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The stresses and dynamics of smallholder coffee systems in Jamaica's Blue Mountains: a case for the potential role of climate services

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Abstract Access to climate information has the potential to build adaptive capacity, improve agricultural profitability, and help manage risks. To achieve these benefits, knowledge of the local context is needed to inform information development, delivery, and use. We examine coffee farming in the Jamaican Blue Mountains (BM) to understand farmer livelihoods, opportunities for climate knowledge to benefit coffee production, and the factors that impinge on farmers' ability to use climate information. Our analysis draws on interviews and 12 focus groups involving 143 participants who largely cultivate small plots. BM farmers currently experience stresses related to climate, coffee leaf rust, and production costs that interrelate concurrently and with time lags. Under conditions that reduce income, BM farmers compensate by adjusting their use of inputs, which can increase their susceptibility to future climate and disease stresses. However, farmers can

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also decrease impacts of future stressors by more efficiently and effectively allocating their limited resources. In this sense, managing climate, like the other stresses, is an ongoing process. While we identify climate products that can help farmers manage climate risk, the local context presents barriers that argue for interactive climate services that go beyond conventional approaches of information production and delivery. We discuss how dialogs between farmers, extension personnel, and climate scientists can create a foundation from which use can emerge.

1 Introduction

Scientists have long asked how climate information can improve livelihoods. It is often argued that access to climate information builds adaptive capacity (Brooks and Adger 2005), improves resource profitability (Hansen et al. 2011), and helps manage risks (Moss et al. 2013). These benefits, however, depend on the fit of information, the integration of new understanding with current knowledge, and the amount and quality of interactions (Lemos et al. 2012). Consequently, there have been concerted efforts in recent years to develop customized climate services that produce knowledge about the climate in collaboration with climate scientists and end users (WMO 2011).

Significant challenges, however, impede the effectiveness of climate services. Many regions lack both time series and cross-sectional data necessary to generate scientifically credible information. Even where data are sufficient in spatial and temporal resolution, climate information is often distilled in products that do not adequately address user needs and/or is communicated with exceedingly technical language (Dilling and Lemos 2011).

The challenges are not surprising. Most climate information originates from experts who have limited interaction with end users or inadequate knowledge of local contexts (e.g., Vogel and O'Brien 2006). Additionally, much of the information is generated in universities or within operational agencies that are predominantly focused on physical climatology. Consequently, there have been calls for an end-to-end approach where scientists and users develop understandings of local contexts in order to inform the creation of information products and translational activities (Lemos et al. 2012).

This research examines the social and environmental context of coffee production in the Blue Mountains (BM) of Jamaica with a focus on the ways climate risk and its management relates to other stressors. In conjunction, we explore the conditions under which information about the climate can benefit the small-scale production within this milieu of stresses. We first document the main stresses farmers experience, their associated impacts on local livelihoods, and the coping strategies they employ. This reveals that farmers experience multiple stresses that interrelate both concurrently and across time periods, and that some of their coping strategies can increase their susceptibility to future stresses. We then document opportunities for knowledge about the climate to mitigate current and future impacts, insights that provide the basis for a more effective offering of climate information. We also document barriers for enhancing the use of climate information including a lack of channels to access information and limited knowledge of how to use climate information to manage coffee production, among other obstacles. These conditions make this case example similar to other contexts, particularly those in developing countries (e.g., Vogel and O'Brien 2006; Dilling and Lemos 2011; Lemos et al. 2012). We conclude by discussing new ways of engaging farmers in multiple-way dialogs that would be an initial step toward improving understanding of the role climate plays in coffee management and addressing issues related to access building a personalized understanding of the utility and value of the information.

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2 Coffee and climate in Jamaica

About 80% of Jamaica's coffee is cultivated in the BMs (Mighty 2015; Fig. 1). There, arabica coffee grows on steep slopes at elevations between 200 and 1600 m. The highest quality coffee is cultivated between 1100 and 1600 m, where cooler temperatures allow berries to mature slowly and produce more desirable flavors (Mighty 2015).

The coffee industry employs approximately 120,000 people across the commodity chain and accounts for one of Jamaica's largest sources of agricultural foreign exchange (BOJ 2015). Japan is the primary trading partner, accounting for approximately 80% of exports (Mighty 2016). Records from the Coffee Industry Board (CIB) suggest that, on average, 80% of the coffee farmers tend plots less than 10 acres but this production accounts for only 20% of the total coffee produced annually. Additionally, many of these farmers cultivate even smaller plots that are less than 5 acres.

