2018, and about USD 60 billion over the past five decades in present value terms (Alston et al., 2020). The CGIAR's focus on smallholder farmers in the global South—most often at the frontline of climate change impacts—makes it a key institution for adaptation in the agriculture sector, and Bill Gates, Co-Chair of the Global Commission on Adaptation and the Bill and Melinda Gates Foundation said, “for poor country farmers, the CGIAR system is the only hope we have” (Gates, 2019).

There is growing recognition within the CGIAR of the impacts of climate change on its clientele (smallholder farming communities), and **Table 1** outlines the evolution of climate change research within the CGIAR in the context of wider reforms. In this context, studying and improving the CGIAR's knowledge generation models in relation to climate change offers an opportunity to identify best practice for institutionalization, and thereby enable the sector as a whole to more effectively support adaptation actions. As the international system for agricultural research, the CGIAR reform process has attracted the attention of various scholars (Mccalla, 2014, 2017; Kamanda et al., 2017; Leeuwis et al., 2018; Byerlee and Lynam, 2020), and in addition to scholarly research, the reforms have also been reviewed by leading international experts as part of CGIAR's evaluation processes (Beddington et al., 2014; Birner and Byerlee, 2016). While Byerlee and Lynam (2020) have argued that the formation of the CGIAR is “the major institutional innovation of the 20th century for foreign assistance to agriculture,” they note that in order to retain its leadership, longstanding organizational and funding issues will need to be resolved (Byerlee and Lynam, 2020). While the reform process brought greater impact orientation and coordination, it has also been critiqued for governance ambiguities, prioritization of research, transaction costs and research quality (Leeuwis et al., 2018). The challenges of institutionalizing new approaches to research within the CGIAR has also been noted (Douthwaite et al., 2017).

Over the past decade, climate change efforts within the CGIAR have been led by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) which made a conscious shift from “research in development” to “research for development,” by taking a theory of change approach to making research more outcome oriented (Vermeulen et al., 2012; Thornton et al., 2017; Dinesh et al., 2018). CCAFS works in four flagship areas: (1) priorities and policies for Climate-Smart Agriculture (CSA); (2) Climate-smart technologies and practices; (3) Low emissions development; and (4) Climate services and safety nets. In addition to the flagships, two cross-cutting areas also exist, gender and social inclusion and scaling climate smart agriculture. Across the flagship areas, outcome targets have been set (CCAFS, 2016), and it is envisaged that these targets will be met through projects under each

TABLE 1 | Evolution of climate change through reforms in the CGIAR.

Year	Description
2007	World Bank Vice President and CGIAR Chair, Katherine Sierra proposes to intensify climate change research in the CGIAR at COP13 of the UNFCCC in Bali CGIAR, 2007.
2009	CGIAR Challenge Program on Climate Change, Agriculture and Food Security established, as a new Challenge Program of the CGIAR CCAFS, 2009, in addition to other thematic programs which were initiated in 2002 in response to calls for reform in the CGIAR Douthwaite et al., 2017.
2011	CGIAR Research Programs launched as an alternative to Challenge Programs, including the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) CCAFS, 2011b; Roy-Macauley et al., 2016.
2014	CGIAR commits to devote 60% of its research to tackle climate change at the UN Climate Action Summit CGIAR, 2014, 2016.
2017	New phase of CGIAR Research Programs announced, with CCAFS as an integrative research program linking multiple CRPs and centers CCAFS, 2016.
2019	New phase of reforms initiated to transition to One CGIAR, with a focus on responding to the climate crisis CGIAR, 2019.

flagship as well as synthesis and science-policy engagement activities. In 2019, CCAFS spent USD 53.6 million (CCAFS, 2020) in over 50 projects across all flagships. These projects mobilize not only the expertise from within the CGIAR, but also advanced research institutions, national agricultural research systems, and development partners. To ensure that the research results address the needs of target stakeholders, CCAFS has developed a regional approach, with programs established in South East Asia, South Asia, East Africa, West Africa and Latin America. In each region, impact pathways have been developed in consultation with partners in the region (Schuetz et al., 2014). A matrix management approach is taken to design and manage projects, wherein projects are designed and managed jointly by flagships and regions, and this is at the crux of its model of “research for development.” In this context, we seek to open up a new pathway for interdisciplinary research for development linking institutional design with science-policy engagement, to help conceptualize what impact-oriented AR4D would mean in an era of climate change. We do this by examining CCAFS’ efforts to enhance credibility, salience and legitimacy in knowledge generation for its key stakeholders. We aim to provide insights relevant for theories of institutional design (e.g., Biermann, 2007; Young et al., 2008; Ostrom, 2011), not only for the benefit of the CGIAR, but also the wider knowledge system for agriculture under climate change, as there has been increasing focus on transforming knowledge systems to catalyze a transformation in food systems (Fanzo et al., 2020; Herrero et al., 2020; Klerkx and Begemann, 2020; Loboguerrero et al.,

2020). We also aim to contribute to the literature on science-policy engagement, addressing a prominent knowledge gap, being the systematic empirical study of knowledge systems for sustainable development. While much conceptual work on this topic has been done, the systematic empirical unpacking of “what works” in different empirical domains is of a more recent date (Hegger et al., 2020). This paper adds to these emerging empirical examples an institutional perspective on how science-policy engagement efforts are institutionalized in a key international institution and a player in the knowledge system on agriculture and climate change. This also includes literature on boundary work drawing on multiple communities of expertise to support decision making in highly different contexts ranging from participatory R&D to political bargaining and earlier insights on boundary work within the CGIAR (Clark et al., 2016).

To achieve the research aims, the following steps will be taken. Section Conceptual Approach and Methods outlines our conceptual approach and methods. Section Results presents the results. This is followed by a discussion (section Discussion) and the conclusion (section Conclusion), focusing on key issues and commonalities as well as potential next steps.

