A web analytics approach to map the influence and reach of CCAFS

Working Paper No. 326

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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CCAFS

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About CCAFS working papers
Titles in this series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

About CCAFS
The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is led by the International Center for Tropical Agriculture (CIAT), part of the Alliance of Bioversity International and CIAT, and carried out with support from the CGIAR Trust Fund and through bilateral funding agreements. For more information, please visit https://ccafs.cgiar.org/donors.

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Abstract

This evaluation sought to understand CCAFS' influence in motivating actors to tackle climate change. In CCAFS' theory of change, a cross-cutting aim is to work with strategic partners to "foster policy and institutional change" that will enable large-scale CSA adoption. A conceptual framework was developed, and an innovative approach based on the Digital Methods epistemology was employed to explore the dynamics of knowledge dissemination and changes in attitude towards CSA among stakeholders at various levels. It considered online networks and narratives as evidence of "offline" program influence. Results show that CCAFS has inspired positive change in government policy; built a global community for climate adaption; and sparked public interest in "Climate Smart Agriculture".

Keywords

Climate change; diffusion of information; big data; internet; social media; digital methods

Executive Summary

This evaluation sought to understand CCAFS' influence in motivating stakeholders to tackle climate change. In CCAFS' theory of change, a cross-cutting aim is to work with strategic partners to "foster policy and institutional change" that will enable large-scale CSA adoption. Flagship Program 1 "Priorities and Policies for CSA" facilitates this outcome, and monitoring progress has included reporting the number of policies and investments informed by CCAFS research.

However, this indicator may not be capturing the full extent of CCAFS' influence, as it does not consider the 'soft power' processes that enable policy or investment decision-making. Based on this notion, a conceptual framework was developed, and an innovative approach based on the Digital Methods epistemology was employed to explore the dynamics of knowledge dissemination and changes in attitude towards CSA among stakeholders at various levels. By considering online networks and narratives as evidence of "offline" program influence, selected web sources and social media platforms were assessed through data-driven, machine learning approaches such as text mining, network analysis, hyperlink analysis, and query analysis. The digital research was framed by qualitative, primary data collection.

Key findings include:

1. CCAFS has inspired positive change in government policy: CCAFS has shifted the debate on climate adaptation among strategic partners. By some estimates, the program's ideas – adopted and transmitted through the social media channels of project partners - have reached nearly 60 million people.

CCAFS has shown itself to be pivotal influence by demonstrably shaping the way governments have adopted climate adaption policies, with nearly 100 policy wins in just the two years up to 2019, around 70 of which were national policy or strategies.

In fact, all the government stakeholders interviewed view CCAFS as a pivotal global influencer in the adoption of national climate adaption policies by countries all around the world.

2. CCAFS has built a global community for climate adaption: The key to CCAFS success, the interviews reveal, is its focus on strengthening local capacity by providing technical training, expert support and the necessary frameworks for the establishment of local agricultural adaptation strategies, and its steadfast commitment to fostering cooperation between countries and communities that face similar challenges, helping them to draw practical lessons from the experience of their peers.

CCAFS has moved to situate itself at the epicentre of a global network of climate action. Its community of 63,000 social media users is growing, and messages are amplified through influential nodes in the network.

3. CCAFS has sparked public interest in "Climate Smart Agriculture": Google searches for "Climate Smart Agriculture" have consistently increased every month since CCAFS was inaugurated in 2011. Observable peaks in these searches reflect the moments when CCAFS was engaged in intensified strategic advocacy through its participation at the UN Climate Summit in 2014 and Climate Week NYC in September 2019.

The reach of CCAFS science is growing exponentially with content from CCAFS projects being disseminated across 35 thousand URLs from 10 thousand unique domains from more than 150 countries, (43 Low Income and Lower Middle Income countries, 37 Upper Middle Income countries, 51 High Income countries).

The analysis elicits three recommendations:

1. To establish indicators that capture influence from a broader perspective, not only from policy numbers, but also in relation to messaging, visibility, knowledge dissemination and engagement.

2. To leverage on existing evidence to uncover insights, by employing innovative, data-driven methods that enable data repurposing to answer new questions.

3. To develop an advocacy strategy that maps the policy actors and proposes specific outreach, in order to further intensify the program's influence.

Acknowledgements

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Contents

Acronyms

CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CSA	Climate Smart Agriculture
IDN	International Domain Names
IPCC	Intergovernmental Panel on Climate Change
MARLO	Managing Agricultural Research for Learning and Outcomes
SDGs	Sustainable Development Goals
TLD	Top Level Domain
URL	Uniform Resource Locator

Background

Several parts of the world are increasingly experiencing the effects of climate change through more frequent extreme weather events, higher average temperatures and increased variability. Agricultural systems are particularly sensitive to these effects due to their dependence on stable, long-term climatic conditions that impact productive capacity, quality and yields (Cradock-Henry et al. 2020). Consequently, climate adaptation of rural environments is crucial to secure social and economic resilience. As defined in current literature, climate adaptation involves both public and private actors adjusting practices, processes, capital and infrastructure in response to actual or expected climate shocks (Cradock-Henry et al. 2020; Henstra 2016). In agriculture, that encompasses the various strategies adopted by farmers, sectors, industries and regions to "minimize risk and reduce exposure; as well as responses in the decision environment, such as changes in social and institutional structures" (Cradock-Henry et al. 2020).

The past two decades have witnessed a significant evolution in climate adaptation policy. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) highlighted of the role of policy as a key enabling factor to achieving adaptation objectives (Henstra 2016; Keskitalo and Preston 2019), whereas the Paris Agreement emphasized the need not only for policy, but also for the development of financing mechanisms (Olazabal et al. 2019; Runhaar et al. 2018). As a result, the debate around the theme has also shifted from initial awareness-raising to actual implementation of plans and programs at all levels of governments across the Global North and South. International organizations have greatly contributed to this policy development process through research, supporting risk assessment, priority setting and planning, as well as engaging stakeholders (Runhaar et al. 2018).

Within this context, the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) recognizes the need to address the relationship between climate change and declining food security. The program aims to "marshal the science and expertise of CGIAR and partners to catalyze positive change towards climate-smart agriculture (CSA), food systems and landscapes, and position CGIAR to play a major role in bringing to scale practices, technologies

and institutions that enable agriculture to meet triple goals of food security, adaptation and mitigation" (CCAFS, 2016).

A key element of the program is the establishment of strategic, broad-based global partnerships with research institutions, as well as with a wide range of government bodies, civil society and the private sector[1]. It is a collaboration among all 15 CGIAR Research Centers led by the Alliance of Bioversity International and the International Centre for Tropical Agriculture. Its programmatic focus is organized around four Research Flagships: FP1. Climate-smart agricultural practices; FP2. Climate information services and climate-informed safety nets; FP3. Low-emissions agricultural development; and FP4. Policies and institutions for climate-resilient food systems.

Three years after the implementation of the program's Phase II, this evaluation sought to understand the influence of CCAFS in motivating actors to tackle climate change. It employed an innovative approach based on the Digital Methods epistemology and Machine Learning techniques to assess content disseminated on the World Wide Web (or simply, the web) that could provide insights about the program's reach at various levels. The digital research was framed by qualitative, primary data collection. This report describes the methodology and presents the main findings from the research carried out between June-September 2020.

The virtual as an extension of the real: The Digital Methods approach

The pervasiveness of the internet in people's lives is undeniable. According to the latest data[2], almost 60 percent of the world's population (4.5 billion) has access to the internet. Last year alone, an additional 300 million people accessed the internet for the first time, most of them from developing countries. Moreover, just under half of the world's population is active on social media, which now counts on 3.8 billion users. On average, people spend 2.5 hours on social media and maintain 8.6 different accounts. 87 percent of registered users actively engage with social media platforms on a regular basis.

As the most prominent part of the internet, the World Wide Web plays a crucial role within the technological infrastructure of society (Fuchs et al., 2010). While from an industry or marketing

[1] https://ccafs.cgiar.org/about-us#.X2k1cy2ZOu4

[2] We Are Social/Hootsuite Digital Report 2020

perspective the Web 2.0 represents a new way of using the internet, from the user-end these new ways are “developing into new social practices and new forms of knowledge exchange” (Song 2010: 250). The continuous transformation of information technologies in the digital era have expanded the reach of communications tools to all aspects of social life through networks that are at the same time global and local, generic and personal, and constantly changing. As argued by Wellman and Haythornthwaite (2002) the internet has been increasingly integrated into existing offline practices and social relationships, rather than existing as a separate element.

This hybridization of online and offline dimensions has effectively established the internet as a space for research on social phenomena. Among various epistemological approaches, 'Digital Methods' (Rogers 2013, 2015) is defined as the provision of techniques to study social and cultural change through online data, with the web as the data set. It is distinct from other approaches because it “relies on born-digital data, and online method as opposed to digitized data and migrated method” (Rogers 2013:4).

As a data-driven approach, Digital Methods often requires Big Data sources. Scholars have shown that Big Data contains information for complex phenomena that may be difficult to observe using traditional methods (di Bella *et al.* 2016; Einav and Levin 2014). In particular, Big Data are available at a larger scale, on novel types of variables (such as text), for a low cost (no new surveys needed to collect information) and in real-time, thus closing the time gap between observation and analysis, which is a typical problem of studies based on traditional surveys (Giannone *et al.* 2008). Of course, some important issues regarding the use of Big Data in the social sciences should be acknowledged. A few of the great challenges of Big Data research include coping with heterogeneity, its dynamic yet time-sensitive information, filtering through the clutter, coming to terms with the fact that much of what is generated is a by-product of other activities not related to the researcher's specific question, and problems of privacy and transparency (di Bella *et al.* 2016; Kitchin 2014).

Employing Digital Methods to assess the influence of CCAFS

In CCAFS’ theory of change, a cross-cutting aim is to “foster policy and institutional change” that will enable large-scale CSA adoption. This is expected to be achieved by working with strategic partners in four action points: building field-based evidence, strengthening

institutions and services, coordinating climate and agricultural policies, and driving investment to reach scale (CCAFS 2016:13). Flagship Program 1 "Priorities and Policies for CSA" is focused on facilitating these changes, and indicators for monitoring progress include reporting on the number of policies, legal instruments, and investments that have been informed by CCAFS research.

However, this indicator may not be capturing the full extent of CCAFS influence, as it does not consider the processes that enable policy or investment decisions, and in which 'soft power' plays an important role in shaping perceptions and gaining visibility of CSA as an attractive and viable approach to climate adaptation.

It has been widely documented in academic literature that web and social media activities can be considered proxies for wider public discourse and engagement (Carneiro and Costa 2021; Lotan et al 2011; Pearce et al. 2019; Resce and Maynard 2019; Rogers and Marres 2000; Schäfer 2012; Niekler and Wencker 2019, among many others). Based on this notion, a conceptual framework was developed, and an innovative approach based on the Digital Methods epistemology was employed to explore the dynamics of knowledge dissemination and changes in attitude towards CSA and climate change among stakeholders at various levels, by considering online networks and narratives as evidence of "offline" program influence.

With over 140 projects implemented in more than 60 countries since its inception in 2011, CCAFS has engaged with hundreds of different partner institutions, with special emphasis on universities and research centers, as well as government bodies at local, national and regional levels. This evaluation considered the 325 project partners identified in MARLO from projects launched between 2017-2019. Appendix 2 presents the frequency with which different types of institutions have been involved in projects.

Through a data-driven mixed methods approach that applied machine learning techniques primarily focused on search engine queries, data mining, text mining and network analysis of an unstructured mass of data generated on the web, the study investigated the following research question:

Has CCAFS influenced and motivated thousands of actors to tackle climate change?

Figure 1 shows the analytical framework devised for this research. It begins at the project level with textual documentation retrieved from the CCAFS monitoring system that formed the basis for the development of project-specific taxonomies from which to map stakeholder activity against. Then, as program delivery is highly focused on strategic partnerships, the influence among stakeholders directly involved with CCAFS was assessed through interviews that uncovered first-hand narratives, and through the analysis of web activity of project partners (social media and websites). Finally, the analysis went one step further to explore how CCAFS may have reached people beyond its interventions by assessing the extent to which CCAFS-generated knowledge was disseminated and public interest in CCAFS' core mission.

While the framework and the bulk of the research considered natively digital platforms and techniques, the framing is grounded on an extensive consultation process with key stakeholders.

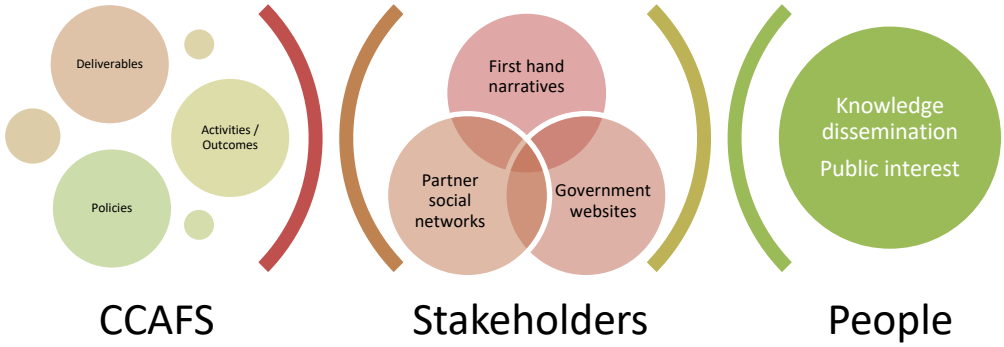

Figure 1 Analytical framework for assessing CCAFS influence among stakeholders and beyond

Data and Methods

Each level of analysis entailed the application of various traditional and innovative techniques, which were divided into five work streams as the mapping exercise moved from the project level towards the general public. The data-driven approach followed the typical machine learning process (Porciello et al, 2020), where data was gathered, processed, and machine learning models were applied to gather insights. The findings were then grounded and framed by the qualitative research. Figure 2 presents the work streams, along with their respective methods. Appendix 1 contains the detailed description of each approach, including information about data collection, algorithms employed and their theoretical foundations.

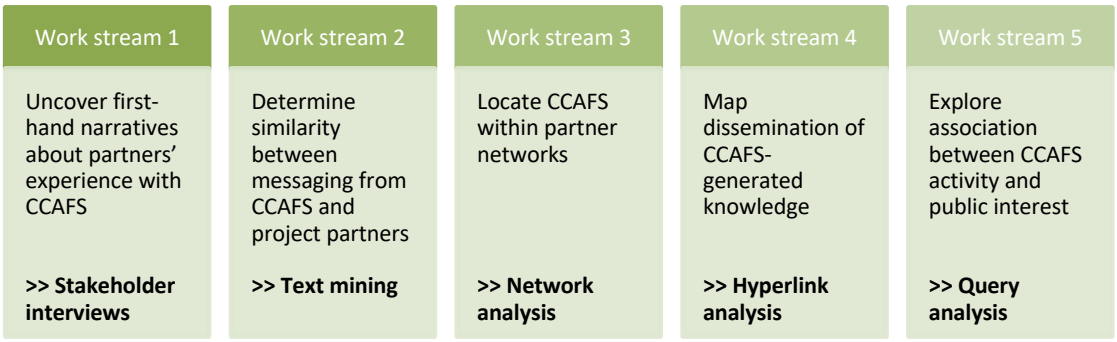

Figure 2 Work streams and their respective methods

The research was computationally intensive and entailed the production of several datasets from which the analysis was performed. Our key data sources were:

- **Project documentation (MARLO):** to gather information on CCAFS interventions, we relied on documentation available from the MARLO platform (Managing Agricultural Research for Learning and Outcomes) for all projects starting between 2017-2019. The following outputs were downloaded: Project reports, Project Partner Summaries, List of Policies and List of Project Deliverables.

- **Social media:** publicly available content from the official Twitter and Facebook accounts of CCAFS project partners for projects starting between 2017-2019.

- **Government websites:** all the news/updates present in a list of more than 50 official government websites among CCAFS partners.

Main results: how has CCAFS influenced stakeholders on climate adaptation?

Narrative from project partners

Key findings

- Qualitative interviews with partners in government and international finance institutions illustrate CCAFS' role in enabling policy development around climate smart agriculture.
- All government stakeholders interviewed view CCAFS as a pivotal global influencer in the adoption of national climate adaption policies by countries all around the world.
- The key to CCAFS' success is its focus on strengthening local capacity by providing technical training, expert support and the necessary frameworks for the establishment of local agricultural adaptation strategies, and it steadfast commitment to fostering cooperation between countries and communities that face similar challenges, helping them to draw practical lessons from the experience of their peers.
- CCAFS capacity development efforts were considered pivotal to increase the confidence of local partners to amplify CCAFS' mission.

Semi-structured interviews with 16 project partners provided significant insight into the mechanisms through which CCAFS helped not only increase awareness of the relationship between climate and agriculture, but also support climate-sensitive policymaking. While the experiences from different countries varied, there were many common threads that reinforced the extended reach of the CCAFS approach.

Awareness raising

First, there was a consistent view that CCAFS helped raise awareness of climate change at the institutional level, making a clear connection between agriculture and climate adaptation, as well as providing reliable solutions at both the technical and policy levels: "CCAFS has been the ignition to awareness creation and capacity building around climate change" (Tanzania). Other statements in this regard include:

> "We had no expertise; our knowledge of climate change was more general… we did not have a specific approach to deal with agriculture." (Central America)
> "Before CCAFS, the ministry had one-off initiatives regarding climate change. To implement a good plan of action, we needed know-how and we found it with CCAFS." (Colombia)

"We had spoken about gender and climate change before, but with CCAFS we found out 'how' it could be done at the technical level." (Guatemala)

"[We] were not working with a climate perspective before, it was fresh ground for us. We saw the Colombian experience and wanted to replicate it in our context." (Honduras)

"[Prior to engaging with CCAFS] our focus for climate change was on floods. We had no knowledge of the extent of CSA, the relationship between climate and agriculture… CCAFS exposed our researchers to CSA." (India)

"CCAFS helped us realize and understand climate change, how to create resilience… how to build awareness of climate change and implement measures to deal with it." (Tanzania)

"CCAFS helped us incorporate climate change into our mainstreaming agenda [gender, youth, indigenous peoples, nutrition]." (IFAD)

Institutional support

As noted in some narratives above, CCAFS has helped strengthen institutional strategies to deal with climate change at various levels. It has provided crucial support to develop and implement agricultural adaptation frameworks across the regions through the expertise of program staff and by building local capacity. Many interviewees noted the ability of CCAFS initiatives to apply scientific evidence to the field and to make this knowledge accessible to different stakeholders: "science needs to be given a human face" (Senegal).

For instance, when speaking about the climate information services developed in Senegal, the interviewee affirmed that while there was prior experience working with farmers, CCAFS made the project more "operational" through support in establishing processes such as planning and M&E. Similarly, in the Philippines, the representative said well-defined guidance received from the program eased the implementation of its Climate Smart Villages project. For Nepal's interviewee, CCAFS helped develop a "clear vision" and consistent working procedures for implementing CSA in the country. In Ethiopia, the representative affirmed that "CCAFS was important for institutional capacity building, for example, through support in monitoring, reporting, and communications."

Such awareness raising and institutional support has translated into increased engagement at the policy level, as noted by several respondents:

"Through CCAFS, we can speak confidently, with technical knowledge, about climate change. We are recognised." (Colombia)

"With better knowledge, we can make better proposals for climate change and gender." (Guatemala)

"We need knowledge to inform policy." (Ghana)

"The process of training, capacity building, and exchanges generates awareness, not only through the work of the technical staff or the farmers, but also the at policy level." (Honduras)

South-south cooperation and knowledge exchange

The value of South-South cooperation and knowledge exchange was highlighted by all interviewees. The opportunity to visit projects in other countries, to take part in international meetings and to exchange experiences were considered a key value-added of CCAFS. Interestingly, respondents mentioned either that they were inspired by what they saw in a country visit, or that they had shared their knowledge for the creation of similar initiatives in other countries. For example, learning from Senegal's climate information services experience was shared with Latin American countries, which then adapted the approach to their national context. Within Latin America, Colombia played a key role in providing a benchmark for the Agroclimatic Committees model that would be replicated in several countries in the region. The Philippines representative affirmed encountering Climate Smart Villages during a field visit to Vietnam – the approach was adjusted and there are now 48 provinces in the country with projects. Likewise, a visit to India helped Nepal's representative think about how to implement a CSA strategy locally. International meetings in Kenya, Indonesia, and Sri Lanka, to name a few, were all mentioned as important opportunities for South-South collaboration and exposure to different perspectives. Significant statements include:

"As an example of social learning, a group of farmers visited a project in Burkina Faso." (Ghana)

"Our engagement with CCAFS began with a visit to Colombia to see a well-established Agroclimatic Committee there, where I thought 'we can do that in Guatemala too'." (Guatemala)

"It all started with a trip to Colombia. It was not an expenditure, it was an investment that has impacted thousands of people… we copied Colombia and improved it, adapted it to our context." (Honduras)

"The most important element of CCAFS is the south-south cooperation. We exchanged experiences with African countries and saw what was being done there, how to bring it to India, and what were the best practices." (India)

> "I went to Leeds to meet with CCAFS experts, to talk about science. Projects don't usually have time for that… To meet people at different levels, with different visions… helps change my mindset and think about how to bring back this knowledge to Senegal." (Senegal)

The cooperation was not restricted within CCAFS project countries. As a regional organization, CAC believes that this knowledge exchange reaches all countries in the region, irrespective of a direct involvement with CCAFS. Whereas at first Honduras adapted the Colombian experience with Agroclimatic Bulletins, they were then multiplication agents themselves by presenting their achievements at the regional level and generating an exchange with Nicaragua. Similarly, Guatemala's gender guide for sustainable development was presented as best practice at CAC, gaining the attention of other countries interested in replicating it. The Tanzania representative also believes that while projects begin at the grassroots level, their outcomes are then shared locally, nationally and regionally: "Outcomes of CCAFS set the standard adopted within the East Africa region" (Tanzania).

Multi-stakeholder engagement

This multiplier effect was also noted at the project level, where participation in CSA platforms was perceived to enable multi-stakeholder engagement, and awareness raising was considered to amplify CCAFS' core message beyond direct beneficiaries. Multi-stakeholder platforms were mentioned in Colombia, Kenya, Ghana and Honduras. In Tanzania, CSA Alliances at the municipal level were incorporated into those districts' municipal plans, serving as examples to all other districts in the country: "Through these alliances, support was gathered for the inclusion of CSA into municipal planning, which encouraged other districts to follow" (Tanzania).