Jamaican coffee has been and remains highly prized on international markets. As early as 1881, Jamaica's coffee commanded some of the highest prices on the world market (Talbot 2015). Since at least 1990, BM farmers have received prices for their harvests that, on average, have been more than twice as high as farmers in other arabica coffee growing countries (ICO 2015). These high levels, however, have been accompanied by high price variability, which presents planning challenges for Jamaican farmers (ICO 2014).

Throughout its history, the Jamaican coffee sector has been affected by market and labor volatility, land degradation, and extreme climate events (Talbot 2015; Thomas 1964). Since the late 1990s, coffee across Jamaica has undergone a general decline in production and exports

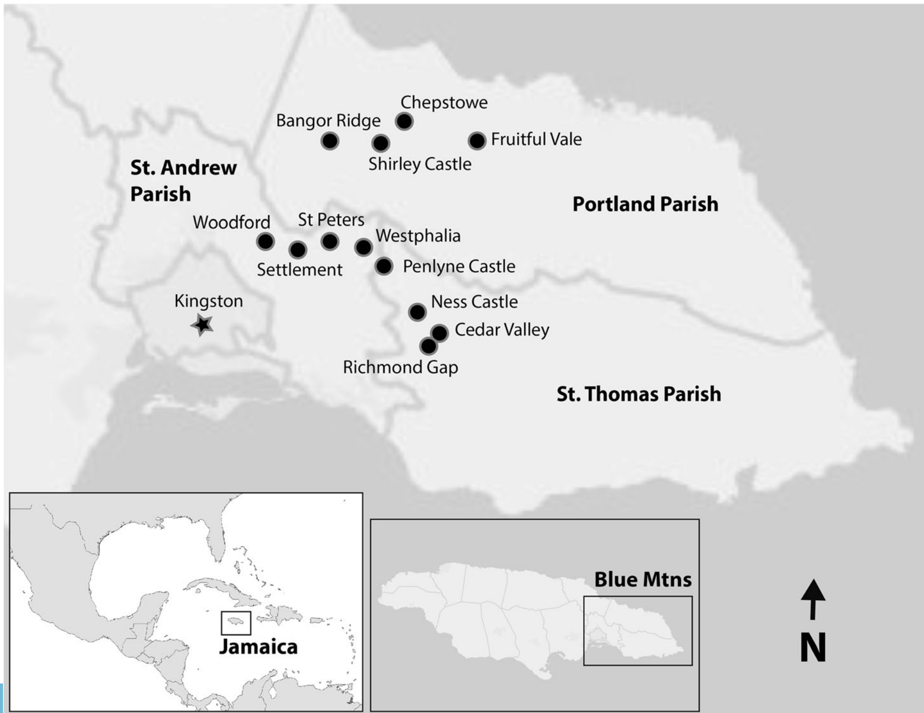

Fig. 1 Locations of the focus group discussions hosted in the 12 Blue Mountain communities

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(Fig. 2). The global recession (which became noticeable around 2008) further impacted production, and soon thereafter the first major coffee leaf rust (CLR) outbreak reduced yields by an estimated 30% in 2012–2013 (Fig. 2; ICO 2013). Between 2013 and 2016, severe drought afflicted the Caribbean (Herrera and Ault 2017), which further compounded the situation for BM coffee farmers.

Managing climate and weather risk within Jamaica's coffee industry is in its infancy. The monitoring of weather and climate principally fall on the Meteorological Service of Jamaica (MSJ); the CIB has no infrastructure or programs set up to monitor climate and weather. The MSJ, however, provides weather forecasts and climate monitoring and seasonal climate forecast at regional- and island-wide resolution. The sparse distribution of weather stations within the Blue Mountains constrain the development of more location-specific information as well as the quantification of climate risks and correlations of climate and coffee impacts.

