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A framework for climate services evaluation and its application to the Caribbean Agrometeorological Initiative

Jason Vogel[a,*], David Letson[b], Charles Herrick[c]

[a] Abt Associates, 1881 9th Street, Suite 201, Boulder, CO 80302, USA
[b] Department of Marine Ecosystems and Society, University of Miami/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149, USA
[c] New York University, Washington, DC Global Academic Center, 1307L Street, NW, Washington, DC 20005, USA

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ABSTRACT

Novel approaches to project evaluations are needed to document the outcomes and lessons to be learned from the numerous and diverse investments international donor organizations, national governments, and regional institutions are making in climate services. This paper describes an elaborated logic model to structure the evaluation of a climate services program, which we demonstrate in a case study of the Caribbean Agrometeorological Initiative (CAMI). Moving beyond the "loading dock" model of scientific information application, this logic model helps evaluators to address all elements of the provision of climate services – including the quality of weather and climate forecasts and agronomic advisories, the distribution of that information, the uptake of that information, and actions taken by farmers (See Fig. 1). Our logic model links the provision of information on weather, climate, and agriculture with decision making, and ultimately with improved social and economic outcomes. While such a logic model necessarily simplifies the full context of any climate services program, it also makes project evaluation much more tractable and generalizable across contexts. Furthermore, this simple logic model can serve to deconstruct conventional thinking about climate services by explicitly addressing the social and process dimensions of climate services that are sometimes neglected in project design, implementation, and evaluation. CAMI partner countries are developing climate outlook bulletins to communicate a three-month seasonal forecast. Despite these high quality seasonal forecasts, we note shortcomings regarding the dissemination of that information, its uptake by farmers, or the ability or willingness of farmers to act on that information.

Practical Implications

We offer a more fully elaborated logic model to structure the evaluation of a climate services program, which we demonstrate in a case study of the Caribbean Agrometeorological Initiative (CAMI). Through use of this logic model, we are able to take a full lifecycle approach to the evaluation of the CAMI program, assessing not only the quality of weather and climate forecasts and agronomic advisories, but also the distribution of that information, the uptake of that information, and actions taken by farmers. Our climate services logic model helps identify weak links in the chain of climate services. While we illustrate the practical implications of this logic model by discussing the CAMI evaluation below, the purpose of this paper is to present the logic model itself as a theoretical development worthy of replication in other contexts. The authors believe that this logic model can serve to deconstruct conventional thinking about climate services by explicitly addressing the social and process dimensions of climate services that are sometimes neglected in project design, implementation, and evaluation. The logic model itself should prove useful beyond the Caribbean region and the agriculture sector.

We tested this logic model by evaluating CAMI, a three-year, ten nation, European Union sponsored project that sought to "increase and sustain agricultural productivity at the farm level in the Caribbean region through improved dissemination and application of weather and climate information using an integrated and coordinated approach" (CAMI, 2010; see Vogel et al., 2014 for the full evaluation). CAMI was funded by the EU as an African, Caribbean, and Pacific Group of States' Science and Technology Programme initiative, and was administered by the Caribbean Institute for Meteorology and Hydrology (CIMH). The initiative involved the countries of Antigua and Barbuda, Barbados, Belize,

* Corresponding author.
E-mail addresses: jason_vogel@abtassoc.com (J. Vogel), dletson@rsmas.miami.edu (D. Letson), ch133@nyu.edu (C. Herrick).

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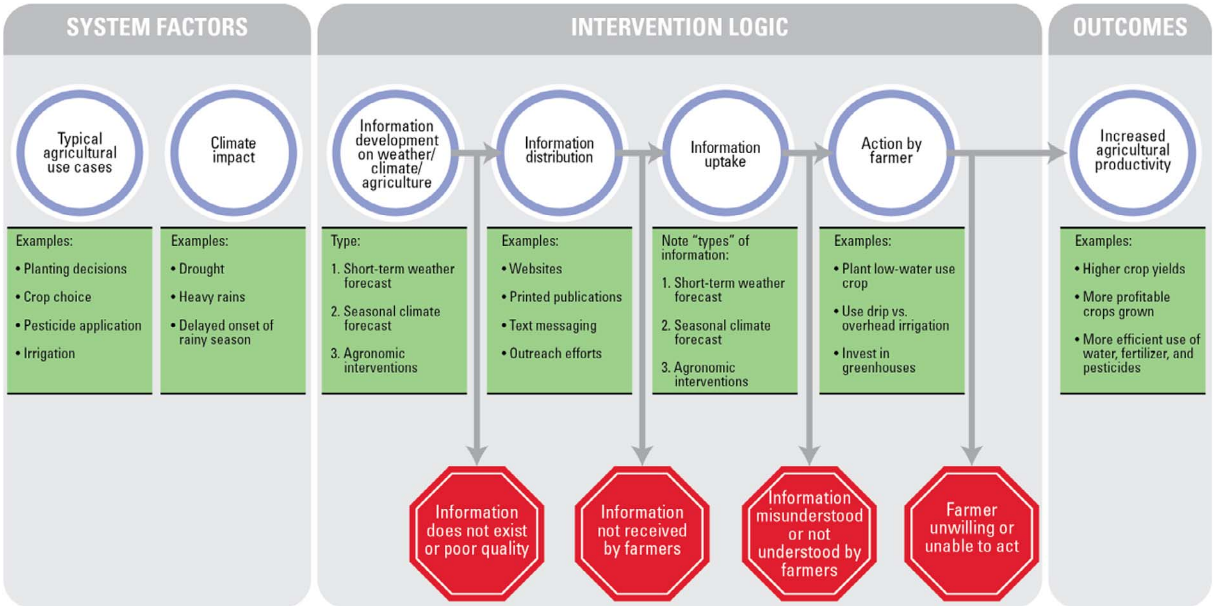

Fig. 1. Agricultural climate services logic model.

