Agricultural Sciences, 2025, 16(10), 1075-1085
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Enhancing Smallholder Access to Improved Cocoa Planting Material in West Africa: Systemic Barriers and Reform Pathways for Sustainability and Climate-Resilience

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How to cite this paper: Adomako, E.E.A. and Lillesø, J.-P.B. (2025) Enhancing Smallholder Access to Improved Cocoa Planting Material in West Africa: Systemic Barriers and Reform Pathways for Sustainability and Climate-Resilience. *Agricultural Sciences*, **16**, 1075-1085.
https://doi.org/10.4236/as.2025.1610061

Received: August 31, 2025
Accepted: September 26, 2025
Published: September 29, 2025

Abstract

Cocoa production in West Africa, particularly in Ghana and Côte d'Ivoire, underpins the livelihoods of millions of smallholder farmers and is central to national economies. However, the sector faces mounting challenges including land scarcity, aging tree stocks, persistent poverty among producers, and climate change. Improved planting materials—bred for higher yields, pest and disease resistance, and climate resilience—are critical for revitalizing cocoa systems and reducing environmental degradation. Despite their potential, smallholder access to improved cocoa planting material remains a major challenge due to institutional and logistical constraints rooted in colonial governance structures, market liberalization reforms, and centralized state control. This paper highlights key issues such as weak seed multiplication systems, inadequate extension services, limited private-sector participation, and farmer risk aversion stemming from knowledge gaps. It argues for a paradigm shift toward decentralized, farmer-focused seed systems supported by policy reforms, public-private partnerships, and participatory breeding and varietal development. By addressing structural inequities and enhancing institutional responsiveness, these strategies will help strengthen seed governance, improve quality assurance, and ensure equitable access to the genetic innovations needed for improved productivity and long-term sustainability of the cocoa sector. The paper emphasizes the integration of improved varieties into climate-smart, agroforestry-based production systems to promote ecological resilience.

Keywords

Cocoa Seed Systems, Smallholder Farmers, Improved Planting Material, Seed Governance, Climate-Smart Agriculture

1. Introduction

Cocoa (*Theobroma cacao* L.) is a vital cash crop for over five million smallholder farmers across the globe and a key contributor to national economies, particularly in Ghana and Côte d'Ivoire, which together produce about two-thirds of the world's cocoa. Yet, many farmers in these West African countries live in poverty [1] [2]. While cocoa production drives gross domestic product (GDP) and export earnings, its expansion has also contributed to deforestation and biodiversity loss [3]-[6].

Much of the growth in cocoa production has come from expanding into forests, where initial investment costs are low because of "forest rent"—the temporary yield advantage gained from clearing forest land due to fertile soils, a favorable microclimate, and low levels of pests and diseases [4]. However, as forests decline, so do these benefits. West Africa may now have no forest frontiers left to exploit, making it critical to shift from forest-dependent farming practices to sustainable, science-based intensification [7]-[10]. Apart from land scarcity, cocoa farming faces climate-related risks and aging trees, which lead to lower yields and higher pest pressures [4] [11] [12]. Meanwhile, global demand for cocoa continues to rise, raising concerns about whether current supply can keep up [13] [14].

2. The Role of Quality Planting Material in Sustainable Cocoa Systems

Improved cocoa varieties are central to building more sustainable and resilient cocoa systems [9] [15]-[17]. Bred for higher yields, early maturity, and resistance to major pests and diseases such as cocoa swollen shoot virus (CSSV) and black pod, these improved planting materials also offer greater tolerance to climatic stressors like drought and heat [18]-[20]. Given that much of West Africa's cocoa is produced from ageing, low-yielding trees, replacing them with improved varieties is essential for reversing productivity decline and reducing pressure to expand into forested areas [3] [10].

However, improved tree genetics alone cannot guarantee sustainable intensification. Their benefits depend on a broader enabling environment—secure land tenure, reliable seed distribution systems, and institutional support for risk mitigation [21] [22]. Without these complementary conditions, the uptake and effective deployment of improved varieties remain limited, undermining efforts to address environmental degradation, climate vulnerability, and persistent low productivity in cocoa systems [8] [19] [23].

