Can Agroforestry Provide a Future for Cocoa? Implications for Policy and Practice

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CHAPTER 6

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Abstract Climate change is threatening cocoa production in Ghana, the world's second largest cocoa exporter. Yet, as we have shown in this book, the impacts of climate change must be understood in the context of the multiple socioeconomic and biophysical pressures facing cocoa farmers, including the conversion of farms for other land uses, increasing hired labor costs as well as pests and diseases. This final chapter summarizes

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M. F. Olwig et al. (eds.), *Agroforestry as Climate Change Adaptation*,
https://doi.org/10.1007/978-3-031-45635-0_6

the book's overall findings on cocoa agroforestry as climate change adaptation and points to ways forward in terms of policy, practice and research. Our findings suggest that a nuanced view of farmers, agroecosystems and sites is necessary and emphasize the need to study shade tree species and species diversity, in addition to shade levels, to optimize the sustainability of cocoa farming. We further suggest that it may not be possible to sustainably grow cocoa in marginal regions of the cocoa belt, where yields are lower and where agroforestry may be unable to mitigate the negative impacts of the adverse climate. Finally, we point to the importance of considering rights and access to trees, land, extension services and resources, and call for more multidisciplinary research on differently situated farmers' opportunities and needs.

Keywords Climate change adaptation · Plant species diversity · Cocoa farmers · Sustainability · Institutional landscape · Multidisciplinary research

6.1 The Future of Cocoa Farming

Cocoa farming in Ghana, the second largest producer of cocoa in the world, is facing multiple pressures. These include biophysical pressures from climate change, pests and diseases, and socioeconomic pressures, such as the conversion of cocoa farms for other land uses, such as gold mines, and the lack of interest in cocoa farming among the young, leading to an aging of the cocoa-farming population. This book takes its point of

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departure in the challenges posed by climate change, but climate change impacts must be understood in the context of these other factors because they together influence the overall sustainability of cocoa farming.

Based on the CLIMCOCOA research project, this book has specifically investigated cocoa agroforestry as a climate change adaptation strategy. Cocoa agroforestry entails planting cocoa trees together with non-cocoa trees, plants and crops. Agroforestry has been advocated in the literature as a way to counteract the negative impacts of climate change by providing shade and micro-climate buffering. It is also encouraged for its ability to mitigate climate change through the above- and below-ground carbon sequestration resulting from tree planting. It can furthermore enhance household food security, as well as improve farmers' livelihoods by diversifying their incomes (e.g., Graefe et al., 2017; Ruf & Schroth, 2004). While findings from previous research have generally been positive, there have also been conflicting findings and concerns regarding the impact of cocoa agroforestry on cocoa yields, pests and diseases, and the overall costs and benefits accrued by the cocoa farmers (e.g., Graefe et al., 2017; Nunoo & Owusu, 2017; Smith Dumont et al., 2014). This book has contributed to further nuancing and substantiating the possibilities and challenges of cocoa agroforestry in times of climate change by:

1. analysing the impacts of climate change on the socio-economic and biophysical bases of cocoa systems in Ghana
2. examining the complex of plant species involved in cocoa agroforestry and their environmental and societal attributes across a climate gradient
3. investigating the social and institutional contexts within which cocoa agroforestry practices are introduced.

Our overall findings indicate that cocoa agroforestry can be a successful way forward for cocoa farming. However, they also show that to succeed, place-specific socioeconomic and biophysical factors must be considered, and that the implementation of cocoa agroforestry must involve cross-sector collaboration between, for example, the state, chiefs, churches, NGOs, the cocoa industry and cocoa-farming communities. In this concluding chapter, we summarize the overall findings of the book and point to ways forward in terms of policy, practice and research on cocoa agroforestry that could ensure the sustainability and future of cocoa farming.

6.2 Key Overall Findings of the Book

The findings that have been presented in this book have nuanced our understanding of cocoa agroforestry as a means of climate change adaptation. They provide a better understanding of how climate changes are likely to influence cocoa farming and whether agroforestry can mitigate this impact. They point to the importance of looking at not just shade levels, but also shade tree species and species diversity when studying cocoa-agroforestry systems. They also emphasize the need to pay careful attention to the complex socioeconomic and institutional landscapes in which cocoa-agroforestry systems are introduced.

6.2.1 Climate Change, Cocoa and Agroforestry

Research on cocoa shows that cocoa cultivation is very vulnerable to climate change (Ameyaw et al., 2018; Schroth et al., 2016). West Africa, primarily Côte d'Ivoire and Ghana, where two thirds of the world's cocoa is farmed, will experience an increasing frequency and severity of drought and heat (see Chapters 1 and 2). A key contribution of this book is its examination of how cocoa yields have responded historically to changes in climate and how this knowledge can help understand the impact of different future climate change scenarios on the sustainability of cocoa farming. Additionally, the book has investigated what exactly happens to the cocoa plant, i.e., to the plant's physiology, when it is exposed to different climate stressors, such as high temperatures and drought. Furthermore, the book has shown how the challenges and potentials of cocoa agroforestry vary under different climates in relation to both biophysical and socioeconomic outcomes.

