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Agricultural Information's Impact on the Adaptive Capacity of Ghana's Smallholder Cocoa Farmers

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Ghanaian smallholders grow one quarter of the world's cocoa, but climate change, individual extreme weather events, such as droughts, as well as deforestation increasingly threaten cocoa production. Pertinent information could bolster adaptive capacity. However, in Ghana's cocoa sector, relevant agricultural information is not available to all farmers, which can exacerbate power asymmetries. This paper focuses on how (i) agricultural and drought-adaptive information and (ii) socio-economic characteristics shape a cocoa farmer's adaptive capacity. We conducted our study in the aftermath of 2015–16's prolonged El Niño-induced drought that negatively impacted the livelihoods of cocoa smallholders across Ghana. In 48 semi-structured interviews and 12 focus groups, we asked smallholders how they responded to the drought to decipher how adaptive capacity compares between farmers receiving four different sources of agricultural information, and of diverse socio-economic status. Overall, agricultural information improved cocoa farmers' adaptive capacity compared to those who received no formal agricultural information. Smallholders detailed adaptive techniques that would be accessible to, and thus replicable by, other poorly-resourced cocoa farmers. Shade tree management and income diversification were identified as pertinent adaptive actions. However, we identified a divergence between exposure to agricultural information and its transformation into substantive adaptive action. Additionally, informal information sharing between smallholders represents an underutilized resource by extension programmes. We found that adaptive capacity is also determined by socio-economic characteristics: particularly gender, and to a lesser extent formal education level, proximity to asphalt roads, and land tenure. Finally, we present evidence that framing adaptive techniques in relatable terms that resonate with farmers' immediate livelihood concerns could narrow the adaptation deficit prevalent in Ghana's cocoa sector.

Keywords: cocoa, adaptive capacity, extension services, drought, agroforestry, climate-smart, livelihoods adaptation, Ghana

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INTRODUCTION

In recent decades, higher temperatures, changes in rainfall patterns, and more frequent and severe droughts have threatened agricultural livelihoods, especially in Sub-Saharan Africa (Antwi-Agyei et al., 2012; Altieri and Nicholls, 2017; Serdeczny et al., 2017). As mean temperatures and the associated number of weather extremes escalate, farmers need some degree of adaptive capacity (Challinor et al., 2010), i.e., an ability to engage their existing resources to "moderate potential damages, take advantage of opportunities, or cope with the consequences" of a changing climate (Füssel and Klein, 2006, 319). However, farmers' ability to adapt successfully may be limited by competing socio-economic risks (Kelly and Adger, 2000; Reid and Vogel, 2006; Tschakert, 2007; Bailey, 2017; Freduah et al., 2017, 2018), and essential resources, such as agricultural information (Tomlinson and Rhiney, 2018). There is, to date, limited empirical examination of agricultural information's role in shaping adaptive capacity. Therefore, we address this gap by exploring how the delivery and content of such information influences a cocoa farmer's adaptive capacity.

This paper draws on a case study in Ghana, where the country's principal agricultural export of cocoa is threatened by climate change. Though the empirical discussion is geographically based on Ghanaian cocoa farms, its applicability in terms of the processes, structures, needs, strategies, and recommendations for sustainable agricultural information provides useful lessons for understanding agrarian adaptation more widely in sub-Saharan Africa and other tropical, economically-developing regions. Ghana faces many climate and crop production challenges and vulnerabilities typical of sub-Saharan Africa (Antwi-Agyei et al., 2012). Vulnerability describes the degree to which a system, such as a community or a farm—is susceptible to the adverse effects of stressors and change (Blaikie et al., 2005; Brooks et al., 2005; Adger, 2006; Birkmann, 2006; Smit and Wandel, 2006; Tschakert, 2007). Tropical countries are extremely vulnerable to changes in rainfall patterns (De Souza et al., 2015) and the livelihoods of those tending to rain-fed farms are even more vulnerable (Parry et al., 2007; Thornton et al., 2011; Morel et al., 2019b). Water stress is a significant yield-determining factor for cocoa (Carr and Lockwood, 2011), yet Ghanaian cocoa smallholders depend on regular rain patterns (Schroth et al., 2016). In recent decades, rainfall has become more erratic which led to projections being developed specifically for cocoa (Owusu and Waylen, 2009; Gockowski and Sonwa, 2011) that indicate how rainfall scarcity will be exacerbated further by the higher temperatures predicted in the coming decades (Läderach et al., 2013; Schroth et al., 2016). The fragile cocoa crop is particularly vulnerable to all of these climatic changes. Irrigation can be used as a 'climate-smart' technique, however irrigating cocoa is rare since poorly-resourced smallholders are impeded by a variety of social, technical, and economic challenges (Bunn et al., 2019b), and likely 0.5% or less of Ghanaian cocoa is irrigated (Carr and Lockwood, 2011). Given irrigation's impracticability, those who farm cocoa must employ other adaptive techniques to minimize the impact that decreased and erratic precipitation will have on their cocoa yields.

Extreme weather events (including droughts, floods, and changes in temperature and precipitation patterns) and overall increased climate variability within Ghana's cocoa sector pose new and cumulative livelihood risks to the already vulnerable smallholders who cultivate cocoa (Anim-Kwapong and Frimpong, 2004; Boon and Ahenkan, 2012; Codjoe et al., 2013; Läderach et al., 2013; Hirons et al., 2018a). The severe El Niño of 2015 caused a prolonged drought in Ghana during the 2015–16 main cocoa crop (Blaser et al., 2018; Whitfield et al., 2019) which resulted in the lowest cocoa production of the past decades (ICCO, 2016; Abdulai et al., 2018; Beauchamp et al., 2019) meaning many cocoa smallholders failed to sustain their livelihoods (Hirons et al., 2018a; Whitfield et al., 2019). Despite multiple compelling reasons for adaptation, Ghana's cocoa smallholders currently face a disconcerting "adaptation deficit," that is a gap between needed action and the extent to which action is undertaken to adapt to climate change (Burton, 2004; Galway et al., 2016). With more extreme weather events, projected decreases in rainfall, climate change threatening cocoa suitability (Läderach et al., 2013; Schroth et al., 2016; Gateau-Rey et al., 2018), and cocoa-suitable, forested land becoming more scarce (Amanor, 2010), Ghana's cocoa sector at large is now more concerned with advancing the science of cocoa ecology and the adaptive capacity of cocoa farmers. Accordingly, "climate-smart" approaches to cocoa cultivation (McKinley et al., 2014; Akrofi-Atitianti et al., 2018; Bunn et al., 2019a,b; Nasser et al., in review[1]) are promoted by major cocoa buyers, confectionery companies, and increasingly by the Ghanaian government through Cocobod so that the smallholders who cultivate cocoa will apply ecologically-sustainable cocoa cultivation practices (Obiri et al., 2007; Gockowski and Sonwa, 2011) and successfully adapt.

Enhancing the adaptive capacity of cocoa smallholders so that they can respond effectively to climatic changes necessitates an understanding of their current preparedness and adaptive capacity (Saito et al., 2018). Since cocoa is a drought-sensitive crop (Carr and Lockwood, 2011), the prolonged drought during the 2015–16 main cocoa crop negatively impacted the livelihoods of Ghanaian cocoa farmers (Abdulai et al., 2018; Hirons et al., 2018a). Although there are an estimated 800,000 smallholders growing cocoa in Ghana (Anim-Kwapong and Frimpong, 2004; Carr and Lockwood, 2011; Friedman, 2015; Dontoh, 2018), how individual cocoa farmers experienced the drought varied, as this paper elucidates.

Extreme weather events notwithstanding, cocoa farmers are also rendered vulnerable by socio-economic and market forces, such as: decline of available land (Ruf and Zadi, 1998; Amanor, 2010; Carr and Lockwood, 2011; Hirons et al., 2018b); soil degradation (Dawoe et al., 2014); corruption in cocoa marketing (Peprah, 2015); cocoa's boom and bust cycles (Ruf and Siswoputranto, 1995; Ruf and Schroth, 2004; Clough et al., 2009); financial exclusion (Zeitlin, 2006; McKinley et al., 2014); poverty (Appiah, 2004; Hirons et al., 2018c); or by virtue of being born female (Oppong et al., 1975; Quisumbing, 1996; Quisumbing et al., 2001; Baffoe-Asare et al., 2013; Barrientos, 2013; Marston, 2016; Friedman et al., 2018). Against this background, this paper studies how Ghanaian cocoa farmers bore the impacts of the 2015–16's prolonged, El Niño-induced drought. Thus, we assess not only their potential adaptive capacity, but also the actual adaptive actions they employed in an attempt to lessen the impact of the drought. We explore how a farmer's socio-economic characteristics and sources of agricultural information

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determine adaptive response to drought, and in particular how four different approaches to agricultural information determined adaptive response to 2015–16's prolonged El Niño-induced drought, by asking the following overarching research question: "*How does agricultural information determine a cocoa farmer's adaptive capacity?*" The following sub-questions also guide this study:

1. What are the current sources of agricultural information related to adaptive capacity available to Ghana's cocoa smallholders?
2. What are key adaptive actions, and how are these supported, or not, by the provision of agricultural information?
3. How important is agricultural information in shaping farmers adaptive actions, relative to socio-economic factors?