3. Barriers to Accessibility

3.1. Historical and Political Economy Dimensions

The governance of cocoa seed systems reflects deeper structural inequalities rooted in both colonial legacies and contemporary global market dynamics. Smallholder farmers—who are critical to the cocoa supply chain—remain largely unorganized and under-represented in global markets, severely limiting their influence over price-setting mechanisms. In stark contrast, market power is concentrated among a few downstream actors, with approximately eight trading and grinding companies and six chocolate manufacturers controlling over 80% of the global cocoa market [6]. Producer prices directly influence farmer behavior—when prices fall, farmers reduce investment and maintenance of their farms [4] [23] [24], including the adoption of improved planting materials.

Colonial and post-independence governance frameworks in West Africa entrenched centralized control over cocoa production and input distribution, thereby limiting farmer autonomy and innovation. During the colonial period, stabilization or marketing boards were established to shield farmers from volatile global markets and climatic shocks. These boards accumulated reserve funds during boom periods to support farm-gate prices during downturns [4] [12]. The funds were also used to subsidize or fully finance critical inputs distributed to farmers such as fertilizers and pesticides [23].

However, most of these boards—except Ghana's Cocoa Board (COCOBOD)—were dismantled in the 1980s and 1990s under structural adjustment programs promoted by the World Bank and IMF [12] [25]. The accompanying erosion of state extension services further fragmented support to smallholders. Privatized input delivery systems that replaced state-led programs often failed to reach marginal farmers, particularly those in remote or low-income areas.

Although Ghana's COCOBOD has maintained a relatively strong presence through programs such as CODAPEC (targeting pest and disease control) and Hi-Tech (providing subsidized fertilizer and improved seed), cocoa yields remain low—averaging between 200 and 700 kg per hectare, far below the crop's potential yield of about 2 tons per hectare under well managed trial conditions [7]. These yield gaps reflect not only biophysical constraints but also deep-seated institutional and structural barriers to accessing quality planting material.

3.2. Institutional and Logistical Constraints

The institutional architecture governing cocoa planting material in West Africa has long been characterized by centralized public sector control [4] [9]. Government-managed seed delivery systems—exemplified by state-sponsored seed gardens and nurseries—form the backbone of formal supply chains. This system corresponds to what Lillesø *et al.* [26] describe as the "government model"—a centrally managed seed delivery system in which a public agency, such as a National Tree Seed Centre, exercises full control over the sourcing, propagation, and distribution of planting material. Lillesø *et al.* [26] contrast this with two other models: the "NGO model", where planning is also centralized but quality control of seed sources is less rigorous, and the "decentralized model", where activities are managed by local actors or community nurseries using seed sources made available by a central authority. These models differ primarily in terms of who controls seed sources, the extent to which technical knowledge is applied, and how transaction costs are shared.

Despite its wide reach, the government model has shown limited success in addressing farmers' location-specific needs or ensuring reliable delivery of quality planting material. For example, a study commissioned by the Sustainable Tree Crops Program (STCP) found that Ghana, Nigeria, and Cameroon lacked systematic procedures to assess farmers' demand for cocoa seed [15]. Without reliable demand forecasting or adaptive planning, national seed production units routinely face shortfalls, which force farmers to depend on informal systems such as farmer-saved seeds, exchanges among peers, or purchases from local markets. These sources often vary greatly in quality, contributing to high seedling mortality [16].

Moreover, the logistical burden placed on farmers is often considerable. Gockowski [12] recounts how smallholders may spend an entire day travelling to centralized seed production units, only to find no seed pods available. Such inefficiencies not only delay field establishment but also erode farmers' trust in formal institutions, perpetuating reliance on informal, sub-optimal sources. Compounding these supply-side challenges are weak extension services, poor road infrastructure, and insufficient access to credit [24] [27] [28]. These deficiencies collectively constrain both the production and uptake of improved planting material, thereby undermining cocoa sector resilience.

3.3. Knowledge Gaps and Farmer Risk Aversion

Even when improved planting material is available, adoption remains uneven due to persistent knowledge gaps and risk perceptions among smallholder farmers [27]. Many are understandably cautious about shifting to new varieties without clear, localized information about performance, input requirements, and long-term profitability [29]. As a result, farmers rely heavily on peer learning and informal networks, which—while important—may perpetuate misconceptions or slow the diffusion of innovations.