We analyzed the relationship between historical cocoa yields and climate in Ghana across the six decades spanning 1960–2020 (see Chapter 1). Overall, the analysis showed that the levels and timing of both temperature and precipitation impacted yields. Annual cocoa production was positively correlated with precipitation in and around the major dry season, particularly in the month of November. Negative correlations were observed between cocoa production and temperatures in the minor dry season around July–August. The minor wet season from September to November coincides with the period when cocoa trees have many maturing pods. A limited water supply during this period can reduce photosynthesis and have a negative effect on pod yields (Asante et al., 2022). Generally, there was a positive correlation between precipitation in the minor wet season and yields across major parts of the cocoa belt in Ghana, including the Western, Eastern, Central, Brong Ahafo, and Ashanti regions. In the Volta region, correlations were weak because production was low after the 1970s. This was in part due to devastating bushfires in the early 1980s, combined with the severe incidence of Cocoa Swollen Shoot Virus (CSSV), which almost wiped out the cocoa farms in the Volta region (Danquah, 2003).

Based on two trials, we documented how cocoa-plant physiology is influenced by increasing temperatures and reduced precipitation, and the mitigating effect of shade (see Chapter 2; also, Mensah et al., 2022). We first demonstrated how cocoa seedlings exposed to temperatures 5–7 °C above their surroundings had an increased risk of damage and reduced photosynthesis. Cacao plants under shade had thin leaves, which is a typical shade-leaf anatomy, and increased rates of photosynthesis. Under heat stress, shade was partially able to mitigate the damaging effects of high temperatures. In another experiment, we showed that mature cocoa trees exposed to reductions in rainfall were increasingly vulnerable to flower abortion and had substantially reduced yields. At all levels of rainfall reduction, cocoa shaded by a 40% shade net performed better in terms of yield compared to unshaded cocoa. This suggests that shade has a positive impact irrespective of water supply under these circumstances.

Comparing yields in cocoa-agroforestry systems along a climate gradient, our research shows that yields from cocoa-agroforestry systems decreased from the wet southern to the dry northern part of the cocoa belt of Ghana (Asitoakor et al., 2022b; Chapter 5). For our data collection and analysis,[1] building on Bunn et al. (2019), we divided the cocoa belt of Ghana into three climate impact zones: the Cope Zone, the Adjust Zone and the Transform Zone. The southern Cope Zone has a current climate that is the most favorable to cocoa farming of the three, and cocoa farming is likely to be able to *cope* with climate change. In the middle Adjust Zone, the current climate is moderately favorable, but some *adjustments* to cocoa farming will likely be needed. The northern Transform Zone currently has the climate that is least favorable to cocoa farming. Here, cocoa farms will likely have to be abandoned or radically *transformed* because of climate changes. Through a cost–benefit analysis

[1] See Chapter 1, as well as individual chapters, for a more in-depth discussion of our methods, as well as a map of the study sites.

of cocoa agroforestry based on household surveys in the three different climate impact zones (see Chapter 5), we found that the costs and benefits differed across the different climate impact zones. Cocoa bean yield per hectare was for example significantly higher in the Cope zone. In a different study, Abdulai et al. (2018b) found that in marginal regions of the cocoa belt, such as in the Transform Zone, cocoa agroforestry has a limited positive effect, and can even have a negative effect under conditions of severe drought. It is important to consider region-specific climate conditions and projections when selecting the appropriate level of shade and shade tree characteristics to implement a sustainable strategy to buffer climate change. In fact, several of our findings indicate that, as the climate continues to change, marginal areas become even less suitable for cocoa farming. It may not be cost-effective to continue cocoa production in these areas, especially since cocoa agroforestry does not appear to buffer these changes sufficiently and may in some cases even worsen climate impacts in such areas.

6.2.2 The Importance of Shade Tree Species and Species Diversity

Another contribution of this book is its focus on the different effects of shade tree species and tree species diversity. Within agroforestry research on cocoa and coffee, there has been a tendency to focus narrowly on the impact of different levels of shade, with little regard to which constellation of trees is providing this shade. However, new research emphasizes that the effects on cocoa may depend on the particular shade tree species involved, as well as the impact of shade tree species diversity (Abdulai et al., 2018a; Asare et al., 2019; Asitoakor et al., 2022a; Graefe et al., 2017; Kaba et al., 2020). Thus, there is a need for broader investigations of (1) the impact of specific shade tree species, and (2) agroecosystem studies that include a focus on viruses, fungi, animals and plants. In coco-agroforestry systems, the foliage density, the root distribution along the soil profile and the associated below-ground complementarity and competition for resources are of key importance and will be influenced differently by different shade tree species (Abdulai et al., 2018b; Critchley et al., 2022; Jaimes-Suarez et al., 2022). Important factors include the depth of the shade tree's root system (Kyereh, 2017) and the water requirements of the species involved across space and time, influencing competition between shade trees and cocoa (Abdulai et al., 2018b; Adams et al., 2016).