AGRICULTURAL INFORMATION AND ADAPTIVE CAPACITY: A CONCEPTUAL FRAMEWORK AND ITS APPLICATION TO GHANA'S COCOA SECTOR

Situating Agricultural Information in Adaptive Capacity

Adaptive capacity is determined by people's access and control of essential resources (Tompkins and Adger, 2004; Diaz, 2016). An individual attempting to bolster their adaptive capacity may struggle to participate in political processes that determine the management, access, use, and distribution of natural goods (Dietz, 2013). The recognition that adaptation is a social process—rather than solely a technical challenge—underscores the need to address socio-economic constraints to enable adaptive capacity (Adger, 2003; Field, 2014; Galway et al., 2016). Our paper focuses on these socially-differentiated, political dimensions of adaptive capacity, and singles out the relative role of formal agricultural information provision in determining adaptive capacity compared to socio-economic factors.

Drawing from Sen's (1981) capabilities theory, adaptive capacity theorists once assumed that adaptive capacity is commensurate with—or is at least improved by—financial capital (IPCC, 2001; Vincent, 2007; Engle, 2011; Notenbaert et al., 2013). Yet a farmer's capacity to cope with and adapt to climate uncertainties depends on many factors beyond financial resources, such as their personal networks (Chaudhury et al., 2017); multiple dimensions and stressors of poverty (Scoones, 1998, 2009; O'Brien et al., 2004, 2009; Lemos et al., 2013; Bailey, 2017); institutional support (Yohe and Tol, 2002; Smit and Pilifosova, 2003; Vincent, 2007; Gupta et al., 2010; Berman et al., 2012); psycho-social dimensions (Grothmann and Patt, 2005; Fazey et al., 2010; Mortreux and Barnett, 2017); and access to relevant information (Jha and Gupta, 2016). The most poorly studied of these factors is how the provision of relevant information impacts adaptive capacity (Mbow et al., 2014; Graefe et al., 2017; Mortreux and Barnett, 2017). A few authors have identified how information is pertinent to one's adaptive capacity (Engle and Lemos, 2010) in order to cope with broad issues of livelihoods and poverty alleviation (Hagmann and Chuma, 2002; Hirons et al., 2018c). However, the most-cited paper on adaptive capacity—(Smit and Wandel, 2006)—refers to neither information acquisition nor learning. Our paper thus seeks to understand the socio-economic, institutional, and agricultural learning processes through which Ghanaian cocoa farmers have engaged, and could engage, in adaptation.

A variety of conceptual approaches have been developed to understand how actors learn to adapt after facing resource limitations (Holt, 2005) or in response to environmental crises (Berkes and Turner, 2006), including cognitive processes, such as experiential learning loops (Turner and Berkes, 2006; Armitage et al., 2008), critical reflection, and social learning (Tschakert and Dietrich, 2010; Ensor and Harvey, 2015; Stone, 2016; De Kraker, 2017). Some authors mention information acquisition's role in achieving climate-resilient agriculture (Simelton et al., 2019) or information's role in adaptive capacity, such as Engle and Lemos (2010) who demonstrate how "adaptive capacity is enhanced by increased flows of information and knowledge" (p. 6). Valdivia et al. (2010) assess knowledge's potential to enhance adaptation, but as per Abdul-Razak and Kruse (2017), knowledge or information is treated as one of many capitals determining adaptive capacity. Very few authors single out information provision or agricultural extension to either empirically evaluate their role in shaping adaptive capacity or assess whether agricultural information provision is a socially-differentiating factor for adaptive action. A major rationale for extension services, farmer education programmes, and various forms of formal and informal agricultural training is the desire to enhance and expand farmers' knowledge (Feder et al., 2004) and thus improve adaptive capacity (Wozniak, 1987; Jha and Gupta, 2016; Tomlinson and Rhiney, 2018). How the sources and content of formal agricultural information (i.e., recommendations, criteria, and principles as written in extension programmes' syllabi) impacts either adaptive capacity or adaptive outcomes is hitherto underexplored. The influence that such unidirectional knowledge, flowing from programmes (be they government, certification, NGO, corporate, etc.) to farmers, bears upon adaptive capacity and action also remains understudied.

Agricultural Information in Ghana's Cocoa Sector

Kwame Nkrumah led the Gold Coast to independence from Britain in 1957, and upon assuming political leadership of decolonized Ghana, Nkrumah nationalized the cocoa sector and provided state extension services (Asuming-Brempong, 2003). Indeed, throughout the 1960s and 1970s, increasing the size of nationalized extension services was prioritized (Eicher, 1990). One long-standing extension service in Ghana's cocoa sector is the agricultural information provided by the state's cocoa board, Cocobod[2]. Prior to the implementation of the World

[2]During the Second World War, the British set up crop marketing boards in its West Africa colonies, and in 1947, Ghana's cocoa board became an independent unit, named the Cocoa Marketing Board (Williams, 2009). After 1984, this state-run Ghanaian Cocoa Marketing Board has been known as the 'Cocoa Board', and even more commonly as Cocobod (*ibid*.). Ghana's state cocoa board (Cocobod) and its regional offices are responsible for managing and overseeing the national cocoa sector.

Bank's and International Monetary Fund's (IMF) structural adjustment programmes (SAPs) from 1983, extension services to cocoa farmers were carried out exclusively by Cocobod's state-controlled subsidiaries. Cocobod's failure to maintain universal extension is likely due in part to the parastatal being debilitated by the World Bank and IMF's SAPs whose mandated privatization reforms resulted in Cocobod staff being reduced by 90% (Roe et al., 1992). Although in theory all of Ghana's cocoa farmers should still receive free extension from Cocobod's universal provision, today fewer farmers receive Cocobod extension than prior to the SAP reforms (Abekoe et al., 2002; Ayenor et al., 2004). The current reality is that Cocobod's extension services are not consistently delivered, meaning that many Ghanaian cocoa farmers (attempt to) rely on a bricolage of information and advice from elsewhere.

Within academic debates of agri-environmental governance, agricultural extension services remain undertheorized (Gallagher, 2015). Yet such indifference—both academically and in terms of policy, as evidenced by a retreat of state-led agricultural services—can result in significant productivity losses for smallholder commodity crop producers (Gallagher, 2015), as the case of Ghana's cocoa sector illustrates. Quarmine et al. (2012) identify "low extension coverage," "inconsistent extension policy," "inadequate knowledge," and "information asymmetry" (**Figure 1**, page 10) as among the institutional causes of the sub-optimal quality performance of cocoa cultivation in Ghana.

Given Cocobod's fragmented reach, alternative extension programmes have emerged to offer agricultural information to cocoa farmers. In Ghana, the industry-wide concern with climate change impacts on cocoa production is evidenced by a proliferation of agricultural extension schemes, along with a recent move toward "climate-smart" interventions that promote agroforestry techniques to grow cocoa under shade. This paper examines the recent resurgence in providing agricultural information as Ghana's cocoa industry tries to address deforestation, adapt to climate change pressures, and address concerns, such as poverty and child labor in its supply chain. We examine the content of different approaches to agricultural information provision and assess their impact upon cocoa smallholders' adaptive capacity. Alternative sources of agricultural information include third-party certification schemes (such as Rainforest Alliance, Fairtrade, Organic, Utz, etc.); increasingly extension services provided by corporations; and some piecemeal or finite engagement by NGOs. These three alternative classes of agricultural provision: certification, a cocoa company, and an NGO provided the basis for this study's sampling of farmers along with those relying on Cocobod extension as our control group. This paper neither interrogates who has access to agricultural information, nor asks why some smallholders can access it while some cannot. Rather this paper examines whether the provision of agricultural information results in more adaptive techniques being employed on-farm by appraising four different approaches to agricultural extension to test whether the information gained therein leads to on-farm adaptation.

CASE STUDY AND METHODS

Study Site Characteristics

This analysis draws on qualitative data collected in 11 villages surrounding the Central Region town of Assin Fosu[3], and in a further six villages surrounding the Ashanti Region town of New Edubiase[4] (see **Figure 1** below). Many of the 17 villages in which we conducted interviews still lack basic amenities, such as electricity, piped water, and paved roads. None of the 11 villages surrounding Assin Fosu in which we interviewed could be accessed by paved roads. Whereas, the six villages surrounding New Edubiase in which we interviewed were all accessible by paved roads. Transportation in both the Ashanti and Central Regions is readily available on asphalt roads but is irregular away from them. Irregular, informal rural taxis run with varying degrees of frequency between the 11 Central Region villages toward the town of Assin Fosu. An individual farmer being able to access to their village via paved, asphalt roads would mean that they would typically (but not in every case) be better connected to information, markets, social services, transport to other places, and that they likely could access fertilizer more easily.

