Climate-smart, sustainable cocoa: challenges and opportunities in Brazil and West Africa

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Summary

Brazil, Ghana and Nigeria are all major producers of cocoa (from *Theobroma cacao*). Yields in all three countries are threatened by climate change, particularly in terms of its impact on rainfall patterns. This further interacts with other pressures (e.g. pests and diseases, impact of illegal mining, and ageing tree material, among other factors) to put future crop yield at risk. Ensuring that cocoa production remains stable and sustainable in these countries requires changes along the value-chain. There are various stakeholders who have capacity and interest in contributing to solutions, including farmers themselves, alongside public sector researchers, agri-tech companies and related industries, chocolate/confectionary companies, and a range of NGOs. At the moment, Nigeria has the lowest average yield per hectare. Brazil has a hi-tech arable sector with many innovations that should be explored for suitability to cocoa and other fruit systems.

Background

The global production of cocoa is around 4.5 to 5 million metric tonnes per year. While the largest producer of cocoa, by a considerable margin, is Cote d'Ivoire, Ghana comes in second, with Nigeria and Brazil in fifth and sixth place respectively (FAOSTAT 2024) (Fig. 1.1). In 2023 a serious harvest failure affected many parts of West Africa, meaning both Nigeria and Ghana saw lower nationwide production than normal, and combined with other factors, sent prices soaring to 5-6x normal levels. The 2024 harvest initially showed some improvement but prices remain high due to weather later during the harvest season in West Africa casting uncertainty on total yields.

Brazil was previously a much larger producer of cocoa, but historical outbreaks of witches' broom disease depressed production for many years. The cocoa sector in Brazil is now recovering from this, with production showing potential to increase again.

Cocoa is native to the South American Amazon area, but is an introduced plant in West Africa.

Country cocoa profiles

Brazil

Annual production: 220k t/year

Yield: 400-500kg/ha on most farms

Main varieties: Forastero, Trinitario, new hybrids

Main markets: Japan, USA, Canada, Europe

Big challenges: Witches' broom (some regions), frosty pod, climate change, cocoa demand > supply.

Outlook: Stable production, recovering from witches' broom, with scope to increase.

Ghana

Annual production: c. 600k t/year

Yield: 500-600kg/ha

Main varieties: Hybrid, including Trinitario, Nacional, Amazonia

Main markets: USA, Europe, Asia

Big challenges: Climate (rainfall), ageing trees, labour, pests and diseases, galamsey (illegal mining)

Outlook: High chance of future crop failures/poor harvests.

Nigeria

Annual production: c. 270k t/year

Yield: <300kg/ha

Main varieties: Amelonado, Trinitario

Main markets: Europe, East Asia

Big challenges: Climate (rainfall), ageing trees, labour, pests and diseases

Outlook: Low and potentially declining yields but interest in improvement.

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Fig. 1.1 Total production of cocoa in "big six" cocoa-producing countries, 2022-23 and 2023-24 (source: FAOSTAT 2024). Ghana's highest production year was 2021-2022, with over 1000k tonnes produced nationwide; considerably less was produced in 2022 onwards.

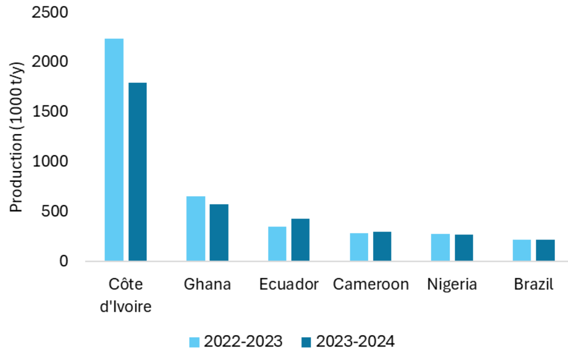
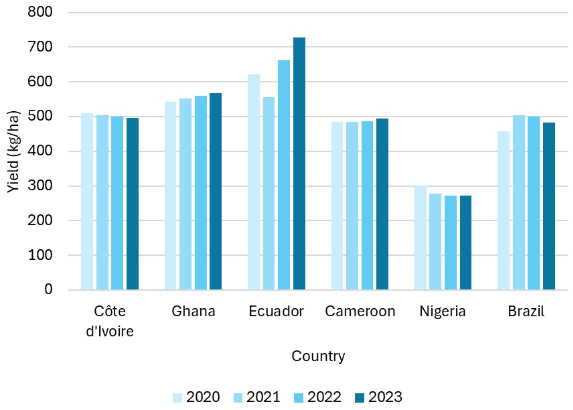


Fig. 1.2 Yields per hectare of cocoa from monitored farms the "big six" production countries. Well-managed farms in other parts of the world can regularly produce 1000-2000 kg/ha or more. While Ghana ostensibly shows a rise in yield per hectare in 2023, many regions suffered near total crop losses that year. Source: FAOSTAT (official figures for Ecuador/Brazil, estimates for other countries).



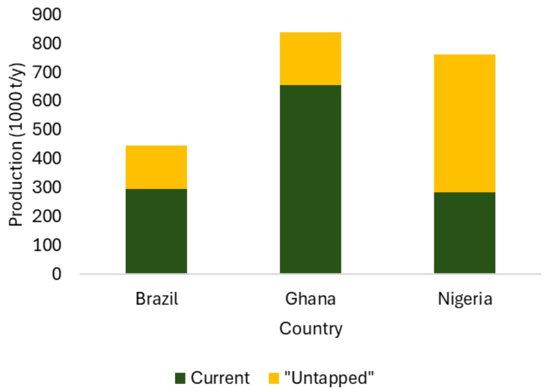
Poor yields

Across all three of the target countries (Brazil, Ghana, Nigeria), yields per hectare are very low (<600kg/ha typical) (Fig. 1.2). According to FAOSTAT, some countries (e.g. Thailand, Guatemala, Fiji) regularly produce yields in excess of 2000 kg/ha (FAOSTAT 2025). Modern farms in Costa Rica reliably achieve around 1500 kg/ha (Ritter Sport, Choco-Tec).

Untapped potential

Cocoa production is a huge contributor to deforestation. With such poor yields among many of the major production countries, there is considerable incentive to expand land areas into natural forest remnants, especially while cocoa prices remain high. The EU Deforestation Regulation (EUDR) requires cocoa to be sourced legally and deforestation-free by 2025-2026[1]. Meanwhile, to meet continuing demand, either area under cultivation, yield per hectare, or both need to increase. Recorded yield deficits imply there is considerable headroom to increase cocoa yield per unit of land area. If Ghana, Nigeria and Brazil increased their mean yields to the level typical of Ecuador (another "top 6" producer) (e.g. 727 kg/ha), that could collectively add at least an additional 800,000 tonnes of cocoa to the world supply using current land area (around 2.8m ha) (Fig. 1.3).

Fig. 1.3 Untapped potential; the additional total annual production for each country that could be possible if yields were increased to around 727 kg/ha in all three cocoa-producing countries.



[1] [Regulation on Deforestation-free products European Commission]

High cocoa prices: the good and bad

Cocoa prices in 2024-2025 were extremely high, up to 4-5 times historical averages. This has presented many challenges, and is a spark-point between farmers and government in countries where the government is the major buyer and farmers feel they are not benefiting from high prices. Conversely, the benefits in some regions (especially Brazil) is that farmers have the potential to take small risks and innovate to improve production, as even small gains will pay handsomely. More permissive markets and systems that enable quality to be rewarded with higher prices paid to farmers particularly incentivize them to try new approaches and technologies.

On the flipside, increasing prices can also drive parallel increases in the cost of inputs and labour as the wider market reacts, so the benefits to farmers in some regions are limited by the higher production costs. The impact of high prices on rates of deforestation is also not fully understood at this time.

Cocoa farmers

Most Ghanaian and Nigerian farmers work on 1-8 ha farms (Adebayo et al. 2022; Umeh et al. 2022) and have limited access to credit and agricultural inputs. Larger farms do exist, and professionals may own family land used for cocoa cultivation (but this may be far from their home/work and so active engagement of such owners in day-to-day farming is sometimes limited). Conversely, Brazilian farmers vary from small-scale to large scale, and the vibrant agri-tech industry and high levels of mechanization in other crops present an opportunity.

Agronomic practice varies greatly. In West Africa, cocoa monocultures are common, but some farmers nonetheless favour agroforestry type approaches with other trees providing shade for the cocoa. This can buffer environmental variability and produce additional marketable products (e.g. fruit). In most of Ghana and Nigeria, trees are arranged relatively haphazardly and grow to 3-4 m high, meaning mechanization potential is currently limited. Agroforestry is more common in Brazil (particularly Bahia state), for example, under acai, cupuaçu (another *Theobroma* species), and rubber trees. In the state of Bahia, a traditional "cabruca" agroforestry system involves growing cocoa under native and other agriculturally-valuable trees. Previous studies in each country indicate that many farmers use high levels of insecticide to manage pests, but that efficacy of these products can vary.