Our trial experiments showed that climate stressors negatively impact cocoa-plant physiology, and that shade has a positive impact both under stress and no-stress conditions (see Chapter 2; also Mensah et al., 2022). A limitation of these trial experiments is that they used shade nets, not shade trees, to achieve a uniform shade cover. To investigate the significance of choosing different shade tree species, we set up a farm study experiment comparing how eight common forest shade trees species affected cocoa trees and their yields, as well as the impact of mirid insects and black pod disease (see Chapter 3). Although this on-farm study experiment is just a first step in this field of study, the findings indicate that some shade tree species significantly outperformed the full-sun control plot with respect to yields and the occurrence of pests and diseases. Previous thinking has been that shade trees reduce yields and enhance the incidence of pests and diseases, particularly under high input conditions and with high-quality cocoa-planting material. However, a recent literature review (Mattalia et al., 2022) challenges this assumption, and our findings furthermore suggest that yields can be higher from shaded cocoa compared to full-sun cocoa, especially under a low input of fertilizer, insecticides and fungicides, if the right shade tree species are selected for the local context.

The impact of the level of tree species diversity (and not just the level of shade) on the various costs and benefits associated with cocoa agroforestry was also explored in our research (see Chapter 5). We found that cocoa agroforestry was more profitable than monocrop systems when combined with income from the sale of other products from diverse agroforestry systems, such as timber, fuelwood, fruit and mushrooms. Moreover, cocoa farmers earned a consistent income from their cocoa plots if they included more tree species in their system. The need for hired labor (e.g., related to manual weeding and applying inputs) was higher for cocoa plots with low tree species diversity compared to those with medium tree species diversity. This finding is important because one of the key concerns regarding the future of cocoa is that it is highly labor-intensive and therefore unattractive to young people with other aspirations and alternative livelihood possibilities (Anyidoho et al., 2012). In addition to weeding and the application of inputs, cocoa farming involves pruning, harvesting, gathering and breaking pods, fermenting, transporting and drying cocoa beans. This can lead to illegal solutions, such as using child labor, to reduce the expenses incurred from hiring adult laborers. The problems of youth disinterest and the use of illegal child labor could potentially be addressed if diverse cocoa-agroforestry systems that are less labor-intensive were to be adopted.

6.2.3 Access and Rights

Research may provide recommendations concerning shade levels and the need for fertilizers and insecticides, as well as the planting, timely harvesting and pruning of cocoa-agroforestry systems. However, none of these recommendations can be implemented in practice if farmers do not have access to seedlings, extension services and key inputs, along with long-term rights to the land and trees (Boadi et al., 2022). A final key overall contribution of this book is to illuminate the importance of the socioeconomic and institutional factors that directly and indirectly influence the outcomes of cocoa-agroforestry systems in relation to benefits to both farmers' livelihoods and the environment.

Farmers' own perspectives were explored through twenty focus-group discussions and interviews (see Chapter 4). Farmers were found to generally agree on the possible benefits of having shade trees in cocoa cultivation. The benefits ranged from creating a better environment for the cocoa trees at different stages of the cocoa plot's lifetime to being able to harvest alternative products, including snails and mushrooms living in the shaded environment, and products from the trees (see Chapter 3, Appendix for a list of common shade tree species adopted in cocoa-agroforestry systems and their additional uses). Despite this common knowledge, most farmers establish new plantations by clearcutting and burning fallow or forested areas, and while some introduce new shade trees, a widespread adoption of agroforestry systems is lacking, as farmers experience a range of obstacles and challenges. One of the main challenges is farmers' access and rights to land, as well as to the trees on the land. Village chiefs have the constitutional right and duty to administer land in the interest of the community (1992 Constitution, article 36(8)). However, many farmers, who were sharecroppers and whose families had migrated to the village several generations previously, complained that they are often still perceived as outsiders, and found that the chiefs used their positions to expropriate their cocoa fields and replace them with, for example, urban expansion, village infrastructure or sand mining. Other farmers who had good relations with their chief, or who possessed ancestral rights of ownership to their land, did not worry about their future ability to access their land. They were therefore more willing to invest in cocoa agroforestry, even though the benefits of planting trees will only accrue after a number of years. Access and rights to land vary between and within regions, villages and even households, with women being a lot less likely to own cocoa land than men (Barrientos & Bobie, 2016).

However, regardless of land rights, farmers do not have the right to fell timber trees they have planted or nurtured on their farm unless they can prove ownership and secure a permit from the Forestry Commission of Ghana. As permits are difficult to obtain because of the bureaucracy involved, several farmers had experienced legal conflicts with forestry personnel over the use of trees, even for their own housing materials, and they therefore saw few incentives to continue caring for trees. Another significant competitor in certain areas is gold mining, which leaves land unusable for cocoa farming, and provides a lucrative alternative livelihood for young people which contributes to their loss of interest in cocoa farming. Several actors come into play here, such as the mining companies that encourage small-scale mining activities in the cocoa communities. Farmers, mostly representing the older generation, talked of defending their lands against outside gold miners and discouraging their own children from engaging in mining.