The 17 villages were selected as part of an on-going study examining the socio-ecological system of smallholder cocoa cultivation in Ghana: ECOLIMITS[5]. The sites were selected because of their proximity to intact forests: a potentially important variable shaping the experience of climate shocks among cocoa farmers (Morel et al., 2019a). All 17 villages are located in Ghana's tropical agro-ecological zone where little old-growth forest remains due to decades of extensive crop cultivation (Norris et al., 2010) and thus decades of less carbon sequestered by forests. This deforestation has led to widespread degradation of soil fertility, and when these two factors are combined, the net result is low cocoa productivity (Anglaaere et al., 2011; Morel et al., 2019a). Such low productivity causes livelihood struggles since cocoa sales provide between 70 and 100% (Ntiamoah and Afrane, 2008; Kolavalli and Vigneri, 2011; McKinley et al., 2014; Friedman, 2015; Tsiboe et al., 2016; Bunn et al., 2019a) of annual household income for Ghana's estimated 800,000 smallholder families. Ghana's low cocoa productivity averages only 400 kg per hectare (Gockowski and Sonwa, 2011; Laven and Boomsma, 2012; Wessel and Quist-Wessel, 2015), which is half that of neighboring Côte d'Ivoire's at 800 kg ha^{-1}, and a quarter of Malaysia's at 1,800 kg ha^{-1} (Kongor et al., 2018). Indeed, in some of our same study sites, Morel et al. (2019a) recorded smallholder productivity as low as 12 kg ha^{-1}. Ghana's low cocoa productivity rate may be the result of "inadequate knowledge," "information asymmetry" (Quarmine et al., 2012: page 10), from inconsistent and inadequate extension services

[3]The 11 villages surrounding Assin Fosu town where we interviewed cocoa smallholders were: Homaho, Dadeso, Nysuokye, Assin Bankyease, Kwame Amoabeng, Aboabo, Atentan, Gold Coast Camp, Agave, Ahante, and Assin Nkranfom.

[4]The six villages surrounding New Edubiase town where we interviewed were: Apayga, Kwaso, Obuboi, Nsata Abu, Amuedrase, and Kwame Asanti.

[5]ECOLIMITS is an international research project under the UK's Ecosystem Services for Poverty Alleviation (ESPA) programme. For more details, please see: www.ecolimits.org.

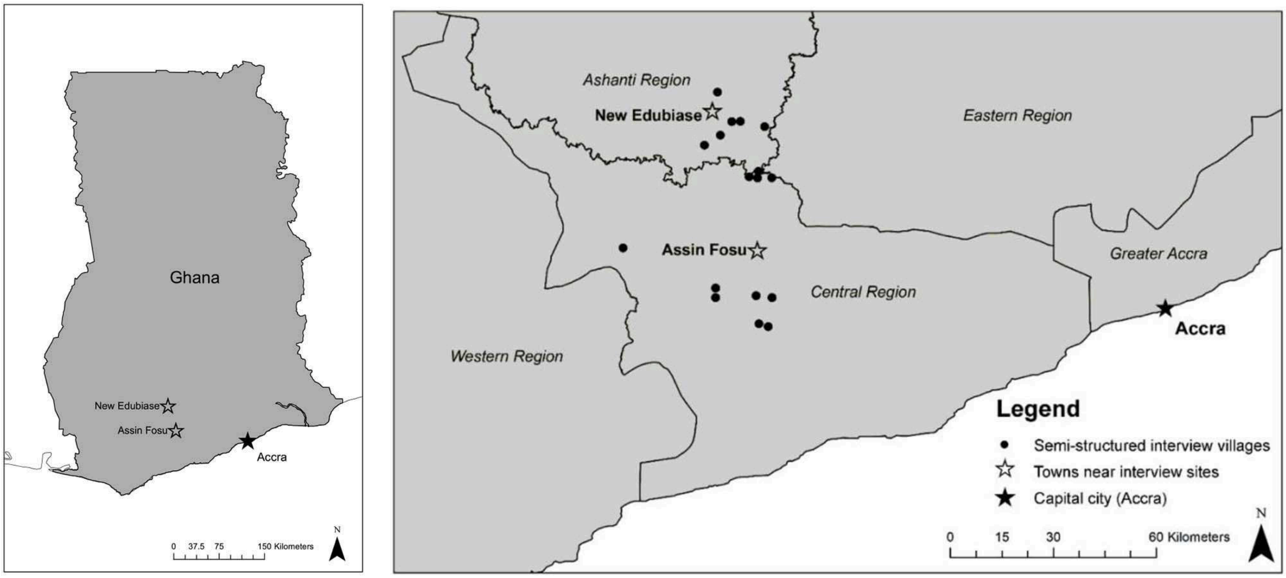

FIGURE 1 | (Left) A map of Ghana, with the capital city of Accra as a black star, and the towns of Assin Fosu and New Edubiase as white stars. (Right) A map of Ghana zoomed in to show study sites, where studied villages are approximately located by circles, and as per the left panel the towns of Assin Fosu and New Edubiase are white stars, and Accra city a black star.

(Dormon et al., 2004; Quarmine et al., 2012). Another reason could be the advanced age of cocoa trees. The exploitation of forest rent in Ghana started decades before Côte d'Ivoire, thus Ghana's cocoa sector reached the structural crisis of aging plants and increased input costs much sooner (Woods, 2004; Wessel and Quist-Wessel, 2015) and insufficient numbers of cocoa trees have been replanted on existing Ghanaian cocoa farms (Ruf and Zadi, 1998; Ruf and Schroth, 2004; McKinley et al., 2014; Ruf et al., 2015). The availability of large tracts of cocoa-suitable forests is scare in Ghana (Amanor, 2010) compared to in Côte d'Ivoire (Hatløy et al., 2012).

Cocoa's biophysical requirements are continual high temperatures of at least 28°C, a regular supply of moisture, and ideally annual rainfall of between 1,500 and 2,000 mm (Ross, 2014) but it can grow under a precipitation range of 1,300 to 2,800 mm (Carr and Lockwood, 2011). The annual average rainfall of the Central Region is around 1,380 mm (Whitfield et al., 2019) and 1,350 mm in the Ashanti Region (Watanabe et al., 2009) which are thus already at the lower threshold of cocoa's essential requirements on average years. Yet during drought years, historical records indicate reduced cocoa production, and during El Niño years, cocoa harvests are even more severely diminished (ICCO, 2016). Ghana's 2015–16 cocoa season was adversely affected by a severe El Niño which caused higher than average temperatures during that year's dry Harmattan[6] (Abdulai et al., 2018), as well as elevated temperatures that heightened water vapor deficits and lowered soil moisture availability (Whitfield et al., 2019). Rather than speculate about how farmers might respond to possible future extreme weather, our inquiry refers to prolonged droughts already experienced, with a particular focus on that 2015–16 El Niño-induced drought. The temporal proximity of our October 2017 interviews to the drought meant that issues with recall were minimized. We asked cocoa smallholders to detail how they coped and adapted, and then we thematically analyzed these details to understand what factors support or hinder adaptive capacity since the hydroclimatic conditions during the prolonged 2015–16 drought are comparable to future climatic change projections (Läderach et al., 2013; Schroth et al., 2016).

Methods

Understanding the finer complexities of a particular context is essential in understanding how farmers could change their farm management to successfully adapt (Cafer and Rikoon, 2018), therefore we collected data during three separate fieldtrips and frequently consulted our local partners since they know the cocoa communities well and work with them often. As a preliminary scoping exercise during the first two fieldtrips, we carried out 12 gender-segregated focus group discussions (FGDs)—on drought impacts, shade trees, extension, informal agricultural advice, adaptive actions, and credit—each comprising five or six cocoa smallholders. Focus group participants were selected purposively to include key informants from the villages. These included traditional leaders, leaders of youth groups, as well as a male and a female representative elected by each community to liaise with the research team. To minimize the influence of gendered power dynamics on data collection and to identify how the impacts and responses to the drought were shaped by gender, we elected each focus group's participants should either be all men or all women.

[6]The annual Harmattan is a very dry, dusty wind which blows from the Sahara Desert over West Africa into the Gulf of Guinea from December to February.

Six of the 12 FGDs were conducted in July 2016 and six more in April 2017. A sub-set of villages were selected for focus groups. Unfortunately, not all villages could be included in the focus groups due to logistical and practical constraints, but it is not felt that this will have any negative impact given the relatively minor differences between, and close spatial proximity of, the villages. Each FGD was led by one of the authors in tandem with a Twi interpreter. One or two of the authors took notes during each FGD.

We reflected on the FGDs to refine the rest of the study. For example, focus group participants detailed cases of how they themselves (or other farmers they knew) had changed their farm management to successfully adapt as well as cases of maladaptive practices. This informed our design of the semi-structured interview guide, which addressed issues concerning: (i) socio-economic status, (ii) shade tree management, (iii) information sources, (iv) formal extension benefits, and (v) adaptive actions undertaken. The choice of agricultural information profiles was also borne from these preliminary FGDs, the authors' previous studies, as well as multiple research trips, and ethnographic observations.