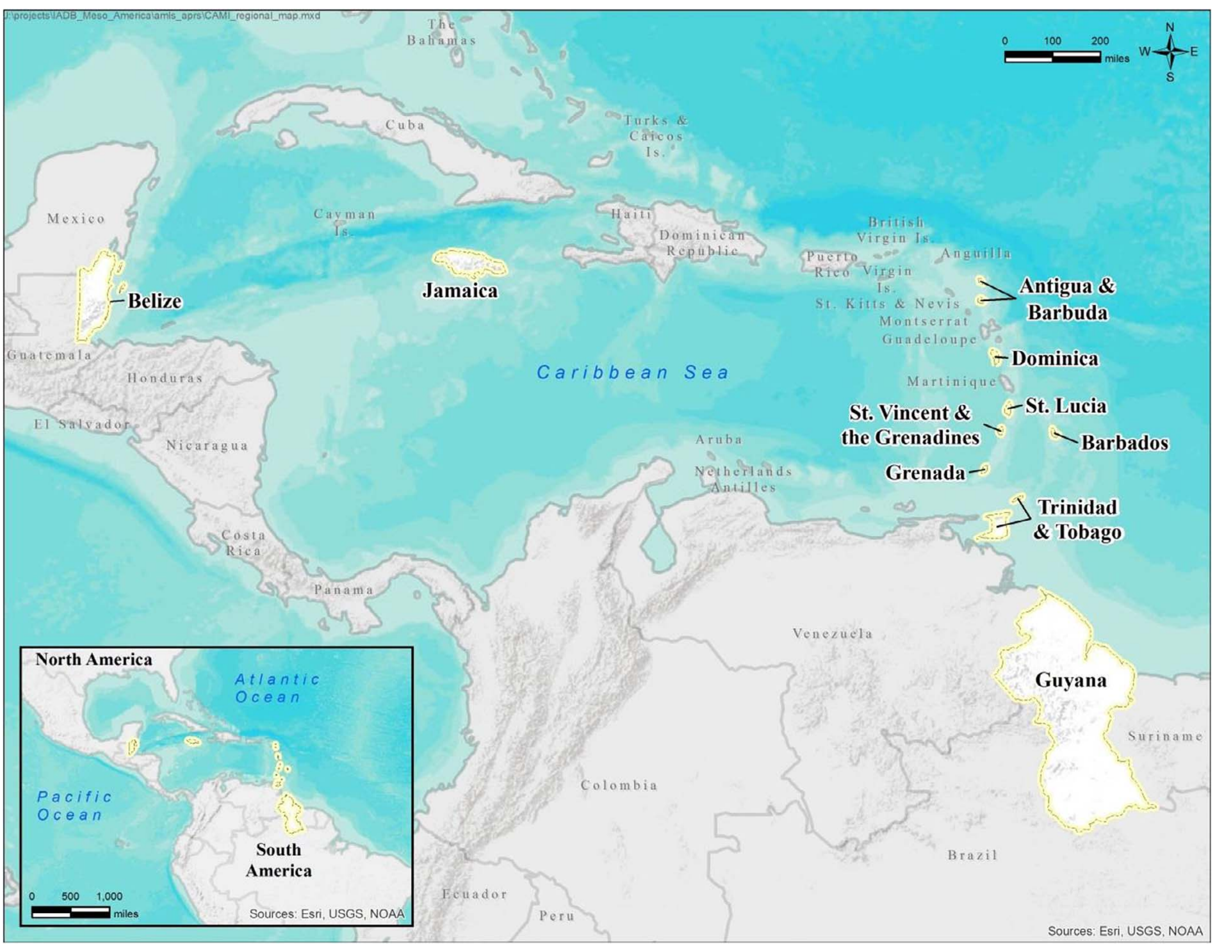

Fig. 2. Map of the Caribbean with CAMI countries highlighted.

Dominica, Grenada, Guyana, Jamaica, Saint Lucia, Saint Vincent and the Grenadines, and Trinidad and Tobago (see Fig. 2 for a map of the region). CAMI began in February 2010 and ended in early 2013.

The provision of climate services might not lead to the desired outcome of increased agricultural productivity for a variety of reasons (depicted as red 'stop signs' in Fig. 1). These constraining factors include low-quality or inadequate information, poor information distribution, inability of farmers to understand the information, and farmer unwillingness or inability to act on that information. In other words, when evaluating CAMI, the context of application involves more than simply the quality and/or quantity of the information produced by CIMH, national meteorological agencies, or national agricultural agencies. Continuing, targeted investments will be needed in order to sustain the climate service capacity built by CAMI. Specifically, we identify the following needs at the conclusion of CAMI:

- ***Fortify cross-agency relationships.*** In many countries, CAMI was the first opportunity for meteorological and agricultural service staff to work collaboratively. Meteorological services staff must continue to collaborate with agricultural services staff for CAMI-initiated efforts to succeed in the future. Moving forward, CAMI partners should look for opportunities to collaborate with their agricultural services counterparts; this will help build the agronomic capabilities with meteorological services and meteorological capabilities in agricultural services.
- ***Place additional emphasis on agricultural interventions.*** While some participants identified this as a challenge, it should remain a goal of CAMI partners to clearly articulate crop impacts and agricultural interventions of the meteorological and climate data they provide.
- ***Track information distribution.*** Currently, CAMI partners do not have a sense of how many farmers they are reaching through their primary climate service – outlook bulletins. In the future CAMI partners should aim to track the distribution of outlook bulletins to better understand their reach. Options include tracking the number of “clicks” or downloads from websites, tracking the number of hard copies distributed, monitoring attendance at forums, and working with extension agents to track information sharing.
- ***Use interactive information-sharing methods.*** CAMI partners should focus on those information distribution methods that allow interaction with end-users. These methods could include one-on-one contact between extension agents and farmers, forums, outreach to effective farmer organizations, and call-in radio programs. In particular, outreach to informal networks has the potential to spread climate services due to farmers’ reliance on peers for guidance. These methods provide opportunities to ensure that information is conveyed clearly, and allows end-users to provide valuable feedback.
- ***Expand the role of agricultural extension agents.*** Agricultural extension agents have great potential to communicate climate information with farmers. However, many agricultural extension officers could benefit from additional training on understanding and communicating climate data and agricultural impacts. CAMI partners are already seeking funding to conduct training sessions with agricultural extension agents to increase their capabilities with regard to climate information.
- ***Seek feedback from end-users.*** CAMI partners should actively seek feedback from farmers on outlook bulletins. This will help ensure that key messages are clearly conveyed, and that their climate services have the information farmers need most. Options for actively seeking feedback include soliciting feedback at farmers forums, tracking questions on radio programs, setting up automated web-based surveys, having agricultural extension officers actively distribute surveys, or sharing websites, email addresses, or telephone numbers where users can provide feedback.
- ***Continue to refine outlook bulletins.*** CAMI partner countries are still working to determine what information is most valuable for farmers. CAMI partners should continue to refine the content of their outlook bulletins based on changing needs – guided by feedback from end-users.
- ***Develop metrics to measure success.*** CAMI has not yet defined how it is measuring the primary goal of “increased agricultural productivity.” This goal can be measured through several metrics. CAMI partners should develop a collective set of metrics and begin taking stock of their progress.
- ***Think long-term.*** Sustainability of CAMI will be a challenge. CAMI is still in the process of scaling-up its climate service and already must seek new funding sources. CAMI partners should seek more stable, longer-term funding if possible.

CAMI is an example of the tremendous amount of ongoing experimentation in the climate information arena under the rubric of ‘climate services.’ Novel approaches to project evaluations are needed to document the outcomes and lessons to be learned from the investments international donor organizations are making. Much of the experimentation in climate services focuses on agriculture, given its traditional role in economic development, but we believe that our logic model could serve as a guide in non-agriculture contexts as well.

1. Introduction

Climate services have the potential to reduce climate-related risks to agrarian livelihoods, but such outcomes are possible only when the climate services deliver information to farmers that is salient, legitimate, and credible (Carr et al., 2016; Cash et al., 2002; McNie, 2007; Vogel et al., 2016). Climate services represent a relatively new, but rapidly growing frontier in the interface between the production of scientific information and the demand for usable, application-relevant information. The problem of reconciling competing agendas from the producers and consumers of such information has been addressed across a range of topical areas (e.g., Guston, 2001; McNie, 2007). But the lack of progress in producing actionable climate information has been noted (e.g., Kirchhoff et al., 2013; Lemos et al., 2012; National Research Council, 2009). Despite this apparent lack of progress, a substantial amount of experimentation is ongoing in the climate information arena under the rubric of ‘climate services’ (Vaughan and Dessai, 2014; Vogel et al., 2016). Novel approaches to project evaluations are needed to document the outcomes and lessons to be learned from the investments international donor organizations, national governments, and regional institutions are making in climate services.