While training is often extensive, uptake of new techniques and technologies can be variable, often due to lack of support and a high ratio of farmers to extensionists/agronomists. Private extension services may be rated more highly by farmers (Tham-Agyekum et al. 2024) but cost can be a barrier to access. Demonstration farms have been considered effective by some studies (Aniagyei et al. 2024) in promoting best agronomic practice, but anecdotal evidence is more equivocal.

During the Scoping Project, the authors were able to meet farmers in Brazil and Ghana, and discuss issues and priorities. Pests and diseases were mentioned extensively by the 16 farmers from Ghana as a priority concern; biopesticides were of interest but pricing was a barrier. The farmers also highlighted contradictory information, e.g. about managing pests but preserving pollinators, clearing cocoa pods to reduce black pod, but being encouraged to retain them as breeding sites for pollinators.

Fact-finding and data gathering approaches

Rapid survey

After ethics approval within Niab, a 12-question survey was distributed via social media, mailing lists and direct e-mails to our extended network. It was also linked via QR code from our poster at the international Choco-Tec congress held in Germany in December 2024. This provided a broader overview from diverse stakeholders on their views around cocoa and climate change.

We received 32 responses across the versions of the survey.

Workshops

Two online workshops further explored key issues and allowed networking among individuals from different countries and specialisms. The first was oriented towards production issues, the second towards processing, but both had scope to cover all key cocoa areas for discussion.

Time was allocated to discuss technological, management and infrastructural solutions to enhance climate resilience in cocoa. There was also a dedicated to allowing small and medium enterprises (SMEs), non-governmental organisations (NGOs) and other initiatives to introduce themselves and their areas of interest.

Workshops were advertised via social media, mailing lists and direct mails to those who had expressed an interest, and were handled via EventBrite and Zoom, with interactivity provided by Mentimeter. Overall, 52 attendees across the two workshops represented a wide range of specialisms (Fig. 3.1), with several being farm owners.

Breakout rooms enabled more of a "deep dive" into specific areas such as IPM, farmer communications, etc.

One-to-one/small group discussions

We held scheduled and unscheduled discussions with around 20 cocoa experts from various countries (Fig. 2.1), and across the value chain (Fig. 2.2, 2.3) to consider sustainability issues, challenges and potential solutions in more depth. Participants were identified at an industry conference (Choco-Tec), from LinkedIn discussions, via directly contacting experts, and during visits to Brazil and Ghana. We aimed to have discussions with a range of industry and academic experts with different expertise and interests.

Overview of cocoa professionals interviewed formally/informally.

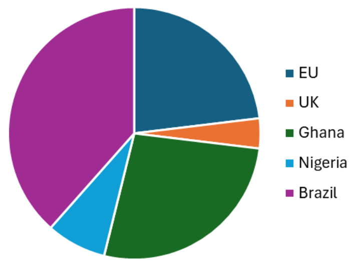


Fig. 2.1 Country or region where the professionals were based.

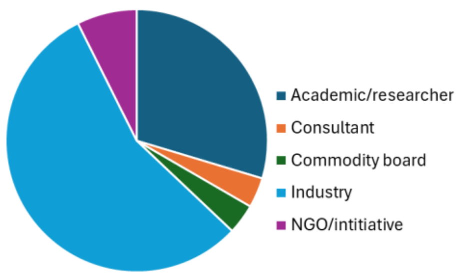


Fig. 2.2 Sector from which professionals originated.

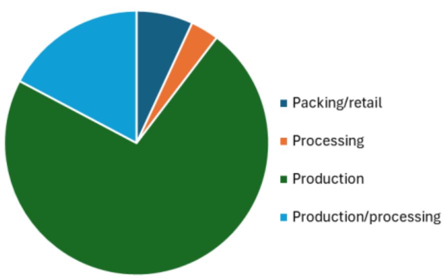


Fig. 2.3 Point in value chain in which professionals had expertise/interest.

Survey responses

The survey had a spread of respondents from across the three focal countries and from other countries (Fig. 3.1a). While most respondents were involved in research as at least part of their role (Fig. 3.1b), a sizeable minority (25%) participated in cocoa farming themselves to at least some extent, and 16% were agronomists (whether in research or practice). There were participants from the public and private sector, and also some from third sector (charity/NGO) and other backgrounds.

All agreed that climate change was affecting cocoa production and/or processing in their country. While the nature of these effects were diverse, the most commonly selected responses had to do with rainfall, specifically droughts or reduced mean rainfall (72% of respondents), and erratic rainfall (56%) (Fig. 3.2a); higher temperature extremes was also viewed as a major impact by 66% of respondents. However, others also named flooding and excess rainfall, extreme weather events, and unseasonal cold as important factors. While rainfall- and heat-related impacts were prominent among experts from all three countries, only Brazilian respondents emphasised extreme weather events, and only Ghanaian respondents selected unseasonal cold as an important consideration.

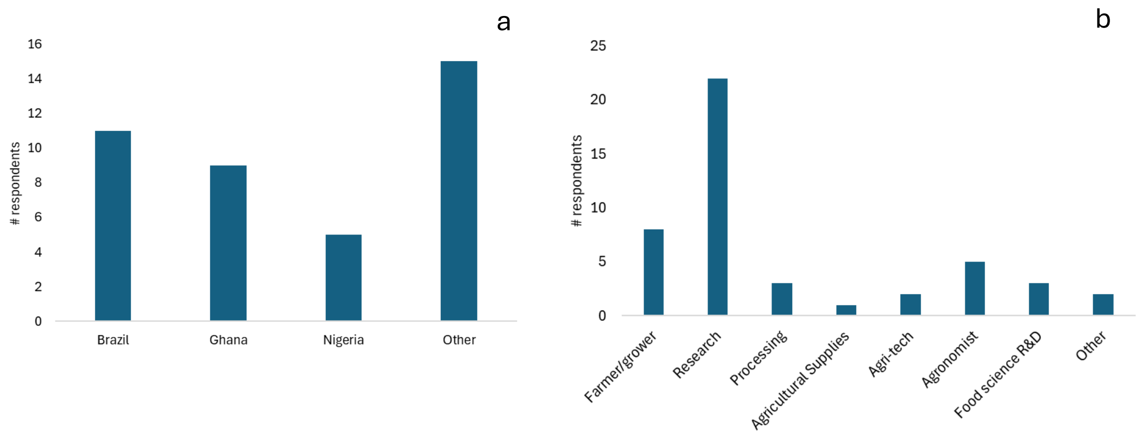


Fig. 3.1 Survey responses by (a) country of expertise (some respondents had multiple countries of experience) and (b) sectors of expertise/professional experience.

The questionnaire asked respondents to select up to five areas they felt needed more research and innovation investment. Overall, production-related areas dominated, which may reflect the networks in which the authors have the most contacts, although we endeavoured to reach out as widely as possible. The commonest answer was integrated pest, pollinator and disease management, selected by around two-thirds of the survey respondents (Fig. 3.2b). The next most common answers were breeding and new variety development, and wider climate resilience, implying that climate-smart cocoa systems require research investment both in terms of improved planting material as well as integrated resilient growing systems.

Survey responses (continued)

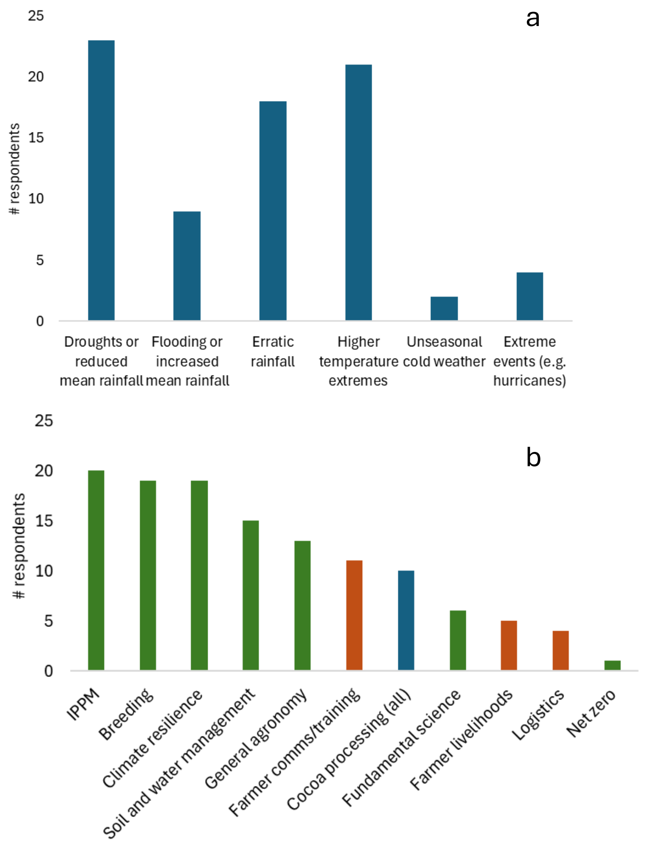


Fig. 3.2 (a) Perceptions of how cocoa production is being affected by climate change, across all respondents; (b) Priority research areas across the respondents. Colour coding: green = production aspects; blue = all processing; orange = social and economic aspects.