Throughout October 2017 during the third fieldtrip, 48 cocoa smallholders in 17 villages (see **Figure 1**) were interviewed. Between one and five semi-structured interviews were conducted in each of the 17 villages. Interview questions probed how farmers had coped with the 2015–16 drought to identify adaptive resourcefulness. Responses revealed which adaptive changes had been enacted as well as described obstacles that may have impeded their desired adaptive change. The challenges of measuring adaptive capacity have been well-versed (Engle, 2011; Lemos et al., 2013; Eakin et al., 2014; Williams et al., 2015; Mortreux and Barnett, 2017), since as per all capacities they are potentially latent. One proxy, which we use here, for adaptive capacity is the adoption of adaptive actions. In this study, adaptive changes enacted and barriers to adaptation were only as farmers reported them, rather than as observed by the authors.

We conducted a further eight complementary key informant interviews with certification managers, senior agronomists, sustainability officers, a cocoa trader, and an NGO representative. As per the focus groups which provided the authors with details on the context and the lived experience, the key informant interviews provided specialized knowledge on: the El Niño-induced drought, the cocoa industry, adaptation, certification, agricultural extension materials and criteria, etc. since we selected key informants who were involved with initiatives that provide agricultural information to cocoa smallholders. Key informants' interviews were used to provide a holistic view by incorporating perspectives beyond village level.

Rather than only considering technical information formally imparted to farmers, lay knowledge and farming advice passed between farmers and across generations were examined. As adaptive capacity dynamics are intertwined with socio-economic characteristics, we also set out to gather data on a broad range of socio-economic factors that influence vulnerability and adaptive capacity.

Since an overriding objective was to decipher how information imparted to Ghana's cocoa smallholders influences their response to drought, and influences their adaptive capacity, we sampled purposively to conduct semi-structured interviews with smallholders associated with the following approaches of delivering agricultural information:

(i) A certification scheme, Rainforest Alliance [16 smallholders];
(ii) An agro-industrial cocoa trader's sustainability scheme, Touton's agricultural extension programme [16 smallholders];
(iii) A Ghanaian NGO offering advice to farmers as part of a research project, the Nature Conservation Research Centre (NCRC) [11 smallholders]; and
(iv) A control group of non-certified farmers without extension services beyond Cocobod's universal provision, who are neither members of any cooperative, nor part of any NGO programme [5 smallholders].

By examining four distinct groups of Ghanaian cocoa farmers, we aim to depict dynamic sectoral adaptation across much of Ghana's cocoa-growing system and account for the heterogeneity of Ghana's cocoa farmers with respect to their socioeconomic status and their access to agricultural information.

Since female farmers have long been disadvantaged in Ghanaian cocoa cultivation (e.g., Oppong et al., 1975; Quisumbing, 1996; Quisumbing et al., 2001; Baffoe-Asare et al., 2013; Barrientos, 2013; Marston, 2016; Friedman et al., 2018), we set out to examine how female farmers fared in their adaptation to drought. As in many economically-developing agrarian communities, Ghanaian women are systematically disadvantaged since they are generally expected to perform most domestic chores as well as carry out farm labor, and they typically hold fewer land titles (Asaaga and Hirons, 2019). Yet, land-ownership is often a precondition for membership in official farmer organizations, participation in training and information programmes, applying for credit, and managing an adequate diversity of crops (Fountain and Hütz-Adams, 2018). Each of the four extension profiles included female interviewees and overall, one third of our respondents were women. In addition, purposive selection was carried out to ensure that youth, widowed, and elderly participants were all interviewed. A summary of the socio-economic characteristics of gender, age, literacy, and formal schooling across the 48 interviewed smallholders is presented in **Table 1** below at the beginning of section Results.

Although the analysis in the paper is predominantly qualitative, we support and illustrate our arguments with descriptive statistics including frequencies, percentages, and medians to summarize the field data gathered. As extreme weather events and other climate shocks are rarely the only stresses constraining adaptation in smallholder agriculture systems, we disaggregated adaptive actions reported between different socio-economic characteristics and disaggregated by the different approaches of agricultural extension. Clearly, the analysis in this paper is not generalizable to the national context in a statistical sense. However, the study draws on data collected from two of Ghana's principal cocoa-growing regions and many

TABLE 1 | The distribution of gender, age, literacy, and formal schooling across the 48 interviewed smallholders.

Socioeconomic characteristic	Count ($n = 48$)	%
Male	31	64.6
Female	17	35.4
Aged <30	1	2.1
Aged 30–39	8	16.7
Aged 40–49	6	12.5
Aged 50–59	17	35.4
Aged 60–69	10	20.8
Aged 70–79	3	6.3
Aged >80	3	6.3
Cannot read or write at all	23	47.9
Can read and write a little	12	25.0
Mastered reading and writing	13	27.1
Zero schooling	10	20.8
Completed primary education	6	12.5
Completed junior high school (JHS)	27	56.3
Completed senior high school (SHS)	2	4.2
Vocational qualification	1	2.1
Tertiary education	2	4.2

of the state-based and market-based institutions we study operate at a national level and therefore it is reasonable to extrapolate, as we do, from these findings to reflect on their significance the cocoa sector in Ghana and elsewhere in West Africa.

RESULTS

This section presents results extracted from our interview data on the following key themes: formal agricultural information sources; informal agricultural information sources; adaptive actions (with a particular focus on shade tree management); and socioeconomic characteristics. We also address themes which were not pre-defined but rather emerged through interactions with cocoa smallholders. **Table 1** below details the distribution of some socio-economic characteristics among the 48 cocoa smallholders we interviewed.

Sources of Agricultural Information

Formal Sources of Agricultural Information

As we stratified this study on adaptive capacity along four approaches of accessing agricultural information, **Table 2** below and this subsection outline how components of these information sources may help or hinder a farmer's ability to adapt to drought.

We found that interviewees who received agricultural information from RA, Touton, or NCRC also received more advice and visits from Cocobod. Whereas, Cocobod's extension services are supposed to serve all of Ghana's cocoa farmers, we found that 4 out of the 5 farmers who were not part of any additional programme offering agricultural information *never* received advice from Cocobod extension agents. The farmer profile who was next most neglected by Cocobod were the farmers who receive periodic advice from NCRC, of whom more than half never receive advice from Cocobod extension agents. Women across all four sampled profiles fared badly with respect to receiving agricultural advice from Cocobod officers. Farmers across all four profiles complained about Cocobod and how rarely their agricultural officers visit, if ever. Our interviews revealed how accessing Cocobod's agricultural information depends in large part on the pro-activeness of individual Cocobod extension officers, as well as the ease of access to a cocoa village. Only one interviewee out of 48 reported receiving Cocobod extension visits often, i.e., at least once per month. He was a 60-years-old male receiving Touton advice and living alongside a major asphalt road.

In the absence of being able to rely on Cocobod's ostensibly-universal extension, some of Ghana's cocoa farmers are fortunate enough to access agricultural information from alternative sources, such as through membership of a cooperative seeking certification, from cocoa-trading corporations, or from an NGO.

In order to gain RA certification, farmers must comply with principles and criteria developed by the Sustainable Agriculture Network (SAN). Most RA/SAN agricultural information is concerned with best management practices (BMPs) to bolster crop productivity, but with an emphasis on shade trees, water conservation, and avoiding contamination of water courses. In brief, RA inform farmers cultivate their crops in a manner that adheres to their founding mission of conserving forests and the surrounding ecosystem. In terms of presenting information to improve knowledge about adaptive capacity, RA did not explicitly frame the agricultural information they disseminate in terms of climate adaptation or bolstering adaptive capacity. Indeed, the concept of climate adaptation was conspicuously absent from both RA's and Touton's agricultural information. This may not prove problematic, but Williams et al. (2015) have suggested that awareness of climate change and how to adapt to it can empower people "in poor and vulnerable communities" with "a better understanding of the kinds of resources and interventions that will be most useful to them and, in the case of scientific knowledge, the information and vocabulary required to communicate their vulnerabilities to actors with conventionally greater decision-making power." Among all four approaches of formal agricultural instruction, there was no advice on which techniques to employ in preparation for a future drought. More often, information given was on general farm resilience rather than on adapting to drought and other extreme weather events. Although some agricultural information actually was about climate adaptation, neither the word "climate" nor "adaptation" featured. One farmer recounted that she "*was taught to plant shade trees to protect the cocoa from dying from strong sunlight.*" Thus, some advice may be (perhaps indirectly) relevant for climate adaptation but was presented in terms with which cocoa smallholders can relate. Another example of imparting ecological instruction via relatable, appropriate language was being advised "*not to fell trees in the forests since forests give fresh air.*" Communicating climate change's impact and deforestation's

TABLE 2 | Summary of key characteristics of agricultural information sources studied.