4. Towards a Systemic Solution: Strategies for Enhancing Access

4.1. Breeding Innovations

Advancements in breeding technologies such as genomic selection (GS), marker-assisted selection (MAS), and accelerated propagation methods, are pivotal in developing climate-resilient, high-yielding cocoa varieties [30]-[32]. These tools enable breeders to efficiently select for complex traits like drought tolerance, disease resistance, and yield stability, thereby reducing the breeding cycle.

Genomic selection, which utilizes genome-wide markers to predict breeding values, has demonstrated significant potential in improving traits such as seed number and size in cocoa. For instance, a study involving 421 cacao accessions identified significant marker-trait associations, facilitating the selection of superior genotypes for yield improvement [33]. Accelerated propagation techniques, including *in vitro* embryogenesis, have also been successfully applied to reduce generation times [34].

Institutions such as the Cocoa Research Institute of Ghana (CRIG) and the International Institute of Tropical Agriculture (IITA) in Nigeria have made notable strides in integrating these technologies into cocoa breeding programs. However, scaling these innovations necessitates enhanced regional collaboration, capacity building, and investment in infrastructure to support widespread adoption and impact.

4.2. Public-Private Partnerships

To enhance the production and uptake of quality planting materials, Gockowski *et al.* [35] proposed that public institutions should maintain their core role in varietal development, while the multiplication and distribution of planting materials should increasingly be delegated to the private sector. Such a public-private partnership (PPP) would position governments to focus on upstream functions such as research and quality assurance, while downstream activities—particularly propagation and delivery—are handled by licensed private and community actors. Progress toward the PPP model has, however, been slow. The current government monopoly on seed production, often linked to regulatory control over producer prices, has stifled private-sector engagement [12]. Additionally, cocoa's long production cycles and lower frequency of seed demand compared to annual crops make the economics less attractive to profit-oriented enterprises.

Nonetheless, there are promising signs of change. In Ghana, an innovation platform facilitated by Adu-Acheampong *et al.* [23] catalyzed a shift from free or heavily subsidized input supply models to market-based ones. Fertilizers are now distributed on credit by licensed cocoa buyers. Similar arrangements exist in Nigeria and Cameroon for fungicides and insecticides [12]. These emerging credit and delivery networks could be extended to include improved planting material, especially if bundled with extension advice and performance guarantees.

Establishing commercial nursery networks, as proposed by Lillesø *et al.* [36], is essential to formalizing the role of private actors. However, such networks will only thrive if they are supported by enabling policies, consistent demand, and reliable access to foundational material from public institutions.

A practical West African example of a successful PPP for cocoa seed delivery is Tree Global's partnership with COCOBOD, Mondelēz International, and other members of the World Cocoa Foundation (WCF). Under this partnership, Tree Global obtains certified hybrid seeds from COCOBOD's Seed Production Division (SPD) and raises them in its private nurseries into robust seedlings in recyclable pots designed to protect tap roots during transport to remote farming communities. This reduces the logistical burden on farmers while improving confidence in seedling quality [37] [38]. Although still modest in scale, the initiative demonstrates the feasibility of nursery based PPPs and highlights how targeted public support combined with private-sector efficiency can expand farmer access to quality planting material.

4.3. Decentralized, Farmer-Focused Seed Systems

A shift from the centralized government model toward decentralized seed systems—anchored in farmer cooperatives, certified local nurseries, and community-based multipliers—offers a viable and scalable alternative. These systems are more responsive to farmers' agro-ecological realities and social networks and can reduce transaction costs while increasing trust and adoption.

An illustrative example is the seed brokerage system developed by Asare *et al.* [16], which connected 375 farmers in Ghana to the most appropriate seed gardens and supported them to raise their own nurseries. By aggregating demand and facilitating group-based procurement and seedling production, the model improved access, reduced costs, and strengthened collective capacity.

Yet decentralized systems must be coupled with robust certification and quality control mechanisms. Without these, farmers risk acquiring poor-quality material from informal channels, which has been a recurring issue across the region [16] [35]. Voluntary sustainability standards and certification schemes such as Cocoa Life and CocoaAction have attempted to improve access to quality inputs, though with limited reach and inconsistent implementation [39] [40].