The respondents were also provided with free text boxes to state their opinions on major challenges and issues in their countries of expertise. Among the Brazil-based respondents, disease (*Moniliophthora perniciosa*, witch's broom and *Moniliophthora roreri*, frosty pod) were mentioned frequently. The responses from all countries discussed pests and diseases extensively. The Ghanaian respondents also mentioned galamsey (illegal mining) in several cases.

There was optimism in responses, with other themes including the potential of certification schemes (e.g. Fairtrade, organic and Rainforest Alliance) to improve conditions for nature and people, and the opportunities presented by new agri-tech. More than one respondent mentioned the research sector as having an important role to play.

The socioeconomic context was also widely discussed among respondents in all countries, such as ensuring uptake of new innovations and improved practice and ensuring farmers have access to

Workshop attendance

The workshops were attended by a variety of professionals (Fig. 4.1) from all countries in the Scoping partnership, and representing public, private, third and academic sectors.

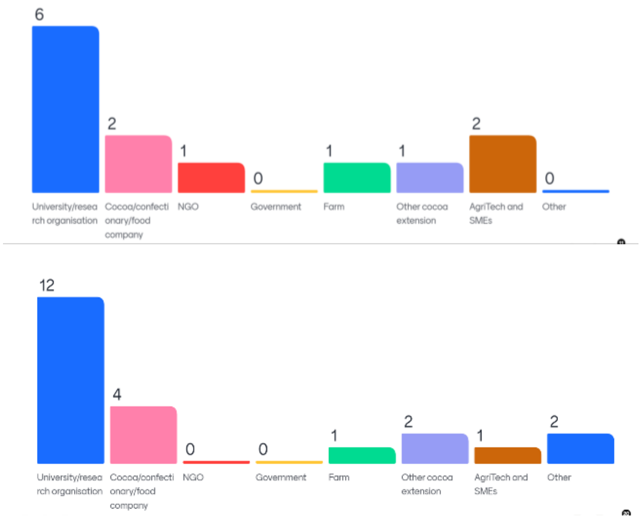


Fig. 4.1 Responses to question, "What type of organization do you work for?" from attendees in sessions.

SME/NGO pitches included digital agriculture providers, companies creating value from waste/by-products, and many organisations working directly with farmers.

There was an overwhelming consensus that cocoa production was being adversely affected by climate change in all three focal countries. Droughts were particularly mentioned.

Discussion also reflected on issues around pests and diseases, and information flow to farmers.

In terms of processing, there was also a strong feeling that climate change was important but more respondents indicated uncertainty or nuance in their answers.

The impact of climate change on production was mainly considered to involve the effects of erratic rainfall, and subsequent impacts on soil (Fig. 4.2a) (e.g. via leaching and erosion). Processing was more affected by reduced yield of material entering processing streams (Fig. 4.2 b).

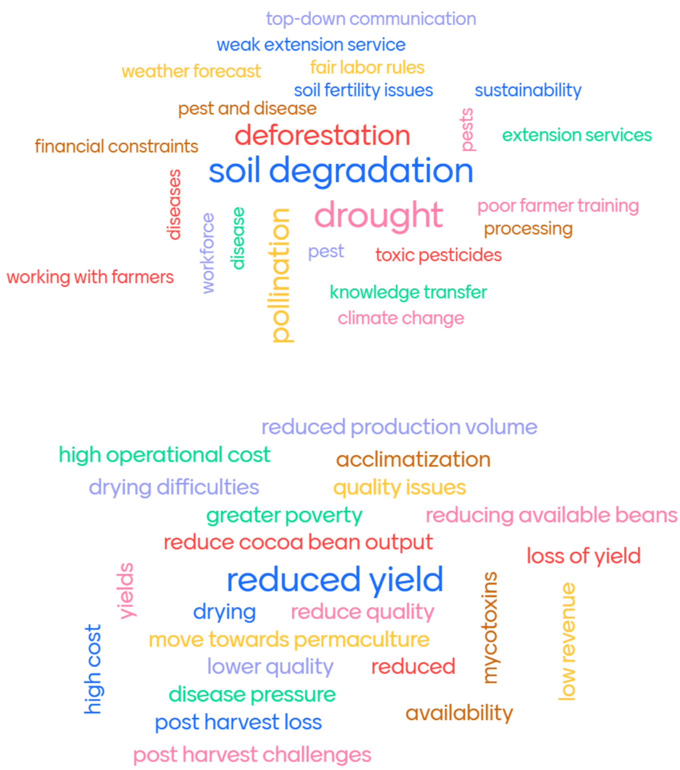


Fig. 4.2 Word clouds based on workshop responses to questions around (a) the major challenges limiting sustainable production of cocoa and (b) the major ways that climate changes affect cocoa processing.

Findings: Overview of Issues

Climate change is affecting cocoa in various ways. The primary concern is the effect on rainfall patterns (e.g. droughts, rains coming late, excessive rain); the West African cocoa crop failure of 2023 is a striking example, sending prices up to 4-5 times normal prices on global commodity markets. Recent literature has also highlighted heat stress as a risk in some regions (Lander et al. 2025).

Other challenges raised in workshops, one-to-one and small group discussions, and via questionnaire included:

Pests and diseases—Black pod (oomycete) is common to all three countries. Consensus among production experts is that the risk is raised where humidity is high (Thorold 1952) and airflow poor, e.g. in the wet season and under heavy shade. However, those involved in dynamic agroforestry felt that the diversified environment mitigated this risk. Witch's broom (fungal) and frosty pod rot (also fungal; both caused by *Moniliophthora* species) is a problem in Brazil but not West Africa; CSSVD (cacao swollen shoot virus disease) (insect-vectored virus) is a problem in Ghana and to some extent, Nigeria.

Heat and drought—Climate change has led to some exceptionally hot, intense dry seasons (especially in West Africa), with unpredictable rain and heat extremes. Drought is a known stressor for cocoa; heat has been understudied in terms of its importance to cocoa and the organisms with which it interacts (e.g. pests, pollinators), but new evidence suggests that heat stress can affect tree health, pollen viability, and other factors important to crop production.

Education, dissemination and outreach—While all three countries have extension and agronomy support and training available through different means, follow-through and uptake among farmers can vary. There is a gap to bridge between knowing what farmers "should" be doing, and translating this into a change in practice. In Brazil it has been flagged that current high cocoa prices mean farmers have a strong incentive to innovate and seek yield gains; this may be stifled somewhat in Ghana where prices are centrally-controlled.

Soil health—Cocoa farms' soils are frequently in poor condition and few inputs are being applied to ensure health is maintained. Fertiliser may be used rarely in some regions, and custom formulations optimized for cocoa based on best evidence are not always available in parts of West Africa. There are controversies over the trees' need for nitrogen, and flooding may cause leaching/erosion.

Planting material—Because issues with inconsistent rainfall, heat/drought, and diseases will persist into the future, there is high interest in planting new cocoa varieties/clones resilient to these challenges that also produce high yields. Availability of planting material, and evidence-based recommendations, can be limited. This is discussed more extensively in the report from the parallel scoping project *Development of a UK, Ghana, Nigeria, and Brazil network on cocoa improvement* led by the University of Reading.

Pollination—Some farmers (especially in Brazil) have expressed an interest in receiving more information on pollinators. Recent studies show that yield can be increased (at least in the short term) through hand-pollination, but this process is laborious and difficult to implement. Increasing pollinators may lead to more pods, but the relative importance of different pollinator taxa in different countries and agricultural systems is poorly understood.

Galamsey—Illegal mining (especially for gold). This is a particularly large problem in Ghana. This can take the form of both non-consensual damage to farms (e.g. by direct damage to the farmland making new mines, or indirect, via contamination and changed hydrology from nearby mines), and by farmers being pressured to sell their land for short-term cash, but consequently losing out on the benefits of long-term production.