To successfully implement agroforestry systems, cocoa farmers must have knowledge of the different appropriate shade tree species, as well as the other plants involved. We found that the more resources and better networks farmers had, and thus the easier access to inputs and knowledge of good management practices, the more likely they were to implement agroforestry systems (see Chapter 5). Another significant finding pertains to the role played by the extension services provided not just by government agencies, but also external institutions like NGOs, research organizations and businesses, such as those tied to the cocoa and chocolate industry. While cocoa farmers learn from each other as they see how other farmers manage their cocoa farms, our study found that those farmers who were most successful in implementing cocoa agroforestry had received assistance from extension services (see Chapter 4). This assistance included advice as well as concrete inputs, such as a more diverse selection of shade tree seedlings. However, most farmers receive only limited training, and only a very limited selection of shade tree species is available from most NGOs, cocoa industry-led sustainability initiatives, or the state. This is especially a problem for women, because they are often not recognized officially as cocoa farmers. Studies show that 80% of registered cocoa farmers are men, even though women carry out close to half of the cocoa work required on farms as unpaid family labor. Because women are unregistered as cocoa farmers, they are often not included in training and do not receive extension services (Barrientos & Bobie, 2016).

Local botanical knowledge is instrumental in the adoption of cocoa-agroforestry practices because farmers can diversify the shade tree species on their cocoa farms through naturally regenerated trees or tree seedlings acquired from other farmers (Rigal et al., 2022). Furthermore, to be successful, both economically and ecologically, cocoa agroforestry necessitates different constellations of non-cocoa tree species and other plants at different times, depending on the height and age of the cocoa trees. Cocoa-agroforestry systems are in effect three-dimensional arrangements of trees and plants: on the ground, in the canopy and under the soil (Asare, 2006) with time constituting a fourth dimension.

6.3 Implications for Policy and Practice

To ensure a more sustainable production of cocoa, several global and national initiatives and policies have been put in place. The Cocoa & Forests Initiative was introduced by the cocoa and chocolate sector in 2017 as a collective commitment to address deforestation and forest degradation in the cocoa supply chain, focusing initially on Ghana and Côte d'Ivoire. Yet, questions have been raised regarding the effectiveness of such voluntary sustainability measures, and calls have been made for the coordinated accountability of public and private activities (Carodenuto & Buluran, 2021). Another initiative is the Emission Reductions Payment Agreements (ERPAs) for the Carbon Fund with the World Bank as a Trustee, signed by the government of Ghana in 2019 (ER-MR, 2021). Under this program, there is a benefit-sharing plan that guides the sharing of Carbon Benefits generated under the Ghana Cocoa Forest REDD+ Program (GCFRP). The GCFRP uses a climate-smart cocoa-production strategy, which is the world's first commodity-based emission reductions program that aims to significantly reduce deforestation and forest degradation-driven emissions, while making sure that smallholders' livelihoods are improved through increases in yields.

A further initiative is the Living Income Differential (LID) policy from 2019, which the cocoa marketing boards of Ghana and Côte d'Ivoire have established with the chocolate companies. The Ghanaian cocoa marketing board (The Ghana Cocoa Board, or Cocobod) regulates the pricing, purchasing, marketing and exportation of cocoa beans in Ghana, and provides support programs to farmers (see Chapter 5). The aim of the LID policy is to add a premium to the price of cocoa to ensure a living income for cocoa farmers, defined as the "net annual income required for a household in a particular place to afford a decent standard of living for all members of that household" (Adams & Carodenuto, 2023, p. 2). It is envisaged that GCFRP and LID together will make Ghana's cocoa and forestry sectors more resilient with earnings from climate-smart cocoa beans that promote the active incorporation of shade trees when establishing new or rehabilitating old plantations. However, studies have pointed to the need for such policies to give greater consideration to farmer diversity in relation to, for example, tenure, farm size and management strategies (Adams & Carodenuto, 2023).

While implementing policies that address the broader institutional landscape, along with land use, is of key importance, this is difficult and takes time. Therefore, in the short term, the institutional challenges farmers face must be taken into consideration by policymakers, practitioners and researchers when researching and implementing cocoa-agroforestry systems. In the following, we provide recommendations for policy and practice in relation to how to optimize the complex of plant species involved in a cocoa-agroforestry system while being mindful of the socioeconomic and institutional landscape. These recommendations can broadly be organized into three categories depending on whether they relate to: (1) the components going into the system, (2) how the system functions, and (3) the outputs of the system.

6.3.1 The Components Going into the Cocoa-Agroforestry System

When cocoa was first introduced to Ghana in the 1880s, it was established as an unplanned agroforestry system that depended on forest-fallow regimes and their natural processes of regeneration, thus enabling the farmers to organize and diversify cocoa-agroforestry systems (Asare & Asare, 2008). Shade trees were maintained either because they were deemed important or because farmers did not have the equipment needed to fell them, and the land was then planted with cocoa seedlings, food and cash crops to provide shade for the seedlings and to obtain food and income (Osei-Bonsu et al., 1998). More recently, cocoa farms have been established by completely clearing the land through felling and burning, after which farmers plant shade trees and food crops followed by cocoa seedlings. Farmers also remove regenerated forest-tree saplings that are seen as competing with the cocoa seedlings while nurturing those that are believed to be of value (Asare & Asare, 2008).