Project evaluations are important because, when done properly, they can help to ensure the engagement of end users in the development and dissemination of climate information. Many discussions of climate services adopt a relatively narrow focus, limited predominantly to the development and provision of high-quality scientific information, following what Cash et al. (2006) refer to as a “loading dock” approach. From the perspective of meteorological and hydrologic service providers, this scope of review may appear appropriate since scientific information on weather and climate has tremendous potential to improve social and economic outcomes. The drawback of this approach is that it assumes the weather and climate information to be useful, with the implication that its production, distribution, and application need not occur in consultation with its end users.

In the context of Caribbean agriculture, Guido et al. (2016) describe the production of climate information products by intermediaries (e.g., meteorologists, agricultural extension agents) at two Caribbean Climate Outlook Forums (CariCOFs). Guido et al. (2016) discussed the role of the Caribbean Institute of Meteorology and Hydrology (CIMH) as a boundary organization, and the iterative process of information development to improve the theoretical utility of climate information products. But importantly, Guido et al. (2016) do not address the distribution of these information products, the uptake of such information by farmers, or whether and how farmers take action based on this information. When climate information producers involve end users only in the development of climate information products but do not seek their involvement in the distribution, uptake, and action elements of climate services, the climate services project or program can fail to meets its objective(s).

In this article, we propose a framework for the systematic evaluation of climate services initiatives in the agricultural sector in order to provide a comprehensive and multi-faceted analysis of the various factors critical to success: including climate information, but also the use- or application-specific factors that enable and constrain how such information can be provided and used, including commonly overlooked social and process dimensions to climate services. A systematic framework for the evaluation of climate services is important because climate services initiatives are often devised, promoted, and funded by scientific experts and agencies, but it is often the social and process factors that constrain the availability, applicability, distribution, usability, and significance of climate information.

Furthermore, as climate impacts gain salience for decision makers across the world (e.g., due to intense storms, severe droughts, catastrophic wildfires, sea level rise), the demands on climate services will grow and the effectiveness of climate services initiatives will be placed under increasing scrutiny. After describing our framework for climate services evaluation, we then illustrate the use of this framework with an evaluation of CAMI. The logic model we developed (Fig. 1) represents our attempt to formalize and substantiate what it means to conduct an evaluation of agricultural climate services, but we believe the basic concepts behind it will be transferrable to other settings.

2. Methods

One way to examine whether climate services may create societal value is, following David Hume's constant conjugation argument (Hume, 1748), to seek a set of necessary connections between the former and latter and to see if in fact they obtain. A number of researchers have taken this approach to evaluate hydrological, meteorological, or climate services as part of a service chain or an end-to-end system (e.g., Hooke and Pielke Jr., 2000; Morss et al., 2008, 2010; Nurmi et al., 2013; and Anderson et al., 2015). We begin this section by describing a logic model generally, the reasoning behind its development, and its utility for project and program evaluation. Next, we describe the CAMI case study we used to test this methodological innovation.

2.1. Logic model methodology

The meteorological community has limited understanding of how people use and interpret weather and climate data, as well as associated services (Anderson et al., 2015; Morss et al., 2010; Lazo et al., 2009; AMS, 2008). Although use of weather data has been the subject of social science research, studies have tended to focus on a relatively limited suite of issues, such as the economic value of improvements to weather data (e.g., improved accuracy, reduced uncertainty), how best to communicate risk to non-technical audiences, and how people interpret and react to uncertainty (Morss et al., 2008). While most of the research focused on the economic value of weather and climate data are derived through so-called "cost-loss" models, other studies have attempted to couch data and information use in terms of an idealized "weather service chain" (Nurmi et al., 2013; Perrels et al., 2012). Weather service chain analysis (WSCA) posits a series of stages that data must pass through in order to achieve a fully realized end-benefit. Performance degradations at any of the stage of the process contribute to an overall reduction in the value of the weather data and/or associated services. The stages considered in a typical WSCA include:

- The extent to which data are accurate
- The extent to which data are appropriate for end-users
- The extent to which users have timely access to the data
- The extent to which users understand the data
- The extent to which users can adapt their behavior to utilize the data
- The extent to which adapted behaviors achieve desired outcomes
- The extent to which actions taken are transferred to other economic agents

The WSCA framework addresses factors that can diminish the potential value of weather and climate information in an idealized application scenario. In other words, the WSCA approach is not configured as a program management tool reflecting factors that control or constrain use of weather data in any given, real-world application. As already mentioned, our research was performed to inform critical evaluation of a specific program of weather and climate information delivery. Rather than model the performance of the CAMI against a conceptualized value chain, we instead constructed a series of use-cases typical of the CAMI program. Drawn from the systems engineering literature, a "use case" is a description of what a particular user in a particular situation seeks to do or to know about a particular thing (Usability.gov, 2017; Stratus Consulting, 2009). To be most helpful, a use case should articulate a series of application-specific factors such as the following:

- Who will be using the information; or what is the role of the data or information user
- What information they need
- Why they need the information; or what are their goals
- How the information will be used; what steps the users will take to use the information
- When the information or service would be needed
- Where the information will be used

For the CAMI evaluation, use cases were configured to generalize typical activities of Caribbean Basin agricultural producers, including planting decisions, choice of crops, whether or when to apply pesticides, and whether or when to irrigate. This was done to help provide a real-world focus and assure adequate specification of a CAMI logic model.

A logic model is one of a set of tools used to characterize and evaluate the effectiveness of a program, policy, project or other type of intervention. Logic models depict the functional relationships between a set of activities intended to alter a specified state or condition and thereby achieve a particular set of desired outcomes. It is closely related to a theory of change and a logic framework; and some experts even argue that these terms are interchangeable (McLaughlin and Jordan, 1999).

Logic models typically take the form of a linear, step-wise process between inputs, initial outputs, intermediate outputs, and outcomes. But the actual categories used in a logic model are less important than the general form, and in our case we define system factors, interventions, and an outcome (see Fig. 1). The key is that each step in a logic model is analytically tractable and can be observed or tested to monitor progress along the envisioned changes in policy or process. We illustrate the various ways in which our theoretical logic model for agricultural climate services may depart from contextual observation with a series of red 'stop signs.'

A logic model is particularly useful as a construct for project and program evaluation. By explicitly defining the step-wise logic by which a project or program is intended to achieve change, each step can be tested against observation. Step-wise verification is particularly important when outcomes may be hard to measure or the contribution of a particular intervention to overall change in the outcome of interest may be difficult to discern.

Our agricultural climate services logic model starts with the system factors of agricultural use cases and climate impact (see the first two blue circles in Fig. 1) that describe the situational context in which an agricultural climate services program operates. The next four blue circles represent an idealized intervention logic – the necessary and sequential activities to achieve the program objective. And the final blue circle represents the desired outcome of an agricultural climate services program. Examples are provided in the green box under each blue circle for illustrative purposes. The red 'stop signs' represent ways in which progress from one activity to the next could be interrupted – effectively preventing a climate services program from achieving its objective. Each step in the intervention logic represents a necessary step in the process of making climate forecasts useful for farmers as well as an opportunity for climate service providers to engage with end users to ensure that the information provided by a climate services program is salient, legitimate, and credible (e.g., Carr et al., 2016; Cash et al., 2002; McNie, 2007; Vogel et al., 2016).