Major challenges facing the cocoa sector that may worsen under climate change

Challenge	Interaction with climate change	Countries affected	Possible solutions
CSSVD	May be aggravated in conditions that promote proliferation/migration of mealybugs	Ghana, Nigeria	**Diagnostics** (under development) **Forecasting** and **monitoring** Consistent **crop compensation** to incentivize control Vector management strategies (effective **pesticides** and **biocontrols** as part of an **IPM approach**; barrier crops/vegetation)
Black pod disease	Can be worse at high humidity and in heavy rainfall	Ghana, Nigeria, Brazil	Research needed (spread and risk factors; tradeoffs). **Biopesticides** and **biostimulants** for control. Long term: **redesign of farms** to make sanitary measures easier to implement, improve air movement and reduce humidity; diversified farms to reduce spore spread
Witches' broom	Spores need water to germinate, so can be affected by rainfall patterns.	Brazil	**Breeding** for resistance; biosecurity. Cultural management (suitable pruning, tree spacing).
Moliniasis (frosty pod)	Increased infection in warmer, wetter weather?	Brazil	**Breeding** for resistance; biosecurity (avoiding transfer of infected material between farms).
Weed control	Weather conditions may favour weed growth and make removal more difficult	Ghana, Nigeria	Short term: **products** and **tools** to make weed removal easier (**bioherbicides** and **mechanical** or **electroweeding**) Long term: **redesign** of farms to improve access for machinery
Pollination	Pollinator populations may be impacted directly by drought periods, and indirectly if high pest pressure leads to pesticide overuse or more	All	**Hand pollination** (using contractors/trained farmers) and **mechanical pollination** (potentially tractor-mounted blowers) are being increasingly explored where expertise and

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	vigorous vegetation/habitat clearance.		resources are available. Natural pollination could be supported by **managed pollinator** releases or potentially **semiochemical** lures.
Galamsey (illegal mining)	Land sales become more appealing when farm is not profitable; once galamsey increases in a community, more farmers are likely to sell or be indirectly affected	Ghana	Improved yields making selling land less inviting. Diversified farms (e.g. **dynamic agroforestry)** reduce income variability. Regulations/ enforcement. Community organization (potentially supported by **digital technology**) may reduce vulnerability.
Access to credit	Erratic weather leading to unreliable income can affect farmers' willingness to take on financial risks	All	**Microfinance** initiatives. Long term: redesign of farms (e.g. dynamic agroforestry) to reduce income variability.
Information flow and uptake by farmers	Erratic weather can affect farmers' willingness to take risks by trying different practices	All	Improved methodology in training (e.g. enhanced farmer field schools and farmer research networks to engage in a more participatory way). Novel information sharing methods, e.g. **mobile phone technologies** and **agronomy helplines**
Drought	Becoming more frequent as climate warms	All	Selective breeding programmes. Agroforestry, shade trees and soil health management will reduce vulnerability to drought **Irrigation** (appropriate to environment; can include solar-powered and low-tech approaches) mitigates drought but is only possible if a water source is available and a way to transport the water
Flooding and excess rain	Incidents of flooding and exceptional rain are becoming more common	All	**Agroforestry** and soil health management will reduce flooding and protect trees from heavy downpours

Soil erosion and degradation	Aggravated by high rainfall/flooding.	All	**Agroforestry** and soil health management will reduce flooding and protect trees from heavy downpours. Soil health amendments such as **biostimulants** and organic matter (potentially including **biochar**) can help to protect soil.

Gender and social difference

Cocoa agriculture is male dominated (e.g. in Ghana around two thirds to three quarters of farmers are men – Tham-Agyekum et al. 2024, Frimpong et al. 2025, Owusu et al. *in prep*), though possibly to a lesser extent in Brazil. These may represent underestimates of those involved in working on the farms, as women may work alongside their spouses without direct land ownership. Women farmers may have less knowledge of certain techniques and inputs (Owusu et al. *in prep*), and may have lower adoption of certain sustainable agriculture practices (e.g. shade tree use, IPM implementation – Frimpong et al. 2025). They may lack access to credit and financial capacity to invest in new technology.

It has been recommended (Tham-Agyekum et al. 2024) that extension services should be better-tailored to the needs of women farmers. It was also raised in some of our meetings that women farmers may particularly benefit from introduction of labour-saving devices such as mechanical or electro-weeders. However, it is important to explore whether women and other disadvantaged groups would also be those least able to afford technologies that may benefit them.

Alongside this, many employees in agri-tech across the three focal countries are men. In our meetings and workshops, most professionals we met were men. Supporting female leadership in agri-tech may also facilitate engagement by women farmers with agri innovation.

Most cocoa farmers are older (mean age is often 40-60 years old), with younger generations often leaving the sector. This can also limit ability to adopt certain techniques such as hand-pollination, as this is precise work that may be carried out in poor or patchy light, and so can be challenging for farmers with poorer eyesight.

Land and tree tenure/ownership may limit the pace of change, when the landowner and tenant farmer, or farmer and owner of the non-cocoa trees on a farm, disagree on the management approach to adopt. Issues around sharecropping, tenant farming and land tenure often have disproportionate negative impacts on women (e.g. Addaney et al. 2022).

Gender and social difference are already included in programmes of work, e.g. Mondelez's CocoaLife, often within sub-programmes related to livelihoods and reduction of exploitation in supply chains.

Solutions: Overview of Technologies

Various innovations could make a big difference to the production of cocoa. These particularly include digital technologies, labour-saving devices, better harnessing of ecosystem services (i.e. nature-based solutions), hand (manual) pollination, and improved biocontrol.

Digital technologies have considerable potential where farmers have access to smartphones—**mobile-phone based support services** with access to call centres provide a range of services and can be accessed from more basic devices. Particularly useful support services for farmers can include phone-based and online agronomy advice, **pest and disease forecasts** (e.g. the platform Strider[2], developed in Brazil and more recently acquired by Syngenta), **weather** and **market information**. In communities where smartphone penetration is poor (e.g. Nigeria, Ghana), issuing some members of a community with tablets can facilitate this. Many digital decision-support companies have local staff to back up the online support. These services have additional potential to integrate with remote sensing data (e.g. satellite imaging of crop health), and as a **dissemination tool** where recommendations are updated or new techniques developed for e.g. pruning or pest management.

The increasing age of cocoa farmers and sometimes limited availability of hired assistants (Fernandes Nogueira et al. 2019) means there is interest in approaches to **reduce physical labour** on farms, but this needs to be affordable and practical - large tractors cannot access most smallholder farms, especially if roads are small or in poor condition (worsened in some areas of Ghana by galamsey). There may be possibilities in mechanical **weeding** devices and even electro-weeding (weed control via bursts of high-voltage electricity) but these need to be suitable. Electro-weeding already is a proven technology in Brazil but is mostly used in arable farming (Landers et al. 2016).

Similarly, solar-powered **irrigation devices** and other methods of delivering water to plants during the dry season are worthy of investigation for suitability and acceptability. There was discussion of this in several one-on-ones – it was raised that this was only a reliable strategy where a fresh water source was available. In farms far from rivers and lakes, either long-term storage or a borehole may be necessary, and not all farms have the capacity to make a borehole. Even where surface freshwater is available, excessive abstraction for irrigation can cause other problems.

Nature-based solutions can include adoption of higher shade levels and integration of multipurpose shade trees into farms, including as part of an **agroforestry** system. The species and species combinations of shade trees that provide optimum services (including: income resilience via alternative crops; drought resilience; shade; protection from pests and diseases; sources of firewood; sources of non-timber forest produce; habitat provision for beneficial biodiversity) is not fully mapped. This can form part of a new shade system (e.g. dynamic agroforestry) or involve most efficient use of traditional systems (e.g. Brazilian cabruca).

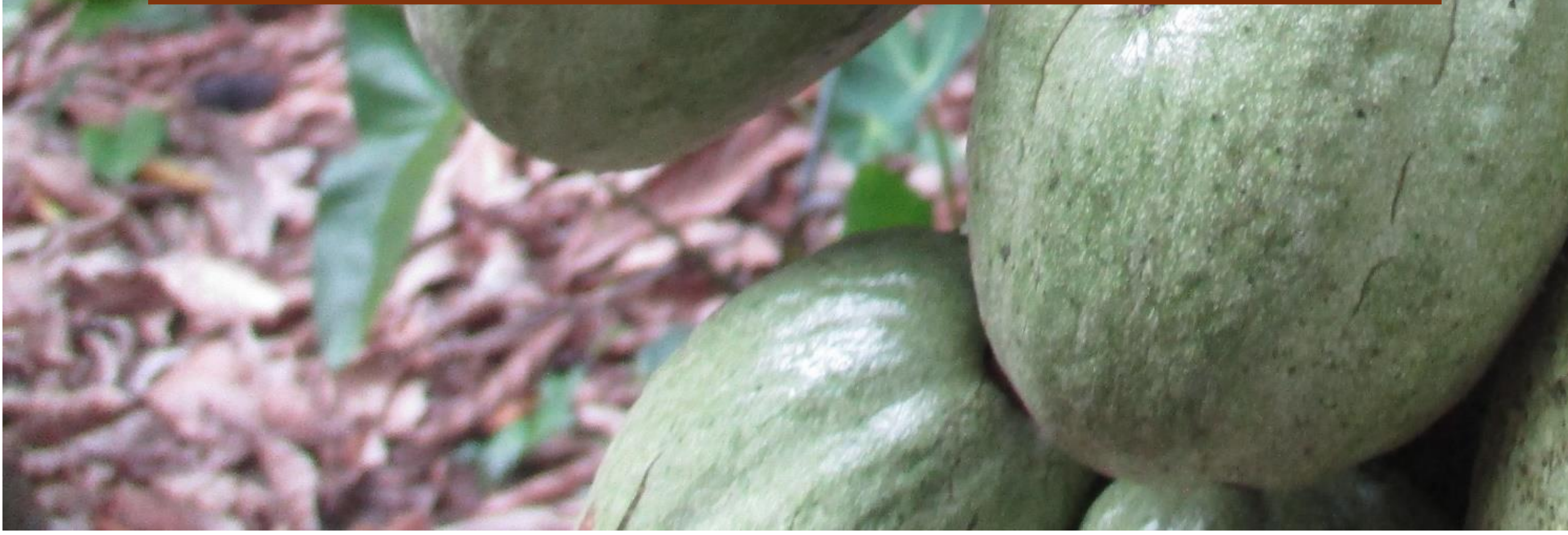
Hand (manual) pollination has been demonstrated to be cost-effective in several countries (including Brazil, Indonesia), requiring intensive labour but providing large yield gains in the short-to-medium term. There is a national program in Ghana but farmers report a mismatch between what is promised and what is observed. In Brazil, there is investigation of **mechanical pollination** (e.g. air blowing) from tractor apparatus. Historical literature (Glendinning 1972) supports the principle that this may have efficacy under some circumstances.