CONCEPTUAL APPROACH AND METHODS

Conceptual Approach: Institutional Analysis for AR4D

In their seminal (2003) paper, Cash et al. have coined the notions of credibility, salience and legitimacy as indicators of quality of knowledge for science-policy engagement efforts to inform societal outcomes (Cash et al., 2003). Credibility refers to the adequacy of scientific information, salience to its relevance to decision makers, and legitimacy the extent to which the information is considered to have been respectful of divergent views (Cash et al., 2003). These notions provide the foundation for improving research for sustainable development and resonate with CGIAR’s interpretation of research quality, wherein the principles of relevance, scientific credibility, legitimacy and effectiveness are key attributes of quality of research (Belcher et al., 2015; ISPC, 2017). In an earlier, related, paper, Cash et al. (2002) propose strategies to institutionalize efforts to enhance salience, credibility and legitimacy in boundary organizations. These strategies have potential applicability in institutional design and reform in the context of climate change.

We use the success conditions based on Cash et al. (2002) and specify these to fit the context of climate change and agriculture in order to understand the patterns of interactions leading to enhanced credibility, legitimacy and salience in knowledge generation. These success conditions are shown in **Table 2**, where we have described, validated and operationalized these against the wider literature. Based on this process, the success conditions provide a conceptual starting point to study the CCAFS program. The concepts proposed are not final and empirical research helps us to specify them.

TABLE 2 | Framework for examining program efforts to enhance salience, credibility and legitimacy.

Success conditions	Description of the condition and outline of the assumed relationship with credibility, salience and legitimacy
Accountability	Research institutions are accountable to both sides of the boundary (i.e., research and action), helping ensure legitimacy Guston, 2001; Cash et al., 2002; Kristjanson et al., 2009. This includes efforts to facilitate participation, transparency, evaluation of results and managing critique Whitty, 2010
Use of boundary objects	Actors involved in science-policy interactions co-produce boundary objects like assessment reports, models, maps and briefs, which enables research institutions to overcome the science-non-science divide and produce more salient research, and build credibility and legitimacy Cash et al., 2002; Kristjanson et al., 2009.
Participation across the boundary	Research institutions effectively mobilize participation from both sides of the boundary to ensure the production of salient, legitimate and credible information to guide action Cash et al., 2002; Kristjanson et al., 2009; Popa et al., 2015; Clark et al., 2016.
Mediation and a selectively permeable boundary	Research institutions actively mediate to reduce the potential trade-offs and conflicts between increasing salience, credibility and legitimacy Cash et al., 2002. It includes efforts to address concerns which can be practical, political or cultural. Meanwhile, having a selectively permeable boundary Kislov, 2018 enables institutions to effectively engage across the boundary.
Translation	Research institutions translate research for users, helping enhance the salience of research results Cash et al., 2002, enabling researchers and users to understand each other's' concepts, and address real world problems Lang et al., 2012.
Coordination and complementary expertise	In addition to enhancing the scale and scope of research Poteete et al., 2010, research institutions actively coordinate among entities with complementary expertise and mandates, provide more salient, legitimate and credible research results, leading to more harmonious actions Cash et al., 2002.

Adapted from Cash et al., 2002.

Methods

We adopted a case study approach (Mills et al., 2010), and information on CCAFS' performance in relation to the criteria is gathered from the literature, independent external evaluations of the program, and complemented with key informant interviews. The CGIAR has a focus on evaluation and impact assessment, therefore a number of evaluations have been conducted on CCAFS. These include an evaluation of the program's themes by regions (Ash, 2013), a management and governance review (Robinson and Flood, 2013), a review of the low-emissions development activities (Smith, 2014), a review of work on climate

services (Feinstein, 2014), a comprehensive external evaluation of the program commissioned by the CGIAR Independent Evaluation Arrangement (Anderson et al., 2016), and two reviews commissioned by the European Commission (Jobbins and Pillot, 2013; Pillot and Dugue, 2018). These external evaluations have a number of findings which are relevant to our study, for example Anderson et al. (2016) examined CCAFS role as a knowledge producer, and found that the program has struck a balance between production of science based knowledge and local application and scaling (Anderson et al., 2016). In another example, Smith (2014) focused on CCAFS work on low emissions development and found that the work was relevant to set objectives, effectively managed, sustainable and efficient. It noted that the scientific impact varied across outputs, and the development impact was likely to be moderate, although it was still too early to make a definitive statement (Smith, 2014).

We relied on external evaluations to ensure the greatest possible reflexivity. At the same time, the authors were in a good position to interpret the findings since the author team comprises researchers with multiple roles. The first author is employed by CCAFS but also has an academic affiliation and has conducted the current study as part of his latter work. The third author leads a project funded by CCAFS, but is an academic together with the second and fourth authors who are in the position to view the empirical field from critical distance.

Twelve key informant interviews with stakeholders were conducted using a semi-structured approach (**Appendix 1**). These interviews served to help interpret the findings from the document study, in particular to validate the way in which we linked the content of the evaluations to Cash et al.'s success conditions. In so doing, we tried to eliminate subjectivity to the greatest extent possible. Four of the interviewees were engaged in CCAFS's Independent Steering Committee (formerly the Independent Science Panel), three of the interviewees were engaged in the CGIAR's Independent Science and Development Council (formerly the Independent Science and Partnership Council), four of the interviewees were in the CCAFS and CGIAR management, as well as two external experts who have published on science-policy interfaces in the CGIAR.¹ These interviews give insight into decisions on institutional design and oversight, which would otherwise have been absent. The interviews were transcribed and key lessons corresponding to the criteria were identified by qualitatively analyzing the transcripts. We also checked if inductive coding pointed us at additional success conditions, which were distinct from those already identified by Cash et al. (2002).

RESULTS

In this section we present results from our literature review and interviews with key informants, wherein we examined the applicability of the success conditions presented in **Table 2** in the CCAFS context.

¹Two of the interviewees have had multiple roles within CCAFS and CGIAR.