3 Data collection methods

This article reports results from an ongoing research that began in 2014 as part of the International Research and Application Project. After several visits to the BM region, the research team, including scientists from the University of the West Indies (UWI), conducted extensive fieldwork in the summer of 2015. This consisted of focus group discussions (FGDs) in 12 different communities—four in each of the three BM coffee-producing parishes of St. Thomas, St. Andrew, and Portland (Fig. 1; Supplemental Table 1)—as well as interviews with the CIB leadership, extension officers, and the MSJ personnel. The FGD dataset constitutes the principal empirical substance of this analysis. We chose focus groups as the data collection method in order to generate rich, detailed, and contextual information that is important for understanding how people experience and respond to challenges. The interactions and group dynamics of FGDs can reveal more understanding about people's knowledge and behavioral practices compared to other methods (Plumer-D'Amato 2008).

The 12 communities met the following criteria: (1) coffee was the primary livelihood activity, (2) the community had at least 50 households, and (3) the community was accessible by vehicle. We sought representation of communities across a large elevation range because elevation influences coffee quality and management practices. The communities are located between 230 and 1270 m, and include some of the highest elevations at which coffee is grown in Jamaica.

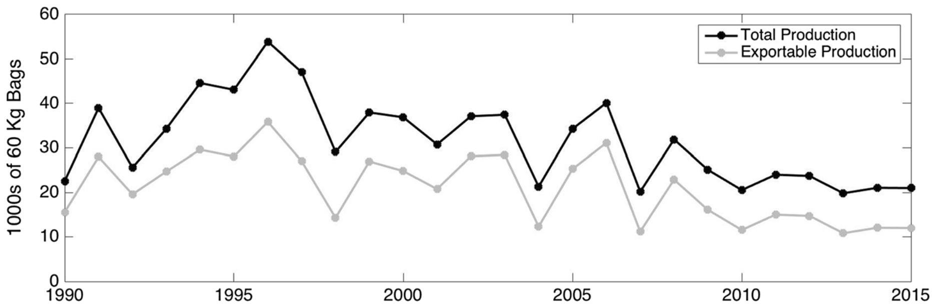

Fig. 2 Total crop year coffee production and exportable coffee production in Jamaica. Crop year occurs from August to July (e.g., the 2005 crop year spans August 2004 to July 2005). Data from International Coffee Organization (ICO 2015)

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The research team visited each community at least once and identified a local farmer to organize the FGDs. We limited bias in this sampling design by communicating to the organizer criteria for participants that gave consideration to differences in sex, age, and farming experiences. Additionally, we invited some participants ourselves and facilitated discussions so no one set of individuals dominated. FGD attendance ranged between 6 and 19 people; 143 people participated, of which 67% were men (Supplemental Table 1). While groups were diverse in age, gender, and experience, most participants farmed plots less than 5 acres. We therefore restrict our interpretations to small-scale producers.

A project team member led the focus group study and all FGDs. The FGDs followed a topic outline, but conversations were allowed to flow organically. Discussions lasted 1–2 h and were facilitated, at times, in local patois. Two note takers recorded the content in all but one case when one rapporteur kept notes. After each session, team members discussed the notes to identify common themes and address issues that surfaced during discussions. We performed content analysis on the notes, building a common set of themes from all discussions.

4 Multiple sources of stress

During the FGDs, participants identified the moments of stress that have affected their livelihoods. Their statements generated a historical sequence of events presented in Fig. 3. This timeline conveys two important insights. First, socioeconomic forces, coffee pests and diseases, and climate phenomena predominantly have impacted farmers. And second, farmers manage multiple stresses that overlap in time and whose impacts set the conditions for future impacts.

Farmers singled 2008 as a time when the global recession led to severe economic stress. It set off a decline in the price farmers received for their coffee cherries that ultimately plummeted to the lowest levels in many farmers' memories. This, in turn, reduced their