New technologies and innovations of relevance to climate-smart cocoa

Technology	Supplier	Countries with particular concentrations of capacity	Purpose/application
Bioinsecticide (including neem seed/leaf extract and derived products)	Various, e.g. Neem Crop Protector, Prime Gold	Brazil, Ghana, Nigeria	Control of pest issues. Efficacy against some diseases...?
Bioinsecticide (entomopathogenic fungus)	e.g. Koppert, Andermatt, etc.	Brazil Research development in Ghana, e.g. at CRIG	Control of pest issues
Bioinsecticide (entomopathogenic nematode)	e.g. Bionema	UK	Control of pest issues
Commercially-bred beneficial insects	e.g. Koppert, Staphyt	UK, Brazil	Control of some pests; parasitoid wasps potential pollinators but mass-release has not been tested
Smart pest monitoring	e.g. Tarvos, Rentokil	UK, Brazil	Early-warning pest monitoring to enable more effective IPM applications

Shade trees – nursery stock	e.g. Primal Group	ALL	Availability of specific tree types varies by region. Appropriate use of shade trees can reduce pest and disease risk, mitigate against drought impacts, reduce flooding and soil erosion, and provide additional income.
Biostimulants and soil amendments	e.g. Bionema, Humic Growth Solutions, Vittia	ALL	Some may help with disease control; mitigates drought; in some parts of the world may also reduce cadmium contamination; reduces soil erosion.
Digital farming tools	e.g. esoko, icrop, Strider, Agronow, Sensix, ClimateFieldView, Omnia Hub	ALL	Various apps provide decision-support, pest and weather forecasting, agronomy advice, plant health clinics, market information, etc. However, many are only fully usable to farmers with smartphone access.
Solar-powered irrigation technology	e.g. Nimsy Agro Solar, FOB Engineering, Havenhill Synergy	Nigeria, Ghana	Provides water access (in some areas/systems) during dry season.

Internet-of-things (IoT) and environmental sensors	e.g. Galembetech	Brazil	Enables precision monitoring of growing conditions to allow efficient resource use and rapid responses to change.
Microfinance initiatives	>1000 suppliers. Examples: Nagro, Terra Magna, Agrolend, Stegenor, Alphamaga, Afro-Arab Microfinance, LAPO, etc.	ALL	Enables farers to invest in new tools, technologies, planting material and inputs.
Dynamic agroforestry farming system **Cabruca farming system**	An approach – promoted by e.g. Sankofa in Ghana. Cabruca is traditional in Bahia (Brazil). Both approaches have similarities (use of shade trees and integration of diverse vegetation to provide ecosystem services) but also differences. (Cabruca uses a higher percentage of natural forest trees and vegetation, and may tolerate more understorey.)	Dynamic agroforesty – Ghana Cabruca – Brazil	Reduces risk of pests and diseases, reduces vulnerability to drought, mitigates income variability. Potential for expansion (wider application in Ghana/Nigeria of DA; expansion of cabruca systems to western Amazon region of Brazil)



Key stakeholders: overview

At the centre of cocoa production are farmers, large and small scale. These are often organized via cooperatives and farmer associations of varying size. They receive information via these associations, and also via extension services (both public and private), as well as via peer-to-peer discussions. They may also receive advice directly from researchers. Private extension services can be highly innovative, using diverse tools and media to provide information and support, and there is high potential for these as dissemination tools for transformational change.

Many of the major cocoa companies have schemes and initiatives around promoting more sustainable cocoa, working with farming communities. This can include further extension services.

Farmers require a variety of inputs and equipment for their farms, depending on their ability and willingness to pay. While some inputs may be government-supplied or subsidized (e.g. fertilizer and pesticide in Ghana), varying availability means farmers usually also purchase some themselves. Agricultural supply companies and agri-tech firms have considerable potential to drive innovation, and there are new products and approaches being developed within companies.

Beyond the farm, the cocoa value chain is relatively complex, with buyers and middlemen, often high government involvement, commodities trading and numerous processing steps involved. The involvement of the futures market is critical as it effectively sets the price of cocoa globally. Several large and influential cocoa companies dominate the processing steps and route to retailers.

The public is also a key stakeholder. For example, consumers can drive demand for biodiversity friendly and deforestation free chocolate products (including government actions such as recent EU regulations around deforestation-free products). Additional interest around issues such as carbon sequestration, contaminants, child labour, and fairtrade practices can lead to further influences.

The global research sector in cocoa is relatively large, with centres almost exclusively dedicated to cocoa (e.g. CRIG and CRIN), those around tropical agriculture/forestry more widely but with expertise in cocoa (e.g. FORIG, IITA, ITV), and specific research groups and experts within universities and research organisations. However, the nature of research funding has meant that some older, valuable work is overlooked.

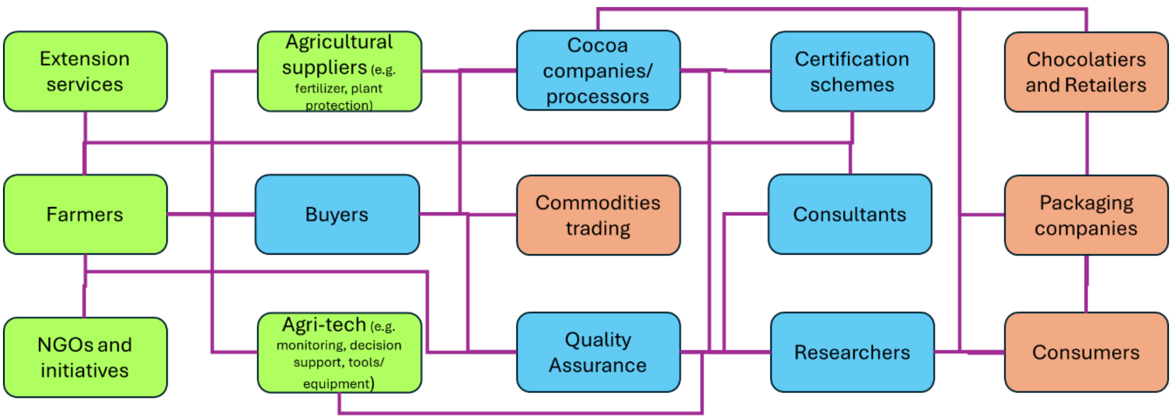


Fig. 5.1 Overview of key stakeholders in the cocoa value chain. Green boxes indicate those most closely connected to the farmers, blue most often in-country and orange most likely to be global actors.

Stakeholders and capacity: Brazil

Brazil has a strong agri-tech innovation space and an active university research network, especially in the states of São Paulo, Bahia and Pará. There is strong presence from major agricultural companies and suppliers, but due to the large arable sector (cereals, soya) and livestock, many products are targeted at these crops and systems rather than agroforestry and cash crops.

Examples (not exhaustive):

Research and government	Cocoa companies	Agri-tech – established	Agri-tech and food tech - startups	Consultancy and certifications	NGOs	Commodity/ produce boards and organisations
University of São Paulo; Instituto Technológico Vale; EMBRAPA	Callebaut; Cargill; Mars; Mondelez; Nestle; OFI	Agrivalle; Bayer; Bioneem; Corteva; Koppert; Primal Group; Staphyt; Syngenta	Fine Instrument Technology; iCrop	Rainforest Alliance	Cocoa Action Brasil	Sociedade Rural Brasileira; National Cacao Producers' Association

Case study: ITV (Institute Technológico Vale), funded by the Brazilian Vale mining company, is a research organisation focused on conservation and sustainable use of landscapes around the Vale Nature Reserve and wider area. It has carried out work around agroforestry systems, pollination ecology of cacao, feasibility of hand-pollination in Brazilian cacao, and various IPM programmes.

Case study: iCrop is a smart irrigation management system. Although the company is still young, it is fast-growing and has supplied irrigation management services to around 5.3m hectares of farmland in Brazil and internationally since 2016. Subscribers have a 96-97% renewal rate year to year. The company has water use models for over 50 crops, including arable, horticulture and tree crops (including coffee) and are adding more. Their app-based management uses crop water demand and weather forecast data to predict when to irrigate, and how much, and provides farmers with detailed information and recommendations on improving water and energy use efficiency, with projected cost savings.