Accountability

Key mechanisms to enhance accountability within CCAFS are the development of impact pathways, efforts to enhance transparency, external evaluations and impact assessments, and effective leadership. CCAFS has endeavored to integrate accountability in its project design process through impact pathways for each project, which correspond to regional and thematic impact pathways at the program level. These impact pathways ensure a route to societal impacts, while also ensuring that activities address major knowledge gaps (Schuetz et al., 2014). Participation of stakeholders from both sides of the boundary, i.e., researchers and decision makers are facilitated in the project design process (Schuetz et al., 2014), with the aim to ensure that research projects as part of the CCAFS portfolio address the needs of decision makers, as well as the knowledge gaps identified by researchers. Conformance to the project designs is monitored through monitoring, evaluation and learning efforts (Schuetz et al., 2017).

Transparency of the program's efforts is provided through annual reporting as well as public facing pages of its projects through which individual projects' progress can be monitored. Evaluation of the program's results have been conducted at different stages of implementation, including evaluation of thematic activities (Ash, 2013; Feinstein, 2014; Smith, 2014), management and governance (Robinson and Flood, 2013), and program level evaluations (Jobbins and Pillot, 2013; Anderson et al., 2016; Pillot and Dugue, 2018). Efforts seem to have been made to address critique as each evaluation has received responses from the management, including on key actions to address recommendations. For example, following the 2016 evaluation (Anderson et al., 2016), the CCAFS management published its responses to all recommendations put forward by the evaluators (CCAFS, 2016). This includes a recommendation to increase its policy informing role, which the management agreed to do, focused on the development of NDCs as well as engaging with regional groupings in climate negotiations. Similar responses to other evaluations are also available.

In addition, a number of impact assessments have also been conducted, to evaluate impact of the program's efforts to end users (Gill, 2014; Aryal et al., 2015; Murendo and Wollni, 2015; Reddy, 2015; Hariharan et al., 2020). The program's accountability to facilitating outcomes also received favorable review in the program-wide evaluation, wherein accountability within the CCAFS program was considered to be enhanced as a result of the results based management and the associated approach of developing theories of change (Anderson et al., 2016). But, the review also called for further strengthening accountability by strengthening the theory of change and impact pathways at the regional and flagship levels (Anderson et al., 2016). The reviewers suggest that the assumptions and risks in these theories of change needs to be defined better and converted into hypotheses which can be tested during implementation (Anderson et al., 2016).

According to those involved in program design, efforts to ensure accountability were crucial, as one of the interviewees who was part of the Independent Science Panel (ISP) noted, "accountability was critically important for us and we took

that very seriously at each of our meetings. I think we put the leadership team of CCAFS under enormous pressure early on in terms of the reporting requirements, and not just in terms of their financial reporting but also in terms of how people were appointed, how people were treated, what the culture was like in the organization, and ultimately whether they were able to deliver on the promised results" (Interviewee-T, 2020). This means that formal processes need to be complemented with informal processes and efforts (Interviewee-O, 2020), and a key aspect of ensuring this is through recruitment of suitable staff. The program's approach of hiring staff accountable entirely to the program as opposed to participating centers was found to be an effective approach (Robinson and Flood, 2013). Interviewees also noted the importance of competitive hiring (Interviewee-O, 2020), strategic leadership (Interviewee-W, 2020), incentives for researchers (Interviewee-X, 2020) and the developing country focus of staff. It was however noted that in maintaining accountability, CCAFS and the wider CGIAR can be affected by shifts in donor priorities (Interviewee-Y, 2020), trust deficits within CGIAR governance processes (Interviewee-Y, 2020), and changes to governance processes (Interviewee-V, 2020). It was also noted that efforts to enhance accountability should ensure that the program is accountable to the right stakeholders and the selection of stakeholders is not influenced by power dynamics, and bias toward current partners and research interests (Interviewee-P, 2020; Interviewee-U, 2020). An example in the CCAFS context to enhance accountability is the focus on gender equality, which was found to be under-developed in the 2016 review (Anderson et al., 2016), and subsequently a new strategy and leadership was brought in (Anderson and Sriram, 2019).

One of the interviewees identified an area of improvement to be accountability and interactions with funders, which can help make the funding environment more conducive for boundary work (Interviewee-T, 2020). This is important because in contrast to academia, scientists in the CGIAR need to be accountable to working for the poorest of the poor, while also publishing articles, and fundraising (Interviewee-Q, 2020), which requires the support of funders.

Use of Boundary Objects

Boundary objects developed in the CCAFS context include models, briefs, websites, conferences etc. which are targeted at practitioners. Key approaches to improve the use of boundary objects are to link these to science-policy engagement processes, capacity building efforts, and participatory knowledge production processes. While the use of boundary objects has not been explicitly noted as a strategy by CCAFS, this appears to be the case and the 2016 review noted that CCAFS produced a number of boundary objects, including briefs and info notes, working papers, reports and conferences (Anderson et al., 2016) next to specific participatory processes. CCAFS put quite a lot of emphasis on boundary objects and communication, as an interviewee on the program's ISP noted, "We needed to have credibility in the science community, so peer reviewed journals and articles were absolutely crucial without that we would not have succeeded but it's not sufficient of course. That's why we developed

the policy briefs for example and other types of publications to reach out to other audiences” (Interviewee-W, 2020). Interviewees found that CCAFS had been fairly successful in the use of boundary objects, particularly when engaging a target audience or process (Interviewee-O, 2020; Interviewee-W, 2020). This was approach was also reiterated by a science-policy expert interviewee, who said, “to me there’s an engagement process and in that engagement process it may be useful to use boundary objects as one of the tools in your engagement process. All of those things are part of what you need to do in order to be effective with your research” (Interviewee-R, 2020). With regard to targeting specific processes and outcomes, the utility of boundary objects was perceived to be higher when focused at the supranational or national scales (Interviewee-S, 2020; Interviewee-V, 2020). Provision of capacity building and sequencing the production of boundary objects with participatory knowledge production was another important factor (Interviewee-T, 2020).