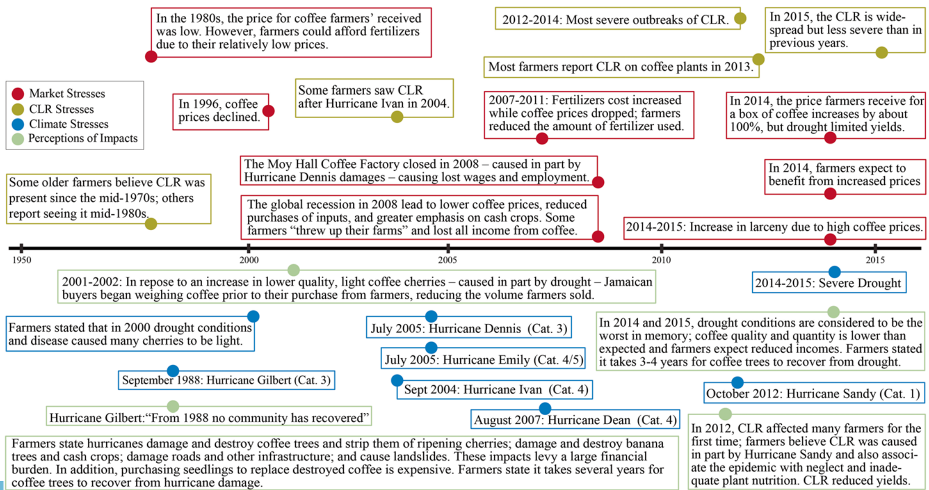

Fig. 3 Memorable events commonly discussed in the FGDs. The filled circle marks the approximate timing of the event

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income. Data on Jamaica's coffee production and exports corroborate the recollections of the FGD participants (Fig. 2). As prices fell, rising costs to fertilizers and chemicals and the devaluation of the Jamaican currency compounded the economic burden. Between the beginning of 2000 and end of 2015, the Jamaican dollar fell relative to the US dollar by approximately 65% (BOJ 2016) while chemical and fertilizer costs rose locally by about 15% between 2009 and 2015 (MICAF 2017a).

As the coffee sector was recovering from the 2008 economic crisis, the first severe CLR outbreak struck the country in the fall of 2012. While the fungus had been observed in Jamaica prior to 2012 (Fig. 3), farmers and CIB personnel noted that it was confined to lower elevations and controlled with fungicides (CIB 2008). During the 2012–2013 period, however, CIB estimated that the incidence swelled to affect an estimated 25–30% of the BM coffee plants and was indiscriminate with respect to elevation. The fungus outbreak compromised both the quantity and quality of berries. Revenues declined by an estimated US$5.2 million during 2012–2013 and the income of farmers fell by approximately 25% in that period (ICO 2013; BOJ 2015). Moreover, some farmers reported high levels of tree mortality. Because seedlings require about 3 years to produce sellable cherries, this caused the production and economic effects to linger for multiple years. Farmers and extension professionals believe the rust proliferated because climate conditions were favorable, plants were in a weakened state due to economic pressures in previous years that reduced crop care, and winds from Hurricane Sandy helped to spread spores across the island, even to the highest elevations. Since 2012, CLR has been most significant problem for coffee production in Jamaica, as one farmer stated: "Di [the] rust a di [is the] biggest problem we right now."

Hurricane Sandy, like most hurricanes that have struck Jamaica, left an indelible mark for many years. One farmer stated, for example, "Hurricane Sandy caused roadblocks which prevented children from attending school and farmers going to sell at the market. It destroyed coffee plants, [caused] landslides. Whenever there is a hurricane, farmers return to square one." Hurricanes are particularly destructive for coffee because the season aligns with the maturation of coffee cherries in many communities. The intense hurricane winds and rain can therefore easily strip the burgeoning trees of large amounts of ripening cherries. Moreover, the high winds also fell fragile limbs from banana and plantain trees, which further reduce income from these supplemental cash crops, removes an immediate wind buffer for the coffee, and eliminates future shade that protects coffee from solar heating. By some farmer estimates, hurricanes have destroyed up to 70% of their coffee crop. Rain and landslides further damage roads, hindering movement of cash crops and coffee to markets.

While market prices, CLR, and hurricanes were dominant sources of past stress, drought emerged as the single most damaging factor in most BM communities between 2013 and 2015. Many participants stated that they experienced the worst drought in their memories during 2014 and 2015. Indeed, precipitation amounts in the BM during the August 2014 to July 2015 agricultural year were the lowest recorded since at least 1981 (Supplemental Fig. 1). These seasons coincided with back-to-back El Niño events, which have been shown to influence precipitation in the Caribbean (Giannini et al. 2000). Farmers stated that the dry conditions caused lighter, fewer, and smaller cherries, and also stressed coffee plants, making them susceptible to pests and diseases. The exceptionally dry conditions also contributed to a large bush fire that destroyed many trees, the first major fire in the lives of many FGD participants.