In Senegal, a community member who actively engaged with a CCAFS project has now gone on to become a member of parliament, taking the approaches offered by the program to the national legislature. Other examples include:

> "With CCAFS support, the platform engaged with several stakeholders critical for representation, such as academia, NGOs, and at the policy level by targeting strategic directors in the Ministry of Agriculture, but also with farmers through farmers' forum, demonstration farms, festivals, and social learning… they are the implementers" (Ghana)

"The farmer learns to work with various issues, for example gender issues. [They] have an 'ancestral' way of working, so a change of paradigm is needed in order to adapt… these exchanges have a multiplier effect" (Honduras)

"When we involve more farmers, support their decision-making based on climate information, we get more involvement" (Senegal)

The importance of engaging at the local level was also highlighted as a key element to reach national level policymaking:

"Local government support is essential. They can only support if they know what they are doing." (Philippines)

"To make politicians aware, we need to reach local level. Climate information happens at the national level, but decisions are taken at local level." (Senegal)

Policy support

At the policy domain, many examples of successful engagement of CCAFS projects with national level policymaking were given by the interviewees. In both the Philippines and Senegal, climate information is now incorporated into the planning processes of agricultural/farming/fishing policies. In Senegal, an important legacy of CCAFS is an early warning system development by the meteorological services that is sent by SMS to farmers: "CCAFS gave us visibility and credibility with the national government, and so they gave us the resources to do this" (Senegal).

In Rwanda, indicators for the Strategic Plan for Agricultural Transformation were directly inspired by the CCAFS climate services project. In Ethiopia, a CSA taskforce supported policy by briefing the ministry about different technologies and experiences. A seminar in Tanzania targeting members of parliament to raise awareness of climate change adaptation was considered a success: "It was an opportunity to reach a higher class of decision makers, which can then support mainstreaming of climate change and speak about it all levels, from the constituency to the national policy level. It is essential to capture these decision makers to get buy-in… When high level decision-makers gain proper knowledge of climate change, they are good elements to persuade people, from their local supporters/constituents to fellow policy-makers." (Tanzania). Other examples from Tanzania include contributions to the CSA Alliance guidelines in 2017, the establishment of the Agriculture Climate Resilience Plan 2014-2019, and the Tanzania CSA Profile.

In Ghana, the program supported the development of a national climate change policy document with a CSA Plan: “The CSA Plan is a critical document that responds to national climate change policy and is put forth by the Ministry of Food and Agriculture. The ministry has taken the plan to the World Bank and is developing Ghana’s CSA investment plan. The platform was involved in drafting this document, which will have a major policy influence” (Ghana). In Vietnam, CCAFS provided technical support to incorporate a CSA plan for the Mekong River Delta into policy.

In Latin America, CCAFS was involved in drafting the Honduras institutional strategic plan. In Guatemala, the gender strategy has influenced the rural development agenda for women in the region and the agriculture/livestock policies, which have strengthened peasant agriculture with an adaptation perspective. A climate change plan developed by the ministry of environment also received many inputs by CCAFS, and climate information services is in the process of institutionalization. Likewise, in Colombia, there are processes in course to incorporate the Technical Agroclimatic Committees into permanent public policy, and knowledge from CCAFS has enabled the development of specific climate change plans for each productive sector in the country. The CAC representative believes that countries in the region are now developing national climate adaptation strategies because of the program’s regional approach.

Within IFAD, CCAFS is considered a key partner in its main climate adaptation program, ASAP: “CCAFS started around the same time as ASAP, which was an important moment to mainstream climate change into programs” (IFAD). The program has contributed with research and solutions to complement IFAD’s M&E and knowledge management mechanisms. It was also pivotal to support the design of several ASAP projects, such as in Mali, Nicaragua, Vietnam and in other countries where climate information services were developed: “Evidence from CCAFS has definitely been used, and impact at the policy level is there, as IFAD always works with government partners” (IFAD).

CCAFS representation at the COP meetings was also highlighted by IFAD and other partners, namely Senegal, Rwanda, Ethiopia and CAC: “Advocacy work at COP helped increase financial contributions from member countries” (IFAD). The program’s successes have also helped secure funding in other instances. For example, in Senegal, USAID was financing the upscaling

of climate information services. In the Philippines, the Department of Agriculture now allocates a yearly budget for climate resilience building; Vietnam secured funding for the maintenance of a climate change fund. When Colombia's livestock program did not have enough funds to complete implementation, producer associations helped cover the costs. Honduras also secured additional funds from USAID, IFAD and the Japanese government to expand work on climate change: "CCAFS planted the seed for CSA, but we still have a long way to go" (Honduras).

Capacity development

Finally, with regards to capacity building, one of the key aims of CCAFS, the general response is that efforts are well targeted and effective. Capacity development was found to be intrinsically connected to the program's influence, as the knowledge acquired through training and other initiatives were pivotal in increasing the confidence of local partners to amplify CCAFS' mission. Interviewees noted that CCAFS capacity development encompassed both technical subjects such as climate-related tools and technologies, but also themes around project management and delivery (project proposal writing, M&E, cost benefit analysis, communications, etc).

> "It is easy to find capacity development for general issues, but CCAFS develops knowledge at the technical level" (Central America)
> "CCAFS has extensive experience, qualified technical experts and a good perspective of applied field research, of applied knowledge." (Colombia)
> "CCAFS supported institutional innovations, such as how to develop concept notes and policy briefs to amplify the work of platforms." (Ghana)
> "A lot of work was done at the national level through support, for example, getting academics to go to the CSA Platform and conduct workshops with the goal of creating awareness and sensitising to climate change." (Ghana)
> "CCAFS exposed us to new tools and helped us train farmers for weather-related issues… We leveraged on this knowledge transfer and now various groups work together. The technical work strengthens cooperation." (Guatemala)
> "We have greatly improved our knowledge about CSA. The first workshops I attended with CCAFS were about how to structure a climate change unit, and another about how to develop a guide for gender-sensitivity… We have been exposed to technical and technological instruments, and to intersectionality." (Guatemala)
> "The CCAFS team built capacity for climate tools, both for IFAD staff and for projects." (IFAD).

"CCAFS was important for institutional capacity building, for example, supporting in monitoring, reporting, and communications." (Ethiopia)

"National and international workshops increased our exposure to technologies, experiences, scientific knowledge, and gave us ideas of how to conduct things in Nepal" (Nepal).

Suggestions to enhance the program's capacity development strategy included improving the assessment of capacity needs among stakeholders in order to target specific gaps in training, increasing the diversity of platforms available to access information (for instance, to include instant messaging services), and providing more support to connect partners to funders.

Evidence from social media

Key findings

- CCAFS has shifted the debate on climate adaptation among strategic partners.
- On Twitter, the text correlation between project-specific taxonomies and tweets by CCAFS strategic partners increases about 5% after the project start date. The increase is statistically significant, amplifying CCAFS' reach to 5.8M followers on the platform (based on the sum of partners' followers)
- On Facebook, CCAFS partners increase content related to the programme's mission afte involvement with projects, though the trend is not statistically significant.

Within the social sciences, content analysis methods allow researchers to identify patterns and changes in political agenda over time and across geographies (Brandt 2019). A proxy for how CCAFS activity influences stakeholders, and how stakeholders in turn amplify the program's mission to a broader audience, is social media activity. To assess the extent to which climate adaptation activities developed through CCAFS projects are represented in the social media profiles of CCAFS partners, we applied text mining techniques to determine a similarity measure between program activities and messaging from partners on two key social media platforms: Twitter and Facebook.

It is important to note that while social media is often discussed in general terms, is not a homogeneous entity. In fact, social media contains many different "platform cultures" arising from a combination of technical affordances and user behaviors. Twitter has been described as a digital forum, and in the literature that has assessed the platform in connection to climate change activity online, it is considered an important "source for climate change information-exchanges" (Pearce et al. 2019). Facebook, given its size and dominance as the leading social media platform globally, is also a source of powerful data for analyzing social and economic behaviors. However, since its contents are more heterogeneous and user-adjustable, they are also more difficult to retrieve and analyze (Blazquez and Domenech 2018). Consequently, our analysis was adapted to suit each platforms' features.

The first step in our approach was the development of a custom taxonomy from CCAFS projects to identify key terminology from which we could map text from partner sources against. For this, machine learning algorithms were applied to carry out unsupervised text mining of selected reports/report sections retrieved from MARLO for all 105 projects

implemented between 2012 and 2019. We used the statistic tf-idf, a widely used measure of how important a word is to a document in a collection (or corpus) of documents (Silge and Robinson, 2017). In our case, the tf-idf combines frequency, i.e. how many times a word is associated to a project, and the inverse of ubiquity, ie. how exclusive the association is between a word and a project (Hidalgo and Hausmann, 2018; 2019). The main outcome of this analysis was a vector of words with an associated vector of weights (importance = tf-idf) for each of the 105 projects. This information constitutes the project-level taxonomy, in which each project had its own set of significant terms.

In Twitter, to measure of the influence of CCAFS on project partners, we assessed the change in the content of the tweets over time, based on the start dates of the projects they were involved in, and in relation to their respective project taxonomies. In essence, we compared the text of tweets before and after their project started. An algorithm was developed to scrape 240 Twitter accounts from 232 different partners and collect all their tweets from 2010 to 2020, in a total of 888,174 unique tweets.

Hashtag use is a typical affordance of Twitter, with topics and issues frequently denoted by specific hashtags (Resce and Maynard, 2018). Hence, a first approximation of prevalent topics covered by CCAFS' partners over the period of analysis can be obtained in Figure 3, which shows Word Clouds (Fellows et al., 2018) for hashtags for all partners, one year before and one year after the project start dates. While #climatechange was already one of the top hashtags before CCAFS interventions, there is an increase in the presence of #foodsecurity and #agriculture, both of which are central elements of the program's agenda.

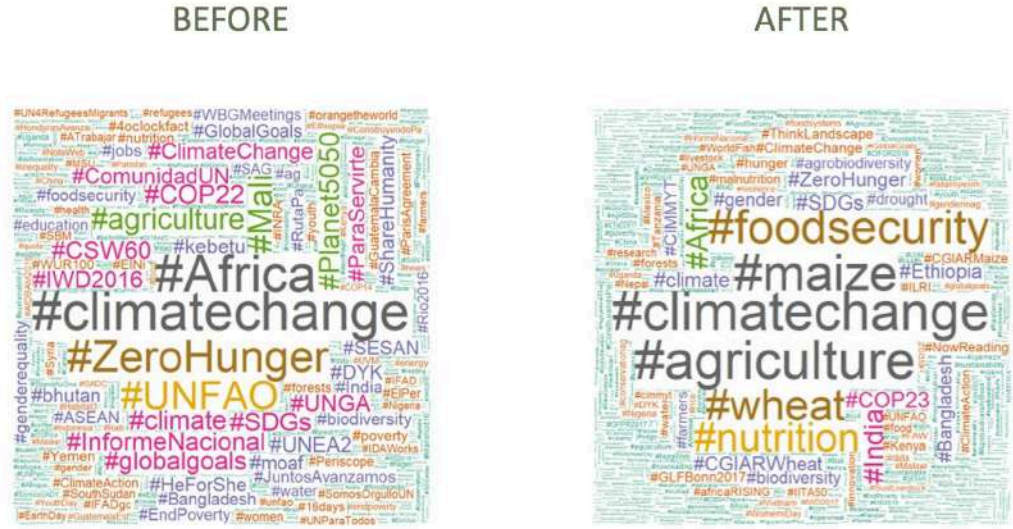

Figure 3 Word Clouds of hashtags for all partners, before and after project start dates.

However, hashtags provide only a visual representation of the communication changes before and after project start. The results can be influenced by the level of activity of particular partners (or partner types, such as CGIAR centers) as they reflect absolute frequencies. For an analytical assessment of Twitter communication, and as a measure of similarity between CCAFS taxonomy and text from the tweets, we use a Text Correlation measure. In the text correlation, biased data is tackled by measuring the whole text of tweets (not only hashtags) against project-specific taxonomies, over a period of time. As such, the potential influence of CGIAR centres is constant throughout the period of analysis.

Between 2017 and 2019, CCAFS implemented 57 projects, from which we have Twitter data for at least one partner for 52 of them. These projects launched in seven different start dates. For each partner we estimate the text correlation between their tweets and the taxonomies for their respective projects by measuring the presence of significant words in the corpus of tweets. By construction, the text correlation is included in the interval [0:1] and gives a measure of how similar the content of tweets is to the taxonomy of CCAFS projects.

Analysis by project start dates is available in Appendix 4. Figure 4 shows the text correlation between CCAFS taxonomy and the corpus of tweets for all partners of projects that started between 2017-2019. The x-axis represents months – we considered 12 months prior and 12 months after for all seven start dates. There is a clear increase over time, after the projects' start date.

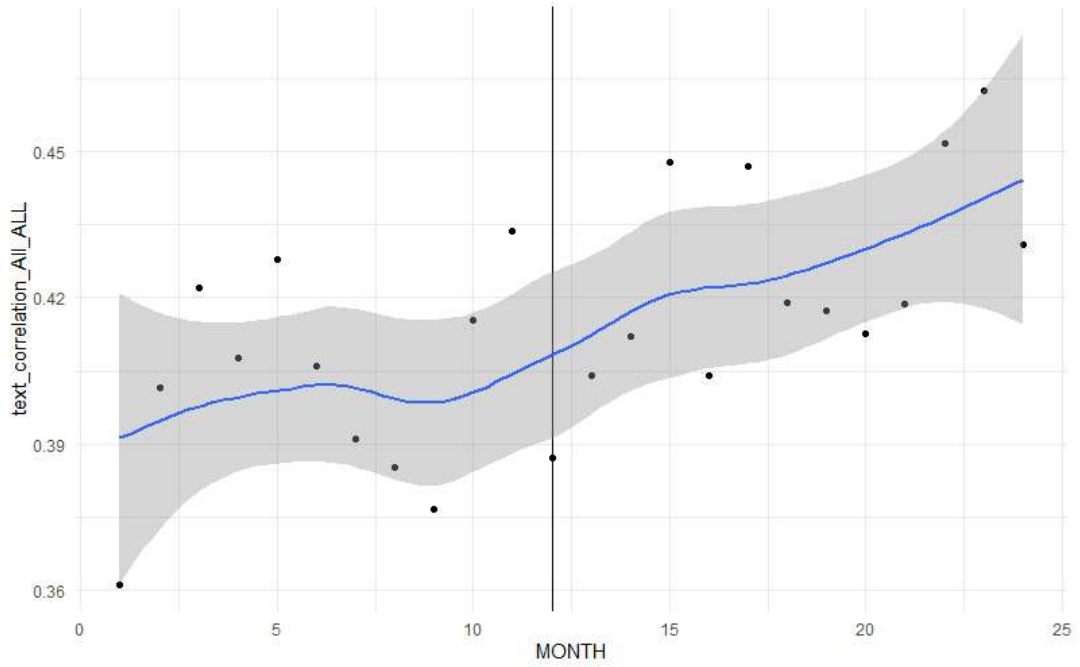

Figure 4 Overall text correlation between CCAFS taxonomy and tweets of partners for all projects started between 2017-2019.

To give an empirical measure to the text correlation over time, and to test whether the correlation after the projects start is significant, a linear regression was performed. Results in Table 1 show that the text correlation increases about 5% after project approval, and that the increase is statistically significant ($p<0.05$)[3].

Table 1 Regression results for text correlation between CCAFS taxonomy and tweets of partners.

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.403	0.007	59.980	0.000	***
After approval	0.022	0.009	2.377	0.027	*
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Residual standard error: 0.02226 on 22 degrees of freedom					
Multiple R-squared: 0.2044, Adjusted R-squared: 0.1682					
F-statistic: 5.651 on 1 and 22 DF, p-value: 0.02657					

As in the case of Twitter, for Facebook the measure of the influence on CCAFS on project partners is estimated by comparing the content of the posts with the start date of the projects they belong to. From 2017 to 2019 we have Facebook accounts for partners participating in 52

[3] Quadratic term not significant.

out of the 57 projects. Overall, 285 Facebook pages of 275 different partners were scraped through another custom algorithm, collecting a total of 799,557 posts.

The seven approval dates considered are the same used for the Twitter analysis. However, as discussed, social media platforms each have their own features and "cultures". In Twitter, the 240-character restriction makes the text much cleaner and to the point. Text is a central element, as Twitter is a space for institutional position-taking and official statements that are considered primary news sources by the media. Facebook, on the other hand, is much less formal and heavily reliant on non-textual media, which made the data extremely noisy.

These differences make it difficult to detect CCAFS' influence by means of text correlation and classical text mining tools. To overcome this issue, in the case of Facebook, the metric used was topic detection (by stemmed words) in the text of posts, where we analysed the terms that can be reconducted to the CCAFS name and main message, i.e.: climate (clim*), change (chan*), agriculture (agric*), food (food*), and security (secur*). Figure 5 shows the overall topic identification in posts on Facebook for partners for all projects approved between 2017-2019, and we can see a slight increase over time. Figure 6 shows the correlation among topics identified in posts on Facebook for partners for all projects approved between 2017-2019, which is a measure of co-occurrence, i.e. how often CCAFS keywords appear together in the same partner post.

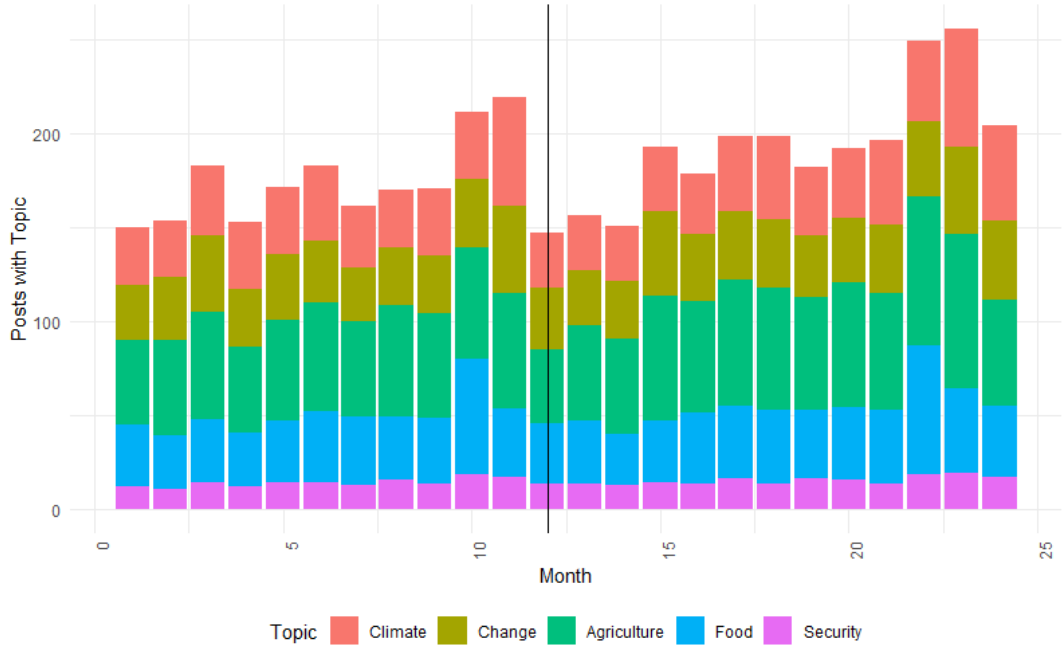

Figure 5 Overall topic identification in posts on Facebook for partners for all projects approved between 2017-2019 (approval date is the black vertical line).

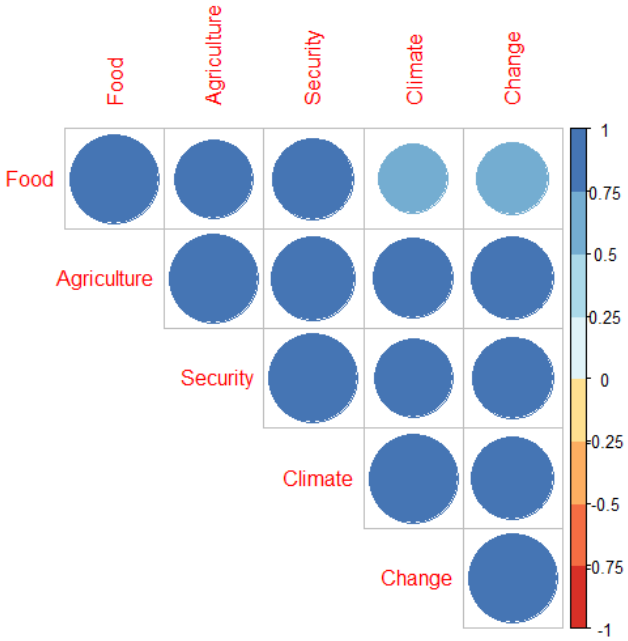

Figure 6 Correlation among topics identified in posts on Facebook for partners for all projects approved between 2017-2019.

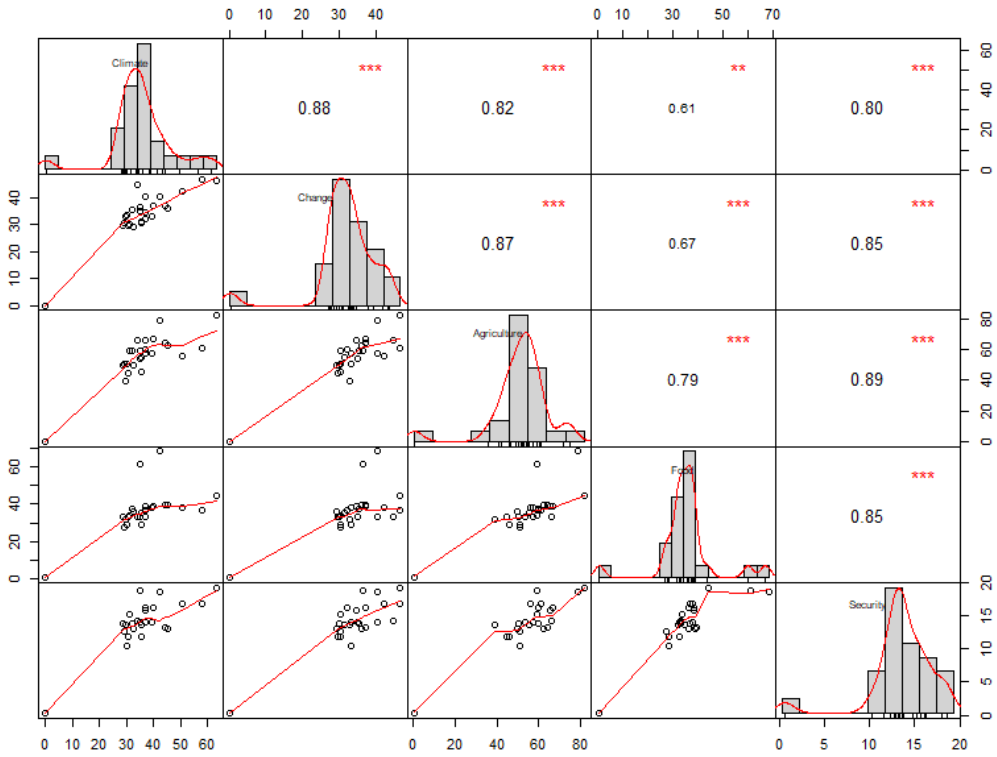

Figure 7 Distribution and correlation significance among topics identified in posts on Facebook for partners for all projects approved between 2017-2019.

The correlation is always positive and significant (see figure 7), with a slightly lower significance in the case of Food compared with Climate and Change. To provide an empirical measure to the increase of CCAFS topics over time and to test whether the change in topic presence after the projects start is significant, we performed a linear regression. The presence of the topics in the Facebook posts of project partners is always increasing after the project in which partners are involved in starts. Yet, the coefficients are not statistically significant, as seen in Table 2. This may be partially due to the issues mentioned above regarding Facebook's affordances, which cause additional noise.