2.2. The CAMI case study methodology

We engaged in an ex post evaluation of the CAMI initiative as an empirical case study of how useful our logic model could be. The full case study, conducted for the United States Agency for International Development, is available on line (Vogel et al., 2014). We do not replicate the case study in its entirety in this article because our focus here is on the theoretical and methodological innovation of the logic model. Consequently, we include details that we believe are necessary to ground the logic model in the concrete experience of a climate services program. For the full case study, readers should refer to the complementary report (Vogel et al., 2014). The next subsections describe the context of our case study and how we conducted semi-structured interviews with key participants in CAMI, including project personnel, meteorologists, agricultural officers, and farmers.

2.2.1. Geographic and institutional setting

Our research team was tasked with conducting an evaluation of the CAMI (http://cimh.edu.bb/cami/) program by the Climate Services Partnership (CSP, http://www.climate-services.org/). CAMI brought together the meteorological and agricultural agencies of 10 Caribbean nations to deliver climate services to farmers. CAMI sought to "increase and sustain agricultural productivity at the farm level in the Caribbean region through improved dissemination and application of weather and climate information using an integrated and coordinated approach" (CAMI, 2010). To meet this objective, the program included the following specific goals (ACP-ST, Undated):

- Train personnel in agrometeorology, climate, and crop modeling;
- Develop rainy season prediction models using seasonal and long-term climate data;
- Interpret climate data and weather information for real-time improved crop management decisions, such as irrigation scheduling;
- Prepare and communicate user-friendly weather and climate information;
- Promote two-way communication between farmers and agencies on weather and climate information;
- Develop an effective pest and disease forecasting system through improved crop monitoring and use of modeling approaches (CAMI, 2011); and
- Invest in data protection methods (i.e., digitize physical hard-copy data, which is prone to damage or loss) (CAMI, 2011).

CAMI was intended to be a comprehensive climate services program that engaged in cutting edge science, developed seasonal climate and weather forecasts, and engaged all stakeholders to increase regional capacity to use information for improving agricultural productivity.

As a practical matter, the question of how effective CAMI has been at meeting its stated objective to "increase agricultural productivity" (CAMI, 2010), is premature. Three years is simply too short a time to find a "CAMI signal" in agricultural productivity within the noise of ongoing developments with trade policy, extreme weather events, the El Niño Southern Oscillation, and agriculture policy initiatives across 10 CAMI participant countries. It is also time-intensive for CAMI partner countries to develop new agro-climatological information, create an effective means to share this information with farmers, and convince farmers across 10 countries to change farming activities at a scale where it would be possible to measure increased agricultural productivity.

Even with a longer timeframe, it might be difficult to attribute specific changes in agricultural productivity to the CAMI program given the many other factors affecting agricultural productivity, such as seed technology, local political and economic support for farming, international trade agreements, local and regional market conditions, and shifting consumer preferences. Since we were not able to measure and attribute productivity gains, our evaluation focused on intermediate measures of success that are more analytically tractable, and related predominately to capacity building. For example:

- As a result of CAMI, do the national meteorological and agricultural agencies have the capacity to produce and distribute high-quality information?
- How are meteorological and agricultural agencies characterizing and assessing farmer's information needs?
- How are meteorological and agricultural agencies tailoring climate information to meet the information needs of farmers?
- Do farmers have access to new or better information as a result of the project?
- Are farmers able to act on the information provided?

Our evaluation focused on four critical potential breakdowns that could and, in some cases, did prevent CAMI from achieving this objective (i.e., the four stop signs in Fig. 1). From this information we determined areas of success, areas where further work is needed, priorities for future climate services work in the Caribbean, and lessons learned that are applicable to climate services in other locations.

As an important note, this evaluation occurred after official funding for CAMI had ceased. Nevertheless, many activities started under CAMI are continuing under the auspices of national meteorological and agricultural agencies or with CIMH. For this reason, the evaluation was not intended to determine the final outcome of CAMI, but rather to characterize the progress of CAMI thus far and determine if any lessons can be shared with other climate services initiatives.

2.2.2. Site visits and interviews

While all of the CAMI nations are located in the Caribbean and share a common language, they are quite different, each with their own unique political, geographical, and economic contexts. These differences mean that each nation must contextualize both climate and agriculture information in appropriate ways based on situations such as the financial viability of meteorological agencies, the relative role of agriculture in the national economy, the availability of extension services or other networks for communicating with farmers, and the literacy and technical capacity of the farming population.

To evaluate CAMI, we visited three countries – Barbados, Dominica, and Jamaica – to gather first-hand accounts of the activities, outputs, and outcomes of the CAMI project as a whole and how it was implemented in these three countries. We interviewed staff from CIMH, the Barbados Meteorological Services, the Ministry of Agriculture Barbados, the Dominica Meteorological Service, the Dominica Ministry of Agriculture and Forestry, the Meteorological Service of Jamaica, the Jamaican Rural Agricultural Development Authority (RADA), as well as two farmers in Barbados, four Dominican farmers, and one Jamaican farmer.

Adopting a broadly ethnographic approach, we used a semi-structured interview protocol based on our agricultural climate services logic model to gather consistent information about climate services from each interviewee, taking into account the different institutional and geographic contexts (e.g., regional versus national institution, country, small island versus mainland country) as well as the characteristics of different interviewees (e.g., CIMH, national meteorological and agricultural agencies, farmers). A formalized protocol, including a prepared list of topics and questions informed and directed the interviews, but the interviewees were encouraged to discuss what was of greatest interest to them. The interviews were open and informal. Primary topics varied depending on the interviewee. For instance, questions directed to CIMH and country meteorological and agricultural officers emphasized their training activities, the creation of outlook bulletins, and outreach to farmers; while questions directed to farmers emphasized access, understanding, and use of climate information. In all cases, discussions of climate services were couched in terms of real world conditions and use-cases, rather than the hypothetical scenarios utilized in survey research to assess the theoretical value of new or improved data or climate services (e.g., Lazo et al., 2009).

Budgetary limits did not allow us to visit all 10 CAMI partner nations. In view of the cultural, technological, and geographic diversity of these nations, we sought to extend our ethnographic efforts. Using the same semi-structured interview protocol, we conducted telephone interviews with three farmers from Grenada, and three staff members at the Grenada Ministry of Agriculture, Lands, Forestry, Fisheries, and Environment. In Guyana, we spoke with a staff member from the Hydrometeorological Service within the Guyana Ministry of Agriculture and an agronomy researcher from the Guyana Sugar Corporation. These interviewees allowed us to improve our understanding of CAMI, and ensure that we covered a broader range of geographical and socioeconomic contexts.

3. Results and discussion

In this section we briefly discuss the results of using our logic model in the case study of CAMI. The discussion presented here is truncated and covers only issues directly relevant to understanding how the logic model helped us understand the full context of the CAMI Initiative as an agricultural climate services program. This is due to the purpose of this article, which is to illustrate the utility of our logic model for climate services evaluations. In other words, our purpose here is to provide sufficient information to illustrate the theoretical and methodological innovation of the logic model. For readers interested in the full CAMI evaluation and the additional evaluative detail contained therein, see Vogel et al. (2014).