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The effects of these stresses on coffee production and livelihoods have resulted in lower production of exportable coffee. Between the 2006 and 2009 agricultural years (spanning August 2005 to July 2009) the harvested coffee in the BM averaged 10,303 metric tons (MICAF 2017b). However, for the 2012 and 2013 crop years, coffee harvested in the BMs declined to 5576 and 5839 metric tons, respectively (MICAF 2017b). Exportable coffee remained relatively constant thereafter according to the ICO (MICAF has not reported BM data after 2013). However, despite steady production, drought stunted what would have been an increase in coffee production. The decline in supply, along with a rebound in external demand, increased farm-gate prices that, in 2015, was higher than at any time in their past; farmers' recollections imply that the prices they received in 2015 were about seven times greater than what they received in 2008.

5 Livelihood responses

The FGDs revealed that the multiple stresses faced by coffee farmers triggered three principal responses. The most common strategy was to vary the expenditures on inputs, which had future consequences for the coffee crop. Additionally, farmers stated they diversified their cropping patterns, expanded, or prioritized other cash crops while also cultivating coffee. Finally, farmers who face insurmountable stress abandoned coffee altogether and moved into other crops. Farmers mentioned other responses, but these appeared less frequent or consequential from our discussions (Supplemental Table 2).

When coffee prices declined in 2008, farmers reduced their expenditures on their primary expenses of fertilizers, chemicals, and labor. It appeared that farmers ratcheted down these expenses and their use over time with some reaching a point where they ceased use altogether. The decisions on input expenditures and allocations are largely unique to each farmer and are mostly influenced by the farm-gate price, yields, and the tradeoffs in allocating limited resources. This response was evident during the recent drought as some farmers decided to apply fewer fertilizers. One farmer noted, for example, "in the drought, the fertilizer kill the farm," referencing the damage to roots that can result from heat released by solid fertilizers in absence of water as well as the wasted investment that can occur as solid fertilizer volatilization occurs more rapidly in drier conditions.

As a second coping strategy, farmers diversified their livelihood activities. Some farmers invested more time in the cultivation of fruits and vegetables and small-scale livestock husbandry. In this case, BM farmers did not simply transfer resources from one activity to another. Rather, they replaced some of the lost coffee income by expanding into activities that required fewer inputs. However, the group discussions revealed that many of the livelihood diversification strategies employed by farmers could not fully compensate for the lost income from coffee. As a result, the farmers we talked to prefer to cultivate coffee.

Finally, the low prices and yields forced some farmers to "throw up their farms," abandoning coffee altogether. In these severe cases, farmers left ripe cherries on the trees instead of harvesting them. There appeared to be a spatial pattern to this response. Coffee farmers living at lower elevations seemed to forego coffee production more quickly after the 2008 recession than those living at higher elevations and they were similarly slower to return to coffee once prices recovered. This is perhaps related to the superior coffee quality and larger yields, and therefore higher income, produced in the cooler conditions at higher elevations.

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6 Limits to managing stress

The use of fertilizers and chemicals is considered by CIB and the farmers to be the primary strategy to sustain and improve productivity. The FGD participants nearly unanimously perceived coffee yields to be dependent on plant nutrition. Moreover, many participants stated that coffee plants are more susceptible to CLR in the absence of both fertilizer and chemical use. Farmers often used a health metaphor to describe this. One participant stated: "If we treat our body well, then we can fight against a disease and build up certain resistance. … If we fertilize on a regular basis, then the coffee will be able to stand against the disease." These perceptions are supported by empirical research. For example, Avelino et al. (2006) found that fertilization of coffee trees was negatively associated with a CLR epidemic in Honduras, although the relationship is complicated. CLR epidemics in Colombia were also associated with decreased fertilizer sales (Cristancho et al. 2012). Furthermore, plant nutrition increases growth, which allows trees to renew leaves lost to CLR that helps limit branch mortality (Avelino et al. 2006). Participants also perceived plant nutrition as important for mitigating drought stress.

In light of this, it appears that the majority of farmers employ livelihood and farm management responses that increase their susceptibility to future adverse conditions. Decreased fertilizer use can generate unhealthier plants that are more at-risk to future drought, CLR, and other ecological threats. Moreover, even with the farm-gate prices at record high levels in 2015, many farmers articulated that they were unable to apply fertilizers with the frequency and amount recommended by extension. A farmer stated, for example, "Even though dem [extension officers] say we [must] fertilize four times, some farmers can only afford it one time." Additionally, a reduction in fungicide use by one farmer can not only result in more CLR impacts on his or her farm but also increase the risk of the fungus to spread to other neighboring farms. In fact, some farmers mentioned their reluctance to spray fungicides because their neighbors do not. Indeed, feedbacks associated with plant nutrition and chemical applications have been cited in all eight CLR epidemics that have caused extensive privation across Latin America since the 1980s (Avelino et al. 2015).