Table 2 Regression Results for topic presence on Facebook.

	Climate	Change	Agriculture	Food	Security	CCAFS
Intercept	36.388 ***	34.125 ***	54.155 ***	36.241 ***	13.975 ***	174.885***
	(3.554)	(2.713)	(4.628)	(3.634)	(1.115)	(14.331)
after	0.391	0.104	3.314	0.048	0.119	3.975
	(4.749)	(3.625)	(6.185)	(4.856)	(1.490)	(19.150)
N	25	25	25	25	25	25
R2	0.000	0.000	0.012	0.000	0.000	0.002
*** p < 0.01; ** p < 0.05; * p < 0.1.						

Evidence from official policy makers websites

Key findings

- CCAFS has shown itself to be pivotal influence by demonstrably shaping the way governments have adopted climate adaption policies, with nearly 100 policy wins in just the two years up to 2019, around 70 of which were national policy or strategies.

- Government partners increase dissemination of content related to CCAFS projects with which they are involved in on their news pages by 10% after project start dates. The increase is statistically significant ($p<0.01$), which indicates heightened sensitivity to climate issues and a more prominent place in government policy-making agendas.

Through monitoring information retrieved from MARLO, we found that CCAFS projects have reported 96 policy outcomes between 2017-2019. Figure 8 shows the types of policies reported, with a significant prevalence of the category "Policy or Strategy", followed by "Budget or Investment".

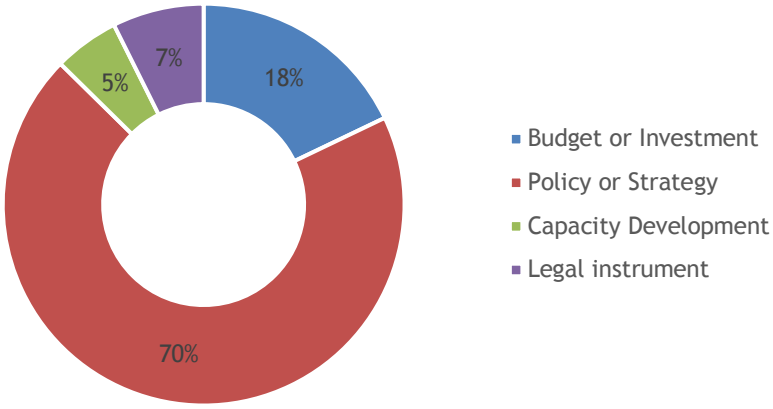

Figure 8 Policies reported in MARLO between 2017-2019, by type (n = 96).

However, this study was interested in identifying any influence beyond the reported policy instruments, through increased space in policymaking to issues related to CCAFS' projects. For this, the same approach as Twitter was applied to assess the news and updates pages of government partners; these were considered as spaces where policy shifts would be reflected in the texts and presented with dates. The dataset of this ecosystem was composed by all the news or updates published on a list of 54 websites of the government partners in CCAFS projects. Of these, 35 were scrapable through custom algorithms, collecting a total of 21,071 news items spanning from 2002 to 2020.

As with social media, the languages were detected by an algorithm, with Spanish as the prevalent language in the corpus. The dataset was then translated to English with Google Translate in order to analyze against the taxonomies. Figure 9 shows a Word Cloud (Fellows et al., 2018) for the entire corpus of government news items.

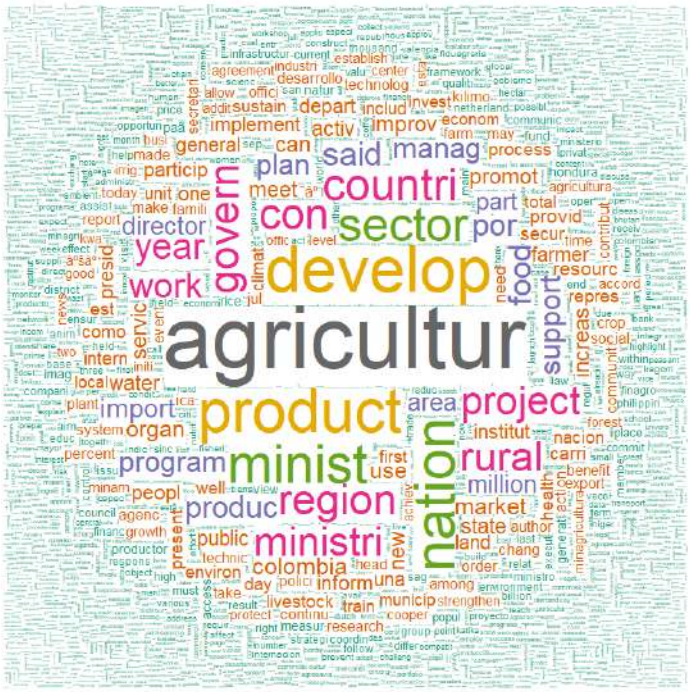

Figure 9 Word Cloud for translated stemmed terms.

Again, three approval dates with a significant number of projects were analysed individually: 2017-01-01, 2018-01-01 and 2019-01-01. Appendix 5 present the results for the individual analysis of the three project start dates. With the exception of the projects started in 2018, they indicate an increase in the use of CCAFS-related terminology in the websites of government partners.

Finally, an overall analysis for all available websites, for all projects started between 2017-2018, was conducted. The Word Cloud in figure 10 illustrates the frequency of stemmed words in the corpus one year prior and one year after the project start dates. The term agricultur* gained significant prominence in the second image.

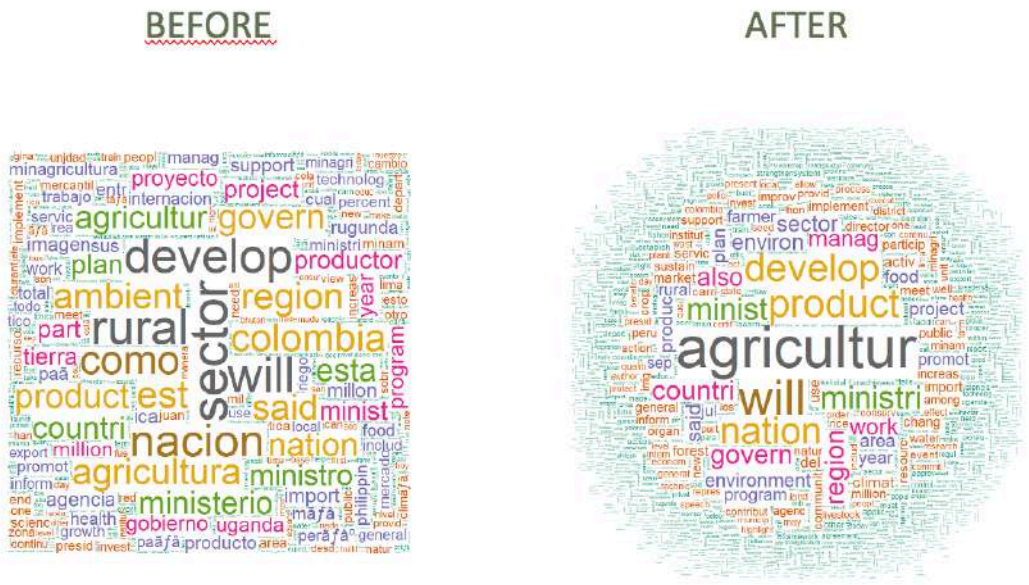

Figure 10 Word clouds for news pages of all government partners in projects launched between 2017-2019.

Figure 11 shows the text correlation between CCAFS projects' taxonomies and text in the news sections of the websites of government partners for all projects launched between 2017-2019. Similarly to Twitter, there is a clear increase over time, after the projects start.

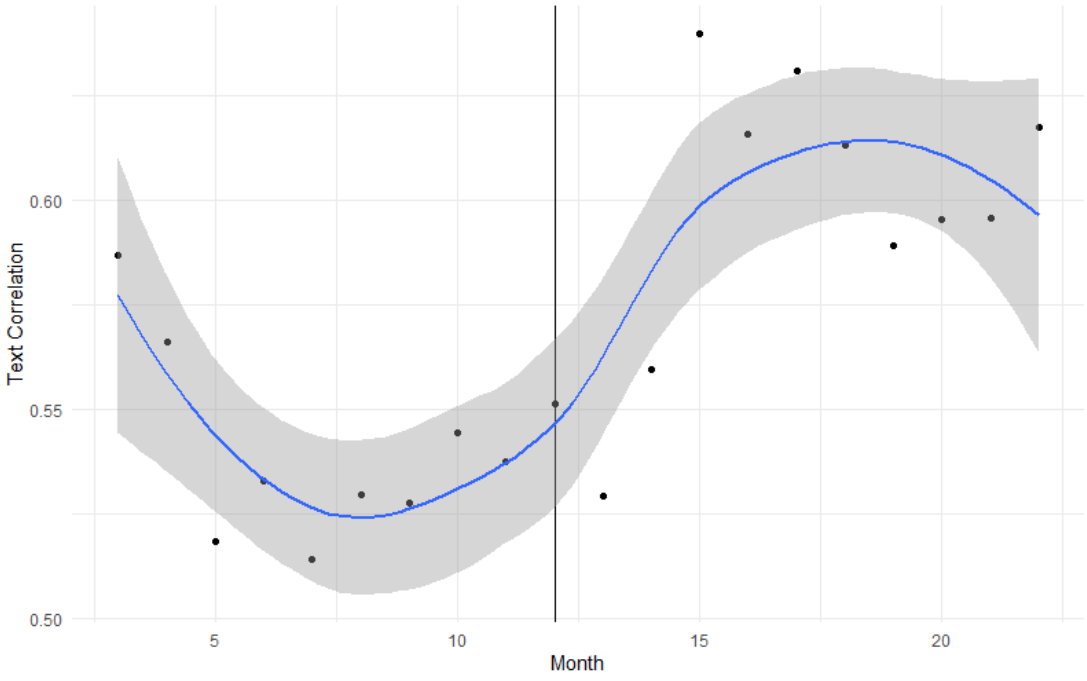

Figure 11 Overall text correlation between CCAFS taxonomy and news pages of government partners for all projects started between 2017-2019.

To give an empirical measure to the text correlation over time and to test whether the correlation after the projects start is significant, we performed a linear regression. Results in Table 3 show that the text correlation increases about 10% after project approval, and that the increase is statistically significant ($p<0.01$).

Table 3 Regression results for text correlation between CCAFS taxonomy and news pages of government partners.

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.540	0.010	53.715	0.000	***
After Approval	0.055	0.014	4.027	0.001	***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Residual standard error: 0.03015 on 18 degrees of freedom					
Multiple R-squared: 0.474, Adjusted R-squared: 0.4447					
F-statistic: 16.22 on 1 and 18 DF, p-value: 0.0007904					

How central is CCAFS in its network of strategic partners?

Key findings

- CCAFS has moved to situate itself at the epicentre of a global network of climate action.
- The broader CCAFS partner network, as measured by Twitter mentions, comprises more than 63 thousand unique users, in which CCAFS is positioned among key players in international development and research.
- Excluding CGIAR-related accounts, the programme's immediate network contains 890 nodes, which represent both Twitter accounts that CCAFS has mentioned, and those that have mentioned CCAFS.

Using the dataset collected from twitter, it was possible to assess CCAFS' place within its network of strategic partners by analyzing the accounts mentioned on partner tweets. A network analysis was performed to explore the relationship between accounts mentioned in the corpus. Network analysis techniques enable the visualization of relational data organized as matrices, where entities are the nodes – in this case, @mentions – and their relations are the lines connecting pairs of nodes. This means that accounts are connected if they are mentioned by another.

A force-directed algorithm was used to construct the network displays. Force- directed graphs show the spatialization of nodes by mapping the proximity and the authority of categories in relation to each other (Jacomy *et al.* 2014). This means that linked nodes are drawn closer while unrelated nodes are pushed farther apart, thus allowing for a visual interpretation of the dynamics between actors in the network. A modularity algorithm (Blondel et al., 2008) was applied to identify "communities", or clusters – as represented by nodes that are more densely connected together than to the rest of the network, and which were coloured accordingly.

The entire network of Twitter mentions is very large, as more than 63 thousand accounts were mentioned by CCAFS partners over the period of analysis, and these were connected almost 100 thousand times (Figure 12).

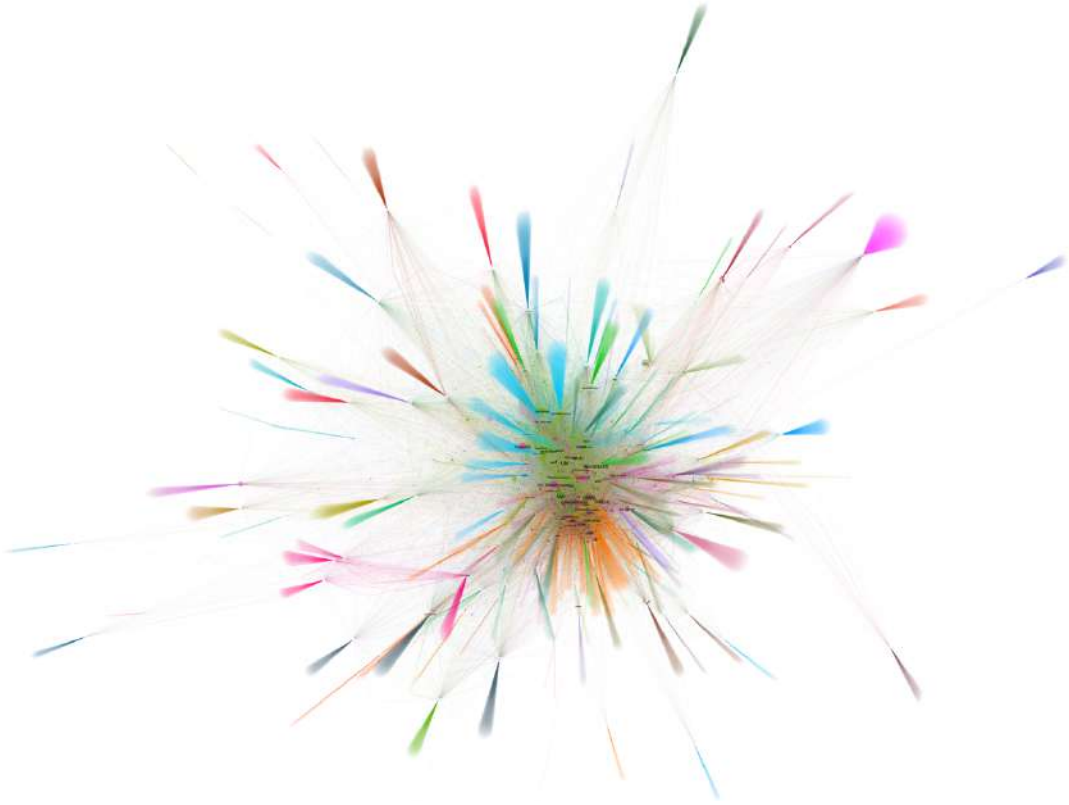

Figure 12 Overall partner network. Parameters: force-directed graph, with node size partitioned as Weighed in-Degree, colored by modularity class. Nodes = 63,690 accounts, edges = 99,775 connections.

In order to understand who the key actors are, we zoomed in to the center and considered only accounts that were mentioned at least five times. This criterion reduced the number of nodes to approximately 2,300, with 23 thousand connections between them. As expected, this filtered network is denser, with nodes connected on average to 9.8 other nodes.

The resulting visualizations in Figure 13 show a few prominent clusters. The largest ones are the green and the brown clusters, which contain international development institutions and large media outlets –CGIAR centres are located within the brown community. There are smaller clusters such as the blue and pink at the bottom, with government accounts from African and Latin American countries, and the purple on the top with academic institutions.

The two graphs show the same network, analyzed through different metrics. In the graph on the left, the size of the nodes and their labels are set according to the number of times they have been mentioned by different accounts. For example, the UN, the World Bank or the EU

Commission are some of the largest accounts in this network, and as such have been mentioned by several others.

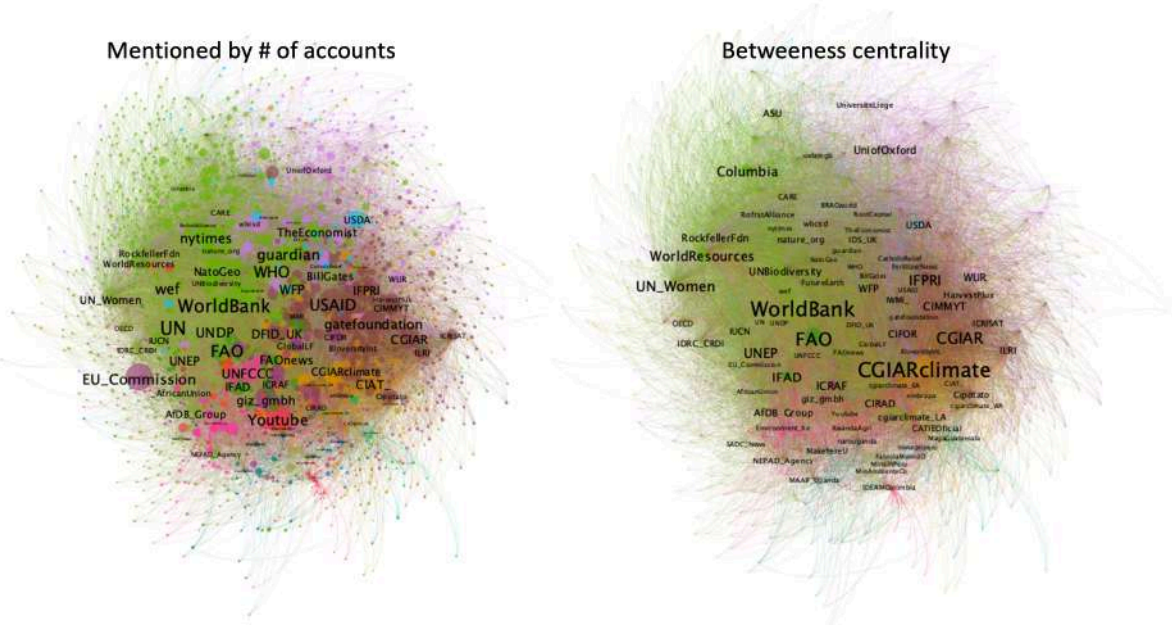

Figure 13 Network of mentions from CCAFS partner twitter accounts. Parameters: force-directed graph, with node size partitioned as Weighed in-Degree, colored by modularity class. Nodes restricted to those mentioned at least twice. Nodes = 2,353 accounts, edges = 23,074.

On the right we have a different analysis, in which the size of the nodes and labels are calculated based on their betweenness centrality. This metric is a measure of how often a node sits between two other nodes, that is, how much a node connects the others in the network. According to literature that has examined the interaction between organizations and the public on Twitter, profiles with high betweenness centrality can be considered "social mediators" and play an important role in reaching out to others that do not interact directly with that organization (Hansen et al, 2011). Moreover, actors with high betweenness centrality often connect entities from different clusters, which can influence information flow across groups. In this case, CCAFS holds a more prominent place, as it dialogues with many accounts within this network.

In both graphs however, it is clear that CCAFS is positioned among key players within international development and research institutions. Within its network of partners, the program has an important role bridging various actors. Lastly, as expected, there is a strong presence of CGIAR research institutes given that CCAFS is a collaboration among its 15 centers,

who are responsible for local delivery of projects and may therefore have a stronger institutional presence.

Finally, figure 14 presents CCAFS's 'ego network', composed of nodes directly connected to @CGIARclimate. There are 909 nodes in this graph, which represent both Twitter accounts that CCAFS has mentioned, and those that have mentioned CCAFS. Out of these, 22 belong to CGIAR centers. Based on the information extracted from the CCAFS account, between 2010-2020 @CGIARclimate has been mentioned 9,873 times and received 2,100 replies on its tweets.

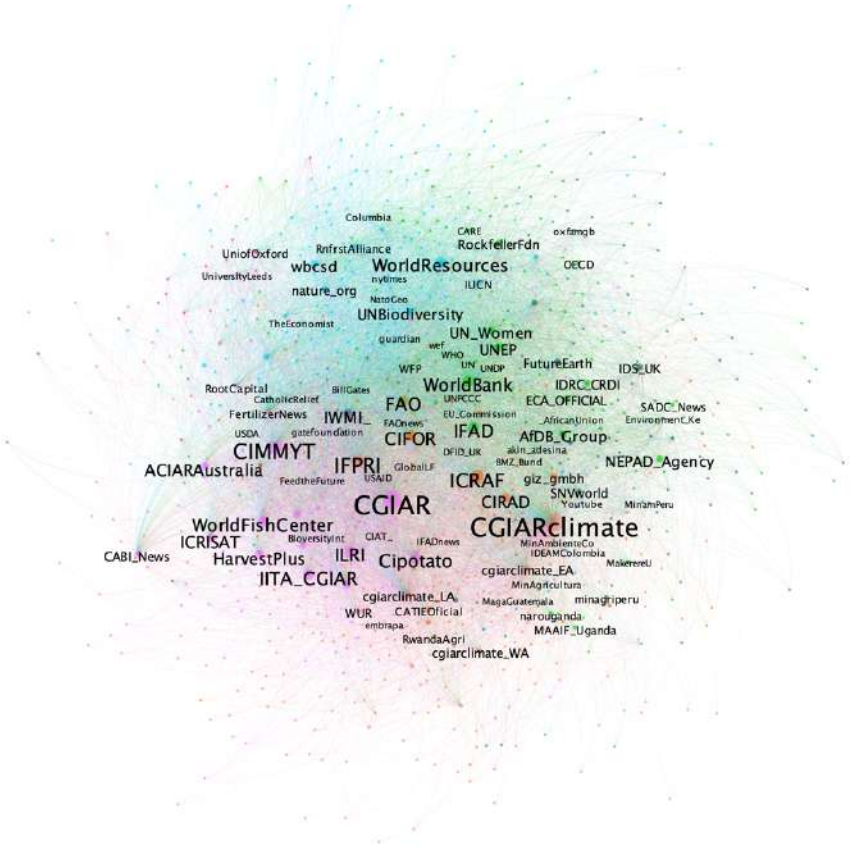

Figure 14 CCAFS Ego Network. Parameters: force-directed graph, with node size partitioned by Degree, colored by modularity class. Nodes restricted to depth of 1 degree from node @CGIARclimate. Nodes = 909 accounts, edges = 12,024.

Nevertheless, it is important to highlight a limitation of this analysis: while we have managed to build a comprehensive network of CCAFS partners, it does not capture the entire extent of reach and engagement on Twitter. That is because two important affordances of the platform are the ability to share a particular tweet – the "retweet" or "RT" feature – and to mark a

particular tweet as “favorite”, as a sign of agreement or support. Between 2010-2020, @CGIARclimate’s 21 thousand tweets received more than 60 thousand retweets and 34 thousand “favorites”.

The identification of accounts that have retweeted or favorited CCAFS content beyond the network of partner accounts was not built into the scraping algorithm due to time and resource limitations. Such capacity to map the profiles that have engaged CCAFS content would significantly enhance this network, as it would encompass actors beyond direct stakeholders and provide insights into the broader public interacting with CCAFS on the platform.