In producing boundary objects, the emphasis should not only be on briefs and info notes: events and processes are equally important. For example an interviewee noted “an event, where the partner deeply buys into it, is much more successful than perhaps an info note produced solely by the research provider” (Interviewee-O, 2020). Participatory scenarios were identified as another innovative boundary object (Interviewee-Y, 2020). In this case, CCAFS developed participatory scenarios with stakeholders (Chaudhury et al., 2013; Palazzo et al., 2017) and a review of these efforts (Carey, 2014) noted that the process had “evolved from an academic approach to a bespoke product to meet the needs of the actors CCAFS wishes to engage.” One of the interviewees also noted this, “I’d say one of CCAFS’ great strength, is how to bridge that divide between science and policy and I would I think the scenario process is a really important boundary object for that” (Interviewee-Y, 2020).

Producing boundary objects relevant to the context is not simple, and at times this happens in the midst of challenges, as an interviewee noted, based on her experience in the wider CGIAR, “There’s such a deep-seated attitudinal issue around needing to be in front, needing to be visible as an individual player and not as part of a bigger team” (Interviewee-X, 2020). While this comment was not specifically about CCAFS, it is important to note that within the wider institutional landscape the need for attribution can be a risk to producing collaborative boundary objects. Capacity was another key challenge noted, as capacity to produce boundary objects cannot be taken for granted as scientists may not necessarily have the right skills to tell the story in a way that it appeals to the users (Interviewee-W, 2020). It was also noted that since the CGIAR has multiple entities producing boundary objects, users tend to receive too many boundary objects and information, and greater coordination and user orientation is needed within the CGIAR (Interviewee-U, 2020).

Participation Across the Boundary

Key mechanisms to improve participation across the boundary included a “partnerships and participate” approach to deliver outcomes, regional engagement and engaging stakeholders from the beginning of the research process. The 2016

external evaluation noted that CCAFS was actively partnering with institutions on the delivery of knowledge (Anderson et al., 2016). The approach to project design, including the design of the impact pathways of projects, together with the matrix management approach involving flagships and regions facilitate participation across the boundary (Anderson et al., 2016). CCAFS also has a strategy in place for engagement and communications, to facilitate participation across the boundary (CCAFS, 2013), and the approach adopted in partner classification and delivery of results was identified as a good example in the CGIAR wide evaluation on partnerships (McLeod et al., 2017). While engagement of partners to deliver outcomes has been noted in the external review (Anderson et al., 2016), particularly at the regional level. Partners in turn perceived the outcome focus adopted by CCAFS as a clear competitive advantage (Anderson et al., 2016).

In the course of the interviews it was noted that participation is a key part of the CCAFS approach (Interviewee-W, 2020), which comes upfront in the research process (Interviewee-T, 2020). One of the interviewees observed that CCAFS in comparison to the wider CGIAR has done well on participation, but that performance across CCAFS was not uniform, with certain scientific leaders being far more open to equal relationships than others (Interviewee-X, 2020). Setting up regional programs with senior leaders was perceived as a success factor (Interviewee-X, 2020). In addition to participation downstream with farmers and stakeholders, upstream participation, i.e., partnerships to achieve scale is important (Interviewee-V, 2020). One interviewee noted this as “partner and participate approaches” (Interviewee-S, 2020), since the quality of the participation is enhanced through high quality partnerships that enable outcome delivery. One of the interviewees noted that within the CGIAR, the classic approach has been that partners came in at the end of the research process for scale, but CCAFS deviated from this approach and engaged partners right from the beginning, to understand their needs and co-designing research questions (Interviewee-X, 2020). This is important as balancing participation with strategic research is inevitable to manage tradeoffs of time and resources (Interviewee-Y, 2020). However, care must be given so that participation is fair and equitable and participants are actively engaged, and have a voice in deciding what the questions are (Interviewee-P, 2020; Interviewee-Y, 2020).

Mediation and a Selectively Permeable Boundary

Key mechanisms for mediation include exchanges based on trust based relationships and inputs from external experts. In terms of permeability of the boundary, facilitating transdisciplinary research was identified as a key mechanism, together with efforts to coordinate across institutions. Mediation as a tool to balance credibility, salience and legitimacy is not explicitly referred to in external evaluations of CCAFS. However, the interviews confirmed that while mediation as a tool has not been used explicitly (Interviewee-O, 2020), implicit mediation does occur in participatory processes which involve partners. These are addressed through trust-based relationships and exchanges with

partners. As one interviewee noted based on his experience in science-policy engagement processes, *“in a political process, it’s a negotiation process and you have to allow some things in order to get the bigger picture.”* (Interviewee-S, 2020).

It was also found that trade-offs between salience and credibility were common when endeavoring to do high quality research and achieve outcomes at the same time (Interviewee-X, 2020). Potential tradeoffs between legitimacy and credibility were also highlighted (Interviewee-R, 2020). CCAFS has a matrix-based management approach in place, and this system seeks to provide a mechanism to mediate and achieve such a balance. An additional dimension to mediation which came out prominently in interviews was the internal “science politics” within the CGIAR, wherein ongoing reforms and governance processes erode trust within the system, and have required mediation, for example by bringing in external experts (Interviewee-S, 2020). An interviewee noted, *“the CGIAR is one of the most over governed organizations that I’ve ever been involved in. And they haven’t done that very effectively, a lot of the governance processes that are set up for some opaque reasons and often do not result in any sort of desirable outcomes”* (Interviewee-T, 2020).

In terms of the permeability of the boundary, there are two dimensions, boundaries among institutions and boundaries among disciplines. The CCAFS approach is one that enables permeability in both, however, within the wider institutional landscape, permeability of the boundary may cause overlap and competition among institutions. For example, within the international agriculture landscape, the CGIAR is responsible for research, FAO for policy and IFAD for funding, but in practice there is tremendous overlap among all these organizations and competition for funding (Interviewee-Y, 2020). With regard to disciplinary boundaries, an interviewee noted that this was a strength of CCAFS, *“they’ve always been very accommodating of those different strands and not just within the physical sciences but also between social science and the physical sciences. They were open to bringing in people from different backgrounds and give them an enabling environment in which they could make meaningful contributions.”* (Interviewee-T, 2020).