Agronomic information approach	Governance	Extent of coverage	Founding mission	Prioritizes	Providing agronomic information since	Agronomic information method	Unique characteristics	Climate change adaptation
Cocobod	Parastatal	Universal extension. In practice though, few of Ghana's 800,000 cocoa farmers receive agronomic extension.	For the state to oversee and manage cocoa production. Increase farmers' productivity to increase export volume of cocoa.	Boost farmer productivity. Quality control to export quality cocoa.	Ghanaian state have provided agronomic extension since colonial times.	Cocobod offices and officers in each of Ghana's 6 cocoa growing regions.	At times and in some villages, providing free (or inexpensive) fertilizer spraying and free pruning.	General farm resilience for increased productivity, not adaptation specific.
Rainforest Alliance	Certification	9.7% of Ghanaian cocoa is RA certified*.	Conserve tropical forests.	Conserve tropical forests and grow cocoa under shade.	RA cocoa certification since 1997. Active in Ghanaian cocoa since 2008.	Designated cooperative manager assists and advises farmers on how to comply with 80% of RA criteria (including 100% with 16 critical criteria).	Integrate biodiversity. Aim for wider community improvement.	Adaptation not mainstreamed. Yet, interviewed RA farmers most knowledgeable about shade trees and forest benefits, and practiced *anticipatory* shade tree management.
Touton	Corporate	11.3% of GH cocoa is exported by Touton** (19.8% of GH cocoa is Utz certified*** which includes programmes by Touton, Hershey's, Ferrero, Olam, and Neuhaus).	Uphold shareholders' commitment to sustainable sourcing.	Guarantee traceability to customers. Boost farmer productivity. Recent and increasingly, forest and landscape conservation.	Since 2010 (when they partnered with NGO, Solidaridad in Ghana).	Farmer business schools (which loosely adhere to Utz standard as do Hersheys', Ferrero's, Olam's, and Neuhaus' farmer business schools).	Piloting farmers' bank. On-farm demonstrations of best management practices.	1 of 12 first signatories of the Cocoa and Forests Initiative. But adaptation not yet mainstreamed in Touton's farmer business schools. Adaptive mainstreaming may occur as 3PRCL: the first pilot of the Ghana Cocoa Forest REDD+ Programme (GCFRP).
Nature Conservation Research Centre	NGO	Only 120 cocoa households, so 0.015% of Ghanaian cocoa.	Raising conservation awareness so that nature that is culturally and economically valued by locals can be conserved.	Holistic engagement to monitor how forest conservation farm and management practices impact multiple dimensions of poverty.	2014 as the local partner of the ECOLIMITS[!] research consortium.	The appointment of technical assistants who are trained by NCRC. Socio-ecological monitoring and frequent research visits.	Cocoa pollinator attraction.	Beyond their remit. But technical assistants well-informed on shade tree density, species, and anticipatory adaptation but other NCRC farmers, much less so.

* *Nyantakyi-Frimpong and Bezner-Kerr (2015).*
***IDH (The Sustainable Trade Initiative) (2018).*
****Ingram et al. (2018).*
[!]*www.ecolimits.org*

impact on cocoa ecology with such familiar terms proved instrumental in motivating these two interviewed farmers to enact climate change adaptation techniques.

Touton is an agro-industrial trader exporting 11.3% of Ghana's cocoa (IDH (The Sustainable Trade Initiative), 2018) which seeks to improve cocoa farmers' productivity through "farmer business schools" in which agronomists teach farmers BMPs and, increasingly, agroforestry principles. Agronomist instructors delivering Touton farmer business school teach with a syllabus that loosely adheres to the UTZ standard. Touton farmers spoke more of income diversification techniques than all other interviewed farmers. Indeed, several Touton farmers also spoke of "*running their farm as a business*." This could reflect Touton's priority—as we understood it from key informant interviews and reviewing their farmer business school documentation—to bolster farm productivity. One adaptive technique unique to Touton farmers was their piloting of a farmers' bank: a service seeking to eradicate an unjust, informal loan system that can force vulnerable smallholders into debt cycles. In each of our 12 focus groups, we heard cases of people undertaking a practice that is hard to sustain: taking out loans in order to cope through the 2015–16 prolonged drought. The discussants revealed how these informal loans can be at 100% interest rates, making repayment difficult, or in most cases impossible. Thus, inescapable poverty traps are created.

As the local partnering NGO of the ECOLIMITS research project, NCRC offered some agricultural information from 2014 to the end of 2017, though only to 120 participating cocoa households. While NCRC's engagement with these cocoa households was both recent and short-term, the engagement was holistic since they implemented a broad range of forest conservation and farm management practices which they have monitored against multiple dimensions, and varying degrees, of poverty. However, three aspects of NGOs as providers of agricultural information should be emphasized. Firstly, the proportion of Ghanaian cocoa farmers receiving information from NGOs is difficult to gauge; secondly, so is the depth of NGO engagement, which likely only lasts for the finite lifespan of a particular project's budget. Thirdly, an individual's NGO outreach is not at a scale commensurate with the state-run marketing board of Cocobod, or commercial extension, such as by RA, Touton, or UTZ. For instance, whereas NCRC engaged with just 120 cocoa households, 9.7% of all of Ghana's cocoa is RA-certified (Newsom and Milder, 2018), while 19.8% is UTZ certified, which includes agricultural extension programmes by Touton, Hershey's, Ferrero, Olam, and Neuhaus (Ingram et al., 2018).

Informal Sources of Agricultural Information

We broadened our consideration of information to include lay knowledge available to cocoa farmers by posing interview questions that explored the influence of informal information sources too, such as advice from a neighbor, family member, pastor, or imam. Almost two thirds of interviewees and focus group discussants related how they valued informal exchange both between neighboring farmers and across generations for acquiring agricultural information. Although in our sample of 48 interviewed smallholders, those who were receiving additional agricultural information (i.e., from RA, Touton, or NCRC) were four times more likely to receive advice from, and three times more likely to give advice to, a neighboring farmer in comparison with the farmers in our control group. After an extended farmer had received advice from a perceived expert, they often felt empowered, especially if they had already attained a high level of formal schooling, such as this farmer: "*I even tried to share my RA knowledge on planting shade trees to those who had not received it, especially those bordering the farms of my friends*." Another RA farmer, a woman who had become extremely knowledgeable on sustainable agriculture and who emphasized "*yes, yes, climate change reduces the cocoa's productivity*," explained how she suggests "*to others that they replicate how I left enough shade trees... I am not being selfish with the knowledge I gained on shade trees from RA. In fact, I advise others... I also encouraged friends to go into oil palm and annual crops, such as plantain and cassava*."

We heard how farmers change their perceptions and make new on-farm decisions after observing the activities of nearby farmers, especially those experimenting with new technologies and adaptive actions. Therefore, not implementing one of the adaptive techniques could be an informed rational judgment, rather than just the result of a lack of formal agricultural information. Our semi-structured interviews probed the source(s) of information—both formal and informal—for individual adaptive techniques and in general we found that when an adaptive technique was not implemented, a smallholder tended to not have knowledge of that practice.

Neighborly and intergenerational exchanges on BMPs, forest protection, climate change awareness, and adaptation techniques were deemed useful by nearly all respondents, yet mobilizing these informal channels remains an underutilized resource by those providing formal agricultural information. In general, sharing experiences and two-way participatory communication are important because information is processed effectively when people can rely on experiential systems (Marx et al., 2007; Valdivia et al., 2010). The encouragement of peer-to-peer learning could be embedded into sustainable cocoa extension schemes and NGO projects. For instance, facilitating informal exchange channels through which formal agricultural information could be shared may prove to be a cost-effective strategy, and may allow agricultural information to be shared beyond the budgetary lifetime of individual extension projects. Those farmers not connected to additional agricultural information and who only rely on potential visits from Cocobod received, gave, and observed less informal agricultural information than farmers receiving agricultural information from their certification cooperative, their cocoa buyer, or the NGO with whom they were connected. Similarly, female farmers on average received, gave, and observed fewer adaptive techniques from, and with, fellow cocoa farmers. What is more, if farmers were encouraged to share advice on shade tree management and other pertinent adaptive actions, adaptive capacity could be bolstered, since the farmers in our study sites who shared formal and pertinent adaptation advice demonstrated clear adaptive advantage.

In every village, we heard how both elders and past generations play a role in ecological conservation. Crucially, though, informal information from elders was rarely framed in terms of the new challenges associated with adapting to climate change pressures. An adaptation imperative was markedly absent in lay knowledge from elders.

Adaptive Actions and Agricultural Information

In order to evaluate how agricultural information can bolster adaptive capacity, it is important to identify which adaptive actions could best serve Ghana's cocoa smallholders. In this subsection, we present some pertinent adaptive actions that could bolster the adaptive capacity of Ghanaian smallholders. These adaptation techniques are deemed pertinent across the literature and by key informants, and cocoa smallholders themselves also asserted these adaptation techniques to be both feasible and effective in our focus groups and interviews. Crucially, the adaptive techniques that this paper details and discusses have been shared by cocoa smallholders themselves, thus such adaptation would be acceptable, and accessible, by poorly resourced smallholder farmers. For instance, in response to the interview question, "Which adaptive techniques are the best to adapt to droughts and extreme weather events?" 60% ($n = 29$) of the 48 interviewed farmers suggested that planting and nursing shade trees was the most effective adaptive technique. Out of all possible drought-adaptation techniques, this response of shade trees was by far the most prevalent, and it should be noted that this was an open interview question with no prescribed adaptation suggestions. Respondents were also welcomed to suggest more than one technique that benefits adaptive capacity.