How far has CCAFS knowledge been disseminated?

Key finding

- The reach of CCAFS science is growing exponentially with content from CCAFS projects disseminated across 35 thousand URLs from 10 thousand unique domains from more than 150 countries (43 Low Income and Lower Middle Income countries, 37 Upper Middle Income countries, 51 High Income countries).

An approximation of how CCAFS activity is disseminated globally was explored through a hyperlink analysis, which used the list of CCAFS deliverables reported in MARLO to explore how they are spread through the web. This led to the identification, by means of web scraping algorithms, of the web pages hyperlinking to every item of the considered list.

Of the 2,709 deliverables searched on the web, the algorithm generated non-ambiguous results for 2,154 items, for a total of 35,501 web pages pointing to them. Out of those, more than 10 thousand were unique domains. Figure 15 breaks down the frequency of URLs by type of deliverable, as identified in MARLO. It shows that scientific research was the most frequently disseminated deliverable, followed by reports and outreach materials.

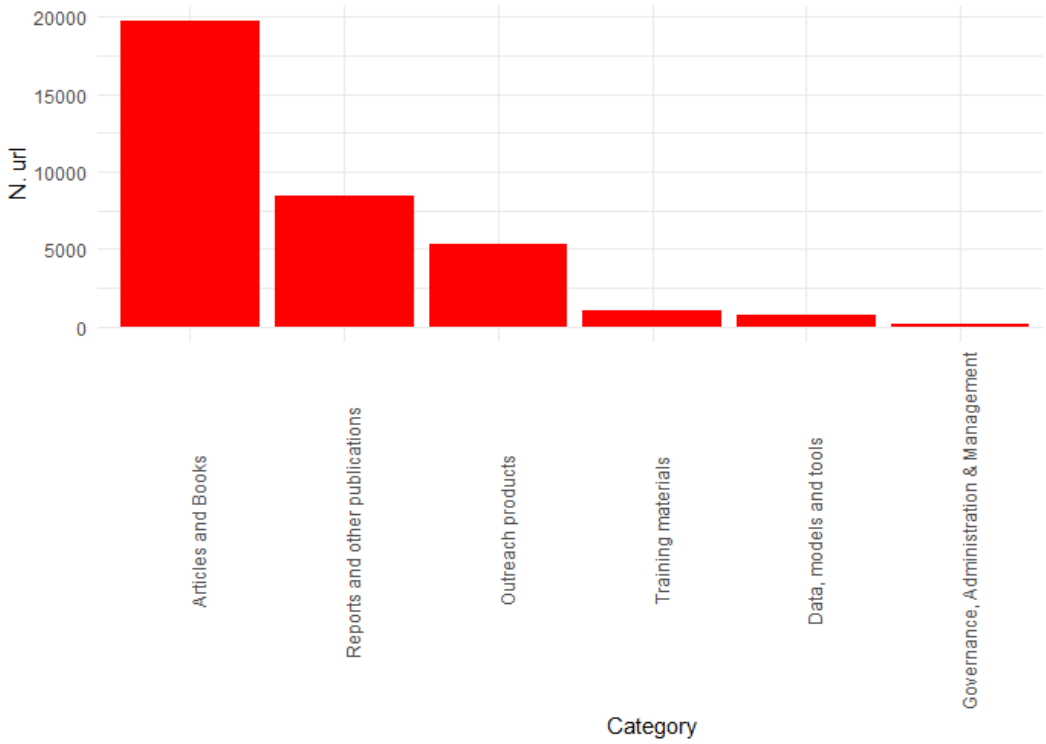

Figure 15 Frequency of URLs, by categories of deliverables.

Figure 16 shows the top domains where content was disseminated. CGIAR-related websites have been excluded. In line with the categories identified above, Google Scholar is the most

frequent domain where CCAFS content is present and/or mentioned. The other top domains also indicate a strong presence in academic platforms such as SemanticScholar and ResearchGate, or publishers like Springer and Wiley, but also show CCAFS knowledge is being distributed across social media and international organizations.

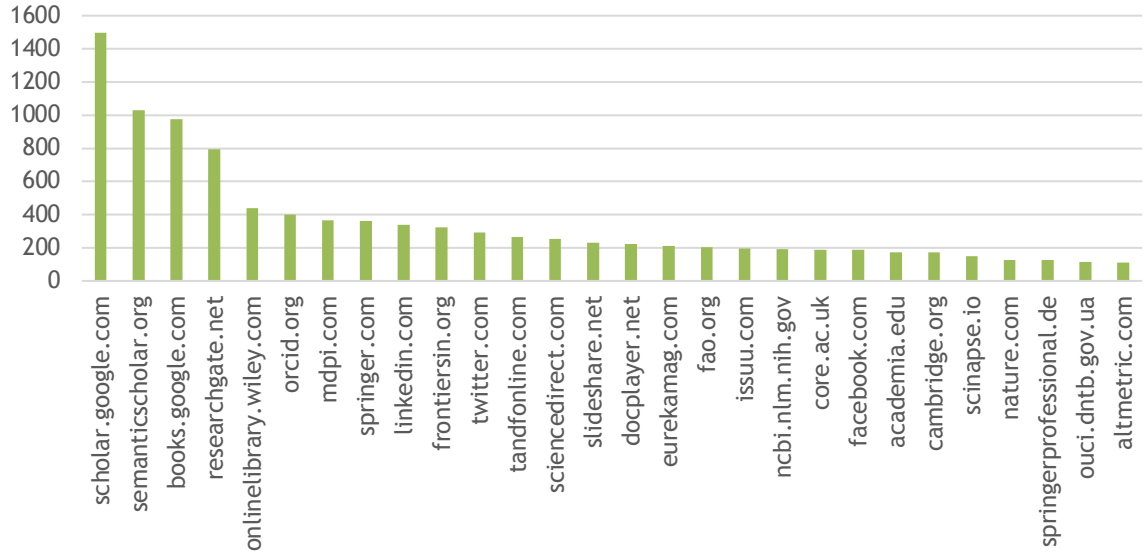

Figure 16 Frequency of domains. Plot contains domains with more than 100 URLs.

Figure 17 shows the overall frequency of Top-Level Domains (TDL), which comprise the last part of the domain name (for instance, .com, .org, etc). This includes International Domain Names (IDN), which are assigned to countries or independent geographic regions and enable some detection of the geographic distribution of CCAFS content. The .com and .org extensions are by far the most prevalent.

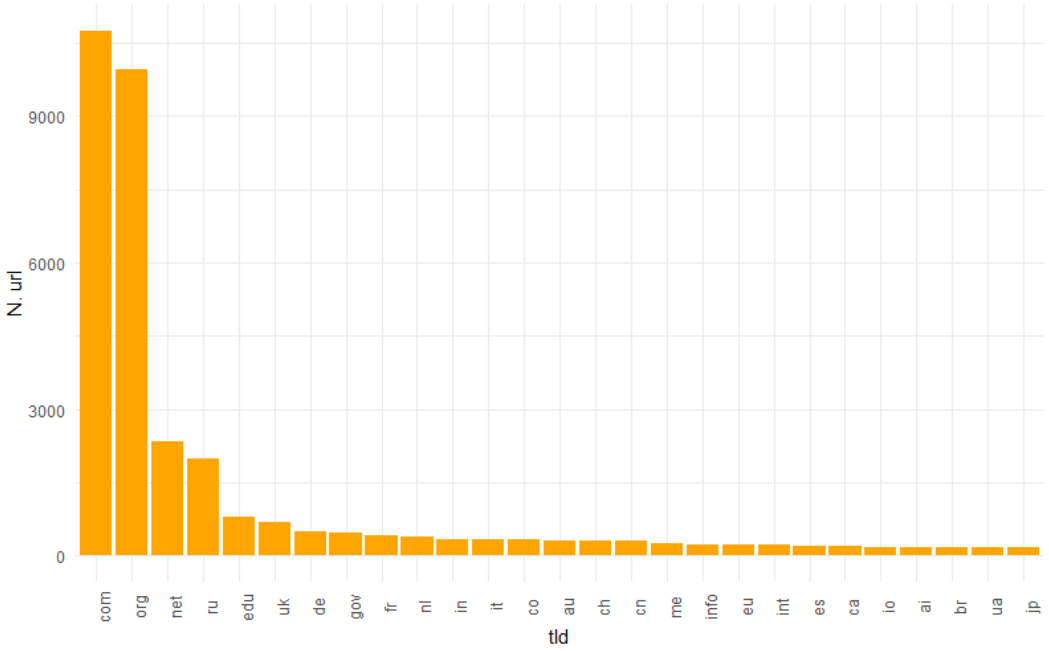

Figure 17 Frequency of Top-Level Domains (TLD). Plot contains TLDs with more than 150 URLs.

Within the .org TLD, which generally comprises non-commercial organisations (covered by the .com TLD), we detected CCAFS' presence in 6,341 URLS from 1300 unique domains. Excluding academic platforms, the top domains include fao.org (with 202 links), worldbank.org (103), iisd.org (34), ifad.org (26), un.org (20), weadapt.org (13), careclimatechange.org (12), genderandsecurity.org (12), adaptationfund.org (11), and thegef.org (9).

Figure 18 represents the country distribution of URLs as detected by the IDN. The countries colored in red contain TLDs with more than 120 URLs; the orange shades are between 40 and 80; and yellow are between 1 and 40. It is possible to see that CCAFS outputs have been distributed to more than 150 countries across all continents, from which 43 are Low Income and Lower Middle Income countries, 37 are Upper Middle Income countries, and 51 High Income countries, with the remainder belonging to territories, protectorates, etc.

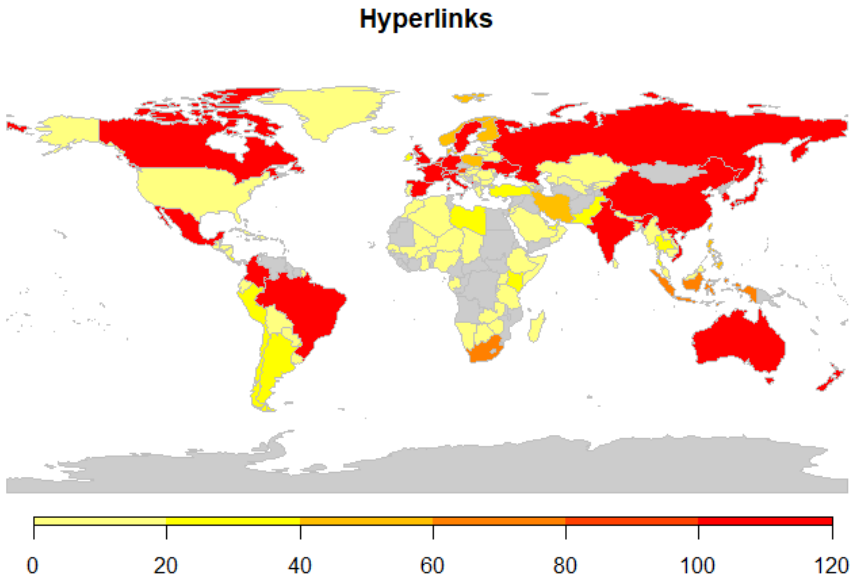

Figure 18 Country detection based on IDN.

By filtering out unique domains with at least three results (i.e. that has disseminated CCAFS content at least three times) and again excluding CGIAR-related URLs, it is possible to further unpack the institutions engaging regularly with CCAFS knowledge. Figure 19 shows the TLD distribution for this filtered subset of 1,234 unique domains. Once again .com and .org are the most common, but there is a more balanced distribution among academic, government and country extensions.

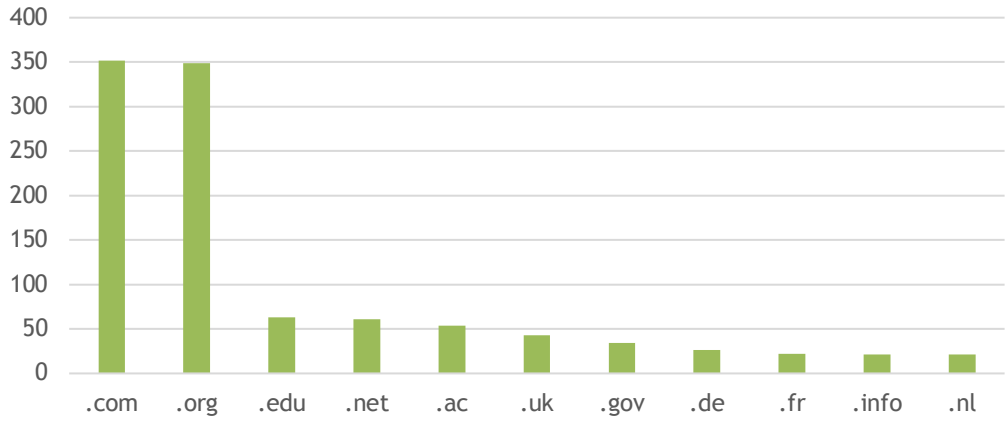

Figure 19 Frequency of Top-Level Domains (TLD) from subset of unique domains with at least three hits (n = 1,234).

What is the public awareness of CCAFS' mandate?

Key findings

- Google searches for "Climate Smart Agriculture" have consistently increased every month since CCAFS was inaugurated in 2011.
- Observable peaks in these searches reflect the moments when CCAFS was engaged in intensified strategic advocacy through its participation at the UN Climate Summit in 2014 and Climate Week NYC in September 2019.

The association between CCAFS activity and public awareness was explored with Google Trends. In recent times, internet search data have been extensively exploited as measures of aggregate issue salience. This step of the analysis assessed changes in Google query searches for one of the key concepts related to CCAFS' scope of action – Climate Smart Agriculture – before and after the start of the program.

The concept of Climate-Smart Agriculture (CSA) was originally developed by FAO and officially presented and at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, through the paper "Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation"[4]. CCAFS has embraced the concept as a priority and stakeholders hold the program as a reference in this approach to climate adaptation in agriculture.

Hence, as patterns in Google search have been documented to reflect public interest and issue dynamics, a final gauge on public awareness of CCAFS' initiatives was a query analysis of "Climate Smart Agriculture". To this aim we downloaded Google searches for "Climate Smart Agriculture" in English and Spanish from 2004, the earliest date available on Google Trends, until 2020. Figure 20 shows the global trend for monthly queries of the term in English. The first search is in August 2010, in line with the timing of the aforementioned conference. From February 2011, the term has been searched on Google every month, with a consistent increase. Several peaks are observed in the months of September (in 2011, 2014, and 2019), which reflect strategic advocacy moments for the program, such as CCAFS' participation in the UN Climate Summit in 2014, and *Climate Week NYC* in September 2019.

[4] http://www.fao.org/3/i1881e/i1881e00.htm

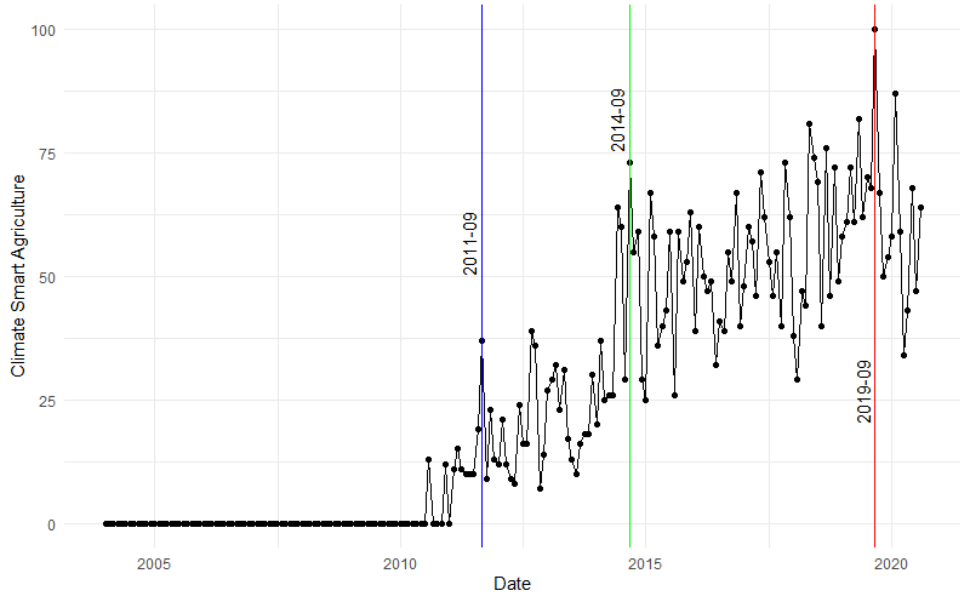

Figure 20 Monthly queries for "Climate Smart Agriculture".

The main limitation of this approach is in terms of language. While Google Trends has the possibility of multilingual topics-based search, "Climate Smart Agriculture" is a term query and as such is restricted to the English language (Fantazzini, 2020). To overcome this limitation, we also analyzed queries for the Spanish term "Agricultura Climáticamente Inteligente". The term "Agricultura Sostenible Adaptada al Clima" and the French term "Agriculture Intelligente Face au Climat" did not generate results. Trends for the Spanish translation are shown in Figure 21. The first search is in 2012-04-01 and, although not continuous as the case of English, the term has been searched with a certain intensity after this date.

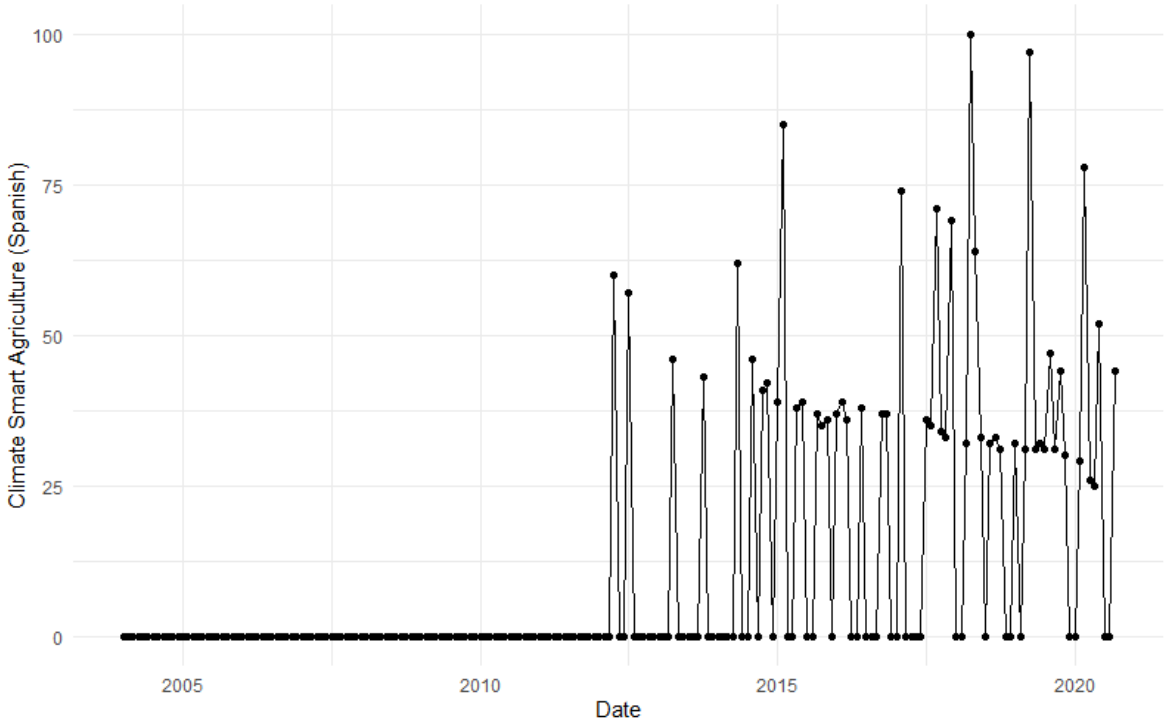

Figure 21 Monthly queries for "Agricultura Climáticamente Inteligente".

Overall, both figures show that there has been a consistent increase in Google queries for the concept consisting of the 'core business' of CCAFS. While CCAFS has not been the originator of this approach, it is noteworthy that this increase began after the foundation of program in 2011. This is an indication that the program's activities have been substantial in raising awareness and harnessing interest in the Climate Smart Agriculture.

Conclusions and recommendations

As an agricultural research for development program, CCAFS' Theory of Change is built on strategic partnerships as key to build evidence, develop institutional capacity, coordinate policy, and inform investments to achieve large-scale CSA (CCAFS, 2016). In this regard, CCAFS has undoubtedly supported the institutions it has worked with to tackle climate adaptation from an agricultural perspective by generating knowledge, raising capacity and encouraging cooperation. In turn, these direct stakeholders amplify the program's purpose across countries and regions.

From a policy outlook, Weiss (1977) argued that research leads to the infiltration of new ideas, which over time become "common knowledge" and can contribute more to the overall issue at stake than any particular policy decision. The interviews that helped frame our study sustain this notion. They indicate CCAFS has laid the foundations for an agriculture-focused approach to climate change by raising the awareness of direct stakeholders, who in turn amplify the program's purpose across countries and regions.

Interviewees affirmed that CCAFS has engaged at all levels: with farmers through applied research on the field, with government bodies through capacity building and institutional support, with international development organizations through strategic partnerships for project design and delivery, and at the global level through advocacy and knowledge dissemination. Such an approach, they believe, has had a multiplier effect for the program's reach.

The digital methods analysis supports this first-hand narrative. As development cooperation, processes and impacts are difficult to evaluate solely by numbers, and taking into account the affordances of the platforms analyzed, the final output is not a single measure of program reach, but an assessment of various dynamics of information flow and discourse amplification as representations of influence. The potential reach of CCAFS is considered based on metrics available for each platform.

On Twitter, the program's strategic partners aligned their messaging with the key concepts of the CCAFS projects they were involved with. There was a significant correlation between project-specific taxonomies and content shared on the platform after projects began. When

considering the networked nature of social media, this amplified messaging has the potential to reach 5.8M users on Twitter, based on the sum of partners' followers. While on Facebook the changes in discourse were not statistically significant, a similar trend was observed, also with potential to reach millions of users.

Considering the websites of government partners as a source of accountability and transparency in public policy, the 10% growth in content related to their respective project taxonomies on news and updates pages indicates heightened sensitivity to climate issues, as well as increased space for interventions related to agricultural adaptation. In addition to the policies reported in MARLO, the text correlation suggests that CCAFS influence is affecting broader government agendas in the countries that have received projects.

As a program built on strategic partnerships, locating CCAFS within its network of stakeholders placed it among key players in development and research sectors, while also playing a central role bridging different actors. It is important to highlight that while social media "echo chambers" are commonly portrayed as a pejorative phenomenon, a connected and cohesive group of likeminded entities can strengthen social movements and calls for climate action, as they are able to amplify their own narratives and organize concerted actions (Pearce et al. 2019).

While the text mining and the network analysis were constrained to program partners, the hyperlink analysis set off from project deliverables to discover their information pathways across the web. It found that knowledge generated through CCAFS projects was disseminated across thousands of websites from almost 150 countries, with a strong presence on academic and research platforms, as well as social media, governments, and international organization websites from both the Global North and South. As knowledge exchange was one of CCAFS' key value additions emphasized by stakeholders, we see a reflection of this practice reproduced online.