Stakeholders and capacity: Nigeria

Nigeria has various universities carrying out cocoa sustainability related research. Cocoa research is also carried out by the government-affiliated Cocoa Research Institute of Nigeria (CRIN), and by the International Institute of Tropical Agriculture (IITA) which is part of CGIAR. Nigeria has a dynamic and ambitious innovation environment, with various start-ups focused on microfinance and access to credit, which can be a key tool to enable farmers to innovate and invest. There is also a growing digital agriculture sector, with capacity around weather prediction, pest forecasting, and farmer decision support. With a diverse farming sector, there are technologies relevant to other crops (e.g. cassava, cashew, maize, rice) that may be adapted or considered for cocoa, or used as inspiration for cocoa-specific approaches.

Research and government	Cocoa /agri companies	Agri-tech – established	Agri-tech and food tech - startups	NGOs, CICs and initiatives	Commodity/ produce boards and organisations
CRIN; IITA; Institute for Agricultural Research, Ahmadu-Bello University; University of Ibadan	FTN; Johnvents Group; Koletti; Mondelez Nestle Wacot	AirSmat Inc.; Havenhill Synergy Ltd.	AgriGrow Analytics; Hello Tractor; Quick Leap; Nimsy Agro Solar	Ajumose Farmers; Babban Gona; CocoaLife (Nigeria); Kitovu; Springboard Nigeria	Cocoa Farmers' Association of Nigeria

Case study: Johnvents Group is a Nigerian-based cocoa processing and commodities trading company. It already has strong links to the UK, with recent investment to increase cocoa processing capacity to 30,000 metric tonnes per annum[1]. Johnvents aims for 100% traceable cocoa by 2027.

[1] Johnvents Group and BII partner to drive sustainability and growth in Nigeria's cocoa sector with $40.5m investment - British International Investment

Stakeholders and capacity: Ghana

Ghana has both public and private sector specialists. Research is focused at the universities (e.g. University of Ghana, University of Cape Coast, and Kwame Nkrumah University of Science and Technology (KNUST)), and also in the public sector research organisations: Cocoa Research Institute of Ghana (CRIG), Council for Scientific and Industrial Research (CSIR), and the Forestry Research Institute of Ghana (FORIG). The long history of cocoa production and research means there is long-term data in some areas. As a major cocoa producing country it also hosts many NGOs, a strong presence from international cocoa companies, farmer cooperatives and smaller national chocolate producers, as well as value-added organisations (e.g. using other parts of the crop to develop products). The technology sector is developing fast, with younger companies related to digital agriculture becoming more prominent.

There is particular interest/innovation around agroforestry initiatives.

Research and government	Cocoa companies	Agri-tech – established	Consultancy and certifications	NGOs and initiatives	Commodity/ produce boards and organisations
CRIG; FORIG/CSIR; KNUST; University of Cape Coast University of Ghana;	Callebaut; Centuries Cocoa; Kuapa Kokoo; Mondelez Nestle	esoko; KOA	Fairtrade; Rainforest Alliance; UTZ	Cocoa Life (Mondelez); Proforest; Sankofa; Three Mountains; WWF	COCOBOD

Case study: esoko was founded in 2008 and provides a phone app, supported by local representatives, a central call centre and data processing. The service provides education, training and agronomy materials for farmers in a range of crops. Around 400,000 cocoa farmers are currently enrolled (pers. comm.). Farmers can phone the call centre for remote advice in local languages. The platform allows considerable data processing, which can feed into crop forecasting and tailored advice to local conditions and trends. Because it also can provide a log of farmers' inputs and transactions, it has potential to aid in traceability.

Stakeholders and capacity: UK

The UK has several active research teams and researchers across universities/independent and public sector research organisations. It also has strong presence from various major cocoa companies, and significant NGO activity. The UK also has an innovative and active agri-tech sector with various startups (e.g. in IPM, digital agriculture, precision spray technologies, sensing and monitoring) – while most are primarily targeting either UK arable or horticultural sector or both, some of the technologies could transfer to the tropics if provided with suitable R&D support.

Examples (not exhaustive):

Research and government	**Cocoa companies**	**Agri-tech – established**	**Agri-tech and food tech - startups**	**Consultancy and certifications**	**NGOs and initiatives**	**Commodity / produce boards and organisations**
University of Reading; University of the West of England, Bristol; Durham University; Niab; University of Greenwich (NRI); University of Cambridge	Mars UK; Mondelez UK; Nestle UK	Agrii; Bayer; Biobest UK; Corteva; Koppert; Omnia Digital Farming; Russell IPM; Syngenta	Numerous examples: AgriSound; Baker Consultants; Bionema; Nukoko; Pherosyn; Olombria; Rootwave; z2o	Peterson solutions; Fairtrade UK	WWF; Flora & Fauna International	Cocoa Research UK

Case study: The University of Reading hosts the International Cocoa Quarantine Centre, a specialised facility to improve biosecurity when moving cocoa material between growing regions. Around this, it also has extensive expertise in cocoa breeding and work on soil amendments. The team have extensive international collaborations.

What would transformational change look like for climate-smart cocoa?

We suggest two likely (and non mutually-exclusive) visions of climate-smart cocoa that could achieve environmental, economic and social sustainability:

1. Increased adoption of agroforestry systems alongside active, evidence-led tree management, well-informed IPM and full harnessing of nature-based solutions.

This model would involve more shade trees and higher plant diversity on farms, supporting beneficial biodiversity such as natural pollinators and natural enemies of pests. Shade trees would be native as far as possible, with well-chosen additional trees to provide suitable alternative income to farmers and confer other ecosystem services (e.g. leguminous trees for soil protection). Planting material on farms would need to be well-adapted for shade-growing, pest and disease resistant, and carefully managed (e.g. suitable pruning, careful fertiliser application, minimum sprays). Yields of over 1000 kg/ha are possible under agroforestry systems (Michel et al. 2024). We recommend drawing information from existing traditional and modern agroforestry systems. This approach could be particularly useful adjacent to natural forest, in regenerating areas (e.g. replacing older and lower productivity trees, areas cleared for disease control), and areas where it has become difficult to source inputs like fertilizer and irrigation. This approach is achievable within smallholder farms with support and investment, and blueprints already exist.

2. Modern sustainably intensified cocoa.

Models for this already exist, e.g. El Cacao[1] (Ritter Sport) farm in Nicaragua. Key elements of this include: row planting (cocoa in rows, similar to apple orchards or olive plantations), which is still not highly used by West African farms; dwarfing rootstocks and smaller trees kept well-pruned for efficient harvesting; sustainable irrigation and water management; retention of semi-natural habitat on farms to support beneficial biodiversity; intercropping; inclusion of selected shade trees; adoption of improved cocoa clones with desirable properties. These systems use the principles of integrated pest, pollinator and disease management (IPDM) to ensure ongoing crop health, with pesticides applied only when needed, where needed, and appropriate to problems detected.

This approach generally requires larger land-areas with good access to resources and intentional design from the outset.

Common features of both approaches include enhanced use of IPDM and pruning, and integration of shade into systems.

[1]Ritter Sport – El Cacao Farm

Recommendations: research priorities for funding/investment

Several key areas require funding focus to ensure sustainability of cocoa under changing climate. Research should be participatory and consider the farmers and other users (e.g. extensionists and buyers) and their needs.

Some highlights include:

1. Integrated pest, pollinator, and disease management (IPPDM) – new smart, sustainable solutions that do not only rely on application of synthetic pesticides. Research should include holistic solutions that enhance beneficial biodiversity and support complex ecological networks for ecosystem services. Particular opportunities around biopesticides and agroforestry.
2. Water management – methods of irrigation appropriate to environment and ways to manage it responsively. Research should include the optimal delivery of water for tree health and the impact on wider biodiversity, and pest and disease risk.
3. Integration of digital tools and technology – reliable and relevant data, delivered in a timely fashion to end-users. Research should address issues around accessibility, interfaces that are user-friendly and accessible, and ethics/data privacy.
4. Making agroforestry work well – optimizing shade levels and inputs, understanding the role of biotic and abiotic elements and management to achieve sustainable yields while minimizing pest and disease issues, promoting climate resilience and supporting biodiversity. A critical element is selection of shade trees for diverse ecosystem services (e.g. fruit, biopesticides, hosting beneficial insects)
5. Improving pollination – this was not actively mentioned as a priority by many of those we spoke to in West Africa but was widely discussed in Brazil. A priority is to understand the pollinator-dependence of cultivars currently grown on farms (especially in West Africa) and compatibility for optimal pod-set. Research should also investigate the long-term sustainability of hand pollination, as well as the communities of insects that pollinate cocoa and the optimal conditions for their populations.
6. Cocoa alternatives – while cocoa is an important income source for many farmers, innovations in some areas are developing cocoa and chocolate alternatives made from temperate crops (e.g. faba bean) and other materials, which may have a lower carbon footprint and/or be less vulnerable to climate change. Research should explore the trade-offs around such products and how to ensure cocoa farming communities do not lose out.
7. Valorisation of underused cocoa tree products – various programmes are investigating the potential of e.g. cocoa pod pulp, endocarp and pod to be processed into higher value products.
8. Breeding – improved genetic material will be key to future resilience. This is expanded on more in the report from University of Reading, *Development of a UK, Ghana, Nigeria, and Brazil network on cocoa improvement* .