Economic, biological, and climatic pressures can each lead to increased stresses in current as well as future years as they influence livelihood and farm management practices. Conversely, under conditions more favorable for investment, susceptibility to future risk can be mitigated. However, it appears that farmers have limited flexibility to allay conditions that exacerbate future risk. The discussions revealed that many farmers do not have access to credit or insurance that can facilitate investment and aid recovery efforts. Participants stated in several of the group discussions, for example, that it is not a normal practice for farmers to acquire loans from banks. Many lack the collateral, bank account, and/or a credit history to do so. Moreover, credit programs offered in the past by coffee buyers and the CIB have proven largely unsuccessful due to farmers' perceptions of unfavorable terms on the one hand, and failed repayment of the loans on the other.

7 Opportunities and barriers for new information tools

In our analysis, we identified new ways of using climate and weather information that can have beneficial outcomes for farmers (Table 1). Seasonal information can help farmers reduce the spread of CLR. Spore germination occurs at any time in the year

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Table 1 Decisions Blue Mountain coffee farmers make that can be informed by climate and weather information

Type of information	Time scale	Target decisions
Climatology	Historical	• Seasonal calendars based on historical climate information from Jamaica can guide recommendations on the timing of management activities (e.g., planting seedlings, pruning, etc.) • Can be used to define a period when messages, based on weather forecasts, could be disseminated to farmers to help increase awareness of the optimal time to spray fungicides
Seasonal precipitation and drought forecasts	Seasonal	• Type of fertilizers (solid vs. liquid) and fungicides (contact vs. systemic) purchased • Type of cash crop grown • Planting of coffee seedlings • Water preparations
Timing of onset of spring rains	Sub-seasonal	• Timing of fungicide applications
Weather forecasts	Weather	• Timing of fertilizer and chemical applications

Weather scale forecasts falls within the 0–10 day period; seasonal forecasts relate to information beyond 1 month; sub-seasonal includes information between 10 days and several months

when leaves are continuously wet for at least 6 h, with greater germination rates around 80% requiring leaf wetness for 24 h (Rayner 1961). However, an outbreak in Jamaica would begin at the onset of the rainy season when conditions are most favorable. Some farmers understand this relationship. One, for example, stated: "The earlier you catch the rust is the better." Moreover, the longer coffee leaves remain moist, the higher the infection rates and greater the potential intensity of the epidemic (Kushalappa and Chaves 1980; Kushalappa et al. 1983). The onset of the spring rains is therefore a critical time to reduce the risk of a CLR epidemic. Many farmers in the BM, however, make decisions based on crop management calendars that do not incorporate climate and weather information and do not change from year to year. Thus, forecasts for the onset of the spring rains could inform the optimal time to spray coffee with fungicides. This information would be particularly helpful when the rains begin earlier than expected; in Nicaragua, a CLR epidemic in 1995–1996 was associated with an early onset of the rainy season (Avelino et al. 2015). In addition to onset forecasts, knowledge of the average of and variance in the historical onset date of the spring rains can identify the period when farmers should have heightened attention to upcoming weather events. Not all BM farmers, for example, routinely consult weather information. Therefore, a form of alerting these farmers to weather conditions could increase awareness and advise on the optimal time to spray fungicides.

We also infer that seasonal rainfall forecasts in the form of total accumulations (or anomalies) and frequencies can inform the types of fertilizers purchased and the timing of application. Many of the participants stated they use both liquid and solid fertilizers, preferring the latter for reasons of cost. However, they acknowledged that solid fertilizers can harm coffee during dry conditions, whereas liquid fertilizers are more effective in dry periods. Therefore, seasonal forecasts could help farmers be aware of the need to purchase a mix of fertilizer types. Advance planning is important because small-scale farmers often do not have excess inputs and their limited resources restrict their ability to make additional purchases to accommodate unexpected weather conditions. Additionally, from the information provided in the focus groups, there seems to be a good opportunity for seasonal forecasts to help farmers determine

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if the spring or fall wet season is more favorable to purchase and plant new coffee seedlings that replace unproductive trees.