Finally, global reaction to Climate Smart Agriculture, CCAFS' central proposition to tackle climate change, was gauged through a query analysis on Google Trends. As the data is

normalized[5], it is possible to clearly observe an upward trend in search interest for the concept since the program inception in 2011. Importantly, interest spiked in moments where CCAFS was engaged in high-level advocacy, an effort also noted in the interviews.

Lastly, we have three recommendations arising from this study:

1. To establish indicators that capture influence from a broader perspective, not only based on policy numbers, but also in relation to messaging, visibility, knowledge dissemination and engagement. As influence is a multifaceted, continuous process, comprehensive monitoring can give a fuller picture of the program's reach.

2. To leverage on existing evidence from program monitoring systems to uncover insights, by employing innovative, data-driven methods that enable data repurposing to answer new questions. Machine learning can help accelerate this process by supporting analysis of large historical datasets to identify trends.

3. Regarding strategies to further intensify the program's influence, if CCAFS intends to increase its policy-informing role (CCAFS, 2016), the development of a strong, focused advocacy strategy is essential. From our work, we have understood that CCAFS engages with policy actors at many levels, from municipal governments of project countries to regional and global institutions. These each have their own agendas and political goals, and thus require targeted approaches. A strong advocacy plan that maps the policy actors and proposes specific outreach, and which contains clear indicators to measure success will ensure that CCAFS efforts in producing evidence to inform effective policy making is reaching its intended audience.

[5] https://medium.com/google-news-lab/what-is-google-trends-data-and-what-does-it-mean-b48f07342ee8

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Appendix 1- Detailed Methodology

Work stream 1: Framing the analysis

Besides the employment of various data analytics approaches, the study included interviews with key programme partners. These interviews intended to validate, frame and complement the digital research through an in-depth understanding of partners' involvement with the programme and the influence CCAFS has had at various levels, especially focused on support to policymaking and capacity development.

The approach was the semi-structured interview, with open ended, targeted questions aimed at eliciting "stories" and narratives based on stakeholders' own experience with the programme. An interview protocol was devised (see Appendix 2) to provide a set of predetermined questions from which to elicit information, but prompts were adjusted and followed-up as needed, depending on the interviewee's responses in order to draw examples or clarifications.

Government partners were selected for interviews as the key stakeholders involved both in local project delivery and policy making. An international finance organisation was also included in the sample. CCAFS regional leaders were consulted in order to obtain the contact information for the most appropriate country partners. Invitations to take part in the study were sent by e-mail to 24 selected contacts. A total of 16 interviews were conducted remotely (through Zoom, Skype and MS Teams calls) between 15 July and 10 August. The calls lasted between 20 minutes to one hour, and were mostly conducted in English, with the exception of four interviews carried out in Spanish with support from local CCAFS staff. Calls were recorded and saved in audio files.

All CCAFS regions are well represented in the final sample, as shown in the table below.

CCAFS project partners interviewed for this study.

Country	Partner	Acronym	Partner type	Projects	Language
West Africa					
Senegal	Agence Nationale de l'Aviation Civile et de la Météorologie	ANACIM	Government	P255 P46	English
Ghana	Council for Scientific & Industrial Research/ Animal research institute	CSIR/ARI	Government	P255 P1590	English
East Africa					
Ethiopia	Ministry of Agriculture and Natural Resources	MoANR	Government	P1586 P785 P812	English
Kenya	Ministry of Agriculture, Livestock, Fisheries and Cooperatives	MALFC	Government	P263 P1586 P1601 P13 P56	English
Rwanda	Ministry of Agriculture and Animal Resources/ Rwanda Agriculture Board (RAB)	RAB	Government	P66	English
Tanzania	Ministry of Agriculture, Food security and Cooperatives	MAFC	Government	P263	English
SOUTH ASIA					
India	Indian Council of Agricultural Research (India)	ICAR	Government / Research	P259	English
Nepal	Ministry of Agriculture and Livestock Development (Nepal)	MOAD	Government	P259	English
LATIN AMERICA					
Honduras	Secretaría de Agricultura y Ganadería	SAG	Government	P771 P1592 P1604 P42	Spanish
Guatemala	Ministerio de Agricultura, Ganadería y Alimentación	MAGA	Government	P771	Spanish
Guatemala	Ministerio de Agricultura, Ganadería y Alimentación	MAGA	Government	P262	Spanish
Colombia	Ministerio de Agricultura y Desarrollo Rural	MADR	Government	P1599 P42	Spanish
Central America	Concejo Agropecuario Centroamericano	CAC	Regional Organization	P274 P1604	English

SOUTH EAST ASIA					
Philippines	Department of Agriculture/ Climate Resilient Agriculture Office	DA	Government	P264	English
Vietnam	Institute for Agricultural Environment	MARD	Government	P49 P264 P1602 P1608	English
INTERNATIONAL FINANCE INSTITUTION					
Internatio nal	International Fund for Agricultural Development	IFAD	International /regional financial institution	P265 P269 P274	English

Interview Protocol

1. Introduction:

    a. Describe your role within your institution and your involvement with CCAFS:

    b. How and why did your institution become a partner in the program?

    c. Describe your organization's involvement in the program:

2. Stakeholder involvement/influence:

    a. Has your institution increased/improved awareness of CSA? If so, can you describe some concrete examples?

    b. Considering the CCAFS projects you are involved in, do you think CCAFS has influenced the various stakeholders to tackle climate change and/or to embrace CSA? If so, which stakeholders has it influenced and how?

    c. As CCAFS has produced a wealth of knowledge over the life of the program, do you think this knowledge reaches the right people? How do you think stakeholders engage with it?

    d. Can you recall specific situations/examples in which CCAFS has influenced your institution? (ex. to establish policy, to build capacity, to adopt new technologies)

e. Specifically regarding policy, do you think CCAFS has engaged with policy makers and or/helped policy makers?

3. Capacity development:

    a. Has your institution benefitted from CCAFS' capacity development strategy? If so, can you describe any specific efforts that you took part in? How was capacity enhanced through these?

    b. Based on your experience, what is your overall assessment of CCAFs' capacity development efforts? How effective is it? What is positive and what can be improved?

4. Additional funds leveraged/changes to investment

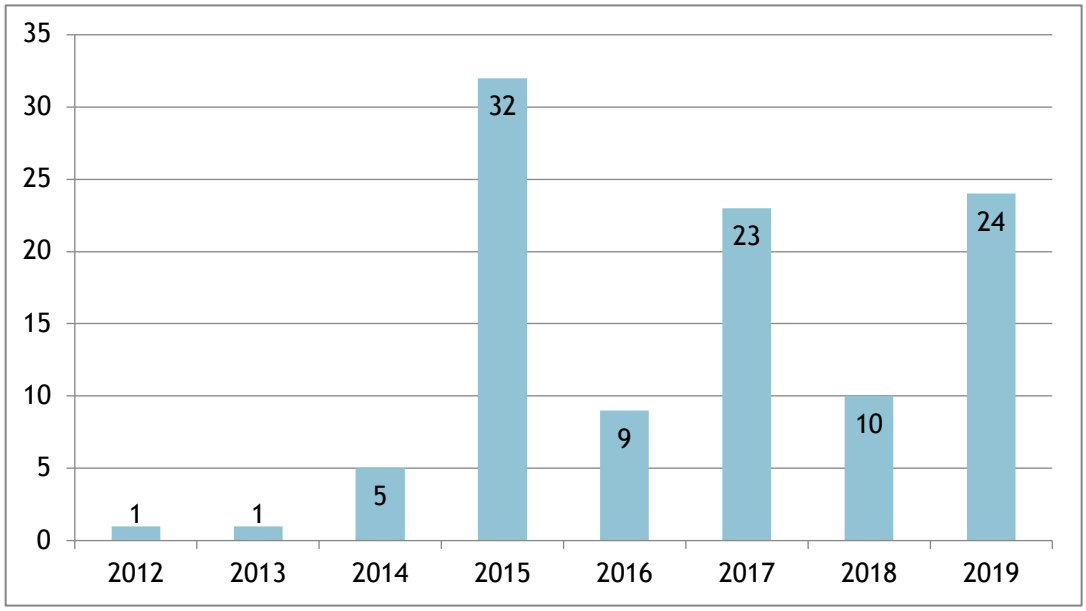
    a. Has CCAFS contributed to increased investments in climate-smart agricultural development or climate change adaptation actions, either by your institution or leveraged by other organisations? If so, can you provide concrete examples?

Work stream 2: Assessing influence through discourse

The second work stream employed text mining techniques to understand the extent to which CCAFS messaging and interventions were represented in the online communications of partners. Text mining is an approach that seeks to automate the retrieval of high-quality information from text, usually by finding patterns and trends through machine learning, statistics and linguistics. Words, the carriers of meaning, are identified and transformed into a processable data structure. As a way to enable the repurposing of existing, unstructured data, and to efficiently extract meaningful information from large datasets, "the combination of interpretative appraisal and statistical techniques has the potential to generate novel insights, ultimately contributing to evidence-based policy-making" (Niekler and Wencker 2019).

Developing a custom taxonomy for CCAFS

The first step was the development of a custom taxonomy from CCAFS projects to identify key terminology from which we could map text from partner sources against. For this, machine learning algorithms were applied to carry out unsupervised text mining of selected reports/report sections retrieved from MARLO. We considered all 105 projects implemented between 2012 and 2019.



Number of projects by year started

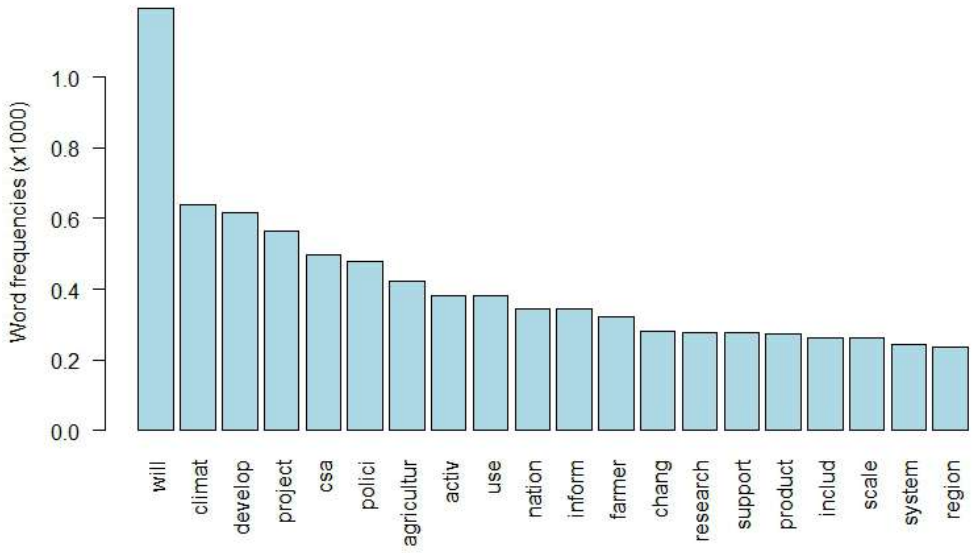
In order to develop the taxonomies, we considered, for each project, text from three report items: Project summaries (105), the descriptions of project Activities (463 in total), and the contribution narratives from project Outcomes (253 in total).

The first step was extracting and aggregating text from the three sources, for all projects. Then, the corpus of analysis was prepared using functions from the R package “tm” (Feinerer and Hornik, 2018; Feinerer, Hornik, and Meyer, 2008): punctuation, stop words (i.e. in English, words like “the”, “is”, “of”, etc), and numbers were removed from the corpus. The words were then converted to lowercase and stemmed. Lastly, a Term Document Matrix was produced, with projects by column (105) and stemmed words by row (4,201 unique terms). The table below shows a small part of the Term Document Matrix as an example.

Part of the Term Document Matrix considering the whole text extracted from MARLO documentation for 105 CCAFS projects

	P1	P11	P12	P13	P1472	P1586	P1589	P1590	P1591	P1592	P1593	P15
access	0	0	0	1	0	1	1	2	0	1	0	0
accompani	0	0	0	0	0	0	0	0	0	0	0	0
accomplish	0	1	0	0	0	0	0	0	0	0	0	0
accord	0	0	0	0	0	0	1	0	0	0	0	1
account	0	0	0	0	0	1	0	0	0	1	0	0
accumul	0	0	0	0	0	0	0	0	0	0	0	0
accur	0	0	0	0	0	0	0	0	0	1	0	0
accuraci	0	0	0	0	0	0	0	0	0	0	0	0
acdrm	0	0	0	0	0	0	0	0	0	0	0	0

The Term Document Matrix indicates the number of times each word appears in each project. It is the starting point of text mining since it transforms unstructured text into numbers and contains quantitative information about the content of a document. The figure below shows the 20 most frequent words considering the entire corpus of text extracted from Project summary, description of Activities, and contribution narrative of Outcomes, at the project level.

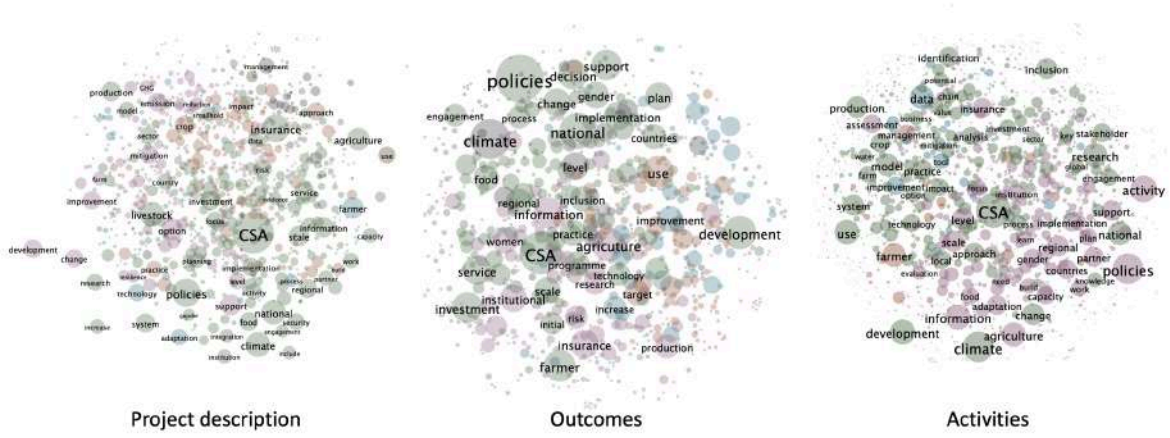


Most frequent words considering the whole text extracted from 105 CCAFS Projects. X-axes shows stemmed words, numbers on y-axes represent the number of times the words appear in the corpus.

A central question in text mining and natural language processing is how to quantify what a document is about. One measure of a word's importance is its term frequency (tf), that is, how frequently a word occurs in a document. Another approach is to look at a term's inverse document frequency (idf), which decreases the weight of commonly used words and increases the weight of words that do not appear frequently in a collection of documents. The two can be combined to calculate a term's tf-idf (the two quantities multiplied together), which measures the frequency of a term adjusted for how rarely it is used (Silge and Robinson, 2017). Formally:

$$(1) \qquad idf(\text{term}) = \ln\left(\frac{n_{\text{documents}}}{n_{\text{documents containing term}}}\right)$$

The statistic tf-idf is widely used to measure how important a word is to a document in a collection (or corpus) of documents (Silge and Robinson, 2017). In our case, the tf-idf combines frequency, i.e. how many times a word is associated to a project, and the inverse of ubiquity, ie. how exclusive the association is between a word and a project (Hidalgo and Hausmann, 2018; 2019). To this regard, it is worth stressing that more ubiquitous words are more likely to have less informative power than exclusive words.



Significant words for each report category, measured by tf-idf.

The figure above shows a visualization of the most significant words in each category of report used in the analysis. For the project level taxonomy, the three were aggregated to produce a single term rank. The main outcome of this part of our analysis is a vector of words with an associated vector of weights (importance = tf-idf) for each of the 105 projects. This information constitutes the project-level taxonomy, where each project has its own set of significant terms, as exemplified in the table below.

Example of a project taxonomy: top 15 most significant stemmed terms for project P785, weighted by td-idf.

P785 - terms (stemmed)	Weight (tf-idf)
Nutrit	22.77699
Uganda	9.405501
Polici	5.038246
Resili	3.215251
Adapt	2.659905
Secur	2.609312
Built	2.574519
Food	2.374069
Climat	2.116078
Data	1.52428
Find	1.518466
Take	1.435085
Use	1.410718
Survey	1.395864
Technolog	1.367337

Based on these project-level taxonomies, the analysis that follows detected the presence of terminology associated to CCAFS interventions among programme partners (through social media) and policy makers (through government partner websites).

Assessing CCAFS' influence on stakeholders through social media

Within the social sciences, content analysis methods allow researchers to identify patterns and changes in political agenda over time and across geographies (Brandt 2019). A proxy for how CCAFS activity influences stakeholders, and how stakeholders in turn amplify the programme's mission to a broader audience, is social media activity. To assess the extent to which the taxonomies from CCAFS projects are represented in the social media profiles of CCAFS partners, this work stream applied text mining techniques to determine a similarity measure between programme activities and messaging from partners.

The process of selecting and scraping social media networks involved different steps:

1. Understanding what specific social media is more suitable for the specific goal

2. Deciding the important data to be extracted

3. Scraping the chosen information

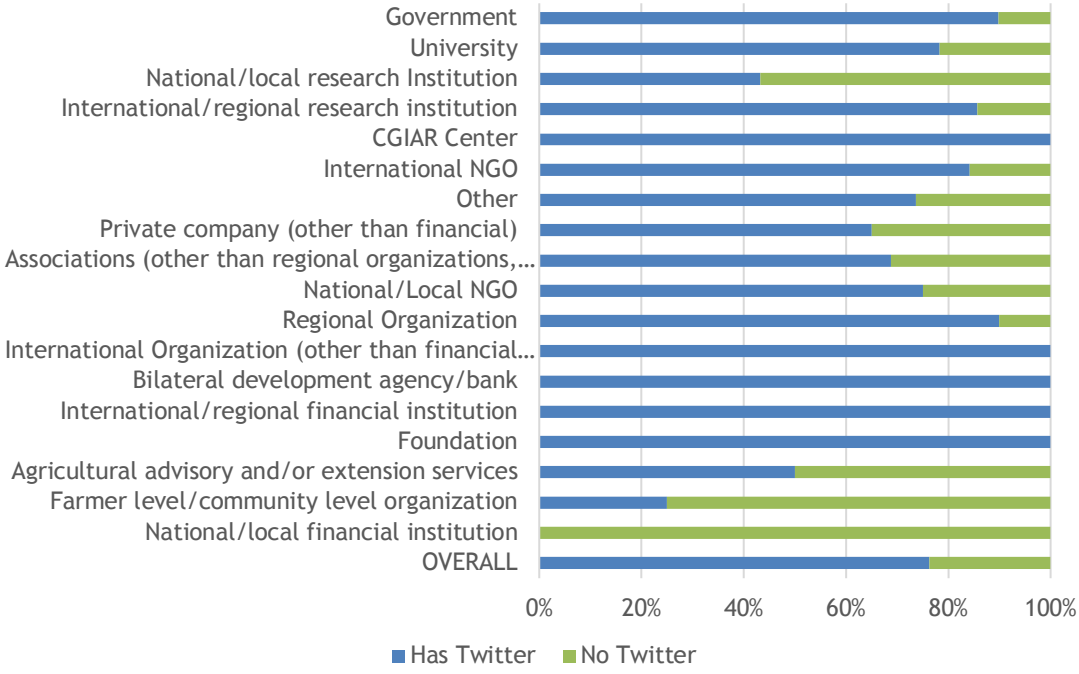
4. Saving clean and well-structured data

Considering the penetration of certain social network sites, four potential platforms were considered and mapped for the 326 partners identified in CCAFS documents: Facebook, Twitter, Instagram and LinkedIn. Overall, we found that:

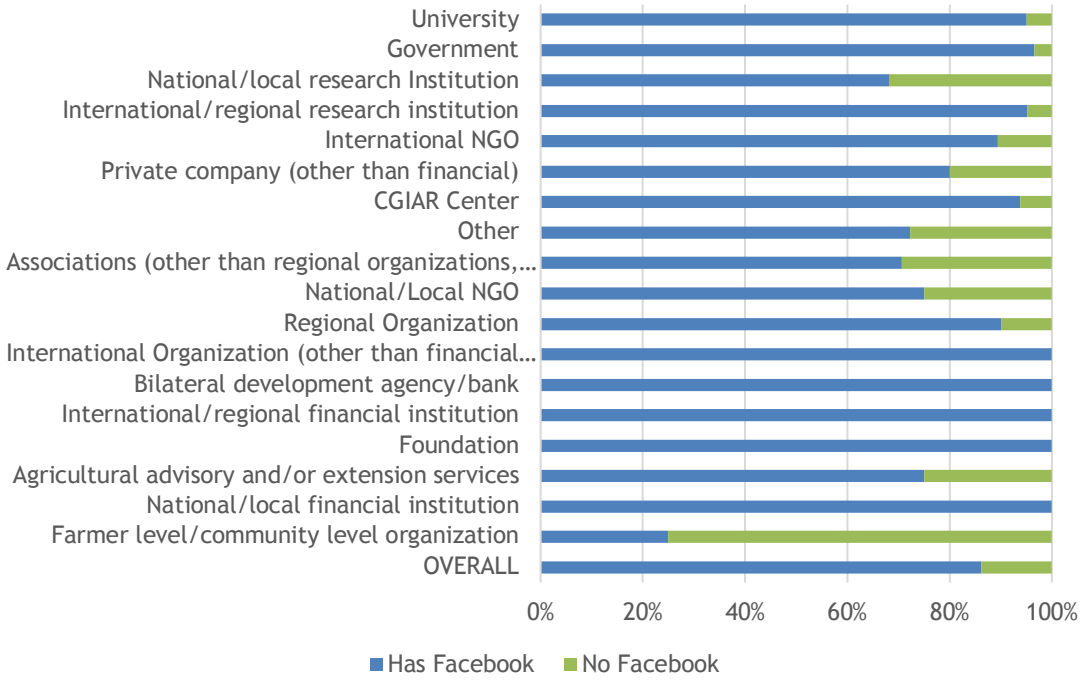
- 89% have a Facebook profile
- 78% have a Twitter profile
- 63% have an Instagram profile
- 58% have a LinkedIn profile

Given their prevalence in our mapping exercise, and that text is the central entity for our evaluation, Twitter and Facebook were selected for the construction of the social media

datasets. The figures below report the coverage of accounts by partner type for Twitter and Facebook, respectively. Partner types are identified according to the categories reported in MARLO.



Overall Twitter coverage, by partner type (%)



Overall Facebook coverage, by partner type (%)

Twitter data collection and processing

In total, 240 Twitter accounts from 232 different partners and all their tweets from 2010 to 2020, were scraped. The figure below shows a typical tweet with all its affordances: account, timestamp, text, #hashtags, @mentions, Retweets and Favourites. For every tweet, the following data was taken:

– Time of publication

– Text of tweet

– Hashtags

– Mentions

– Number of favourites

– Number of replies

– Number of retweets

– URL of tweet

A typical tweet, with text, @mentions, #hashtags and timestamp.