Wider value chain issues

Considering the wider cocoa value chain "from bean to bar", there are various other stages where either climate change can impact (directly or indirectly) on parts of the process, or where certain points are associated with high carbon emissions and there is scope to reduce these in the interests of making cocoa more climate-friendly as well as climate-smart. There are wider social issues associated with cocoa that are largely out of scope for this report.

Breeding—There is considerable potential to improve planting material to make it more resilient – to droughts and flooding, pests and diseases, and to temperature extremes. Self-compatible clones do not always perform consistently, but may mitigate pollinator shortages. Please also see University of Reading report: *Development of a UK, Ghana, Nigeria, and Brazil network on cocoa improvement*

Processing—Most processing steps (e.g. fermentation, drying, chocolate making) are dependent on supply. Batch processing can become less efficient if batches arriving are small or poor quality; this can particularly be the case for small/regional plants.

Labour—Ageing farmer demographics and unappealing nature of cocoa farming (unreliable yields and income) resulting in discontinuation of farming, especially among youth; this is also linked to labour migrations within e.g. Nigeria, causing other societal tensions

Roasting and drying—These are energy-intensive processes. The sources of energy can vary, and the technologies involved can vary in their energy-efficiency, emissions and particulates. Optimising this step will be a key part of climate-smart and sustainable value chains. New technology in Europe is available to scrub emissions before release and capture excess heat to reduce the carbon footprint. For drying, some countries use solar dryers or sun-dry outdoors (which can be affected by unseasonal rainfall); other countries favour heating the beans, which can cause smoked flavour notes in the beans and usually involves burning wood.

Global and national prices—Price for product available to farmers affect their willingness to invest and innovate and take risks. Price structures that reward quality will incentivize higher effort into ensuring high quality product. At the same time, high costs of inputs will limit their accessibility.

Regulation—The European Commission's directives around deforestation are a high-priority concern across all three countries, in terms of compliance and demonstrating this. Digital technologies (e.g. satellite and drone mapping of farms, and maintaining a digital record of farmers' holdings and inputs) are becoming increasingly available to facilitate this.

Packaging—trade-offs around plastics (fossil fuels; but less food waste due to robustness maintaining freshness/quality of product) versus paper and fibre derived wrappings (more renewable; but risks of increased food waste if packaging is easily damaged or less airtight) versus bioplastics (more renewable; but depending on source may take land out of food production). Suggestion: Life cycle analysis to compare different approaches for chocolate products.

Consumer behaviour—some sustainability certifications do increase consumer willingness-to-pay in academic studies (Duran Gabela et al. 2023), but the translation of this through to real purchasing behaviour is less pronounced (Li & Kallas 2021).

Outlook and conclusions

Within the topic area, what are the challenges, barriers and technology gaps impacting the potential for climate-smart agriculture and sustainable food production systems in Ghana and Nigeria?

The biggest challenges around climate-smart cocoa adoption in West Africa include:

1. The high impacts of climate change already, meaning farmers face regular crop failures (especially on monoculture farms) and so lack capital to invest or take risks.
2. Poverty and infrastructure issues mean that uptake of technology (e.g. mobile phone technology, irrigation or biocontrol) is out of reach for many farmers.
3. Education levels, information availability, and overtraining – farmers receive lots of information from the sector but may have difficulty evaluating its usefulness or practicality for their farm, and little support to enable changes to be fully integrated into their farming systems. This has reduced adoption of new approaches.
4. Resource availability (inputs, planting material, labour) is variable, meaning that the resources may not be there for higher-intensity farming.
5. Poor access to optimized/improved varieties of cocoa, best-suited to climate, pest and disease resistance and good yields, and poor understanding of the existing varieties being used by many farms.
6. Continuous challenges (see previous sections) around climate, pests, galamsey, soil, etc. mean people are leaving the sector.

Within the topic area, what are the opportunities to collaboratively transfer, develop, commercialise, adopt and scale-out technologies and practices to address these challenges?

1. Private extension services, including remote/app-centred are often well thought of by farmers if they can access them, and these provide support with adoption.
2. Some models of scaling and adoption featuring mentoring (e.g. Cocoa Life) or demonstration farms accompanied by high levels of ongoing support to farmers can be effective in some areas.
3. Growing digital technology in Ghana and Nigeria and increasing smartphone penetration presents an opportunity.
4. Young companies such as KOA enable additional income gain from farms; high enthusiasm for dynamic agroforestry will allow resilience if implemented.

Who are the key stakeholders in each country who would be relevant partners for collaborative projects within the topic area? Please ensure you consider the role of industry and commercialisation.

1. See previous sections. In addition to public sector and university research organisations, we would particularly highlight private sector biocontrol firms (e.g. Koppert, Bionema, Staphyt) in each country, the cocoa industry itself (e.g. large players such as Callebaut, Mondelez, Nestle and smaller players such as Kuapa Kokoo), and digital agriculture startups (e.g. esoko and iCrop), including those providing extension services.
2. There are various investors to facilitate startups in the UK but less support elsewhere. However, increasing access to microfinance is an opportunity for entrepreneurship.
   Brazil already has a strong history of university innovations leading to startups and/or startups scaling up to national scale. Examples include a soil sensor design developed at University of São Paulo that was licensed/sold to Galembetech, who is now developing routes to scale this

technology. Another example is Promip, a Brazilian startup biocontrol company, that was later acquired by Staphyt, and Strider, a Brazilian pest forecasting platform, that was acquired by Syngenta. A further example is iCrop (profiled above), an irrigation management technology platform that could assist farmers in making rational irrigation decisions.

How could technologies or practices be applied or developed within this topic area to reduce i) gender and ii) social inequality in climate vulnerable populations?

1. A particular focus on affordability is essential. Women farmers may struggle more with access to capital funding. Microfinance initiatives can reduce some of these barriers.
2. Labour-saving technologies that are safe and accessible may enable women and older farmers to achieve more with less physical effort, and compensate for a reducing workforce. These can include tools for e.g. weeding and pruning. Innovations such as moving to dwarfing rootstocks or smaller trees could also be beneficial for all farmers, but women and older farmers in particular.
3. Dissemination and publicity must focus on women farmers' needs specifically and address them. This is likely to be context- and community-specific and so should be developed in a strongly participatory way.
4. Complexities around land tenure and ownership of both shade and cocoa trees may disproportionately affect women in some regions, and so management plans should take into account these inequalities.
5. Dynamic agroforestry may particularly be suited to socially disadvantaged farmers if support is provided to transition to this system, as the systems are more resilient against climate change and pests and diseases, and inclusion of other saleable crops (e.g. fruit, pesticidal plants, firewood) spreads risk.

Notably, to a large extent all smallholder cocoa farmers in Ghana and Nigeria can be considered climate-vulnerable.

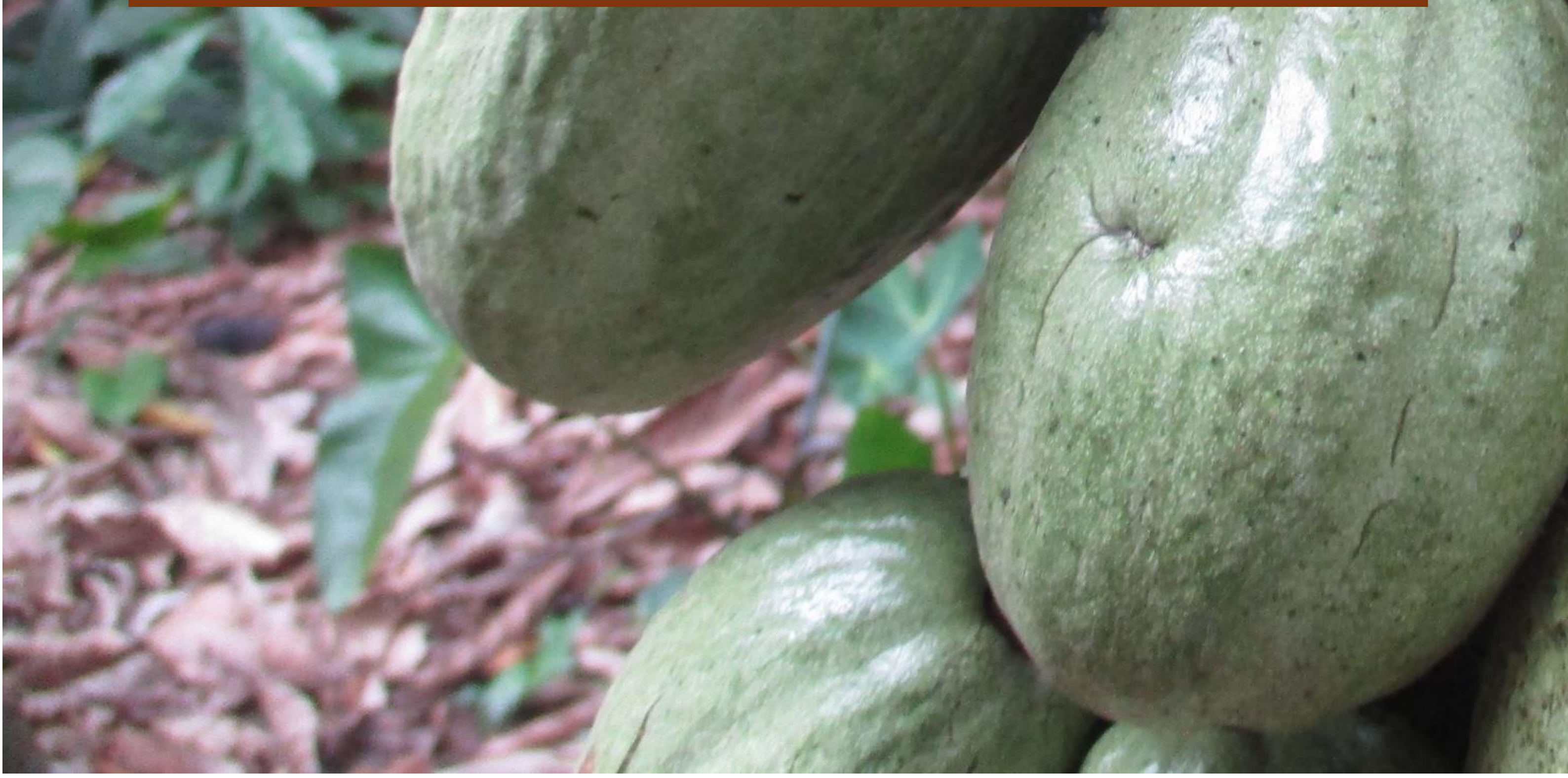
What are the barriers preventing 'transformational change' within the topic area?