Translation

Key mechanisms for effective translation of research include ensuring a two directional process to secure stakeholder input and changing the culture to ensure a more long term and impact oriented view of translation. Translation of research into usable formats is a big part of the CCAFS approach (Kristjanson et al., 2014), and a dedicated research area focused on translation, with emphasis on innovative research and communications, gender and social inclusion and future scenarios. The approach to translation was one wherein the users of research results were engaged at the outset to define the scope of research and thereafter throughout the research process (Kristjanson et al., 2014), which helps ensure salience of results. This is important as noted by one of the interviewees as translation needs to be a two directional process as opposed to scientists talking to users (Interviewee-P, 2020).

Challenges in this area included the timelines, wherein the impact was not visible during project cycles of 2–3

years, and difficulties in forming and maintaining non-research partnerships. The interviews also noted that translation cannot be a one way process, and needs to have the strong buy in of the target users, as an interviewee noted, *“translation needs commitment also from the target audience to read the research and a willingness to be informed”* (Interviewee-Y, 2020). This means that researchers need to have the right skills and capacity to be able to take that on (Interviewee-S, 2020). Cultural issues need to be addressed too, for example within the CGIAR communications is not understood as a tool for science-user engagement, communications is understood as a tool for advertising and fundraising (Interviewee-X, 2020). These deep seated cultural issues need to be overcome to be more effective in translation and this seems to have been the case in CCAFS (Interviewee-W, 2020).

Coordination and Complementary Expertise

Key mechanisms for effective coordination and mobilizing complementary expertise include mobilizing expertise from outside the CGIAR, more effective internal coordination of expertise, and a transdisciplinary approaches to address the needs of policy makers. At the time of CCAFS inception, CGIAR was lagging behind on global research for climate change as it had retained a very strong disciplinary focus, particularly on plant breeding without branching out into the broader areas that needed to be addressed in food systems and were important to policymakers (Interviewee-Q, 2020; Interviewee-T, 2020). CCAFS was initiated as a partnership between the CGIAR and the Earth System Science Partnership (now Future Earth) which had expertise in climate change research, which would complement the CGIAR’s work (Interviewee-Q, 2020). CCAFS was being designed specifically to address policy needs, as one of the interviewees on the Independent Steering Committee (ISC) noted, *“when we transitioned CCAFS from what used to be a challenge program into a CRP under the new structure, we did that very much keeping in mind that we wanted to create an entity that firstly connects sensibly across all of the core disciplines within the CGIAR. But at the same time becomes really influential in providing evidence-based policy support at various levels. Because that’s where clearly the need was”* (Interviewee-T, 2020). CCAFS has the mandate to coordinate across the CGIAR on climate change issues and mobilize complementary expertise toward societal outcomes. In addition to the intra CGIAR role, CCAFS also has a focus on mobilizing partners out with the CGIAR, where capacity is lacking within the system. The external evaluation noted that CCAFS has made progress with integration, but greater integration and linking is needed (Anderson et al., 2016). The approach to mobilizing expertise from advanced research institutes in areas where the CGIAR system had limited expertise was noted as key feature (Anderson et al., 2016; Pillot and Dugue, 2018).

This coordination and mobilization of complementary expertise is all the more relevant in the context of transdisciplinary research (Interviewee-R, 2020), and a former member of the ISC noted, *“everybody talks about the importance*

of inter and transdisciplinary research, but very few organizations know how to engender that and how to provide the supporting networks that are actually necessary for that” (Interviewee-T, 2020). Often, institutional structures and incentives do not encourage such collaboration (Interviewee-O, 2020), and in the end the onus falls on “a relatively small group of people that are really competent, dedicated and committed to the same outcome” (Interviewee-O, 2020). This seems to have been the principle behind the design of the core CCAFS team (Interviewee-Y, 2020).

Coordinating climate change research in the CGIAR has not been an easy task, an interviewee associated to CGIAR management noted, “(Interviewee-T, 2020) *The prevailing view across CGIAR is that there is no need for any specialist knowledge on climate. Climate is not associated with any kind of specific skill sets or knowledge sets. And what this leads to is that climate change is used as an additional justification, a rationale for research projects. But then the research proposed is the same as it would have been, you know, prior to any awareness of climate change*” (Interviewee-X, 2020). In this context, another interviewee noted, “*my perception is that CCAFS focus on maintaining its coordination internally is very strong, much more than with the other CG centers or as a system*” (Interviewee-Y, 2020).

Additional Success Conditions Identified

In addition to insights about the success conditions from Cash et al. (2002), we inductively identified additional success conditions from the evaluations and during interviews, which were not contained in the initial Cash et al. framework.

Role of Leadership

Key mechanisms to enable effective leadership include selection of results oriented and strategic leaders, skills development, ensuring regional and national focus, funding allocation to enable efforts, and facilitating a shift in culture. It is evident from the evaluations and interviews that selection of the right leaders has been a key success factor in the CCAFS context. This means strategic leadership, as one interviewee noted, “We need leadership that has a clear vision on an outcome-oriented approach. Clear vision that you should almost work backwards, you know what is the target and then put the research in place that’s needed to achieve their target” (Interviewee-O, 2020). Good leadership can help to ensure that best practices are effectively institutionalized. Leadership should also be relevant to regional and national issues as noted by an interviewee based on the success of regional programs in CCAFS, “*I think one of the things that have helped with CCAFS, has been the permanent presence of the regional program leaders in the regions*” (Interviewee-X, 2020). At the same time, it is important for leaders to steer clear of bias (Interviewee-R, 2020).

However, it may not be assumed that strategic leadership skills exist within the system, and where this is the case, skills development is important (Interviewee-S, 2020). In a complex environment such as that of the CGIAR, good leadership was noted as being, “*more bottom-up leadership, you are empowering people within the system to do good things as a leader rather than leading from the top down*” (Interviewee-S, 2020), and such skills

need to be developed. Competitive hiring is another approach to fill skills gaps and secure leaders who are highly practical but also able to navigate the complexity of the CGIAR system, stakeholders and research challenges. Multiple interviewees engaged in CCAFS design and selection of leadership noted that leaders were selected based on their ability to navigate complexity and deliver results (Interviewee-Q, 2020; Interviewee-T, 2020; Interviewee-W, 2020). CCAFS also made a conscious attempt to recruit leaders from developing countries due to its focus on the Global South, this also helped, as an interviewee noted, “*I do think that with leadership, that does make a difference, If you come from a background where you identify with the partners*” (Interviewee-X, 2020).