While Twitter is still the most searchable social media platform and is used extensively for academic research, accessing data through its API[6] has two important limitations:

- Rate limit on requests
- Only allows gathering back data from 8 eight days in the past

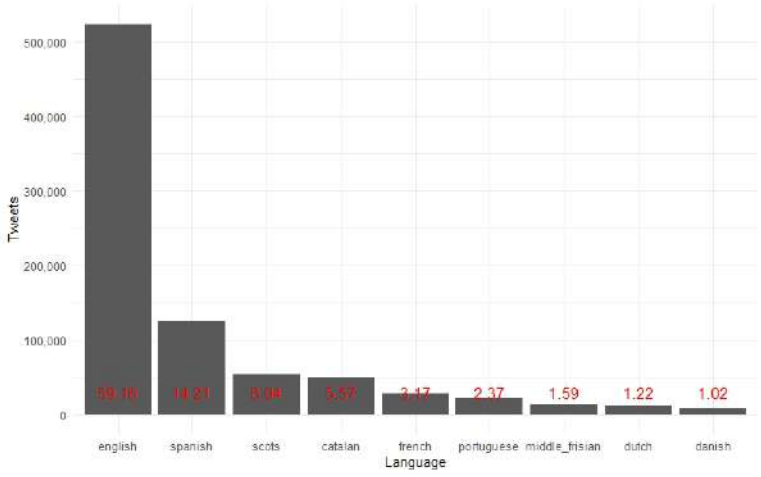
For the above reasons, a custom program was developed in Python language to enable extracting all the tweets from 2010 to 2020, and, by means of anti-block algorithms, in a reasonable amount of time. In total, 888,174 tweets were gathered for 231 accounts, in the period between 2010-01-12 to 2020-06-29, with a runtime of about 50 hours on a single machine. The accounts scraped and considered in the analysis are shown below:

_AfricanUnion	100KIT	a2i_bd	AarhusUni	aberdeenuni
ACF_France	ACIARAustralia	ACICAFOCca	ACTSNET	AdamSmithInt
AfDB_Group	AfricaRice	AGNESAfrika	AgrhymetInfos	agri_ministere
AIMSacza	AITtomorrow2day	AlqueriaOficial	APFGlobal	arrozFLAR
ASEAN	ASU	atencionusac	BiovIntCIAT_eng	BRACworld
CABI_News	CafedeGuatemala	Cardno	CARE	care_internet
CARE_Nederland	CatholicRelief	CATIEOficial	CDEunibe	CGIAR
CGIARclimate	cgiarclimate_EA	cgiarclimate_LA	cgiarclimate_WA	CIFOR
CIMMYT	Cipotato	Cirad	CIVguate	Columbia
comesa_lusaka	CSIR	CSIR_ARI	csir_ghana	CSIR_WRI
CSIRO	CtdtZimbabwe	CusoIntl	DAFF_ZA	DeHaatTM
DrreaO	EAPZamorano	earthinstitute	ECA_OFFICIAL	Eco_habitats
ecoSERVICES	ecowas_cedeao	efccc14	embrapa	Environment_Ke
EnvironmentRw	Esoko	EthiopianATA	FAO	FENALCE
FertilizerNews	FoodLab_SFL	FrisianFlagID	FutureEarth	FutureForAll
giz_gmbh	GlobalGators	gouvernementBF	GouvMali	GRA_GHG
HarvestPlus	HDFCERGOGIC	Heifer	Hello_MOALD	ICAR_CSSRI
ICARDA	icarindia	icpac_igad	ICRAF	ICRISAT
IDEAMColombia	IDRC_CRDI	IDS_UK	IFAD	IFDCnews
IFPRI	IICAnoticias	IIRR	IITA_CGIAR	ILRI
Imaflora	INIAPeru	INRAE_Intl	inran_Niger	IowaStateU
ipbofficial	irri	ISRA_Senegal	iubedu	IUCN
IWMI_	JohnsHopkinsSPH	jumuiya	kalromkulima	kilimoKE
KNUSTGH	leadpakistan	libirdnepal	livelih00ds	LocalMbale
MAAIF_Uganda	MagaGuatemala	MakerereU	MalawiGovt	MaliMeteo

[6] An API (Application Programming Interface) is a programming interface between otherwise separate applications that allows each application to connect, communicate and share information with the other.

MekUniETH	michiganstateu	min_waterUg	MinAgricultura	minagriperu
MinamPeru	minwater_sani	MoA_Ethiopia	moafbhutan	mocghana
moesgoi	mssrf	MTTASN	museugoeldi	narcjournal
narouganda	nature_org	NEDAhq	NEPAD_Agency	NitishKumar
npckkenya	nuigalway	NWONieuws	OECD	OPMUganda
oxfamgb	OxfaminUganda	PACJA1	PeacePalaceKH	pelum_uganda
planttreaty	PMEthiopia	PR_Senegal	PrecisionAgDev	PresidenceNiger
presidenciacr	PrimatureMDG	QUT	rikolto	RIMES_news
RnfrstAlliance	RockefellerFdn	RootCapital	RTI_Intl	RwandaAgri
SaarcSec	SADC_News	saghonduras	ScuolaSantAnna	Secretaria_CAC
SecretariaSESAN	SID_INT	SNVworld	SokoineU	spacebelsa
Stats4SD	sthlmresilience	SwissRe	TARITZ10	teriin
TerraNIS_EO	tzagriculture	UADYoficial	ucicr	UniofGhana
UMontreal	UN_Women	UNALOficial	UNBiodiversity	UNEP
uni_copenhagen	UniBonn	unicauca	unillanos_	UniNMBU
UniofOxford	UniofReading	UniUtrecht	UniversiteLiege	UniversityLeeds
UNLincoln	uonbi	USDA	usponline	uvmvermont
UZimbabwe	VHL_University	ViAgroforestry	visualiti	Viverisgroupe
VNGovtPortal	vpo_tanzania	VUamsterdam	wbcsd	WCRP_CLIVAR
WFP	WOCANupdates	WorldBank	WorldCocoa	WorldFishCenter
WorldResources	WorldUniService	WRMSLTD	WUR	WUR_WCDI
yara				

As a first step in data processing, the languages of the tweets were identified with R package 'textcat' (Feinerer et al. 2013). The figure below shows that English and Spanish were the most frequent languages, representing 59% and 14% of the tweets, respectively ('Scottish' and 'Catalan' present in graph are due to the algorithm recognizing different patterns in English and Spanish use). Then, as the CCAFS taxonomy was developed in English, all non-English tweets were translated with Google Translate in order to identify the similarity between the texts.



Nine most frequent languages detected on corpus of tweets.

Between 2017 and 2019, CCAFS implemented 57 projects, from which we have Twitter data for at least one partner for 52 of them. These projects launched in seven different start dates, namely: "2017-01-01"; "2019-01-01"; "2018-01-01"; "2017-12-01"; "2017-01-25"; "2018-10-01"; "2017-04-01". The first (2017-01-01) is the start date for 17 projects involving 102 partners with at least one Twitter account; the second (2017-01-25) is the start date for 1 project involving 2 partners with at least one Twitter account; the third (2017-04-01) is the start date for 1 project involving 3 partners with at least one Twitter account; the fourth (2017-12-01) is the start date for 2 projects involving 4 partners with at least one Twitter account; the fifth (2018-01-01) is the start date for 6 projects involving 22 partners with at least one Twitter account; the sixth (2018-01-01) is the start date for 1 project involving 5 partners with at least one Twitter account; finally, the seventh (2019-01-01) is the start date for 24 projects involving 87 partners with at least one Twitter account.

For each partner i, participating in project P we estimated the following at time t:

$$(2) \qquad Text\ Correlation_{iPt} = \left[\frac{\sum\left(tf\_idf_P \in\ Words_{Tweet_{it}}\right)}{\sum tf\_idf_P}\right]$$

Where tf_idf_P is the term frequency inverse document frequency (see equation (1)) which measures how important each word is in project P, and $Words_{Tweet_{it}}$ are words in the corpus of the partner's Twitter i at time t. By construction $Text\ Correlation_{iPt}$ is included in the interval [0:1] and gives a measure of how similar the content of tweets is to the taxonomy of CCAFS.

To give an empirical measure to the text correlation over time, and to test whether the correlation after the projects start is significant, we perform the following regression:

$$(3) \qquad Text\ Correlation_{iPt} = \beta * After_{it} + \varepsilon$$

Where $After_{it}$ is a dummy variable taking value 1 if the project in which the partner i is involved in has been launched. The parameter of interest is β, which captures the change in text correlation after the projects start.

Facebook data collection and processing

As in the case of Twitter, for Facebook the measure of the influence on CCAFS on project partners is estimated by comparing the content of the posts with the start date of the projects they belong to. From 2017 to 2019 we have Facebook accounts for partners participating in 52 out of the 57 projects. The seven approval dates considered are the same used for the Twitter analysis: "2017-01-01"; "2019-01-01"; "2018-01-01"; "2017-12-01"; "2017-01-25"; "2018-10-01"; "2017-04-01". The first (2017-01-01) is the start date for 17 projects involving 103 partners with at least one Facebook account; the second (2017-01-25) is the start date for 1 project involving 1 partner with at least one Facebook account; the third (2017-04-01) is the start date for 1 project involving 3 partners with at least one Facebook account; the fourth (2017-12-01) is the start date for 2 projects involving 4 partners with at least one Facebook account; the fifth (2018-01-01) is the start date for 6 projects involving 19 partners with at least one Facebook account; the sixth (2018-01-01) is the start date for 1 project involving 6 partners with at least one Facebook account; and the seventh (2019-01-01) is the start date for 24 project involving 93 partners with at least one Facebook account.

Overall, 285 Facebook pages of 275 different partners were scraped. As per Twitter, the considered time range was from 2010 to 2020. The figure below shows a typical post with its affordances: page name, timestamp, text, #hashtags, Reactions, comments and shares. In particular, the following parts of each post were extracted:

– Time of the post publication

– Text of post

– Number of likes

– Number of shares

– Number of comments

– URL of post

A typical Facebook post with text, comments, shares and reactions.

After the Cambridge Analytica scandal that exposed Facebook's privacy issues, and due to the increasing monetarisation of its data services, the platform has severely limited open access to its API, which makes scraping very difficult. In order to accomplish this complex task, a dedicated Python program was developed, with satisfactory results.

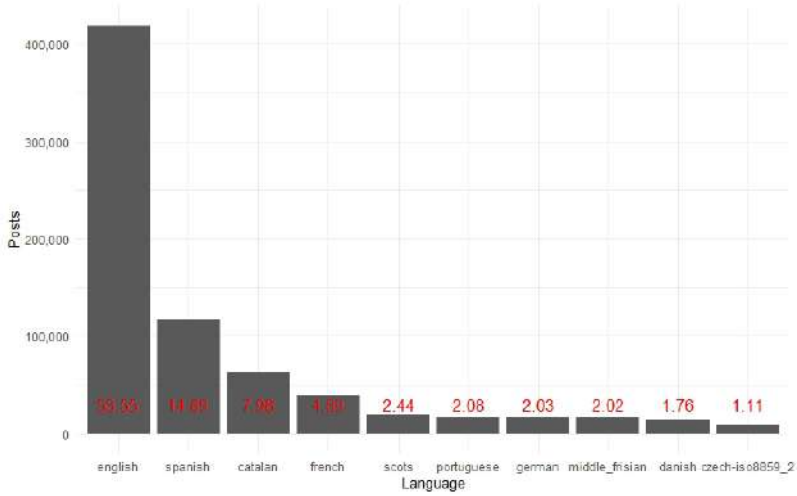
We collected 799,557 posts from the Facebook pages of 270 partners between 2010 to 2020, in a runtime of about 3 days on a single machine. The pages scraped and considered in the analysis are shown below.

ACIARAustralia; Acicafoc-Centroamerica-589630161078673; actioncontrelafaim; adamsmithinternational.ltd; Addis-Ababa-University-496255483792611; AfDBGroup; Africa-CSA-293874224130047; AfricanUnionCommission; AfricaRiceCenter; AgnesAfrica1; agrhymetinfos; AgricultureZA; AgriProFocus; aicofindialtd; AIMSacza; AITtomorrow2day; AlqueriaOficial; Amhara-Agricultural-Research-Institute-ARARI-357803487569964; anacafe; ANSISPatna; Aphivat-Strey-AS-935122423212727; arcos.albertinerift; arizonastateuniversity; arrozFLAR; aseansecretariat; atencionusac2.0; BAIFofficial; Bangladesh-Agricultural-Research-Council-BARC-181030988607464; Bangladesh-Centre-for-Advanced-Studies-1201000569972747; BD.GOV.BARI; bhutanmoaf; BiovIntCIAT.eng; biovision; Borlaug-Institute-for-South-Asia-653993268047173; BRACWorld; CABI.development; CardnoGlobal; care.internet.services; care.nederland; carefans; CATIEOficial; CCLVientiane; CDEunibe; cedac.org; CGIAR-270424969671619; cicp.org.kh; cifor; CIMMYT; cipotato; Cirad-La-recherche-agronomique-pour-le-d%C3%A9veloppement-177761502350452; civguate; clivar; cnrapage; columbia; ComesaSecretariat; Conseil-National-de-lEnvironnement-pour-un-Developpement-Durable-265686147189836; copeco.hn; CSA.YouthNetwork; CSIR-Animal-Research-Institute-106345454101653; csir.gh; CSIROnews; csirsari; CSIRWATER; ctdtzim; CTUDHCT;

CusoInternational; cutsjaipur; Cuulong-Delta-Rice-Research-Institute-1454944671409038; dacentralphilippines; daebangladesh; dbu.edu.et; DcpmMTMUSR; DeHaatTM; Direction-National-de-lAgriculture-DNA-179307078919632; DOSTPh; eapzamorano; earthinstitute; EconomicCommissionforAfrica; Ecowas.Cedeao; embrapa; EnvironmentKe; EnvironmentRwanda; EsokoNews; EthiopiaATA; face.uady; Fenalce; FrisianFlagID; fundacionecohabitats; futureearth.org; gizprofile; GlobalGators; Gunaso.moald; HarvestPlusNutrition; HDFCERGO; heiferinternational; hocviennongnghiep; hunsencambodia; HydrometLao; icar.cssri; icarda; ICPACigad; ICRISAT; IDRC.CRDI; idsuk; IERInstitut-dEconomie-Rurale-128634160527498; IFAD; IFDCnews; IICAnoticias; IIRR.org; IITA.CGIAR; ILRICommunications; imaflora; InAgrisearch; INIAPeru; Inrae.France; Institut-National-de-la-Recherche-Agronomique-du-Niger-1812718968955428; Institute-of-Agriculture-Animal-Science-559725427502183; IowaStateU; ipbuniversity; IRRI.Official; ISRA-Institut-S%C3%A9n%C3%A9galais-de-Recherches-Agricoles-181118848588161; ITPGRFA; iub.edu; iucn.org; iwm.bd; IWMIonFB; JohnsHopkinsSPH; Kalromkulima; Kenya-Dairy-Board-554260251326033; KNUSTksi; KTHuniversitet; LaoNAFRI; leadpakistan; libirdkochautari; Livelihoods-191607447583042; MAAH.Burkina; MAAIFUganda; maep.Madagascar; maergouvsn; maff.gov.kh; maga.gt; MAGCOSTARICA; Makerere; malawigovernment; MaliMeteo; Manobi-247901802054239; Mbale-District-Local-Government-384119978362130; MefEth; MekelleUniversity; Mekong-Development-Center-292306587975457; minagriperu; MinamPeru; Minist%C3%A8re-de-lEnvironnementde-lAssainissement-622524788226904; MinisteriodeAgriculturayDesarrolloRural; Ministry-of-Agriculture-and-Animal-Resources-MINAGRI-170019823062863; Ministry-of-Agriculture-Livestock-Fisheries-579459792174932; Ministry-Of-Energy-Malawi-113065160070427; MINWATERSANITATIONIRRIGATION; MoAEthiopia; moc.gov.gh; moc.gov.kh; moesgoi; mofaghanasite; monrevietnam; mssrf.org; museugoeldi; naecmn; narcnepal; narouganda1; nationalportalbangladesh; nedahq; nepad.page; NitishKumarJDU; npckkenya; nuigalway; NWOYA-District-LOCAL-Governmnet-527581173992396; OMRTanzania; opmuganda; Orissa-University-of-Agriculture-and-Technology-OUAT-158919397464101; oxfamGB; oxfaminuganda; PACJA2008; pelumug; plandiv.gov.bd; PMOEthiopia; posts; PrecisionAgDev; Primature.Faso; proudlyeastafrican; QUTBrisbane; RainforestAlliance; rice.matters; Rijksoverheid; rikoltoWA; rimes.int; rockefellerfoundation; rootcapital; rti.international; ruralbroadcasters.pfrb; SADC-Plant-Genetic-Resources-Centre-485268774852421; SAGHN; Savannakhet-University-Laos-210630459052577; scuolasuperioresantanna; seameo.searca; SECAC; Sesangt; SIDSecretariat; SNVworld; SokoineUniversityOfAgriculture; somagroupcambodia; spartans.msu; stockholmresilience; sustainablefoodlab; sustainablericeplatform; sv.wfp; SwissReGroup; TERIIN; the.university.of.oxford; thenatureconservancy; theOECD; theuniversityofreading; TOURISMETRANSPORTSAERIENSSENEGAL; Tropeninstituut; trouwnutritionindonesia; trunguonghoilienhiepphunuvietnam; truongdaihocnonglamhue; tzagriculture; UCI.Internacional; umontreal; UNALOficial; UNBiodiversity; unep; UNFAO; UniAarhus; unibonn; UnillanosOficial; UniNMBU; universidadelcauca; universitedeliege; universitet; universityofaberdeen; universityofleeds; UniversityofVermont; universityofzimbabwe; UNLincoln; unwomen; uonbi.ac.ke; USDA; usponline; UtrechtUniversity; VHLUniversity;

Viagroforestryeastafrica; visualiti; viveris; voiceofsaarc; vuamsterdam; wageningendevelopmentinnovation; WOCANupdates; worldagroforestry; worldbank; WorldCocoaFoundation; worldfishcenter; worldresources; WRMSLTD; WUR; wusc.ca; www.primature.gov.ml; yarainternational; YezinAgriculturalUniversity; ZambiaAgricultureResearchInstitute;

As in the case of Twitter, the language of posts was detected by means of the R package 'textcat' (Feinerer et al. 2013). The figure below shows that English and Spanish were also the most frequent languages, with 54% and 15%, respectively. All non-English posts were translated before processing, by means of Google Translate.



Nine most frequent languages of Facebook posts

In the case of Facebook, the metric used was topic detection (by stemmed words) in the text of posts, where we analysed the terms that can be reconducted to the CCAFS name and main message, i.e.: climate (clim*), change (chan*), agriculture (agric*), food (food*), and security (secur*).

To provide an empirical measure to the increase of CCAFS topics over time and to test whether the change in topic presence after the projects start is significant, we performed the following regression:

$$(4) \qquad Topic_{iTt} = \beta * After_{it} + \varepsilon$$

Where $Topic_{iTt}$ is the presence of Topic T ($T =$ Climate; Change; Agriculture; Food; Security) in posts from partner i at time t; $After_{it}$ is a dummy variable taking value 1 if the project in which the partner i is involved has been launched. The parameter of interest is β, which captures the change in presence after the projects start.

Results of regression (4) are shown for:

- $T = \text{Climate}$;
- $T = \text{Change}$;
- $T = \text{Agriculture}$;
- $T = \text{Food}$;
- $T = \text{Security}$;
- $T = (\text{Climate} + \text{Change} + \text{Agricolture} + \text{Food} + \text{Security}) = \text{CCAFS}$

Exploring CCAFS influence on policymaking through government websites

At the policy level, the adoption of CCAFS priorities on local/national policy was assessed by text mining the webpages of government partners. The same procedure for text mining social media was employed to determine a measure of similarity between CCAFS projects' taxonomies and the news/updates sections of government partners' websites, as these contain dates from which we can assess changes over time.

Data collection and processing

The dataset of this ecosystem is composed by all the news or updates published on a list of 54 websites of the government partners in CCAFS projects. The data extraction process comprised four steps:

1. Identifying the websites for each government partner and, in particular, the news/updates sections;

2. Assessing which websites had suitable news sections for our purposes, i.e. have relevant content (not just technical and/or administrative announcements) and contain information about the publication dates for the news items;

3. Writing a scraping program and customising based on the sites' structures

4. Extracting and saving well-structured data

Some of the websites, in fact, did not provide publication time on their news or contained only administrative announcements in their news sections, which excluded them from this analysis. The following is the complete list of government partners whose news pages were scraped:

Ministry of Planning (Bangladesh)

Ministry of Agriculture and Forests (Bhutan)

Ministére de l'Agriculture et des Aménagements Hydrauliques (Burkina Faso)

Ministére des transports, de la mobilité urbaine et de la sécurité routiére (Burkina Faso)

Ministerio de Agricultura y Desarrollo Rural (Colombia)

Agricultural Transformation Agency (Ethiopia)

Ministerio de Agricultura, Ganaderìa y AlimentaciÙn (Guatemala)

Secretaría de Seguridad Alimentaria y Nutricional (Guatemala)

Comisión Permanente de Contingencias (Honduras)

Secretaría de Agricultura y Ganadería (Honduras)

Ministry of Environment and Forestry (Kenya)

Ministry of Water and Irrigation (Kenya)

Ministry of Natural Resources and Environment (Lao PDR)

Ministry of Agriculture (Madagascar)

Ministére de l'Environnement ,de l'assainissement et du Développement Durable (Mali)

Government of Netherlands

Conseil National de l'Environnement pour un Développement Durable (Niger)

Ministerio de Agricultura y Riego (Peru)

Ministerio del Ambiente (Peru)

Department of Agriculture (Philippines)

Department of Science and Technology (Philippines)

National Economic and Development Authority (Philippines)

Ministry of Environment (Rwanda)

Rwanda Agriculture and Animal Resources Development Board (Rwanda)

Mbale District Local Government (Uganda)

Ministry of Agriculture Animal Industry and Fisheries (Uganda)

Ministry of Water and Environment (Uganda)
Nwoya District Local Government (Uganda)
Office of the Prime Minister (Uganda
Ministry of Agriculture, Food security and Cooperatives (United Republic of Tanzania)
Vice President's Office (United Republic of Tanzania)
U.S. Department of Agriculture (USA)
Ministry of Agriculture and Rural Development (Vietnam)
Ministry of Natural Resources and Environment (Vietnam)

For every news/update item, the following fields were extracted:

- Publication date
- Body of text
- Partner name
- URL (permalink to item)

As discussed, of the 54 identified websites, 35 were scrapable. The 19 discarded ones were either abandoned, without relevant news (just technical communications) or without publication date information. In terms of developing time, this was quite a demanding process, as dedicated Python scripts were developed for each of the 35 scraped websites. Ultimately, a total of 21,071 news items spanning from 2002 to 2020 were scraped, in about a day of script runtime on a single machine.