1. Limited uptake of new techniques and general good agronomic practice. While, for example, professionals agree that pruning of trees is essential for productivity, many farmers in Nigeria and Ghana view pruning as harmful or unnecessary, and so do not prune or use poor techniques. Weed control and pest management approaches also may vary from best practice recommendations by extension services. Farmers receive a lot of information, whether from large cocoa companies, researchers, or agri-tech salespeople, leading to mixed messages, sometimes poor outcomes, and distrust. Any new technologies will ideally come from farmer recommendations/experiences or from demonstration farms and need to be accompanied by long-term support, training and troubleshooting to facilitate uptake.
2. Poor basic scientific knowledge of key aspects of cocoa growing, e.g. the interrelationship between fertilizer and pollination, sustainability of hand-pollination over the years, role of different pollinator species, pest/disease and yield tradeoffs from management such as increasing plant diversity and agroforestry adoption. This is critical for updating evidence-informed recommendations to farmers.
3. External forces may affect the viability of the crop in whole regions – e.g. changing rainfall patterns, extreme heat, natural disasters, pests and diseases, contaminants (e.g. cadmium) and regulatory requirements (e.g. deforestation regulations). As a result, at a farm level, transformational change may be impaired by farmers leaving the sector by choice or necessity

(this is already viewed as a risk in West Africa). At a global level, transformational change may be achieved by new regions intensifying the cocoa sector and having more capacity to adopt new techniques such as dwarfing rootstocks, row cultivation, mechanization (as is demonstrated, for example, on the Ritter Sport El Cacao farm in Nicaragua). This is possible in countries such as India and Vietnam where new investment is incoming.

Further developments may also change demand for cocoa; for example, there is work in the sector to develop chocolate alternatives made from non-cocoa products, such as Nukoko's chocolate alternative made from fava bean. In the short term, these will have different uses and may not compete directly, but in the long-term as food processing improves it is unclear whether there will be a shift in ingredients used by cocoa processors, confectioners, etc. This could especially be a risk when climate change leads to further crop failures, resulting in price volatility of cocoa beans.

4. Infrastructure and local/national regulatory restrictions. Currently, some countries have a restricted market where most or all beans are sold through the government at a set price. This can limit innovation as there is no reward for quality. It also means that prices may not reflect global market price fluctuations, which demoralizes farmers. Similarly, where there are national programmes of spraying, fertilizer or other inputs, timeliness of delivery is raised by farmers and other actors as a challenge. This means farmers lack resources and may be skeptical about new innovations.
5. Risk management and return-on-investment. Newly planted cocoa will not yield useful crop for 3-4 years, and conversion to agroforestry will usually also not deliver immediate return-on-investment. Smallholder farmers usually cannot afford to replant without crop compensation if they have no alternative income in that establishment period. Adopting row-planted improved varieties would require availability of improved planting material and some way to ensure adequate income while that establishes. Conversely, larger-scale farmers (and farms owned by large companies) have the financial capital to invest like this.



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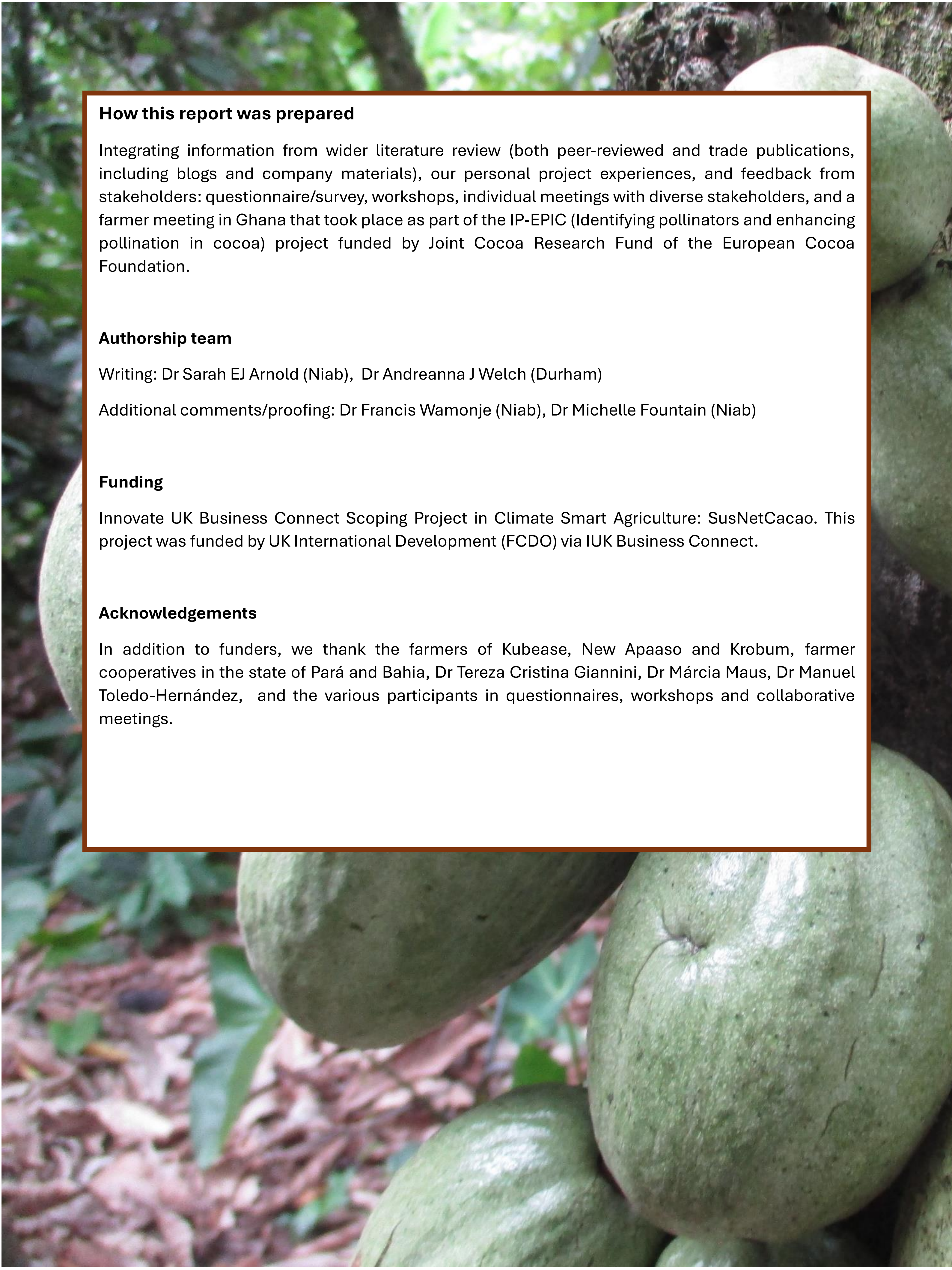

How this report was prepared

Integrating information from wider literature review (both peer-reviewed and trade publications, including blogs and company materials), our personal project experiences, and feedback from stakeholders: questionnaire/survey, workshops, individual meetings with diverse stakeholders, and a farmer meeting in Ghana that took place as part of the IP-EPIC (Identifying pollinators and enhancing pollination in cocoa) project funded by Joint Cocoa Research Fund of the European Cocoa Foundation.

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