At the weather timescale, we infer that forecasts can help farmers more precisely time their input applications. The discussions also revealed that many BM farmers perceive more benefits when fertilizing occurs shortly before precipitation rather than after it, provided the rain is not too intense. If a forecast calls for heavy rains within 3 days, for example, several farmers stated that they would wait to fertilize in order to limit losses from runoff. Forecasts for moderate to light rains would therefore be more ideal times to fertilize. For chemical applications, farmers are advised to avoid spraying prior to rain in order to minimize the wash-off effect. Weather forecasts that convey a high likelihood of rain would therefore alert farmers to delay a chemical application.

Despite the potential for these information products to inform coffee management practices, we document that the use of these products will encounter impediments. First, forecasts for the onset of the spring rain as well as seasonal forecasts are currently in research and development by the MSJ and its collaborators. The skill of these forecasts will need to be scientifically assessed prior to use.

Second, farmers' access to existing information is limited in part because dissemination channels are not well developed. The MSJ currently distributes information about the climate, including tercile seasonal forecasts, via a website. However, our discussions revealed that few coffee farmers have access to Internet either by computers or smart phones. Moreover, many FGD participants have had limited, if any, interaction with the MSJ, and they were generally unaware of climate products offered. The MSJ representatives that were interviewed pointed out that the institution is hamstrung by resources and acknowledge they have infrequent contact with farmers. Rather, the MSJ is better able to indirectly connect weather and climate information to the farmers via CIB and the existing extension services that have mandates to interact with farmers. There are several examples from Central America in which climate information has been combined with CLR incidence data and management recommendations and communicated as an early warning informational resource (e.g., ICAFE 2017; IHCAFE 2017). In the case of CIB, the MJS has only recently begun collaborations, in part as a result of the research project reported on here.

Additionally, although information sharing via extension does occur, limited human and financial resources prevent extension officers from contacting many farmers. CIB has only three extension officers while each extension officer in the Jamaican agriculture ministry serves roughly 2000 farmers. Therefore, the infrequency with which extension has interacted with farmers was a frequent topic in the FGDs. This reality seemed to influence the relationship between farmers and extension. Participants stated, for example: "big farmers get help" and "round here we don't get any help," highlighting a suspicion that larger landholder farmers are given preferential treatment. This perception may conflate extension services offered by the coffee buyers—who appear to target larger landholders to develop strong relationships, informal contracts, and greater returns on their investment—compared with those of publicly funded efforts by the CIB and the agriculture ministry who represent the entire industry. Nonetheless, with limited resources, public extension efforts have trouble interacting with many farmers. Consequently, any forms of communicating solely built on extension will have a limited reach.

Third, expanding the use of climate information requires considerable capacity development, both within extension and at the farmer level. Extension can be assisted to better understand what information is useful for coffee farmer. This was colorfully articulated by

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one farmer who stated: "You can't give a shoemaker a house to build …. Unless you are aware of the farmers' struggles, you can't help them." However, capacity building also needs to target farmers, many of whom have not finished high school. There is a move toward text messaging to overcome human resource limitations and to reach more farmers. However, messaging alone in absence of training overlooks the comprehension and cognitive challenges many people experience with weather and climate information. The MSJ has recently experimented with text messaging with farmers in non-coffee-growing regions and has accompanied this with community training sessions to some degree of success (Rahman et al. 2016). Additionally, some farmers perceive they have no available strategies to respond to climate events. A farmer mentioned, for example, "Wi haffi [we have to] just sit back and tek [take] it normally. We can't do anything about the drought." While this sentiment may reflect a lack of resources to plant different cash crops or the use of liquid fertilizers, it also may reflect an unawareness of these strategies as well.

8 Climate dialogs

In light of the BM context, we ask how climate information can be used effectively by small-scale producers. A model that has gained favor in climate adaptation and development activities calls for routine engagement with the end users in processes that are collaborative, emphasize mutual learning, and aim to generate information that is credible, legitimate, and relevant (Lemos et al. 2012; Reid et al. 2009; WMO 2011). We suspect that a model of routine interactions between climate information providers, extension, and farmers has the potential to overcome the barriers documented in the BMs. Collaborative processes have been shown to generate knowledge and information that is more accepted and used by decision makers (Meadow et al. 2015), and small-scale farmers have also preferred having the ability to discuss and clarify climate forecasts with scientists (Ingram et al. 2002). However, there lacks examples and evidence of the effectiveness and viability of climate services for vulnerable farmers.