Three approval dates with a significant number of projects were analysed individually: 2017-01-01, 2018-01-01 and 2019-01-01. The first date considered three projects (P264, P274, P263) with nine government partners: "Department Of Science And Technology (Philippines)", "Ministerio Del Ambiente (Peru)", "Ministry Of Agriculture And Rural Development (Vietnam)", "Ministry Of Agriculture, Food Security And Cooperatives (United Republic Of Tanzania)", "Ministry Of Environment And Forestry (Kenya)", "Ministry Of Natural Resources And

Environment (Vietnam)", "Ministry Of Water And Environment (Uganda)", "Secretaría De Agricultura Y Ganadería (Honduras)", "Vice President's Office (United Republic Of Tanzania)".

The second date considered two projects (P785 and P771), with five government partners: "Mbale District Local Government (Uganda)", "Ministerio De Agricultura, Ganadería Y Alimentación (Guatemala)", "Nwoya District Local Government (Uganda)", "Office Of The Prime Minister (Uganda)", "Secretaría De Agricultura Y Ganadería (Honduras)".

Lastly, the third date considered nine projects (P1604, P1590, P1606, P1599, P786, P1602, P1608, P1591, P1592) with 11 partners: "Comisión Permanente De Contingencias (Honduras)", "Conseil National De L'environnement Pour Un Développement Durable (Niger)", "Government Of Bangladesh", "Ministerio De Agricultura Y Desarrollo Rural (Colombia)", "Ministerio De Agricultura Y Riego (Peru)", "Ministerio De Agricultura, Ganadería Y Alimentación (Guatemala)", "Ministry Of Agriculture And Forests (Bhutan)", "Ministry Of Agriculture And Rural Development (Vietnam)", "National Economic And Development Authority (Philippines)", "Secretaría De Agricultura Y Ganadería (Honduras)", "Secretaría De Seguridad Alimentaria Y Nutricional (Guatemala)".

Similarly to Twitter and Facebook, to give an empirical measure to the text correlation over time and to test whether the correlation after the projects start is significant, we performed the following regression:

$$Text\ Correlation_{iPt} = \beta * After_{it} + \varepsilon \quad (3)$$

Where $After_{it}$ is a dummy variable taking value 1 if the project in which the partner i is involved in has been launched. The parameter of interest is β, which captures the change in text correlation after the projects start.

Work stream 3: Placing CCAFS within its network of strategic partners

Using the dataset collected from twitter, it was possible to assess CCAFS' place within its network of strategic partners by analysing the accounts mentioned on partner tweets. A network analysis was performed to explore the relationship between accounts mentioned in the corpus.

Network analysis techniques enable the visualization of relational data organised as matrices, where entities are the nodes – in this case, @mentions – and their relations are the lines connecting pairs of nodes – here calculated by the weighted in-degree of connection. This means that accounts are connected if they are mentioned by another. The strength (or weight) of this connection is based on the times mentioned by the same account, which captures both the extensive and the intensive margins of connections, that is, not just the presence of a connection, but also the strength of the connection as a measure of significance. The complete network of mentions derived from the corpus contained 63,000 accounts mentioned through 100,000 connections.

A force-directed algorithm was used to construct the network displays. Force-directed graphs show the spatialization of nodes by mapping the proximity and the authority of categories in relation to each other (Jacomy *et al.* 2014). This means that linked nodes are drawn closer while unrelated nodes are pushed farther apart, thus allowing for a visual interpretation of the dynamics between actors in the network. A modularity algorithm (Blondel et al., 2008) was applied to identify "communities", or clusters – as represented by nodes that are more densely connected together than to the rest of the network, and which were coloured accordingly.

Work stream 4: Mapping CCAFS knowledge dissemination

An approximation of how CCAFS activity is disseminated globally was explored through a hyperlink analysis, which used the list of CCAFS deliverables reported in MARLO to explore how they are spread through the web. This led to the identification, by means of web scraping algorithms, of the web pages hyperlinking to every item of the considered list.

Data collection and processing

The dataset can be thought of as sets of pairs composed of a CCAFS deliverable and a web page, either hyperlinking or mentioning that deliverable. The starting point for the creation of this dataset was a list of more than 2,700 CCAFS outputs marked as "already disseminated" in the Deliverables Report (of 4,510 in total), and which contained the following information:

– **Disseminated URL:** the URL where the deliverable was first published

– **Disseminated title:** the exact title or reference of the deliverable

Examples of deliverables considered for scraping

Disseminated url	Disseminated title
hdl.handle.net/10568/106068	2019 State of Climate Services: Agriculture and Food Security
allafrica.com/stories/201712140408.html	Africa: When Climate Policy Fails on the Ground

The table above shows some examples of deliverables used for the dataset. Consequently, for every deliverable, a search for all the web pages hyperlinking to it was carried out. The task of finding hyperlinks through the whole web is very ambitious; in fact, dedicated projects exist with the goal of building up updated and comprehensive hyperlink graphs, such as the Web Data Commons project. Results are promising, but some limitations have to be considered:

1. Coverage of the entire web: as far as we know, the most complete collection of web pages is still provided by private companies such as Google, Yahoo, and Microsoft, which monetise their services. Public web archives exist (e.g. WayBackMachine or CommonCrawl), and they are suitable for many research projects. Unfortunately, as stated on articles such as Stolz and Hepp (2015), they might miss a good number of web pages, resulting in not optimal results.

2. Building a search engine: although not strictly crucial, it is something to be considered in terms of time and resources. A web search engine is something that takes time to be written, especially when dealing with billions of records and petabytes of data. Ordinary technology cannot be used, but instead, dedicated Big Data infrastructures should be involved in the process.

As a good balance between coverage and resource problems, commercial search engines have been used for this task, and in particular:

- Google
- Bing
- DuckDuckGo

The advantages of this strategy are the great web coverage of the chosen platforms, and the ability to use their existing search engines. Yet, some limitations include:

- they do not allow to search directly for hyperlinks
- they have anti-scraping policies that have to be overcome

The developed algorithm searches for the exact title of the deliverable and a string of the disseminated URL (not a link). For instance, with the second example from the table above, the corresponding query would be:

```
"Africa: When Climate Policy Fails on the Ground" OR
"allafrica.com/stories/201712140408.html"
```

This approach works very well when deliverables have specific titles, such as the example above, but broad titles can lead to ambiguous results. To tackle this, as a part of the scraping program, an algorithm able to spot such ambiguous results was developed. Every extracted record is composed of the following fields:

- Title and URL of disseminated deliverable
- URL of web page containing a reference to the deliverable

- Domain of the found URL (e.g. ccafs.cgiar.org from https://ccafs.cgiar.org/node/55969)
- Top Level Domain (TLD) of found URL (e.g. .org from https://ccafs.cgiar.org/node/55969)

Due to strict anti-scraping policies of some search engines, the use of automated browsers such as Selenium was necessary, resulting in an elapsing time of almost two days on a single machine.

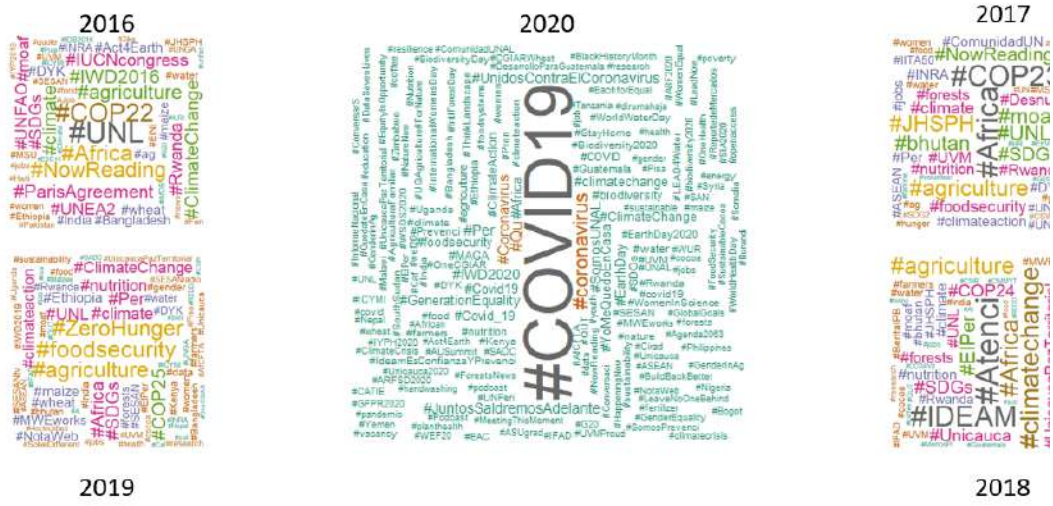
Work stream 5: Exploring public awareness of CCAFS' core message

The association between CCAFS activity and public awareness was explored with Google Trends. In recent times, internet search data have been extensively exploited as measures of aggregate issue salience. These data have clear advantages over survey data in terms of cost, availability and frequency.

This step of the analysis assessed changes in Google query searches for one of the key concepts related to CCAFS' scope of action – Climate Smart Agriculture – before and after the start of the programme. To this aim we downloaded queries for "Climate Smart Agriculture" in English and Spanish from 2004, the earliest date available on Google Trends, until 2020 (the query in French did not yield results).

Appendix 2 – Twitter analysis by project start date

Word Clouds of hashtags for all partners, by year (2016-2020)

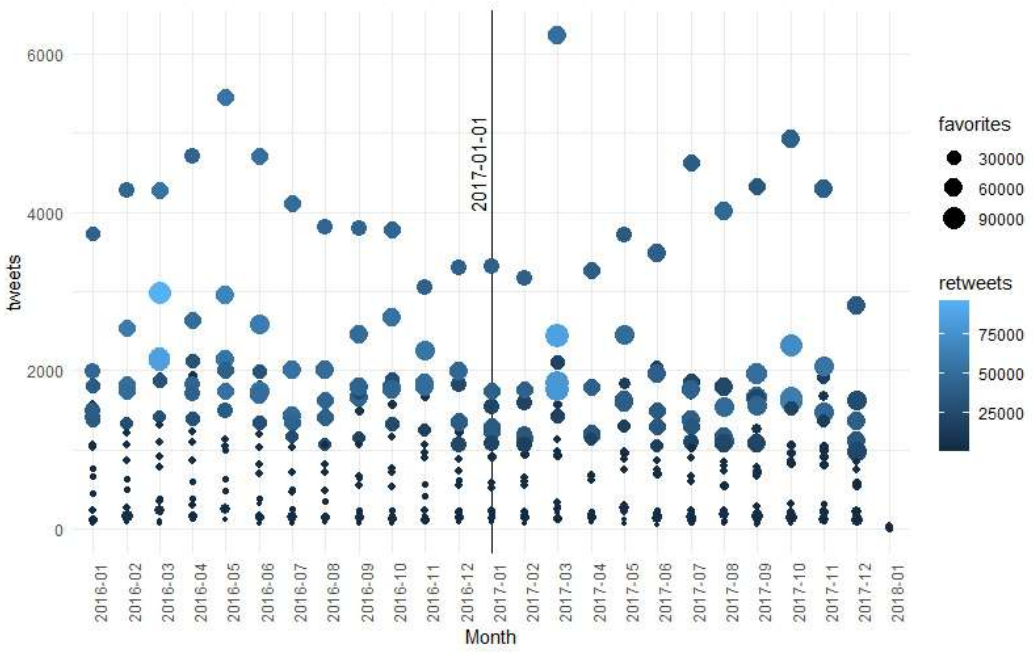


Twitter accounts and overall activity for partners in projects starting on 2017-01-01

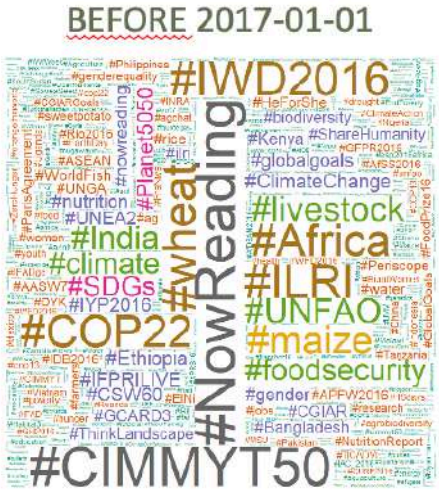
Partner type	Tweets	Accounts	Tweets per capita
Association	2662	3	887
Bilateral development agency/bank	10580	2	5290
CGIAR Centre	185535	14	13252
Foundation	268	2	134
Government	14396	14	1028
International NGO	53123	9	5902
International Organization (other than financial or research)	30217	3	10072
International/regional financial institution	31229	3	10409
International/regional research institution	15995	9	1777
National/Local NGO	21778	3	7259

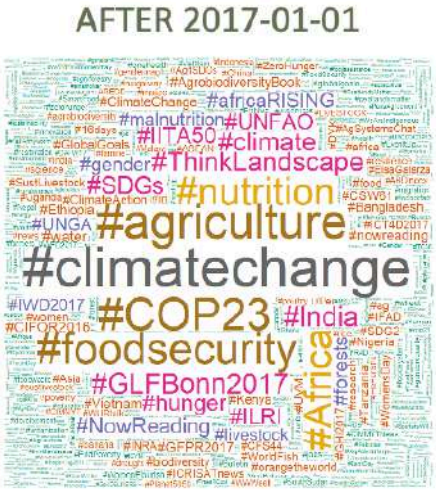
National/local research Institution	4654	6	775
Other	2033	7	290
Regional Organization	4515	5	903
University	59579	22	2708

Twitter activity metrics for partners in projects starting 2017-01-01, by month, one year prior and one year after start date.

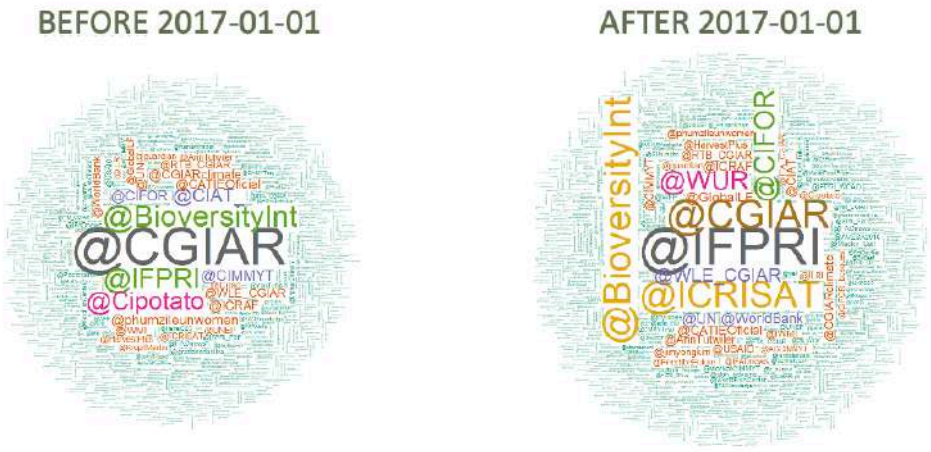


Word cloud of hashtags used by partners before and after project start date 2017-01-01

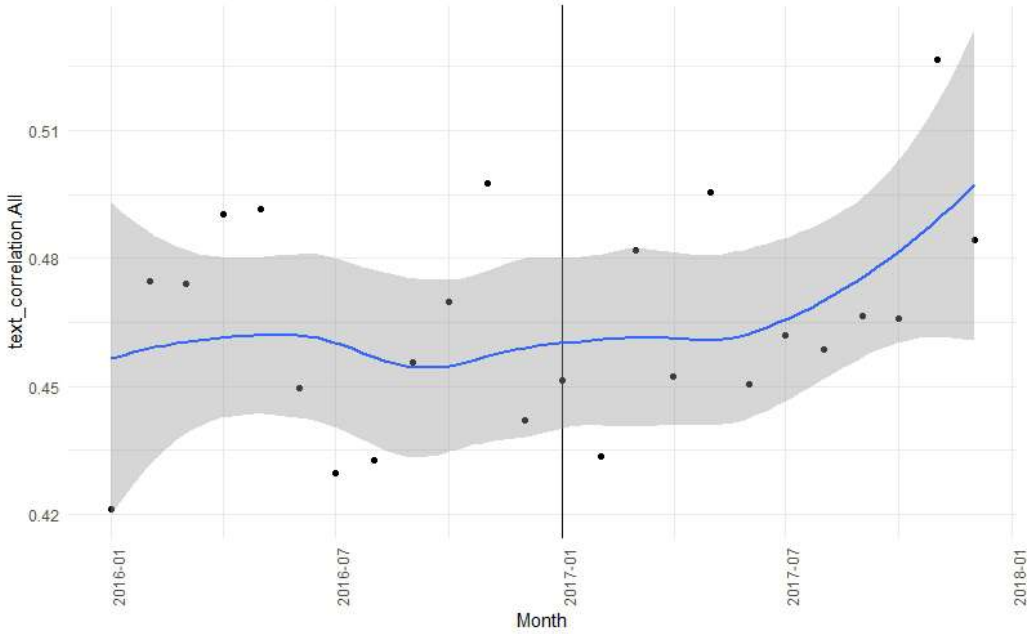




Word cloud of accounts mentioned by partners before and after project start date 2017-01-01



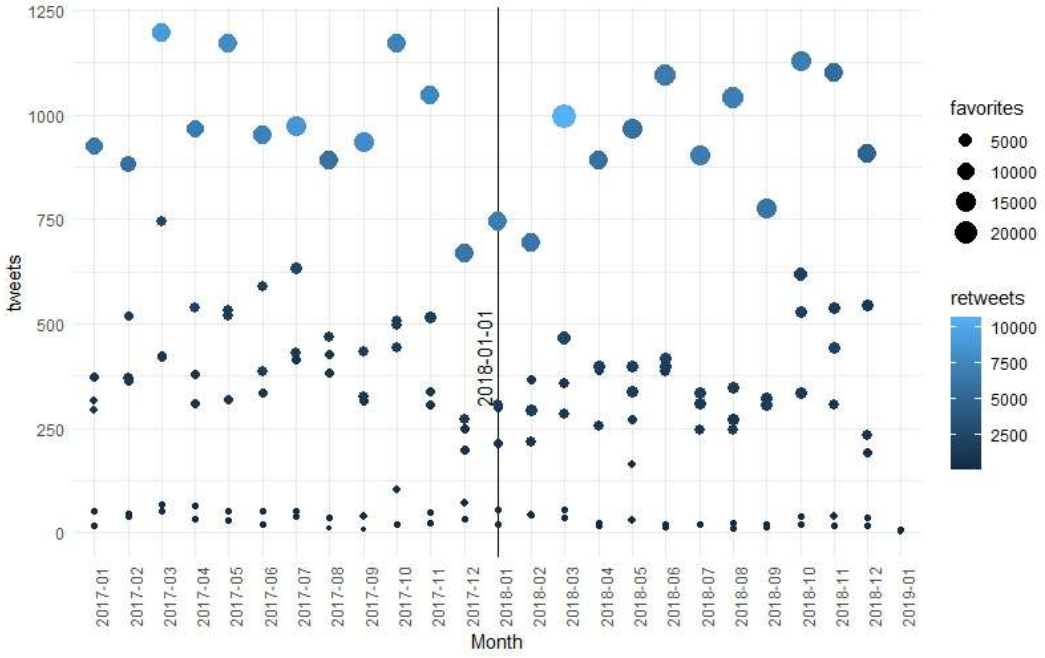
Text correlation between CCAFS taxonomy and tweets of partners for projects started 2017-01-01



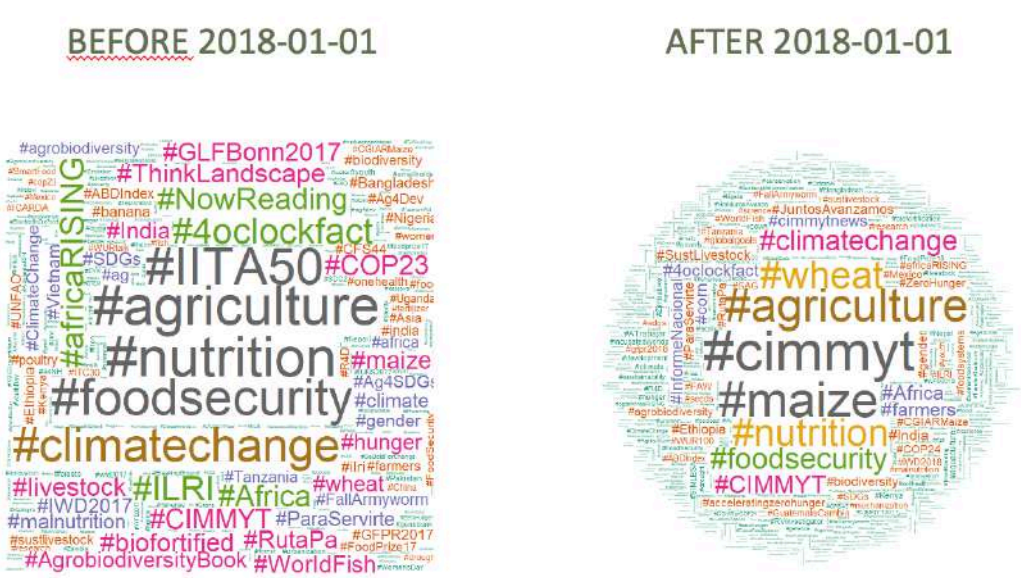
Twitter accounts and overall activity for partners in projects starting 2018-01-01

Type	Tweets	Freq	Tweets per capita
CGIAR Center	27469	8	3433
Government	5098	5	1019
International Organization (other than financial or research)	1166	1	1166
International/regional research institution	5161	2	2580
Regional Organization	1341	1	1341
University	11999	5	2399

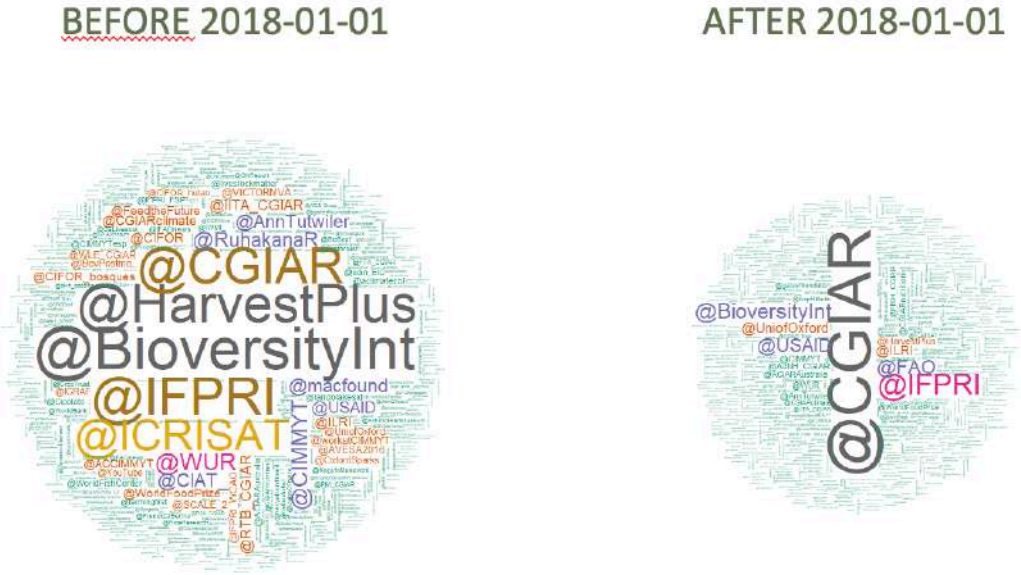
Twitter metrics for partners in projects starting 2018-01-01, by month, one year prior and one year after start date.