3.1. Agricultural use cases

Farmers in the CAMI countries engage in a variety of agricultural activities, mostly at a small scale (i.e., 0.5–8 acres). Large farming operations, typically operated by the most economically successful farmers, were reported on the scale of 30 acres, but were not common. In some countries there are remnant plantations on the order of 50–200 acres. These large plantations, however, are on the decline and were reported to be “a thing of the past.” In Guyana, a continental country, farming operations as large as 10,000 acres were reported. Guyana and Belize are notably different than the other eight CAMI countries because, as continental countries, they have the economies of scale, geography, geology, and market access to support mechanized farming practices and industrial scale agriculture.

On the whole, most farmers in the CAMI countries have small plots of land and most of the work must be done by hand because the economics and geography of these small islands do not facilitate mechanization. This resource setting also prevents the development of large-scale export industries. The farmers we spoke with in Barbados each worked 25–30 acres of land. The farmers we spoke with in Dominica, a much more mountainous island, each worked between 0.5 and 17 acres, often in multiple, disjointed plots. Similarly, in Grenada the majority of farmers worked less than 10 acres of land, often in multiple, disjointed plots. In the Montego Bay area of Jamaica, where we conducted our interview, most farmers reportedly work between 2 and 5 acres of land in relatively mountainous areas, and it was reported that there remained about a half dozen 100+ acre farms island-wide.

The farmers we interviewed engaged in a number of agricultural activities that were the focus of our analysis. They made decisions about what and when to plant, whether to invest in greenhouses and other capital, how and when to irrigate their crops, what to do when threatened by a hurricane, and the application of fertilizers and pesticides. As already mentioned, these activities were used as the basis for our analytical use-cases. The farmers and government agriculture officers that we interviewed mentioned that these decisions were often constrained by a number of non-climate factors, including national import and export laws, regional markets, unavailability of cold storage facilities, market gluts, poor information availability, inconsistent government support, and international trade rules, any of which could lower the perceived value of climate services (Millner and Washington, 2011). An awareness of these constraints helped to assure that our logic model was consistent with on-the-ground attributes in each CAMI country.

3.2. Climate impact

On the island countries in particular, there was significant sensitivity to climate due to micro-variation in topography and weather. For example, the higher elevations of Barbados support broccoli and tomato production, which cannot be supported at lower elevations. Rainfall and temperatures on Dominica vary dramatically from coastal areas to inland, higher-elevation areas, with significant implications for crop choice and irrigation needs. Additionally, conditions on distinct portions of Caribbean island nations can experience different weather due to varying wind patterns. Furthermore, farmers in the region are used to dealing with a dry and a wet season that can have significant implications for agriculture. But variations such as a drier than typical-dry season (i.e. a dry-dry season), wet-wet season, wet-dry season, or dry-wet season can cause significant crop losses and poor harvests. It is in these variations in the dry and wet seasons that most interviewed CAMI participants expressed optimism that climate forecasts could assist farmers. Both the variability of island climates and the exposure of their agriculture to this source of risk suggest a potentially impactful role for climate services (Dilling and Lemos, 2011).

In interviews with CIMH personnel, national meteorological and agricultural agencies, and farmers, it became clear that a variety of climate events impact agricultural activities. Examples include the possibility of a delayed rainy season, severe rainfall events that could affect the effectiveness of fertilizer or pesticide application, and drought or delay of the rainy season that could affect crop productivity. A number of additional concerns with the impacts of weather were raised, particularly by farmers. In Jamaica, for example, the agricultural extension agent and farmer we spoke with were more concerned with daily/monthly weather information versus climate data, as weather impacts were a major concern. However, because this evaluation focuses on the usefulness of three month climate forecasts, we address weather-related agriculture impacts only in passing.

3.3. Information development on weather/climate and agriculture

One potential breakdown in the CAMI intervention process involves development of weather and climate information for growers (i.e., the first stop sign in Fig. 1). This information includes both a technical and procedural component, neither of which can be neglected to generate useful information. The structure and governance of a climate service is an important determinant of its effectiveness (Broad et al., 2002; Lemos

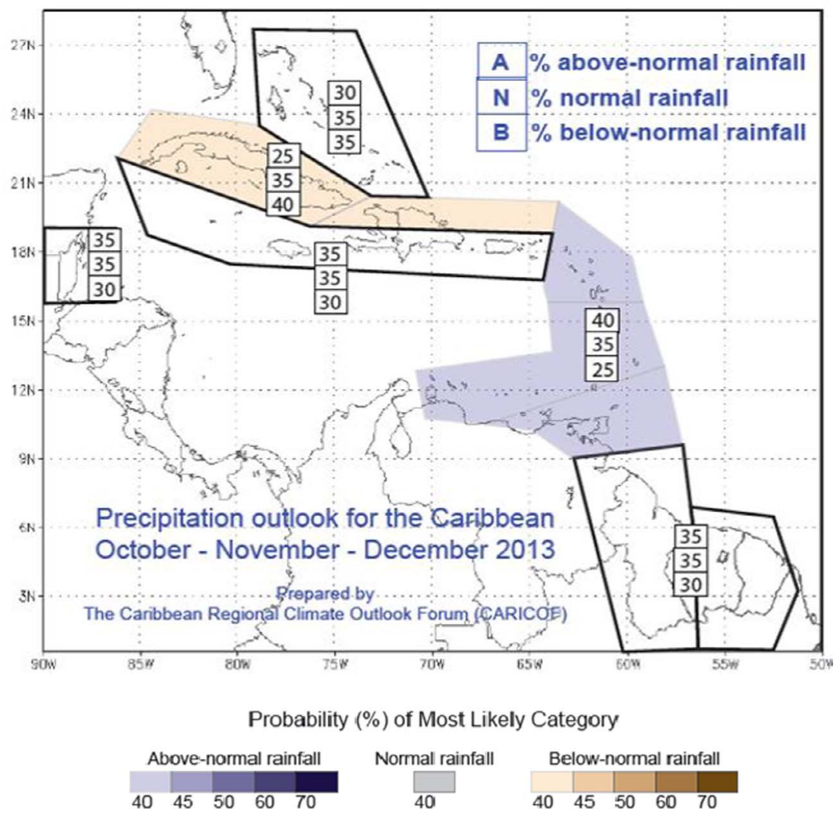

Fig. 3. Rainfall outlook prediction created by CariCOF for October–December 2013. Note that the region is separated into several climatologically similar sub-regions, each of which has a vertical row of numbers indicating the likelihood of above-normal, normal, and below-normal rainfall over the following three months (Source: CIMH, 2013).

et al., 2012). The evaluation team did not provide a technical review of the quality of the climate forecasts provided by CIMH regionally or by each meteorological office nationally. However, we did note that the process for developing these forecasts provides a number of opportunities to ensure quality. For example, the regional climate forecast produced by CIMH underwent a process of technical review through CariCOF, which was established in March 2012. While the regional seasonal bulletins were originally based on CIMH forecasts, they have evolved into a consensus process through CariCOF, which allows meteorological officers and climate forecasters to come to a technical consensus for a seasonal forecast (see Fig. 3 for an example). The seasonal bulletin is released monthly and forecasts climate, particularly precipitation, three months out by projecting the likelihood that precipitation will be "above-normal," "normal," or "below-normal." There are reportedly 18 participants in CariCOF representing 25 different territories. Their consensus forecast is released as a regional bulletin, which is a World Meteorological Organization-driven process (see Guido et al., 2016 for a detailed description of this process). Furthermore, CariCOF holds a general assembly once per year to update stakeholders (including ministry personnel, extension agents, permanent secretaries, nongovernmental organizations, CARDI, and the Caribbean Farmers Network) on their process improvements and forecasts, as well as the forecast implications for various socioeconomic sectors, including agriculture.