Diversifying income streams was the second most frequently suggested ($n = 6$) best adaptive technique. Interviewees were asked, what proportion of their household income came from the sale of cocoa beans. This question was not asked in terms of a currency value, but rather as a fraction of household income earned. On average, the 48 farmers who we interviewed receive 75% of their household income from cocoa sales, thus a drought or other extreme weather event can severely reduce income, with dire consequences for livelihoods. Therefore, diversifying by planting other crops—particularly oil palm, planting timber species, or seeking other non-agricultural income streams were identified as important adaptive actions. A common motivation for cocoa farmers to grow oil palm trees is that they yield many different products and that they provide a year-round income source (Khatun et al., 2020); for example, this farmer justified diversifying into palm because: "*When cocoa is off-season, I can earn a little from palm every fortnight or so*." Other farmers elaborated on palm's performance despite extreme weather events, such as droughts: "*You cannot depend on cocoa only, because there are only two cocoa seasons. Whereas, palm you can harvest it every day, even under drought conditions*" and "*Palm can help, because you can harvest and sell it even when there is no rain*."

Another factor that impeded transforming information on adaptive techniques into adaptive action was farmers' limited belief in their own ability to change their circumstances. For instance, in response to which adaptive action would be best: one respondent felt that "*praying, since God decides,*" was the best adaptive technique to employ. Three other respondents did not know at all what technique is best to adapt to droughts; and all three expressed a sense of fatalism when interviewed. Even those who did suggest a single adaptive technique appeared to struggle to come up with one suggestion and expressed similar fatalistic attitudes. Overall, belief in farmer agency—that is a belief that making changes to farm management could actually improve one's situation in the face of extreme weather events—was lowest among the control group, i.e., those with no additional agricultural information, our control group ($n = 5$). Additionally, both widows displayed little belief in their own agency. A typical response by the widowed farmers or those with no additional extension about making adaptive changes to drought was: "*When the [weather] conditions are very bad, and the rains don't come, we tend to not go to the farm as much as usual, since there is little we can do*."

Although agreeing on universally-reliable ways to measure adaptive capacity remains elusive (Engle, 2011; Lemos et al., 2013; Eakin et al., 2014; Williams et al., 2015; Mortreux and Barnett, 2017), in our study sites, several adaptive techniques that resulted in improved adaptive capacity in the face of 2015–16's prolonged El Niño-induced drought emerged and recurred in key informant interviews, FGDs, and semi-structured interviews. These adaptive techniques were identified as pertinent by respondents and broadly corroborate the wider literature on cocoa adaptation and drought adaptation in tropical West African smallholder agriculture. What is more, smallholders described in the semi-structured interviews how implementing an adaptive technique resulted in their faring better in the drought. For instance, one farmer who implemented the adaptive technique of crop diversification described how it boosted his drought-adaptive capacity: "*During the drought, I sold a lot of plantain and maize since they were scarce at the time, and received a good market price for them*." **Table 3** below outlines pertinent techniques to adapt to drought and to other climate change processes. Two columns are assigned to each adaptive technique, the left represents whether that information source provided information about that type of adaptive technique, and the right represents whether farmers receiving instruction from a specific information source implemented that technique or not. Although within each agricultural information profile, individual farmer implementation was heterogeneous, a checked cell reflects that the *majority* of farmers in that agricultural information profile implemented that certain adaptive technique. Thus, **Table 3** defines implementation as the majority of smallholders in their agricultural information profile reporting that they enacted one of these pertinent adaptive techniques. This table illustrates the discrepancy between receiving agricultural information and its implementation as an adaptive action.

Adaptation in Practice

The Case of Shade Trees

Since cocoa requires shade from other trees higher in the canopy to yield well, this paper prioritizes the maintenance of shade trees

TABLE 3 | Adaptive techniques (columns) as instructed by the agronomic information profiles (rows), and whether those adaptive actions were reportedly implemented by farmers.

	BMPs		Attract pollinators		Crop diversification		Off-farm diversification		CRIG density		Shade tree species		Shade tree tenure		Financial advice		Manual irrigation	
	Instr.	Impl.	Instr.	Impl.	Instr.	Impl.	Instr.	Impl.	Instr.	Impl.	Instr.	Impl.	Instr.	Impl.	Instr.	Impl.	Instr.	Impl.
NCRC	✓	✓	✓	✓	✓	–	–	–	✓	–	✓	–	✓	–	✓	–	–	–
Rainforest Alliance	✓	✓	–	–	✓	–	–	–	✓	–	✓	–	✓	–	–	–	✓	✓
Touton	✓	✓	–	–	✓	✓	✓	–	✓	–	✓	–	✓	–	✓	✓	–	–
No extension	n/a	–	n/a	–	n/a	–	n/a	–	n/a	–	n/a	–	n/a	–	n/a	–	n/a	–

Here, "instr." and "impl." stand for "instructed" and "implemented," respectively.

as a key adaptive action for both environmental stewardship and livelihood provision. Accordingly, four out of the nine adaptive techniques identified as pertinent in **Table 3** relate to shade trees, namely: (i) diversifying into other crops which could shade cocoa; (ii) the Cocoa Research Institute of Ghana (CRIG)—the research division of Cocobod—recommendation of maintaining a density of 16–18 shade trees per hectare (Manu and Tetteh, 1987), to provide canopy cover of 30–40% shade (Anim-Kwapong and Frimpong, 2004; Asare and Ræbild, 2016); (iii) information on shade tree species; and (iv) advice on registering shade trees to strengthen farmers' claims to have rights to their shade trees. Although Cocobod—through its research division, CRIG—does uphold the recommendation of 16–18 shade trees (of about 12 m in height) per hectare, imparting the complex particulars of this recommendation to Ghana's 800,000 cocoa farmers via a limited number of government extension officers is cumbersome at best, and impossible at worst. **Table 3** shows that while the three extension profiles studied do instruct farmers with the CRIG recommendation, farmers are unable to implement it on their farms. While 60% of smallholders suggested that maintaining shade trees was the most effective adaptive technique, only 35% had actually implemented this by planting shade trees in advance of the 2015–16 drought, and proportionally more men than women carried out this anticipatory adaptive action. Furthermore, farmers who planted trees in advance of the 2015–16 drought were less affected both in terms of cocoa production and subsistence crops.

The interviewed farmers in our control group who were only relying on potential Cocobod visits ($n = 5$) knew the least about shade trees. Although these farmers who received no agricultural information beyond maybe receiving some free, sporadic Cocobod advice *did* mention shade trees in their interviews, none of them had planted or nurtured any shade trees on their farms to either cope with droughts or bolster cocoa productivity. Rainforest Alliance officers heavily promote the maintenance of shade trees and forest protection to their cooperative members. For instance, **Table 4** shows that 81% of RA farmers asserted that nursing shade trees is one of the best adaptation techniques against extreme weather events. 70% of NCRC farmers advocated for shade trees' adaptation benefits, and this high proportion could be due to the NGO's conservation mission, and/or the fact that NCRC was for 3 years part of the ECOLIMITS research project that varied shade gradients to determine forest and shade impact on cocoa productivity.

An adaptive, resilient society requires a critical mass of people who value proactivity (Fazey et al., 2010), and certainly amongst the RA farmers interviewed, there was a critical mass who valued the proactive, anticipatory adaptive action of planting shade trees since 69% of them had planted shade trees *in advance* of the 2015–16 drought. Upholding RA's forest conservation founding mission, both the interviewed RA officers and RA farmers were most knowledgeable on shade trees, and were the most concerned with forest protection among the interviewees.

Although the non-RA farmers were less prepared *before* the 2015–16 drought, the experience of suffering through that prolonged and severe drought had pushed one fifth of these non-RA farmers to begin the adaptation technique of maintaining

TABLE 4 | Percentage of farmers—in each of the four agricultural information profiles—who (middle column) suggested that maintaining shade trees is one of the best adaptation techniques, and who (rightmost column) had actually planted shade trees as an anticipatory adaptive action against extreme weather and climate change pressures *before* the 2015–16 extended drought.

Agricultural information approach	State that shade trees are one of best adaptation techniques	Had planted shade trees *in advance* of the 2015–16 prolonged drought
Rainforest Alliance cooperative members	81%	69%
Farmers receiving advice as part of NCRC's research collaboration	70%	25%
Receiving agricultural information through Touton's programme	64%	17%
Control group, relying only on potential Cocobod visits	0%	0%

shade trees in anticipatory defense for future extreme weather events. This uptake of maintaining shade trees following the experience of coping through the prolonged drought was most prevalent among the farmers receiving Touton's agricultural information. However, overall, farmers who had successfully learned about shade trees' drought-resilient benefits and even those who readily extolled shade trees' benefits were not always able to implement that into adaptive action. Some such well-informed farmers did not have the economic means, and/or tenure security to plant and nurse as many shade trees as they wished on their own cocoa farms. The case of shade trees is illustrative of a wider finding—that various contextual factors are critical in mediating the relationship between information and adaptive capacity; these are explored below.