Selecting good leaders is not sufficient, funding allocation needs to be in place to support leaders to take a strategic approach, as noted, “*I would say the most important thing to pay attention to is who controls the purse strings and who is accountable for making the results happen from those investments and expenditures*” (Interviewee-X, 2020). Supporting mechanisms, i.e., management is important to ensure that processes reflect the intentions at the governance level and making sure that people are on board and get the view (Interviewee-U, 2020). Institutionalizing high-quality knowledge generation requires a shift in culture, and leadership and supporting mechanisms need to be in a position to support this shift, as a former member of the ISC noted, “*Culture eats strategy for breakfast, so you can have all the strategy in the world, but the culture will just squash it, so it is essential to have leadership that is absolutely consistent with the culture that you’re trying to head towards*” (Interviewee-Z, 2020). Another interviewee also noted, “*I feel the problem is very deep in the culture of CGIAR and it’s a way of working, and CCAFS has been quite radical in trying to break out of that CGIAR only model and be far more open to partnership, bringing in partners even to run parts of the program, being very open to being an equal or even junior partner. And I guess that was established by the kind of attitudes across CCAFS leadership that could sort of break open that CGIAR culture a little bit*” (Interviewee-X, 2020).

Role of Incentives

Key incentives can be provided at the level of funders (long term commitment to boundary work), program level (linking project performance to achieving outcomes), and individuals (offering a career track for boundary scientists and incentives for achieving outcomes). One of our interviewees noted, “*in research as in many other areas of life, people have habits and it’s very difficult to make them change their habits*” (Interviewee-Q, 2020). In order to change habits and realize impact, AR4D institutions should provide incentives to staff (Interviewee-P, 2020; Interviewee-X, 2020). Currently within the CGIAR the incentives for boundary work are limited, as an interviewee noted, “*There is no career track for the true boundary scientists or science policy interface people or whatever you want to call them. The people who are about research into action, who are there for the development part of AR4D. There are no jobs and that’s zero, it’s not taken seriously at all and is considered to be a kind of an add on, done by the scientists.*” (Interviewee-X, 2020). The CGIAR has been very

dominated by crop breeding as a legacy of the green revolution (Interviewee-U, 2020), but there are examples of incentives being established to generate greater engagement in other institutions (Interviewee-S, 2020), which can offer lessons to the CGIAR.

Incentives are needed at the programmatic level from funders, as one of the challenges noted in the interviews was the changing expectations of funders and the unpredictability in funding cycles as one interviewee noted, “*CCAFS did have influence and managed to get agriculture on the global agenda on climate change. I think it’s one of those major breakthroughs, but it has not been very effective in engaging the funders of the CGIAR in such a way that there would be comfortable to continue with that model*” (Interviewee-T, 2020). The current phase of CGIAR reforms are therefore going in the direction of funders wanting more line-of-sight in terms of investment and the outcomes and results, but the interviewee noted, “*this is going against the very nature of a boundary organization because in a boundary organization, you actually don’t have that clear line of sight and often the attribution of those outcomes is incredibly difficult because so many other factors are involved in it*” (Interviewee-T, 2020). At the level of individual scientists, incentives can be offered through annual appraisals, salary levels etc. (Interviewee-X, 2020). An example that was highlighted from CCAFS was the approach to reporting and evaluating outcomes (Interviewee-X, 2020), which was established early on in the program and results were a key factor that determined performance of projects and associated staff (Interviewee-O, 2020). Incentives should also go beyond rhetoric, as one interviewee noted, “*there’s a lot of rhetoric about partnership, in reality we usually have to do it on a shoestring and I think that’s one of the key problems that CCAFS is also experiencing*” (Interviewee-T, 2020).

DISCUSSION

Success Conditions for Institutionalizing Efforts to Enhance Salience, Credibility, and Legitimacy

Based on the results, which illustrate how the Cash et al. (2002) success conditions relate to CCAFS in the context of wider CGIAR reforms, we revisit the conditions. Our results indicate broad applicability for these success conditions in efforts to institutionalize high-quality knowledge generation that enhances salience, credibility and legitimacy, thereby supporting science-policy engagement efforts. However, we also identified a need to specify the conditions for the domain of climate change, agriculture and food security and we identified additional success conditions through the CCAFS case study, which pertain to leadership and incentives. These point to the need to extend Cash et al.’s original framework. Cash et al. (2002) do allude to the importance of leadership in the context of accountability, when leaders are chosen to be accountable to both sides of the boundary, but our results show that the role of leadership goes beyond being accountable, to ensuring that knowledge generation also enhances credibility and salience, manages trade-offs and supports science-policy engagement efforts. The effectiveness of empowered and competitive leadership, and

TABLE 3 | Success conditions and lessons for institutionalization.

Success conditions	Key lessons for institutionalization
Accountability	- Formal systems for developing theories of change and impact pathways are important, but need to be complemented with informal efforts which rely on individual researchers and research leaders.
Use of boundary objects	- Boundary objects need to be linked to impact pathways, partners, and policy-engagement processes to realize maximum impact. - Focus should not only be on boundary objects but also boundary processes.
Participation across the boundary	- The quality of participation can be enhanced if combined with partnership efforts, i.e., an approach to partner and participate. - Participation should be fair and equitable, enabling stakeholders to have their say in the process.
Mediation and a selectively permeable boundary	- Efforts must be taken to manage trade-offs between salience and credibility which may arise in a negotiation process. - Mediation also becomes essential in the “science politics” space especially in a complex institutional environment such as the CGIAR.
Translation	- Translation should be a two way process, with the target audience engaged early on in the process.
Coordination and complementary expertise	- Establish incentives which promote efforts to coordinate and mobilize complementary expertise.
Leadership	- Identify appropriate leadership and empower leaders to change culture. - Develop leadership at the regional level for better engagement with stakeholders.
Incentives	- Establish incentives for science-policy engagement efforts that enhance salience, credibility and legitimacy. This can be through linking performance with delivery of outcomes.

indeed the success conditions identified by Cash et al. (2002) will also depend on the incentive structures which are in place, and this is the second additional success condition that we have identified. In **Table 3**, we revisit the success conditions proposed at the outset, together with additional success conditions identified from the results. Using this framing, we have identified key empirical lessons for institutionalization of each of these success conditions.