As we have shown, to implement a cocoa-agroforestry system, seedlings and other plants must be obtained, labor is needed, and various inputs such as fertilizer and insecticide must be applied. Time is also a factor, specifically how much time the farmer can put into the system before outcomes are required. This will in part depend on farmers' rights and access to the land. Extension services that provide guidance on how and when to plant, prune, harvest and apply inputs can affect outcomes. What constitutes an optimal complex of plant species depends on these different elements. Thus, if a farmer has little time and labor, and no access to inputs or regular extension services, a different complex of plant species will be more advantageous than is the case for a farmer who has a longer time horizon, can afford paid labor or has family labor available, and who has easy access to inputs and services. The ability to access these different elements varies from place to place and from farmer to farmer, hence it is important for policymakers and practitioners to understand the local context when seeking to support and implement cocoa agroforestry. That said, in general, many farmers in Ghana operate with short time horizons, need to minimize labor and other inputs, and do not have easy access to seedlings or extension services (Boadi et al., 2022). Furthermore, current tree-tenure arrangements specific to the Ghanaian regulatory context require farmers to register the trees on their farms with the Forestry Commission. This effectively creates an unnecessary disincentive for farmers to care for trees. We therefore recommend that research, policy and practice focus on how to optimize the complex of plant species for this group of farmers—biophysically, socio-ecologically and in terms of regulations. Overall, our findings that are relevant in this regard indicate that shade reduces the need for inputs and that greater shade tree species diversity in cocoa-agroforestry systems reduces labor needs.

6.3.2 How the Cocoa-Agroforestry System Functions

In addition to being aware of the different components going into the cocoa-agroforestry system, it is important to pay attention to how the complex of plant species influences system processes. These processes include competition and complementarity between species (both in terms of water and nutrients) and the occurrence of pests and diseases. Moreover, shade levels will affect the climate resilience of the system (Asitoakor et al., 2022a, 2022b; Mensah et al., 2022). These processes vary between climate zones and sites, and we therefore recommend that this must be considered by researchers, policymakers and practitioners. Our findings that are relevant in this regard indicate that implementing cocoa agroforestry sustainably in the Transform Zone, the zone with the least suitable climate for cocoa farming, may not be possible. Agroforestry was unable to mitigate the negative impacts of the adverse climate and could in fact have a negative effect. Besides, as shown in our cost–benefit analysis, cocoa agroforestry in this zone produced the lowest yields.

It should be pointed out, however, that with more research it may be possible to identify shade tree species that better buffer the negative impacts of climate change in climates corresponding to the Transform Zone. This, coupled with breeding for drought-resistant cocoa, could make cocoa farming in marginal areas viable. Nevertheless, our results indicate that resources would be better utilized if research efforts were focused on sustainable cocoa farming in the other two zones, in particular the Cope Zone. In these two zones, our findings show, shade leads to a more optimal plant physiology under stress conditions instigated by changes in the climate. Impacts depend, however, on complementarity in water use between shade tree species and cocoa. Deep-rooted shade trees that tap soil water below the cocoa root zone may work best. Furthermore, different shade tree species appear to lead to different levels of pest and disease incidence.

6.3.3 Outputs from the Cocoa-Agroforestry System

The output of the cocoa-agroforestry system can be assessed in terms of improvements to the productivity of cocoa beans, fruit and timber as well as the lifespan of the cocoa trees, and in terms of the possibilities for on-farm or off-farm diversification. Research has shown that shade can prolong the economic lifespan of cocoa trees (Obiri et al., 2007), and our findings indicate that different shade tree species may affect overall yields differently. For the farmer, the degree to which the benefits outweigh the costs of the cocoa-agroforestry system does not just depend on the yield of cocoa. The integration of trees and crops that provide marketable products such as timber and fruit is also important.

If done correctly, cocoa agroforestry can be more consistently profitable, while being less labor-intensive than monocrop systems. This could free up labor for other livelihood activities, reduce the use of illegal child labor and make cocoa farming a more attractive option for the young. We therefore recommend that farmers are supported in diversifying cocoa-agroforestry systems in terms of shade tree species and involving fruits and other products for household consumption and sale. This includes making the best use of easily available self-sown shade tree seedlings to maximize outputs of foodstuffs and timber for household consumption and sale. It is also important to encourage farmers to choose shade tree species that increase cocoa yields while reducing pests and diseases without competing with cocoa trees for water and nutrients. Importantly, extension services should pay particular attention to cocoa farmers that are not officially registered and therefore easily bypassed, often women and migrants that are less likely to own cocoa land yet carry out a significant proportion of cocoa work.