In this absence, we conceptualize climate dialogs as a model to test. We choose the word dialogs to stress that all parties involved in the dialog are exchanging information. This in theory helps increase farmers' awareness of climate information and its role in the management of their coffee while providing to technical experts the contextual knowledge needed to develop more fitting information and dissemination modes. Importantly, these dialogs require diverse participants because each group brings critical knowledge. Extension officers have specialized information about best practices they relate to plant care and disease control. Climatologists have nuanced knowledge about the climate and weather system, the information tools available, and their interpretations. And each farmer brings a unique set of assets that dictate their ability to act. Combining these allows for correct interpretations, connections to be drawn between the information and coffee management, and the ability for farmers to decide if the information is worth acting on. For example, some farmers cited the dry conditions in 2014 and 2015 as evidence that climate is not predictable. Yet, this dry period unfolded during one of the strongest El Niño events on record, conditions that increased confidence about future conditions and that led to dry seasonal forecasts issued for Jamaica. Additionally, some farmers are unaware of effective techniques to apply fungicides. Without proper management practices, any benefits that could be generated by timing input applications based on weather and climate will be limited. Finally, many farmers in the BMs have

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different assets, live at different elevations, have different experience with climate and weather information, and have different levels of education. Disseminating the same content to this entire group incorrectly assumes all farmers are the same. At the same time, it is scientifically and practically infeasible for climate and weather information to be tailored to each farmer. Rather, the farmer ultimately derives the meaning. This requires discussing the nuances of the information, including its limitations, with sufficient detail that allows farmers to decide to use the information. We suggest that dialogs can help develop this personalized understanding. As a thought experiment, we wonder how new information tools, technical in nature and that address known challenges, would reach farmers in ways that lead to use in absence of dialog-like activities. Disseminating the information through existing channels will have only limited success, as it has elsewhere (e.g., Dilling and Lemos 2011).

We recognize challenges to this model. Climate dialogs require substantial human and financial resources. Both of which are in short supply in Jamaica and in many other countries. This calls into question both the sustainability and viability of this approach. Agriculture extension offers a well-tested example. Farmer field schools (FFS) have been implemented because they facilitate active learning spaces (Braun et al. 2006). Yet, FFS are criticized for their high cost and difficulty in bringing to scale (Braun et al. 2006). Additionally, scientists working for the meteorological service and academics do not have agriculture extension in their mandates. What incentives do they have for sustaining engagement? These challenges do have not immediate solutions. However, we propose that developing and evaluating climate dialogs is a needed step to learn and refine strategies to better incorporate climate information into farmer systems, particularly in cases like Jamaica where exposure to climate information has been low, communication channels are undeveloped, and knowledge of the potential benefits of climate information is incomplete.

9 Conclusion

We have shown that small-scale coffee farmers in Jamaica experience stressors related to production costs, weather and climate, and coffee disease—a situation that makes this case similar to other coffee-growing regions (Castellanos et al. 2013). Under conditions that reduce income, BM farmers compensate by adjusting their use of inputs, which can increase their susceptibility to future climate and disease stresses as plants become undernourished and the ability to purchase inputs further declines. However, farmers can also decrease their susceptibility to future stressors by more efficiently and effectively allocating their limited resources. In this sense, managing climate, like the other stresses, is an ongoing process. Climate and weather information identified in this study, therefore, has a potential role to play with these coffee farmers regardless of the stress levels. Yet, a formidable challenge is transforming potentially useful climate information into information that is used. We propose that climate dialogs between coffee farmers, extension specialists, and weather and climate scientists offer one potentially fruitful avenue to explore and test. Because climate services have been expanding in recent years and are focused on the agriculture sector (e.g., WMO 2011), explicating the content and empirically assessing the outcomes of a dialog-like activity would assess tradeoffs in the approach's ability to build local climate resilience.

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Compliance with ethical standards

Conflict of interest Mr. Gusland McCook is employed by the Jamaican Coffee Industry Board. All other authors declare no conflict of interest.

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