Creating an Environment for “Enlightened” Boundary Work

In 2011, the global agricultural research and development expenditure was USD 56 billion (Fuglie et al., 2020), in the same year, CCAFS annual budget was only USD 62 million (CCAFS, 2011a). Therefore, for lessons derived to be institutionalized at scale, greater commitment from research funders and leadership is needed. As one of the interviewees noted, “*It’s hard for isolated project outputs to get traction in the policy space. It needs a broader more cultivated space if you like a more fertile ground that’s been cultivated more at the programmatic or institutional*

level” (Interviewee-Z, 2020). In endeavoring to drive changes to the wider knowledge system, researchers need to be cognizant that they are in the “science in politics” space, and without enormous commitment on their part, they end up, intentionally or not, serving the already empowered in the globalization of food systems. Clark et al. (2016) provides a useful framework on how boundary work can support “enlightenment,” decisions, and negotiations. Enlightenment is framed as being about advancing basic understanding around key issues without concerns for short term application (Clark et al., 2016), and mobilizes multiple disciplines and thus true integrative research and development. While efforts within CCAFS focus on the use of knowledge to support decisions and negotiations, a greater focus on this kind of enlightenment is needed across the knowledge system. In the context of AR4D, effective science-policy engagement efforts can be found at the level of individual projects or programs, but there is a need to go beyond these in order to reach the enlightenment stage.

As science-policy engagement moves from informing decisions and negotiations in the short term to a systematic approach to enlightenment, research efforts will be characterized by enhanced credibility, legitimacy and salience. At this stage, the roles of different actors which are currently clearly differentiated, e.g., knowledge producers, intermediaries, users etc., may merge. In the CCAFS case, we do indeed see these roles merging, with the same institution producing knowledge, translating it, and facilitating partnerships for greater uptake. While the advances in research on the roles of institutions which have specialized roles is welcome, the Cash et al. (2002) success conditions provide a helpful framing for institutions which may have multiple roles. As an interviewee noted, “*what you’re aiming for is that sweet spot where a very well thought out and delivered theory of change comes together with excellent leadership capabilities, a really strong vision, and with that ability to engage a whole range of different stakeholder communities*” (Interviewee-T, 2020). Such blurred boundaries need to be taken into account also for the CGIAR reform processes, to enable the CGIAR to more effectively deliver outcomes. As one of the interviewees noted, “*We now understand that there are multiple kinds of boundaries and it’s quite likely that it’s different kinds of boundary work, still guided by the notion it’s a two-way exchange, still guided by the notion of accountability and so on.*” (Interviewee-P, 2020). Therefore, the emphasis needs to be on enabling boundary work within the institution, through institutional arrangements, norms, and procedures to support evidence-based policy making (Cash et al., 2002). Getting the institutional arrangements right, i.e., boundary settings (Mollinga, 2010) is crucial for the production of high-quality knowledge that enhances salience, credibility and legitimacy.

To catalyze institutional reform at scale and move toward enlightenment for science-policy interactions, efforts are needed in the wider institutional landscape for AR4D. Firstly, a shift in institutional governance which promotes a culture of evaluation and reflexivity amongst actors’ is important. Such a culture can be achieved through strategies including facilitating participation, transparency, evaluation of results and managing critique (Whitty, 2010). Our interviews show that

the CCAFS governance mechanisms placed a huge emphasis on accountability, but within the wider CGIAR, trust deficits were noted in governance processes, which can undermine efforts to ensure accountability. A multi-scale approach to accountability (project, program, institutional), can help enhance legitimacy of knowledge produced over and beyond an individual project or researcher.

We find that that several of the success conditions proposed by Cash et al. (2002): the use of boundary objects, participation across the boundary, mediation and translation, are not universal in applicability. Their applicability is dependent on the context, linking to policy engagement efforts and goals. To facilitate the development of context-specific approaches, institutional governance mechanisms need to foster a suitable environment where efforts to achieve impact are valued and incentivized, and capacity and skills are developed to enable researchers to make this shift.

The leadership of AR4D institutions needs to show commitment to knowledge generation which is credible, salient and legitimate, helping advance policy outcomes and impact on the ground. Such leaders need to be identified and appointed through competitive hiring processes, empowered to make decisions, and bring an entrepreneurial approach to science-policy engagement and achievement of outcomes. In the CCAFS context where the focus is on the Global South, regional leaders and those with developing country experience was found valuable. However, care must be taken so that the leaders thus selected are not overly involved in policy making processes causing research efforts to be biased.

Cash et al. (2002) have proposed coordination and complementary expertise as a key strategy. In the context of climate change adaptation in agriculture, this becomes all the more pertinent, and there is a need to break silos which may exist to make generate high quality and usable knowledge for decision makers. Strategies to do this can include developing partnerships, building transdisciplinary teams, and offering incentives for transdisciplinary work, which corroborates findings derived in the context of spatial climate adaptation in the Netherlands (Hegger and Dieperink, 2014). These have applicability in the CGIAR as well as other transdisciplinary research institutions operating to help adapt to climate change. These efforts can improve interactions among stakeholders, leading to better outcomes for salience, credibility and legitimacy.

The actions which have been highlighted here imply a change in culture within AR4D institutions, and this culture change needs to underpin actions as institutionalizing high quality knowledge generation for climate change is not just about policies and procedures within an institution but about changing the cultural foundations to address climate change.