6.4 Moving Forward

The future of cocoa is unclear. As a result of climate change, diseases and weather variations, supply deficits are projected (ICCO, 2023). The impact of supply deficits on cocoa management, prices and quality requirements is uncertain. One possible response is an intensification of cocoa farming that involves low to no shade trees and a high need for agricultural inputs. However, this will come at the expense of the environment and likely the small-scale farmers. New regulations on the world's main chocolate market—the EU—have set new requirements for companies that import and trade cocoa beans and their derivatives. From 2025, importers must document that the products are not associated with deforestation or forest degradation, among other environmental concerns. While this may not affect areas deforested before 2021, it is expected to influence the expansion of new cocoa areas (Li et al., 2022). Moreover, it may increase the number of sustainability projects licensed cocoa-buying companies conduct in producing countries. It is anticipated that these projects will focus on the dissemination of shade trees, as well as information on environmental and social issues. Demand for quality cocoa is also expanding rapidly, with Ghana and Côte d'Ivoire poorly positioned because cocoa beans originating from these countries are of far lower organoleptic (sensory) quality than beans from Latin America (Fountain & Hütz-Adams, 2022). There is an increasing interest in assessing the effect of shade trees on cocoa quality. This book argues that agroforestry can address many of the challenges currently faced by cocoa farmers in Ghana, and more broadly in West Africa, and therefore provides a sustainable future pathway for cocoa. Nevertheless, more research is needed to better understand and implement cocoa agroforestry.

6.4.1 More Focus on Shade Tree Species

In contemporary research, policy and practice, there is a global tendency to regard and present tree planting as a straightforward and inexpensive panacea ameliorating climate change. The findings presented in this book offer an informed alternative to this simplistic approach to, and understanding of, tree planting. We have stressed that to increase cocoa farmers' engagement in cocoa agroforestry and make cocoa farming more sustainable, place-specific knowledge concerning the effects of shade tree species is needed. It is time to move beyond the generic focus on shade levels and cocoa yields.

We have suggested that research needs to place particular emphasis on how to minimize the need for inputs, including time, labor and fertilizers. One potential avenue for research in this regard is to look at the relationship between specific shade tree species and the need for inputs in cocoa farming. Some shade tree species will, for example, host pests that would otherwise have concentrated on the cocoa tree. Research is needed to understand the net effect of shade trees on the incidence of pests on cocoa trees, which impacts the need for chemicals. Another important avenue for research is to investigate the impacts of the age of both shade trees and cocoa trees.

6.4.2 Multidisciplinary Research

The book has investigated the potential of cocoa agroforestry in times of climate change, focusing not just on cocoa yields, but also on how to ensure that cocoa farming remains a viable and attractive livelihood option for farmers, including future generations of farmers. This has only been possible by employing multidisciplinary approaches. Unfortunately, in practice, such approaches are difficult to implement for several reasons. Researchers may not be used to communicating across disciplines, and it is difficult to receive funding for multidisciplinary approaches, which can involve greater expense because different research methods can require different equipment and research set-ups. In relation to research on trees and climate change, studies need to be longitudinal to obtain results, and many funding bodies will only fund a maximum of three to five years of research.

In the CLIMCOCOA research project, we worked deliberately on ensuring communication across disciplines. This was done in different ways, first by associating researchers from different disciplines from the beginning of the study design. We also organized reading groups where we discussed texts from different disciplines and presented our research and approaches to other team members, as well as to a broader audience, for example through conference panels where both the biophysical and socioeconomic findings were presented. This enabled us to identify findings that cut across both the biophysical and the socioeconomic, such as our finding that it may not be possible to implement cocoa agroforestry sustainably in marginal regions of the cocoa belt (e.g., the Transform zone).

Perhaps the most important outcome of multidisciplinary research is that it enables researchers to understand and communicate research topics in a larger context, rather than focusing on a narrow research agenda. Thereby, the societal relevance of the research becomes greater. In this sense, the present book represents a step toward a better understanding of the interrelations of biophysical and socioeconomic factors and points to the need for further multidisciplinary research on climate change, sustainability and agriculture.

6.4.3 More Focus on Farmers

In recent years, research on the sustainability of cocoa farming has expanded significantly. This is not only due to the threats caused by climate change, but also because cocoa and chocolate consumers and investors are increasingly expecting the cocoa industry to address sustainability concerns in the cocoa sector. This includes both environmental and social aspects, such as acceptable working conditions and the elimination of child labor. This has created an opportunity for researchers, civil society, NGOs and policymakers to direct research activities toward sustainable cocoa farming and challenged the chocolate industry to be actively involved in research on sustainability in the cocoa sector.

We welcome this concern for the sustainability of farming cocoa, which has been studied less than other cash crops such as coffee. However, it is important that research is not only site- and species-specific, but that it also considers that farmers are individuals with different options and interests. This includes paying particular attention to farmers who are systematically underrepresented in research on cocoa farming because they are not the official landowners, or are not officially registered as cocoa farmers, such as women and migrants. At present, and given the growing age of cocoa farmers, the lack of interest among the young may be one of the biggest threat to the future of cocoa in Ghana. It is therefore of crucial importance that research on cocoa agroforestry not only examines the climate resilience of the agroecosystem, but also systematically investigates the vital role of both socioeconomic and institutional factors and concerns. Without farmers, there will be no cocoa farming.