While technical personnel at CIMH said that they work in a data-limited environment (with 146 weather stations over 25 territories), they also claimed that the existing data were adequate to work with, although it would not be sufficient for academic research purposes. Still, as part of CAMI, participating countries shared past meteorological information with CIMH, in part, to increase the robustness of their modeling, and also to improve recordkeeping and the digitization of data where it had not occurred in the past. Despite adequate meteorological data, data on agricultural impacts were not as well developed regionally and presented a limiting factor in the context of developing information packages suitable for use in the context of Caribbean farming practices. The lack of research on agricultural impacts is unfortunate since researchers in other settings have found that the success of a climate service depends on the extent that information is appropriately tailored to meet users need (Furman et al., 2011; Harrison and Williams, 2007).

Regional bulletins are produced by CariCOF and CIMH, while each nation produces (or intends to produce) bulletins with localized information. These bulletins vary in their content among countries. Most include fairly extensive discussions of weather from the past month and limited forecast information for the upcoming 1–3 months, including rainfall predictions and sometimes temperature predictions (see Fig. 4, for Antigua and Barbuda). The outlook bulletins vary most in drawing connections to agriculture. Several bulletins have no mention of agriculture and only provide the meteorological forecast. Some draw some basic connections and provide recommendations on when to irrigate or store water (for example see Fig. 5, for Barbados). Few of the bulletins provide concrete agricultural advice with details, for instance, on what to plant and when. But in at least one of the countries that we evaluated, Jamaica, they had dramatically improved upon the initial CAMI-inspired work through further development of their meteorological and agricultural information development capabilities.

After the initiative, working relationships across agencies were developed and a new purpose was instilled in most of the meteorological agencies. Agricultural officers seemed to recognize value in the climate forecasts, but did not indicate a clear sense of purpose across countries as the meteorological officers did. Several interview participants noted that, through CAMI, additional attention and resources have been devoted to their respective offices. This augmentation of resources has included additional staff training, the hiring of new staff, and the placement of staff with integrating skillsets in sister agencies – such as individuals with agrometeorological skills being placed in the meteorological or agricultural agencies (depending on the country).

WEATHER AND CLIMATE OUTLOOKS FOR ANTIGUA

MONTLY WEATHER OUTLOOK – JUNE

Rainfall
Above normal rainfall is most likely with greater than **3.20 inches**. Probabilistically, there is a

- **45%** chance of above normal rainfall;
- **35%** chance of near normal rainfall and
- **20%** chance of below normal rainfall.

Temperature
Above normal temperature is most likely with greater than **28.0°C**. Probabilistically, there is a

- **50%** chance of above normal temperature;
- **35%** chance of near normal temperature and
- **15%** chance of below normal temperature.

SEASONAL OUTLOOKS – JUNE TO AUGUST

Rainfall
Above normal rainfall is most likely with greater than **11.74 inches**. Probabilistically, there is a

- **50%** chance of above normal rainfall;
- **35%** chance of near normal rainfall and
- **15%** chance of below normal rainfall.

Temperature
Above normal temperature is most likely with greater than **28.2°C**. Probabilistically, there is a

- **45%** chance of above normal temperature;
- **35%** chance of near normal temperature and
- **20%** chance of below normal temperature.

Fig. 4. Example of localized meteorological information included in the May 2013 outlook bulletin for Antigua and Barbuda (Source: Antigua and Barbuda Meteorological Service, 2013).

3.4. Information distribution to farmers

A second potential breakdown in the CAMI intervention process involves distribution of climate information and information on agriculture interventions to end-users, in this case agricultural extension agents and farmers (i.e., the second stop sign in Fig. 1). In CAMI, the distribution of the outlook bulletins varied across partner countries. However, bulletins for all countries except Grenada and Trinidad and Tobago are available on the CAMI website for public access. Grenada has not yet produced outlook bulletins, but had planned to do so in 2014. In Dominica, the meteorological and agricultural agencies split the cost of printing the outlook bulletin so they could pass out hard copies. The role of agricultural extension agents in the distribution of this information varied widely. While in all countries the agricultural agency was involved in the CAMI project, it was often unclear whether the agricultural agency was actively promoting and distributing the climate outlook bulletin through agriculture extension agents or other means (e.g., radio, TV, websites, email, texting, farmers' associations, farmers' forums, informal networks).

Many interviewees noted that some of the farmers' forums were particularly useful because Mr. Adrian Trotman of CIMH was able to explain the science of climate forecasting in simple terms and connect climate events to specific consequences for agricultural crops and pest and disease outbreaks. In multiple countries it was reported that these interactive discussions helped generate buy-in by the farmers present. Furthermore, CAMI held a communications workshop in 2011 to begin a dialogue among meteorological and agricultural officers and extension agents, farmers, and others. The sessions covered preferred modes of communication in addition to exploring how to frame information for specific audiences. But little follow-up effort has been reported in either CIMH outreach to farmers or workshops for capacity building among country meteorological and agricultural officers. CAMI partners, however, are reportedly seeking additional funding to conduct training sessions with agricultural extension officers.

There are many options to share climate services with farmers. While email and internet options are easy, low-cost, and sustainable, they are not the best way to reach farmers. From the farmers forums it might seem that text messaging and cell phone alerts are popular among farmers; however, the forums may have biased farmers by showing them a video from the World Meteorological Organization on disseminating agricultural information via text message. None of the farmers or agriculture officers interviewed felt that text messaging was a popular option for sharing information. In farmers' forums and interviews, popular options included informal networks, one-on-one outreach, and radio programming. To a lesser extent, farmers indicated internet or email, farmer's associations, forums, and hard copy

Recommendations for the Period

Livestock

Fertilize your pastures before the next set of heavy rains. This is also a good time to seed your pastures with seeds of legume vines. They should grow quickly with the moisture available. This will improve the quality of your pastures during the dry period.

Plant deep rooted legumes like Leucaena (wild tamarind) and gliricidia around your pastures. This will provide some high protein forage during the dry period to help boost production.

Vegetables

The high humidity experienced during August may have caused some problems with fruit set of your tomatoes and sweet peppers. Chances are you will also have some problems with the mildews on squash.

Snails

The snails have not gone away! The rains have seen a resurgence of this pest, so be on the lookout and bait areas of high prevalence. If you know of an area where lots of small ones are use the liquid metaldehyde. This gives a good kill of the young snails and reduce your future numbers.

Water Capture

With the high rainfall of August you should have had a good chance to look over your land space and see where are the best places to locate water catchment areas. Remember now may not be the time to start work but it sure is a good time to make some decisions of what and where to site such a facility.

Fig. 5. Agricultural information included in the August 2013 outlook bulletin for Barbados (Source: Barbados Meteorological Services, 2013).

distribution as preferred information channels.