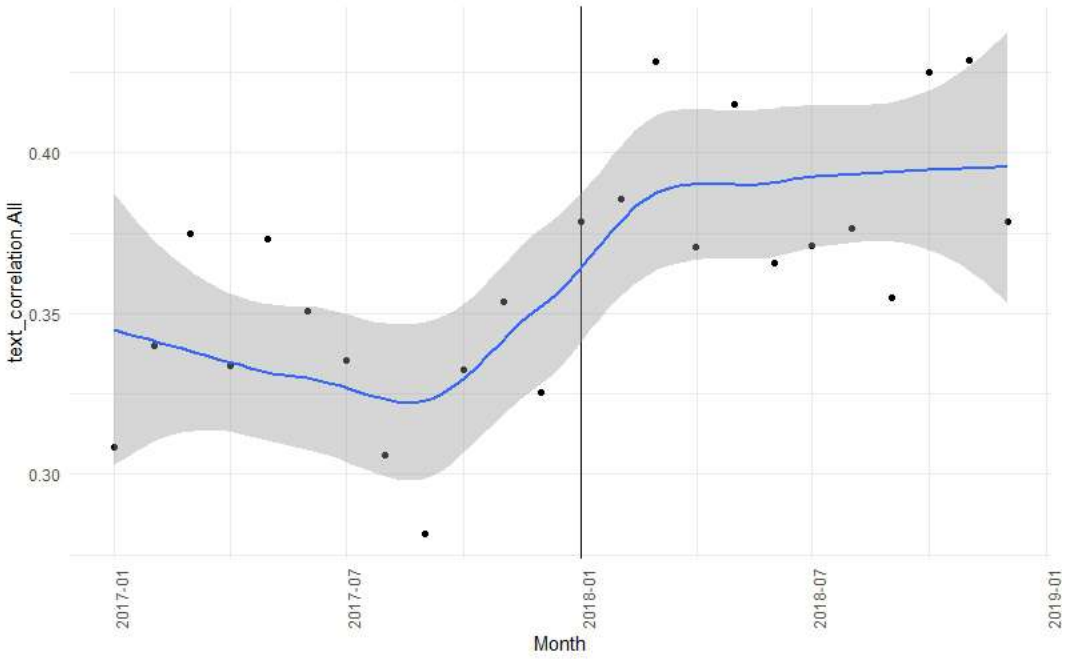
Word cloud of hashtags used by partners before and after project start date 2018-01-01



Word cloud of accounts mentioned by partners before and after project start date 2018-01-01



Text correlation between CCAFS taxonomy and tweets of partners for projects started 2018-01-01

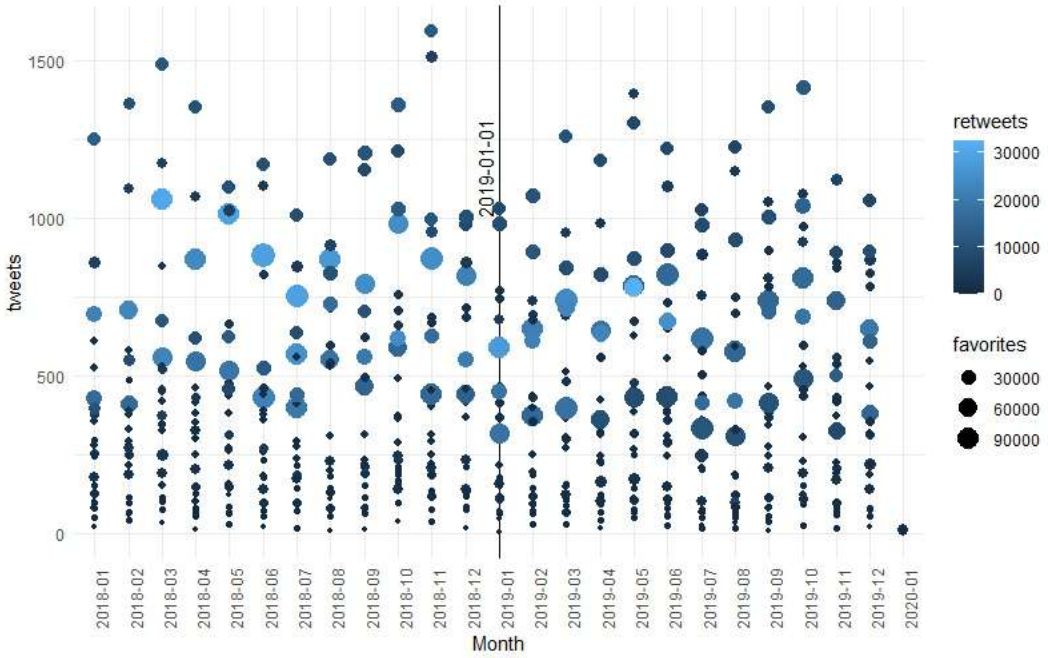


Twitter accounts and overall activity for partners in projects starting on 2019-01-01

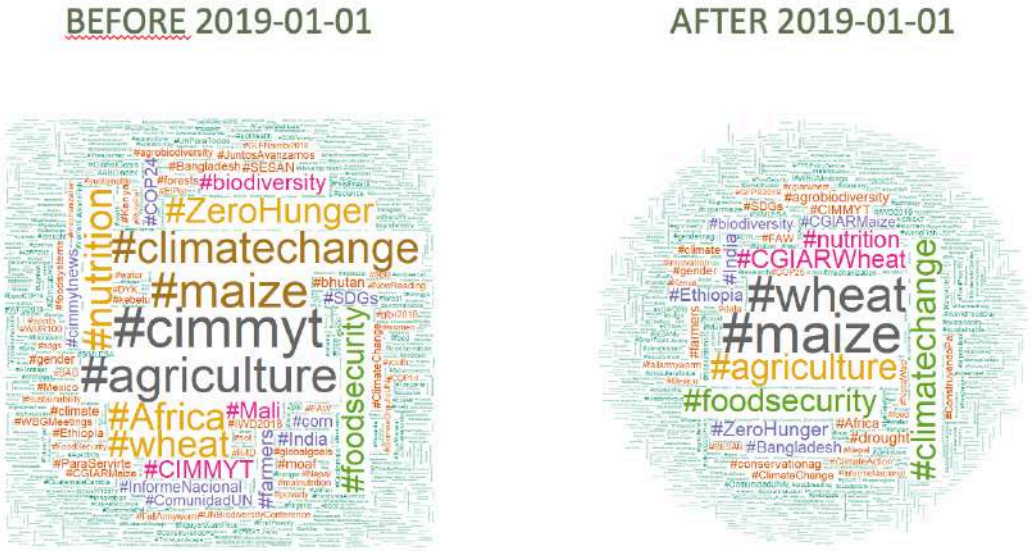
Type	Tweets	Freq	Tweets per capita
Agricultural advisory and/or extension services	97	1	97
Associations	3323	6	553.8333
CGIAR Center	79147	11	7195.182
Government	50244	17	2955.529
International NGO	11322	6	1887
International Organization (other than financial or research)	9547	3	3182.333
International/regional financial institution	19972	3	6657.333
International/regional research institution	464	2	232
National/Local NGO	698	3	232.6667
National/local research Institution	4779	10	477.9
Other	5154	4	1288.5
Private company (other than financial)	11540	5	2308

Regional Organization	1084	2	542
University	37992	14	2713.714

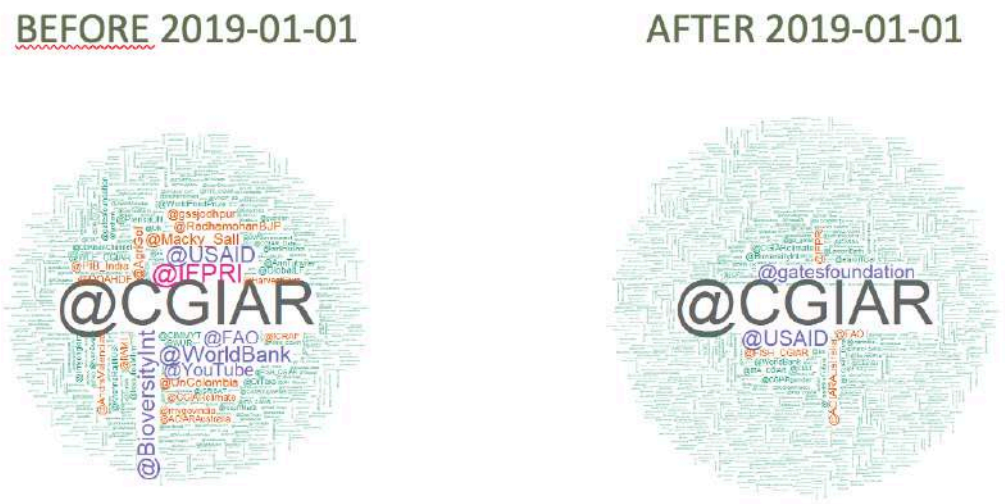
Twitter metrics for partners in projects starting 2019-01-01, by month, one year prior and one year after start date.



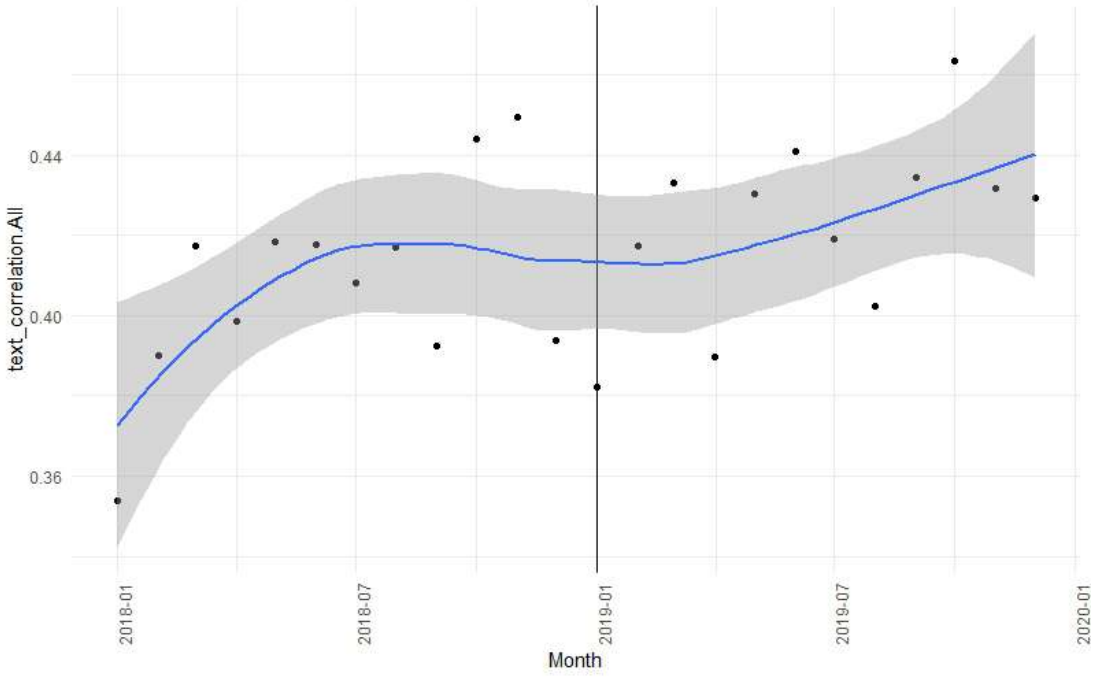
Word cloud of hashtags used by partners before and after project start date 2018-01-01



Word cloud of accounts mentioned by partners before and after project start date 2019-01-01

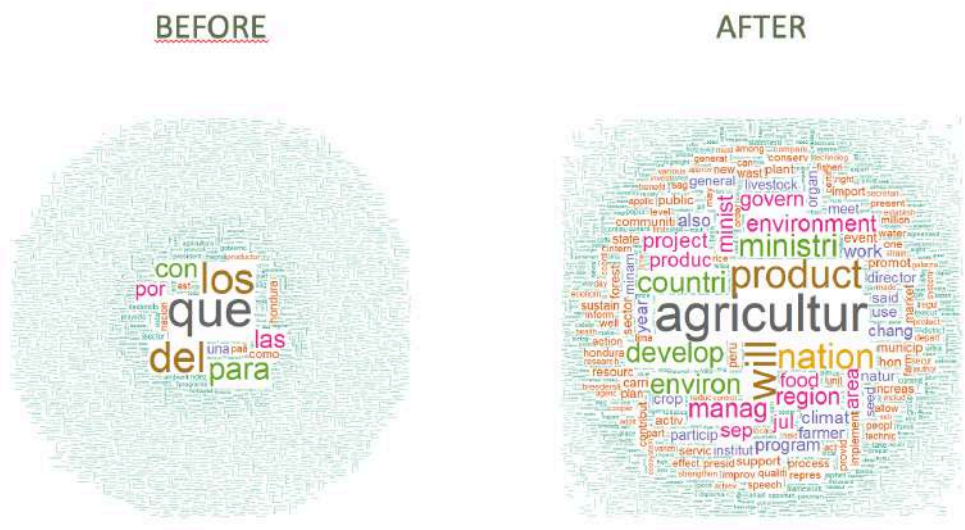


Text correlation between CCAFS taxonomy and tweets of partners for projects started 2019-01-01

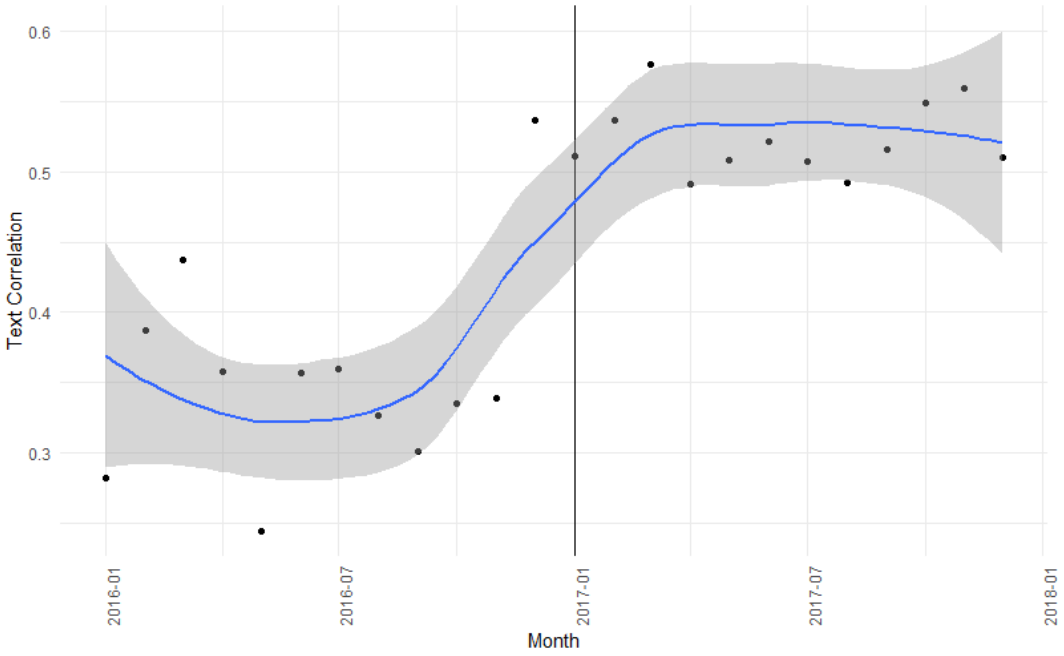


Appendix 3 - Government websites analysis by project start date

Word clouds for news pages of government partners in projects launched 2017-01-01



Text correlation between CCAFS taxonomy and news pages of government partners in projects launched 2017-01-01

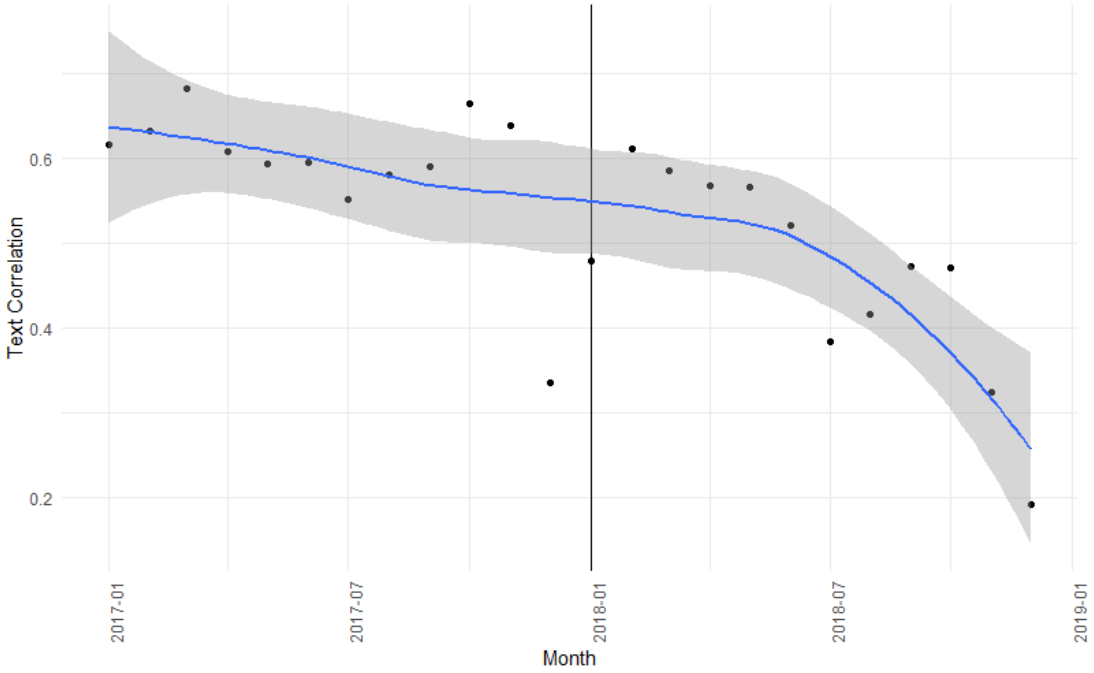


Word clouds for news pages of government partners in projects launched 2018-01-01

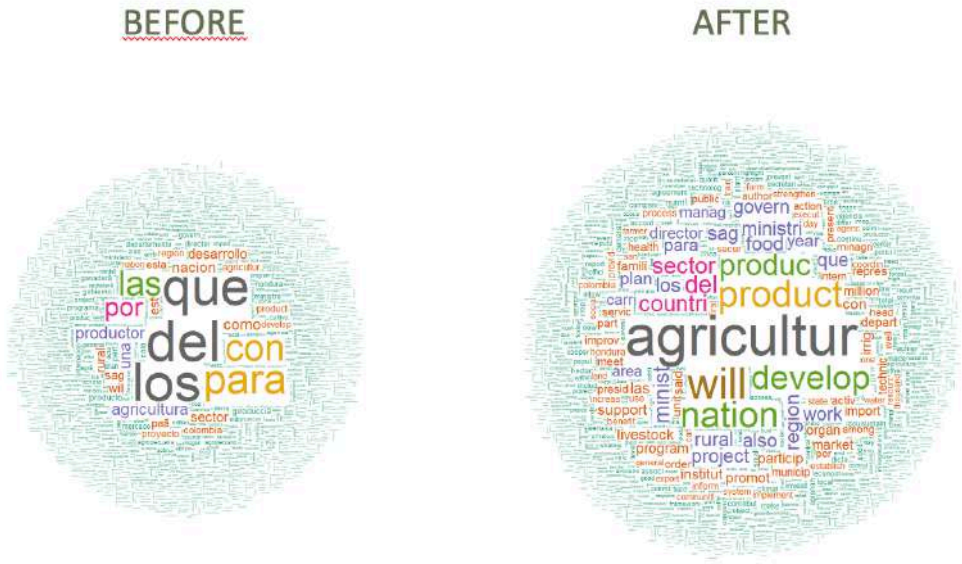
BEFORE

AFTER

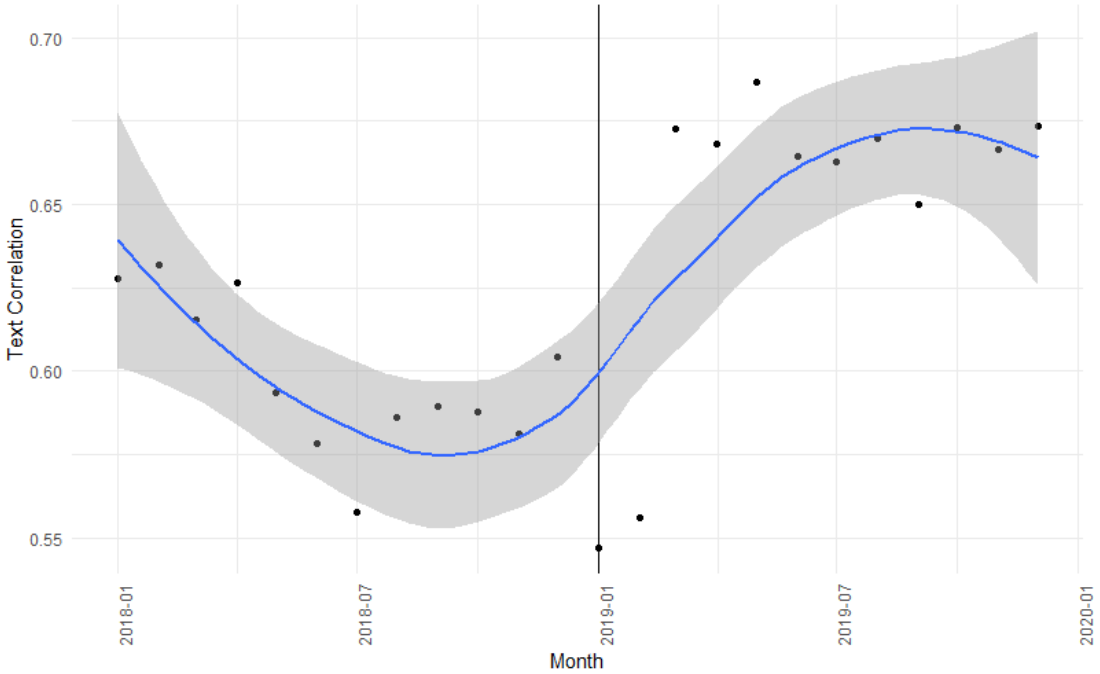
Text correlation between CCAFS taxonomy and news pages of government partners in projects launched 2017-01-01



Word clouds for news pages of government partners in projects launched 2019-01-01



Text correlation between CCAFS taxonomy and news pages of government partners in projects launched 2017-01-01



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