References

Abdulai, I., Jassogne, L., Graefe, S., Asare, R., Van Asten, P., Läderach, P., & Vaast, P. (2018a). Characterization of cocoa production, income diversification and shade tree management along a climate gradient in Ghana. *PLoS ONE, 13*(4), 1–17. https://doi.org/10.1371/journal.pone.0195777

Abdulai, I., Vaast, P., Hoffman, M., Asare, R., Jassogne, L., Asten, V. P., Rotter, P. R., & Graefe, S. (2018b). Cocoa agroforestry is less resilient to sub-optimal and extreme climate than cocoa in full sun. *Global Change Biology, 24*(1), 273–286.

Adams, M. A., Turnbulla, T. L., Sprent, J. I., & Buchmannc, N. (2016). Legumes are different: Leaf nitrogen, photosynthesis, and water use efficiency. *PNAS, 113*, 4098–4113.

Adams, M. A., & Carodenuto, S. (2023). Stakeholder perspectives on cocoa's living income differential and sustainability trade-offs in Ghana. *World Development, 165*. https://doi.org/10.1016/j.worlddev.2023.106201

Ameyaw, L. K., Ettl, G. J., Leissle, K., & Anim-Kwapong, G. J. (2018). Cocoa and climate change: Insights from smallholder cocoa producers in Ghana regarding challenges in implementing climate change mitigation strategies. *Forests, 9*(12), 742.

Anyidoho, N. A., Leavy, J., & Asenso-Okyere, K. (2012). Perceptions and aspirations: A case study of young people in Ghana's cocoa sector. *IDS Bulletin, 43*(6), 20–32. https://doi.org/10.1111/j.1759-5436.2012.00376.x

Asante, P. A., Rahn, E., Zuidema, P. A., Rozendall, D. M. A., van der Baan, M. E. G., Läderach, P., Asare, R., Cryer, N. C., & Anten, N. P. R. (2022). The cocoa yield gap in Ghana: A quantification and an analysis of factors that could narrow the gap. *Agricultural Systems, 201*, 103473. https://doi.org/10.1016/j.agsy.2022.103473

Asare, R. (2006). *Learning about neighbour trees in cocoa growing systems—A manual for farmer trainers* (Development and Environment Series 4-2006). Forest & Landscape Denmark.

Asare, R., & Asare, A. R. (2008, September). *A participatory approach for tree diversification in cocoa farms: Ghanaian farmers' experience* (STCP Working Paper Series 9). International Institute of Tropical Agriculture.

Asare, R., Markussen, B., Asare, R. A., Anim-Kwapong, G., & Ræbild, A. (2019). On-farm cocoa yields increase with canopy cover of shade trees in two agro-ecological zones in Ghana. *Climate and Development, 11*(5), 1–12. https://doi.org/10.1080/17565529.2018.1442805

Asitoakor, B. K., Asare, R., Ræbild, A., Ravn, H. P., Eziah, V. Y., Owusu, K., Mensah, E. O., & Vaast, P. (2022b). Influences of climate variability on cocoa health and productivity in agroforestry systems in Ghana. *Agricultural and Forest Meteorology, 327*(109199), 1–13. https://doi.org/10.1016/j.agrformet.2022.109199

Asitoakor, B. K., Vaast, P., Ræbild, A., Ravn, H. P., Eziah, V. Y., Owusu, K., Mensah, E. O., & Asare, R. (2022a). Selected shade tree species improved cocoa yields in low-input agroforestry systems in Ghana. *Agricultural Systems, 202*(103476), 1–9. https://doi.org/10.1016/j.agsy.2022.103476

Barrientos, S., & Bobie, A. O. (2016). *Promoting gender equality in the cocoa-chocolate value chain: Opportunities and challenges in Ghana* (GDI Working Paper 2016-006). University of Manchester.

Boadi, S. A., Olwig, M. F., Asare, R., Bosselmann, A. S., & Owusu, K. (2022). The role of innovation in sustainable cocoa cultivation: Moving beyond mitigation and adaptation. In M. Coromaldi & S. Auci (Eds.), *Climate-induced innovation: Mitigation and adaptation to climate change* (pp. 47–80). Springer.

Bunn, C., Fernandez-Kolb, P., Asare, R., & Lundy, M. (2019, September). *Climate smart cocoa in Ghana: Towards climate resilient production at scale*. CCAFS Info Note. https://cgspace.cgiar.org/bitstream/handle/10568/103770/CCAFS%20Info%20Note_%20cocoa%20Ghana%20finalized_20190930.pdf

Carodenuto, S., & Buluran, M. (2021). The effect of supply chain position on zero-deforestation commitments: Evidence from the cocoa industry. *Journal of Environmental Policy & Planning, 23*(6), 716–731. https://doi.org/10.1080/1523908X.2021.1910020

Critchley, M., Sasse, M., Rahn, E., Ashiagbior, G., Soesbergen, A., & Maney, C. (2022). *Identifying opportunity areas for cocoa agroforestry in Ghana to meet policy objectives*. United Nations Environmental Programme of World Conservation Monitoring Centre.