3.5. Information uptake by farmers

A third potential breakdown in the CAMI intervention process involves the ability of farmers to understand or apply climate and agriculture information (i.e., the third stop sign in Fig. 1). Access, comprehension, and adoption are each necessary if climate services are to be broadly beneficial (Lemos and Dilling, 2007). Certainly most farmers have demonstrated their capacity to use agrometeorological information through their ability to earn a livelihood. The issue here is whether the investment in skill acquisition necessary to make productive use of information products (e.g., Fig. 3) is perceived by farmers as a potentially useful activity. And if it is not, whether that probabilistic information can be simplified and communicated in a way that is understandable, situationally applicable, and relevant. Those farmers that access a climate outlook bulletin must be able to take that information and apply it to their unique situation. This relies on two key factors: (1) farmers understand the meteorological information, and (2) farmers can translate meteorological information into actionable agricultural implications. Without satisfying the first of these factors, the farmer may not be able to act because the information is overly complex or technical. Even if you satisfy the first factor but not the second, farmers could make poor decisions by misinterpreting the precipitation information in a way that causes them to take incorrect or suboptimal actions (e.g., planting a crop at the wrong time).

Thus, the information (in the form of a climate outlook bulletin or otherwise) must be targeted to farmers to convey the projected meteorological conditions in clear terms, and for the meteorological information to be translated to agricultural impacts and interventions. First, the provided information should tie the meteorological conditions to agricultural impacts. For example, if drought conditions are expected, the information should state that heavily water-dependent crops will not produce high yields or may not even germinate. Second, the provided information should suggest agricultural interventions to address the potential impacts. For example, if drought conditions are expected, the information should state that farmers should plant an alternative crop that is drought-tolerant and/or store water for irrigation.

Information uptake is one of the most difficult steps in the CAMI intervention logic to explore systematically. Few, if any, of the CAMI countries had any mechanisms in place to collect feedback from farmers on any of the CAMI activities – including farmers' forums and the climate outlook bulletins. In Barbados, the climate outlook bulletins include only contact email addresses for feedback or comments. However, agriculture officers reported, in seeming contradiction, that they did not have feedback mechanisms in place and expressed low confidence that such mechanisms would be effective. Similarly, no other CAMI countries reported actively soliciting feedback, although many others also list contact numbers or email addresses on outlook bulletins. We are not aware of any concerted effort by any CAMI country to use web analytics to identify and track who was accessing the climate outlook bulletins and with what frequency. While this would not provide a complete picture of information uptake by farmers, it could tell us how many people accessed the relevant websites, if users raised questions or had other forms of feedback, and perhaps might indicate if users previously or subsequently sought to gather related information (e.g., prices of chemical inputs). Consequently, we are left with anecdotal information as the sole means of developing a preliminary understanding of whether and how the climate outlook bulletin information was digested by farmers.

Most Caribbean farmers are reported to be older, with little formal education, and limited motivation to deviate from traditional farming practices. This "average farmer" may need specific information on agricultural interventions in order to change their behavior based on climate projections. But it is certainly possible to change their behavior. It was reported, for example, in the Barbados farmers' forums, that Mr. Adrian Trotman of CIMH was able to engage participants, including some typical farmers, by describing in common terms the climatological reasons why certain crops were not germinating. Upon understanding the cause and effect of the climate on crop behavior, farmers reportedly began to immediately see value in Mr. Trotman's knowledge and take the remainder of the farmers' forums quite seriously.

Notably, the key information component needed to ensure engagement was the agricultural implications of the climate information. While meteorological information was provided with consistency across CAMI countries, the agricultural impacts were not. For example, agriculture officers in Guyana told us that providing climate and agriculture information directly to farmers would not be fruitful. Instead, they reported that the extension agents worked directly with farmers one-on-one to describe the seasonal precipitation outlook and what it would mean for their particular circumstances. This sentiment was echoed in Jamaica. The possibility of agricultural impacts as a weak link suggests an important role for capacity building among the farmer population and/or capacity building among agricultural agency staff.

On the other hand, there are high-capacity farmers, with greater acreage and more technological sophistication, who can and do understand and make use of the complex meteorological forecasts. We had an opportunity to speak with two such high-capacity farmers in Barbados, and it was clear that they understood the information in the Barbados climate outlook bulletin. One of these farmers reported having an extensive collection of literature on the implications of climate and other factors on crops, pests, and disease that allowed direct use of the climate forecast to make informed decisions. The farmer that we interviewed in Jamaica – one of the 100+ acre farmers – was also capable of making use of complex meteorological forecasts. These high-capacity farmers understood not only the implications of climate information for their crops, but also for the market conditions that would evolve under such climatological conditions based on their understanding of farmer behavior island-wide.

The high capacity farmers we spoke with bore two characteristics that could prove useful in targeting future agricultural interventions: their gender and their kinship networks. The most entrepreneurial growers we spoke to were mostly female, and while our sample size is quite small, the female growers made a strong impression. It seemed that a selection process was likely at work: if a woman is able to make a living farming in this setting, then she must possess superior business acumen. Consistent with Carr et al. (2016), we find that women in agrarian settings have different climate and weather information needs, as well as different abilities to act on that information. In terms of kinship, not surprisingly, inheriting a sizable farm seemed to be a big advantage. The operators of that farm are certainly wealthier and also have better access to mentors. The long tenured, family farm operators we spoke with are technically sophisticated. But with land moving out of agriculture and farms getting smaller in the Caribbean, kinship networks are being overwhelmed by larger forces, particularly tourism and development. To motivate early adoption of agricultural innovations, future interventions might benefit by targeting female-led and family farms.

The information provided by CAMI is only valuable if it is understood by farmers. The national climate outlook bulletins generated by national governments under CAMI have already provided some high-capacity famers with information that they can understand and use. However, to reach the larger population of lower-capacity farmers, national meteorological and agricultural agencies may need to refine their information and convey not just meteorological data, but also agricultural actions in simple and clear terms. This outreach could involve, for example, engaging in capacity-building activities with farmers, farmer's associations, or agriculture extension agents.

3.6. Actions by farmers

A fourth potential breakdown in the CAMI intervention process involves farmers' willingness to act on climate and agriculture information (i.e. the fourth stop sign in Fig. 1). With the appropriate information, farmers should be able to take action to reduce impacts or take advantage of projected climate conditions. However, not all farmers will have the resources to act. For example, if a drought is predicted and the information provided by a national meteorological or agricultural agency recommends that farmers store water, not all farmers will have the capacity or resources to do so. Alternatively, some farmers may understand the information provided, but choose not to act because they do not trust the information source or because they prefer to engage in traditional farming practices that may be less sensitive to climate factors.

In our discussions with farmers in Barbados and Dominica, we heard from farmers who had used their national climate outlook bulletins to make different decisions about farming practices based on climate information. This ranged from decisions about pesticide and fertilizer application based on near-term weather forecasts, to decisions about which crops to plant, how to set up irrigation systems, and when to irrigate based on seasonal projections of precipitation. When we asked farmers who were unaware of the climate outlook bulletins whether such information might cause them to change their practices, they expressed a more mixed outlook. Some of them confirmed that such information would be useful and lead them to make decisions as suggested above. Others freely admitted that they had more trust in traditional farming practices. In Grenada, one agriculture officer suggested that many local farmers had more trust in the local farmer's almanac than in scientific projections. Older farmers, in particular, were less apt to change their practices based on the outlook forecast. It appears that farmer attitudes may also vary across use-cases; for example, Jamaican farmers suggested that climate information could be used primarily for irrigation and fertilization decisions.

Small-scale farmers in the Caribbean may not have the resources to act on data provided by the CAMI partner countries. Likewise, they may not trust CAMI data as much as their existing sources of information, such as traditional farming practices or fellow farmers. CAMI participating countries must keep in mind that their agricultural recommendations should be scaled to inform farmers with adequate resources, as well as those with limited resources. Over time and through ongoing collaboration with agricultural agencies and agricultural extension agents, each country's climate outlook bulletin could become a trusted resource for more and more farmers.