Opportunities for Institutional Analysis

The lessons on institutional mechanisms to enhance salience, credibility and legitimacy have implications for theories on institutional analysis in the context of institutional design and reform. The Institutional Analysis and Development (IAD) Framework developed by Ostrom et al. (Ostrom et al., 1994; Ostrom, 2011), is a useful framework to unpack the lessons

for institutional design. Within the context of climate change impacts on agriculture, which enhances the risk of resource poor rural farmers, institutional arrangements are crucial to support farmers in climate change adaptation. Action research on climate change, agriculture and food security such as that conducted by CCAFS may be viewed as an “*action arena*” for institutional design. The CGIAR as the international entity responsible for agricultural research and through its ongoing reform to address climate change may be considered to be the “*action area*,” which involves actors in this area including the CGIAR leadership, governance processes, funders, and users. With the CGIAR’s emphasis on enhancing credibility, salience and legitimacy, as acknowledged by its interpretation of research quality (ISPC, 2017), institutional analysis of this arena and area, and effective institutionalization of success conditions identified, offer a major opportunity to advance theory and action. The IAD framework has been developed to study institutions in different contexts (e.g., Nigussie et al., 2018), but its application to knowledge production could offer new insights for theory and practice.

CONCLUSION

This paper focuses on a pressing knowledge gap: the need for more systematic empirical studies into the institutional design of knowledge action systems in the field of climate change and agriculture. We find that the success conditions proposed by Cash et al. (2002) are relevant to the CCAFS context, although CCAFS as a program was not designed using these as the basis. We see this as an indication that the success conditions are useful guidance for the design and reform of institutions to enhance their ability for science-policy engagement and to deliver societal outcomes. However, though our analysis shows the strengths of the success conditions and their ability to enhance salience, credibility and legitimacy, these success conditions can be strengthened through the addition of two additional conditions - leadership and incentives. These were found to be crucial in the CCAFS case.

The refined success conditions for institutional design can help advance literature on science-policy engagement, offering perspectives on institutionalizing efforts. We have expanded empirical studies of science-policy interactions, offering practical perspectives and applied it to an issue area that is in urgent need of more and more systematic attention of scholars, namely AR4D. While papers which laid the foundation for studying science-policy interactions including Cash et al. (2003) and Clark et al. (2016) draw on CGIAR case studies, the sector has been understudied, and we seek to further build on these foundations offering fresh perspectives around institutionalization. These perspectives on institutionalization also draw upon and contribute to the literature on institutional analysis and development. Our in-depth study of CCAFS has also led to novel insights on how to create an environment conducive to high-quality knowledge generation. It would be useful for future research to pursue such in-depth and interdisciplinary studies in other domains and issue areas.

The success conditions also have practical application in the design and reform of institutions for AR4D. Specifically, the CGIAR is now going through another round of reforms, which will see it transition to “One CGIAR” a more cohesive international institution with climate change as one of the key priorities. The fact that the success conditions also relate to the CGIAR perception of research quality further enhances their credibility to be applied in institutional design for agricultural research for development under climate change. Applying these success conditions in the CGIAR reform process can further enhance the CGIAR’s ability to advance action in the context of climate change. Moreover, addressing challenges within the CGIAR for applying these success conditions including trust deficit, accountability, transaction costs etc., can help the reform process. These lessons also have applicability in the reform of other institutions, amidst the growing call to transform agricultural innovation systems (Fanzo et al., 2020; Klerkx and Begemann, 2020; Steiner et al., 2020). This requires a systemic shift in the institutional landscape, to create a suitable environment to apply the success conditions, by creating a culture of evaluation and reflexivity amongst actors, building capacity and skills to undertake science-policy engagement, transformative leadership that emphasizes boundary work, and transdisciplinary research to address climate change issues.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because qualitative data was collected through semi-structured interviews, however in order to protect the anonymity of interviewees, this data is not made available. Requests to access the datasets should be directed to d.dinesh@cgiar.org.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

Material preparation, data collection, and analysis were performed by DD. The first draft of the manuscript was written by DD and all authors commented on previous versions of the manuscript. All authors contributed to the study conception and design, read, and approved the final manuscript.

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The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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APPENDIX 1: INTERVIEW QUESTIONS

1. Accountability

- 1.1 In order for research results to be credible, salient and legitimate, research institutions need to be accountable to both sides of the boundary (i.e., research and action). In your view, how important is this? Do you have an example to illustrate your answer?
- 1.2 In your view, how does CCAFS fare in terms of being accountable to both sides of the boundary?

2. Participation across the boundary

- 2.1 What are your views on participation across the boundary as a strategy to institutionalize high quality knowledge generation?
- 2.2 How effective do you think CCAFS has been in mobilizing participation from both sides of the boundary? Are there key successes/shortfalls that you would like to mention?

3. Use of boundary objects (briefs, info notes, working papers, conferences, maps, models etc.)

- 3.1 What are your views on the use of boundary objects to institutionalize high quality knowledge generation?
- 3.2 In your view, how well is CCAFS using boundary objects to do more outcome oriented research? Do you have any examples of boundary objects produced by CCAFS which were very good or bad, why?

4. Translation

- 4.1 Translating research for users, helps enhance their salience. How well do you think CCAFS is translating

research for users? Is there an example you would like to share?

5. Mediation and a selectively permeable boundary

- 5.1 Mediation is a tool to balance credibility, salience and legitimacy. Have you found this to be important? Please illustrate with an example.
 - 5.1.1 Is this something you have observed in CCAFS?
- 5.2 Do you find that CCAFS design and management enabled a selectively permeable boundary to advance action?

6. Coordination and complementary expertise

- 6.1 In addition to enhancing the scale and scope of research, active coordination among institutions with complementary expertise produce more effective actions. In your view how does CCAFS perform on coordination and mobilizing complementary expertise? Can you provide an example?
- 5.2 The external evaluation noted that CCAFS has made progress with integration of climate change research in the CGIAR, but greater integration and linking is needed. What is missing in terms of integrated climate change research across the CGIAR?

7. Interactions

- 7.1 What role does interactions among different actors (e.g., through CGIAR/CCAFS governance processes) play to ensure or deter the success conditions discussed above?
- 7.2 What role does CCAFS leadership play in outcome orientation of the portfolio?