Danquah, F. K. (2003). Sustaining a West African cocoa economy: Agricultural science and the Swollen Shoot contagion in Ghana, 1936–1965. *African Economic History* (31), 43–74.

ER-MR. (2021). Forest Carbon Partnership Facility (FCPF) carbon fund ER Monitoring Report (ER-MR), Forestry Commission.

Fountain, A. C., & Hütz-Adams, F. (2022). *2022 cocoa barometer*.

Graefe, S., Meyer-Sand, L. F., Chauvette, K., Abdulai, I., Jassogne, L., Vaast, P., & Asare, R. (2017). Evaluating farmers' knowledge of shade trees in different cocoa agro-ecological zones in Ghana. *Human Ecology, 45*(3), 321–332. https://doi.org/10.1007/s10745-017-9899-0

ICCO. (2023.) *Quarterly Bulletin of Cocoa Statistics*, Vol. XLIX, No.1, Cocoa year 2022/2023.

Jaimes-Suarez, Y. Y., Carvajal-Rivera, A. S., Galvis-Neira, D. A., Carvalho, F. E. L., & Rojas-Molina, J. (2022). Cacao agroforestry systems beyond the stigmas: Biotic and abiotic stress incidence impact. *Frontiers in Plant Science, 13*, 921469.

Kaba, J. S., Otu-nyanteh, A., & Abunyewa, A. A. (2020). The role of shade trees in influencing farmers' adoption of cocoa agroforestry systems: Insight from semi-deciduous rain forest agroecological zone of Ghana. *NJAS—Wageningen Journal of Life Sciences, 92*(100332), 1–7. https://doi.org/10.1016/j.njas.2020.100332

Kyereh, D. (2017). Shade trees in cocoa agroforestry systems in Ghana: Influence on water and light availability in dry seasons. *Journal of Agriculture and Ecology Research International, 10*(2), 1–7.

Li, B., Schneider, T., Stolle, F., &. Veldhoven, S. (2022). *How a new EU regulation can reduce deforestation globally*. World Resources Institute. https://www.wri.org/insights/eu-deforestation-regulation

Mattalia, G., Wezel, A., Costet, P., Jagoret, P., Deheuvels, O., Migliorini, P., & David, C. (2022). Contribution of cacao agroforestry versus monocropping systems for enhanced sustainability. A review with a focus on yield. *Agroforestry Systems, 96*(1). https://doi.org/10.1007/s10457-022-00765-4

Mensah, E. O., Asare, R., Vaast, P., Amoatey, C. A., Markussen, B., Owusu, K., Asitoakor, B. K., & Ræbild, A. (2022). Limited effects of shade on physiological performances of cocoa (Theobroma cacao L.) under elevated temperature. *Environmental and Experimental Botany, 201*(104983), 1–11.

Nunoo, I., & Owusu, V. (2017). Comparative analysis on financial viability of cocoa agroforestry systems in Ghana. *Environment, Development and Sustainability, 19*(1), 83–98. https://doi.org/10.1007/s10668-015-9733-z

Obiri, B. D., Bright, G. A., McDonald, M. A., Anglaaere, L. C., & Cobbina, J. (2007). Financial analysis of shaded cocoa in Ghana. *Agroforestry Systems, 71*, 139–149.

Osei-Bonsu, K., Amoah, F. M., & Oppong, F. K. (1998). The establishment and early yield of cocoa intercropped with food crops in Ghana. *Ghana Journal of Agricultural Science, 31*, 45–53.
Rigal, C., Wagner, S., Nguyen, M. P., Jassogne, L., & Vaast, P. (2022). ShadeTreeAdvice methodology: Guiding tree-species selection using local knowledge. *People and Nature*, 16 pp. https://doi.org/10.1002/pan3.10374
Ruf, F., & Schroth, G. (2004). Chocolate forests and monocultures: A historical review of cocoa growing and its conflicting role in tropical deforestation and forest conservation. In G. Schroth, A.-M. N. Izac, H. L. Vasconcelos, C. Gascon, G. A. B. da Fonseca, & C. A. Harvey (Eds.), *Agroforestry and biodiversity conservation in tropical landscapes* (Vol. 06). Island Press. https://doi.org/10.1017/CBO9781107415324.004
Schroth, G., Läderach, P., Martinez-Valle, A. I., Bunn, C., & Jassogne, L. (2016). Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities, and limits to adaptation. *Science of the Total Environment, 556*, 231–241.
Smith Dumont, E., Gnahoua, G. M., Ohouo, L., Sinclair, F. L., & Vaast, P. (2014). Farmers in Côte d'Ivoire value integrating tree diversity in cocoa for the provision of ecosystem services. *Agroforestry Systems, 88*(6), 1047–1066. https://doi.org/10.1007/s10457-014-9679-4