Contextual Challenges to Adaptation

Concern over long-term changes to the climate proved to be low among the farmers studied. Therefore, it is important to include an analysis of socio-economic issues and barriers to adaptation raised through our fieldwork. A third of interviewed farmers were women, who detailed restrictions on their adaptive choices, both on-farm (since their husbands made those choices including crop diversification strategies) and off-farm. Choices for off-farm income diversification are shaped by local supply and demand, but female interviewees described how a more decisive factor is locally-defined socio-cultural norms dictating which alternate sources of income are "appropriate" for women. The two women who had been widowed were unequivocally the most limited in enacting adaptive action on their farms.

Farmers' levels of education, literacy, and numeracy emerged in interviews as socio-economic factors that influence understanding of agronomic information and subsequent implementation of adaptive techniques. Only five of the interviewed farmers had been educated at a level higher than junior high school (JHS), while ten had received no schooling whatsoever (see **Table 1**). Only one quarter of the interviewed farmers could read and write, even though 80% had completed primary school or above[7]. In most cases where a farmer had an advanced level of formal schooling and either partial or full literacy, they described how they had employed more attempts at adaptation to lessen the impact of the drought. Even when our interviewed farmers received extension information, we found that among those with limited formal education, little or none of the extension information had been implemented into adaptive action. The 2015–16 drought negatively impacted the cocoa harvests of nearly all interviewed farmers. But farmers with no, or a low level of, formal education suffered proportionally worse cocoa harvests and subsistence crop harvests during the drought than those who had finished senior high school or tertiary education. We also found that farmers with no education or only primary education tended to employ fewer, and in some cases *zero*, adaptive actions on their farm or in their household to lessen the drought's impact compared to farmers with any higher educational attainment. These results were consistent for Touton, NCRC, and farmers in the control group. Only RA farmers were able to surmount their limited formal education and/or inability to read and write despite the prolonged drought because their RA facilitators had informed them to plant shade trees as an anticipatory adaptive measure against extreme weather events, such as droughts, storms, and floods.

Our relatively small sample of cocoa smallholders limited the feasibility of using simple quantitative analyses to produce statistically-significant corroboration of findings from our richer qualitative data. Nevertheless, quantitative analysis did at least indicate that the socio-economic characteristic that most strongly influenced adaptation to drought was gender. For instance, the average number of reported adaptive actions carried out was 1.36 ($SD = 1.00$) for men and 0.76 ($SD = 1.03$) for women: the difference in the average number of adaptive actions carried out by men and women is statistically significant at $p < 0.05$, based on a one-tailed t-test [$t_{(46)} = -1.95$, $p = 0.03$]. For context, the maximum number of actions reported by any individual was four, and the minimum was zero. More than double the proportion of men reported being aware of planting shade trees as a possible anticipatory adaptive action (45 vs. 18%); these proportions are significantly different, based on a one-tailed z-test ($z = 1.91$, $p = 0.03$). 29% of women and only 6% of men (again significantly different proportions, with $z = -2.19$, $p = 0.01$) reported that 18 months after the end of the prolonged drought, their cocoa production was worse than before the drought. On the other hand, 32% of men reported little ongoing impact or indeed an improvement following the drought, vs. only 17% of women. The latter two proportions are not, however, significantly different ($z = 1.12$, $p = 0.13$). When stratifying responses by education level (say) rather than gender, and repeating all of the aforementioned quantitative comparisons, we found that respondents with no education or primary schooling fared worse than those with secondary or tertiary schooling, echoing the gender results. However, as education level was not in itself binary, our conclusions were sensitive to the fine-grained categorization we used (for example,

[7]This discrepancy highlights the value of collecting multiple variables on related factors associated with information and knowledge.

having separate categories for those with tertiary education and those with secondary education only, vs. combining both into a single category), and observed differences were usually not statistically significant.

Another socio-economic barrier which emerged in interviews was the complexity surrounding land tenure. Land tenure refers to whether a farmer owns their farmland (and thus has the power to implement their own adaptative actions on the farmland), whereas land size is just the area of land they farm, regardless of whether they own it. Relationships between land tenure and land size were not linear. We found that adaptive capacity to the El Niño-induced drought depended more on tenure than on the size of the area farmed which corroborates Antwi-Agyei's, Dougill and Stringer (2015) observation that land tenure arrangements significantly impact adaptive capacity. Farmers who held tenure deeds over their farm performed more drought-adaptive actions and evinced stronger adaptive capacity. Indeed, some of the most land-poor farmers were actually among the most productive and most well-informed about drought adaptive actions. This may be because insecure tenure actually incentivizes productive investments as farmers attempt to increase their security over land. However, further work is required to provide detailed explanation of the causal dynamics between land tenure and adoption of adaptive management practices.

Another tenure issue that impeded desired adaptive action was retaining timber trees to shade cocoa (cf. Hirons et al., 2018b). RA interviewees stated how their cooperative's management assists with tenure ambiguities, which by statutory law belong to the state, by helping them register the timber trees that shade cocoa on their land. While the RA management was the most proactive in assisting its members get on this registry, there were also Touton farmers who reported how their extension agents informed them that registering shade trees can strengthen their claims to have rights to their shade trees.

Other contextual barriers impeding adaptive capacity that emerged from discussions with the smallholder farmers were an inability to farm on wetlands, long distance to an asphalt road, and no access to a bank account or insurance. Our interviews probed each village's relations with Cocobod's extension officers to reveal how receiving information from Cocobod is in practice not universal, but is rather shaped by gender, one's status in a village, and proximity to asphalt road; thus, exacerbating prevailing socio-economic disadvantages. In a single village there were discrepancies between how often Cocobod visited individual farmers. In all villages where such discrepancies occurred, male farmers received Cocobod advice more frequently than female farmers. Across all four extension approaches, male farmers were better placed to receive advice from, and maintain relations with, Cocobod officers. Some village chiefs and senior, respected men reported how they had a contact person at their Cocobod district office whom they could call for urgent farm issues.

Focus group discussants and farmer interviewees unanimously recounted how the prolonged 2015–16 drought resulted in lower yields of both the cash-crop of cocoa and subsistence crops. One adaptation the farmers enacted to cope with the drought's resultant shortage of cash income and food was to diversify by growing maize and subsistence vegetables on wetlands. However, implementing this adaptive action necessitates access to wetlands, and fewer than half of the interviewed farmers could procure wetlands, and even then, they were restricted to short-term leases. The smallholders revealed the reluctance of wetland owners to lease their wetlands, and how rare it is for wetlands to be offered for sale.

DISCUSSION

Climate change is rarely the only stress constraining livelihoods in rural, resource-poor sub-Saharan African communities (Reid and Vogel, 2006; Tschakert, 2007; Bailey, 2017; Cavanagh et al., 2017). Other studies have suggested that reducing climate vulnerability and bolstering adaptive capacity can only be achieved by reducing poverty and socio-economic inequalities (e.g., Smit and Wandel, 2006; Giller et al., 2009; Tschakert et al., 2010). Thus, we set out to test these claims in our interviews by examining pertinent (Smit and Pilifosova, 2003; Lemos et al., 2013), locally-identified (Hirons et al., 2018a) socio-economic indicators, including, *inter alia*: age, gender, land tenure, formal schooling, literacy, and proportion of income from cocoa sales. While agricultural information in our study sites did improve farmers' adaptation to drought, the ability of agricultural information alone to enhance adaptive capacity is limited by socio-economic disadvantages, in particular, gender and lack of formal schooling. Weak adaptive capacity was most pronounced among those receiving zero agricultural information, then among widows, women in general, and those with the lowest educational attainment. Although farmers voiced several climate stressors during interviews and focus groups, the predominate worries that perturbed these famers' lives were socio-economic or structural-poverty challenges, such as failing to secure enough subsistence crops for their family, struggling to pay their children's school fees, caring for sick family members without adequate medical care, or repaying high interest rate loans, e.g., increasing yields and thus incomes, as opposed to more abstract and longer-term climate threats.

Insecure or informal land tenure are frequently identified as significant constraints to the implementation of adaptation techniques to climate change's adverse impacts in Ghana (e.g., Antwi-Agyei et al., 2015; Carodenuto, 2019). Likewise, among our studied farmers, vulnerability to drought and concomitant adaptive capacity to droughts were shaped by tenure arrangements, rather than the size of a farm. Adding to the complexity of tenure arrangements is the fact that naturally-occurring (i.e., not planted) trees are owned by the Ghanaian state as defined by the Constitution of Ghana (Hirons et al., 2018b; Nasser et al., in review[1]). Therefore, perhaps even more than a lack of locally-specific tree species information, significant impediments to practicing the key adaptive action of agroforestry are tenure insecurity (Damnyag et al., 2012; Graefe et al., 2017) and the disincentive that timber concessions could remove shade trees on a farmer's land (Hirons et al., 2018b), possibly compounding farmers' socio-economic disadvantage. Rural Ghana's pluralistic land and tree tenure systems implicitly determine the adaptive capacity of cocoa smallholders by restricting adaptation options. Access to wetlands did improve short-term coping with the 2015–16 drought, but farming on wetlands may compromise the hydrological basin on the wider landscape and thus not bolster long-term adaptive capacity (Hirons et al., 2018a). Thus, while Ghana's climate-threatened cocoa sector requires adaptation, our results suggest that adaptation information alone may not be sufficient and rather poorly-resourced smallholders require support with land tenure issues in order to implement techniques to adequately adapt.