3.7. Increased agricultural productivity

In this element of the logic model, the outcome of interest is the objective of CAMI, to "increase and sustain agricultural productivity at the farm level in the Caribbean region through improved dissemination and application of weather and climate information using an integrated and coordinated approach" (CAMI, 2010). For purposes of this evaluation, we propose that "increased agricultural productivity" means that farmers are more economically successful. From an anecdotal perspective, there are clear examples of farmers using the climate information to increase their productivity in terms of crop yields and economic gains – but only among high-capacity farmers that (1) can access the climate outlook bulletins in an electronic format and (2) are sophisticated enough to translate the meteorological information into agricultural interventions on their own.

However, three years is too short a time to expect CAMI partner countries to develop new agro-meteorological information, create an effective means to share this information with farmers, and convince farmers across 10 countries to change farming activities at a scale which would allow measurement of increased agricultural productivity. A tractable alternative would be to identify specific intermediate outcomes as yardsticks for measuring progress, such as the number of climate outlook bulletins produced or the number of times a bulletin was accessed on a website. But CAMI did not identify such intermediate outcomes and such a metric-driven evaluation of progress was not within the scope of this evaluation. Consequently, we focus on intermediate progress in each step of the intervention logic, which was done in detail in the above sections. Our findings are summarized below.

3.7.1. Information development on weather/climate and agriculture

The majority of CAMI countries have the ability to produce accurate climate information. While the CAMI participating countries had existing technical meteorological capabilities, in some cases CAMI improved their technical competency and capacity. Moving forward, the partner countries need to focus on providing not just meteorological data, but also on applications of meteorological data that clearly articulate crop impacts and agricultural interventions.

3.7.2. Information distribution

Through CAMI, lines of communication have been opened with farmers. The farmers forums held across the Caribbean brought meteorological agency officers and farmers together. The production of climate outlook bulletins provides an ongoing opportunity for outreach to farmers. Still, there is room for CAMI countries to further refine appropriate modes of communication to distribute climate forecasts. Part of this process will include identifying the best means for getting climate information into the hands of farmers. This distribution of information has not yet been tackled in a significant way in any of the CAMI countries that were part of this evaluation.

3.7.3. Information uptake

CAMI's farmers' forums and communications workshop have helped meteorological and agricultural agencies officers consider how to convey climate information to farmers. There is a general understanding among meteorological and agricultural officers that information should not be overly complex, and that information should be conveyed in multiple ways if possible (e.g., written text and diagrams). It is difficult to gauge CAMI's success in this area. Most of the farmers interviewed for this evaluation had not seen the outlook bulletins, and therefore could not inform us about their level of comfort with the information presented. High-capacity farmers clearly did understand the information. However, the consensus among nearly all interviewees was that the majority of farmers would not be able to understand the current climate outlook bulletins without significant assistance.

3.7.4. Action by farmers

While there is evidence that farmers are interested in high-quality data, they must be able and willing to act on information. The high-capacity farmers that we interviewed reported that they were using the information in the climate outlook bulletins to make decisions, especially about crop and irrigation. However, many farmers may not have the financial resources to invest or they may not trust the information provided. These issues will become more important as the CAMI partner countries continue to expand their activities to reach more farmers.

Unfortunately, there is almost no way to quantitatively determine how much of the economic success of farmers is due to good farming practices (or the use of climate information). Definitive metrics of "increased agricultural productivity" are at present hard to come by. For example, it is nearly impossible to collect reliable information on agricultural production in most CAMI countries because most food production is fruits and vegetables on small plots of land sold to the local market, either by individual farmers or through in-country distributors. As such, there is no centralized data collection on total amount of produce and land in production, variety and quantity of crops grown, etc. While the quantitative evaluation of farm productivity and profitability is certainly possible, it would require a more intensive effort than is feasible under this evaluation.

4. Conclusions

We offer a new climate services logic model as a simplified framework for breaking down the components of climate services into a logical sequence of activities necessary for success. We then applied our climate services logic model to CAMI. Our approach facilitated the identification of areas where the lack of progress at one step could cause problems that would prevent CAMI from achieving its objective to "increase and sustain agricultural productivity at the farm level in the Caribbean region" (CAMI, 2010).

While three years is too short a time to expect CAMI partner countries to develop new agro-meteorological information, create an effective means to share this information with farmers, and convince farmers across 10 countries to change farming activities at a scale where we can measure increased agricultural productivity, CAMI and many of its partner countries have made significant progress. With additional effort each of these countries can move forward and further develop effective climate services.

Out of necessity, we have focused on intermediate measures of success that are more analytically tractable, and related predominately to capacity building. CIMH, under the direction of Mr. Adrian Trotman, played an important facilitation and capacity-building role for many of the CAMI country meteorological and agricultural agencies, including, through their training activities, data sharing, and outreach efforts, providing new skills, new networks, and new staff. CAMI was successful at expanding the focus of many national meteorological agencies from aviation to a broader view of climate services – not just to agriculture, but potentially other client sectors (e.g., forestry and fisheries) as well. CAMI successfully developed a dialogue among national meteorological agricultural agencies. In Jamaica, specifically, it helped to garner additional resources from outside funding agencies to continue or improve the program.

CAMI enhanced the regional networking of meteorologists through CariCOF. CAMI also improved networking between meteorological and agricultural officers in each member country. This led primarily to climate outlook bulletins that were developed by most of the 10 countries to communicate a three-month seasonal forecast to agriculture extension agents and farmers. These bulletins contained high-quality meteorological data, but information on agriculture impacts and interventions varied from one country to the next.

In nearly all countries, these bulletins have been put online, but this is clearly not the best means to reach most farmers. Nevertheless, this information reached some high-capacity farmers who could understand the complex meteorological forecast data, and these farmers reported using this information to make decisions to increase their productivity – such as crop choice and irrigation decisions. Some work remains on improving the quality of the agricultural information included in the climate outlook bulletins.

A crucial link in our logic model reflects the reality that information provided by CAMI can be valuable only if it can be applied by farmers. Much more work remains on information distribution and building farmer and extension agent capacity if CAMI is to be more widely relevant. We did find that a small group of high-capacity farmers was able to understand and make use of the complex meteorological forecasts, even without accompanying information on agricultural impacts and interventions. On the other hand, most Caribbean farmers were reported to be older, with little formal education, and limited motivation to deviate from traditional farming practices. To reach the larger population of lower-capacity farmers, national meteorological and agricultural agencies may need to refine their information and convey not just meteorological data, but also agricultural actions in simple and clear terms. This delivery mode could involve, for example, engaging in capacity-building activities with farmers, farmer's associations, or agriculture extension agents. Through CAMI activities, including the communications workshop and farmers forums, many of the countries are thinking critically about how to best convey information to farmers, in language and diagrams that the majority of farmers can understand.

In brief, CAMI made progress in the three years that it operated. Many of its successes were focused on the early stages of the climate services intervention logic – mostly on the production and compilation of high-quality meteorological information with potential agricultural implications. However, many critical steps in the climate services intervention pathway have not yet seen significant effort or attention. On balance, CAMI made significant progress in a short time and has set in motion a number of critical components for a successful agricultural climate services program.

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