We set out to examine sources of agricultural information available to Ghana's cocoa smallholders provide by the RA/SAN certification scheme, the major cocoa buyer, Touton, and by an NGO, the NCRC, and overall, we found that they all disseminated useful agricultural information. However, at the time of our fieldwork, that information was not overtly framed in terms of climate adaptation[8]. While agricultural information did generally improve a farmer's ability to adapt to climate change, when that agricultural information explicitly spelled out climate threats and advised on feasible adaptive actions, the improvement to adaptive capacity was much greater. For instance, agricultural information that focused on shade tree management boosted the proportion of farmers taking up that key adaptive action, because nurturing shade trees is an appropriate adaptive intervention to the rain-fed, agroforestry context which is currently a low-input, low-output system. Moving toward agro-industrial irrigation is not suitable for farmers tending to small plots, which in our studied sample averaged 6 acres.

There was some evidence of tailoring information to the theme of climate adaptation and farmers seemed to grasp the concepts better when information was presented through relatable and immediately understandable language, such as "*shading cocoa from the sun's intensity*" or through the use of locally-appropriate taboo to prevent over-hunting animals and aggressive felling of trees. Framing adaptation information in terms relatable to farmers could result in adaptive capacity improvement at scale. Given Ghana's very low cocoa productivity (cf. section Study Site Characteristics), agricultural instruction focused on increasing yields could contribute significantly to individual livelihood improvement and wider rural development. As suggested earlier, framing information in a manner that resonates with farmers' lives and daily concerns could also lead to more tangible improvements: interviewees repeatedly expressed enthusiasm when a best management practices (BMP) suggested potential for increased cocoa yields.

In a similar vein, rather than only considering technical information formally imparted to farmers, we included in our study lay knowledge (Engle and Lemos, 2010; Diaz, 2016). An unexpected finding was that pastors and imams in the study area also preached about climate change issues. Indeed, one quarter of female focus group discussants received nearly *all* of their climate change knowledge from a religious leader. The importance of religious leaders in the arena of climate change and adaptation information is still markedly absent from the climate change adaptation literature, particularly in Ghana's cocoa sector.

Our interview questions also asked if and how formal agricultural information was shared between, or transferred to, family members or neighbors, and across generations. Farmer-to-farmer and intergenerational information exchange are readily available, and their utilization does not impose high transaction costs (Feder et al., 2004, 2008); in our study, they proved to be a common resource amongst all four profiles of agricultural information.

Diaz (2016) posits that individuals or communities imbued with the capacity to produce, disseminate, and store information—perhaps with high formal educational levels or efficient communication among producers to disseminate successful practices—have a better ability to understand and predict climate hazards, and to reduce their vulnerability to extreme weather events. Similarly, Codjoe et al. (2013) contend that a farmer's low educational status compromises adoption and use of new technologies, as well as uptake of extension information. Several studies have established a positive correlation between education and farmer's ability to perceive climate change, and the likelihood of technological adoption (Bryan et al., 2009; Gbetibouo et al., 2010; Yegbemey et al., 2013). Corroborating these studies, we found that farmers with zero or only primary school education tended to employ fewer adaptive actions (an average of 1.06 adaptive actions, but in some cases *zero*) on their farm or in their household to lessen the drought's impact compared to those with any higher educational attainment (an average of 1.19 adaptive actions).

Our farmer interviews revealed that infrastructure also impacts adaptive capacity: those living close to asphalt roads received significantly more visits from Cocobod officers. While more asphalt roads could widen farmers' access to agricultural information and essential agro-inputs, further infrastructural development would need to be planned with careful prior assessment of environmental impacts since Ghana's cocoa is grown in an already heavily deforested landscape that sequesters less and less carbon. By some estimates, 80% of Ghana's original tropical forest extent is now an agriculture-forest mosaic (Mayaux et al., 2003; Norris et al., 2010).

Our results on how gender, education, and infrastructure impact farmers' adaptive capacity are consistent with many studies that demonstrate how access to productive resources and adaptation resources are shaped by prevailing social and political structures at varying scales (Bryant and Bailey, 1997; Scoones, 1998, 2009; Ellis et al., 2003; O'Brien et al., 2004, 2009; Bailey, 2017). Thus, reducing vulnerability to climate change and bolstering adaptive capacity must also address the reduction of poverty and socio-economic inequalities (Lemos et al., 2013). Considering that forest-dependent, low-income smallholders are more concerned with immediate socio-economic challenges rather than climate change, research and programmatic interventions must reflect this reality (Nyantakyi-Frimpong and Bezner-Kerr, 2015). Our results echo Harvey's, Carlile, Ensor, Garside and Patterson (2012) warning that focusing only on information provision to

[8]In 2018, the Rainforest Alliance (RA) merged with UTZ. In December 2018, RA and UTZ together launched the first round of public consultation for the new standard. This public consultation process may lead to climate adaptation featuring more heavily in later certification criteria and principles.

build adaptive capacity is inadequate. Drought-adaptive and sustainable cocoa policies could be more effective and could sustain into the future if devised within the context of broader socio-economic interdependent stressors that dominate cocoa smallholders' concerns.

In concluding this discussion, we may note that because this study only examined adaptation as farmers reported it, in future it may be worth observing adaptive actions on farms and even monitoring actions longitudinally. Another possible limitation of this study is that a given famer may have reported an activity consistent with adaptation, such as maintaining a shade tree, but may have done this for a number of reasons, and not necessarily adaptation as academic science defines it.

CONCLUSION

This paper focused on agricultural information as a potential determinant of adaptive capacity since few empirical analyses single out information provision or agricultural extension to either evaluate their role in shaping adaptive capacity or assess whether agricultural information provision is a socially differentiating factor for adaptive action. We examined four sources of agricultural extension in Ghana's cocoa sector and how the information provided through these (i) shaped the adaptive capacity of cocoa smallholder farmers during the 2015–16 prolonged drought and (ii) shapes anticipatory adaptive actions to prepare for future droughts and higher temperatures. Overall, we showed that the agricultural information disseminated by agricultural extension in our study sites *did* improve farmers' adaptation to drought. This was particularly evident in the fact that the adaptation deficit was most acute among those farmers who received zero formal agricultural information.

However, we also stressed that the ability of agricultural information alone to enhance adaptive capacity is compromised when socio-economic challenges and existing structural poverty are not taken into account. We highlighted the divergence between exposure to agricultural information and the implementation of adaptive action by illuminating some of the barriers that prevent cocoa farmers from enacting their desired adaptation. As our study detailed adaptive techniques which smallholder farmers themselves identified and suggested, these techniques could thus be potentially replicated by other cocoa smallholders and with the right support they could reach significant scale. However, many of these techniques were low-change adaptations akin to short-term coping, rather than transforming to robust 'climate-smart' cocoa strategies to sustain cocoa production for future generations, such as overcoming tenure issues to nurse more shade trees, effectively rehabilitating aging trees, or even changing to more drought-resistant cocoa varieties.

We also noted the importance of formal information channels that advise (i) specifically on feasible adaptation techniques, (ii) in relatable language that is relevant to cocoa smallholders, and (iii) in a way that resonates with their urgent livelihood considerations. We demonstrated that shade tree management, for instance, is an adaptive intervention that meets all three of the aforesaid criteria in Ghanaian cocoa's rain-fed, low-input, low-output smallholder system. Our study shows that adaptation-specific information advising on locally-appropriate and feasible techniques, disseminated in a manner suited to a farmer's level of educational attainment, can serve to inform on extreme weather events, change smallholders' attitudes and lead to adaptive actions. Embedding climate change adaptation advice into mainstream and larger-scale extension programmes could narrow the adaptation deficit in Ghana's cocoa sector, and thus protect cocoa smallholders' livelihoods.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Oxford's Central University Research Ethics Committee (CUREC). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

VM-R and KK conceptualized the paper's ideas, formulated the research questions, guiding objectives, wrote the semi-structured interview guide, and conducted the interviews together, with VM-R leading both the interview process and field logistics. MH was involved with some of the early conceptualization in his role as one of VM-R's doctoral supervisors. VM-R analyzed the data, and thereafter critically discussed the interpretation of the analyzed data with both KK and MH. VM-R led the writing of the manuscript. KK contributed the writing and editorial feedback to each iteration of the manuscript, and MH contributed significantly to the final few drafts.

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