Improved communication strategies are also critical. Research from Nigeria shows that farmers' exposure to diverse communication channels significantly influences adoption decisions [41]. Extension models must therefore evolve from top-down dissemination to participatory, dialogue-driven approaches that empower farmers as co-producers of knowledge.

4.4. Climate Adaptation and Landscape Integration

Studies have shown that integrating cocoa within diversified agroforestry systems—incorporating nitrogen-fixing trees, timber species, and food crops—enhances microclimatic stability, biodiversity conservation, and carbon sequestration [42] [43]. Embedding improved planting materials within such climate-smart, landscape-based approaches is central to sustainable cocoa production, as illustrated by the Cocoa & Forests Initiative (CFI)—a PPP between the governments of Ghana and Côte d'Ivoire and leading cocoa ad chocolate companies aimed at tackling deforestation and restoring forest areas [44] [45]. Within this framework, Mondelēz International's Cocoa Life program not only distributes millions of improved cocoa seedlings to farmers but also supports the integration of shade, fruit, and timber trees into cocoa farms, thereby improving soil health and biodiversity while contributing to carbon sequestration [46].

However, realizing the full potential of these integrated approaches depends not only on access to improved planting material but also on ensuring that varietal selection aligns with system design. For instance, full-sun hybrids may yield more initially but often lead to quicker soil degradation and require higher nutrient inputs. By contrast, shaded systems may offer more resilience and longevity [12] [16]. CRIG's recommendation for farmers to retain 30% - 40% crown cover in improved cocoa agroforestry systems provides a policy benchmark that aligns productivity with ecological stewardship [47].

To support such transitions, farmers need access to climate-appropriate varieties, clear information on trade-offs, and supportive extension services. Landscape-scale planning and local experimentation will be essential to tailoring solutions to specific zones, especially as climate gradients shift across the cocoa belt.

5. Conclusion

Improved cocoa planting material holds significant promise for transforming West African cocoa landscapes in the face of declining productivity, climate change, and ecological degradation. Yet, realizing this promise requires more than technical solutions—it demands policy reforms that lower adoption barriers while enhancing quality assurance. Although this review has provided a broad synthesis of systemic barriers and reform pathways, the available evidence is skewed toward Ghana. This reflects Ghana's distinctive seed system governance through COCOBOD, as well as the greater availability of peer-reviewed, English-language literature on Ghana's cocoa seed system compared with other countries. In Côte d'Ivoire, relevant research exists but is less accessible in the peer-reviewed, English-language literature and often emphasizes marketing and price reforms rather than planting material. By contrast, empirical work from lower cocoa-producing countries such as Nigeria, Cameroon, Togo, and Liberia remains very limited. Addressing this imbalance through more field-based studies across a wider range of producing contexts will be important to complement and deepen the insights presented here. This paper has also highlighted the need for a shift toward decentralized, participatory, and inclusive seed systems that facilitate public-private partnerships and better farmer engagement. Integrating improved planting material within broader climate adaptation and landscape restoration strategies will be essential to ensuring long-term sustainability and resilience.

Acknowledgements

Support from the authors' affiliate institutions and the World Agroforestry Centre (ICRAF) is gratefully acknowledged.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Kozicka, M., Tacconi, F., Horner, D. and Gotor, E. (2018) Forecasting Cocoa Yields for 2050. Bioversity International.

[2] Squicciarini, M.P. and Swinnen, J. (2016) A Brief Economic History of Chocolate. Oxford Scholarship Online.

[3] Abdulai, I., Hoffmann, M.P., Jassogne, L., Asare, R., Graefe, S., Tao, H., *et al.* (2020) Variations in Yield Gaps of Smallholder Cocoa Systems and the Main Determining Factors along a Climate Gradient in Ghana. *Agricultural Systems*, **181**, Article 102812. https://doi.org/10.1016/j.agsy.2020.102812

[4] Gunnarsson, C. (2018) Ghana's Recurrent Miracle: Cocoa Cycles and Deficient Structural Change. In: Pinilla, V. and Willebald, H., Eds., *Agricultural Development in the World Periphery*, Springer International Publishing, 121-151. https://doi.org/10.1007/978-3-319-66020-2_5

[5] Ingram, V., Van Rijn, F., Waarts, Y. and Gilhuis, H. (2018) The Impacts of Cocoa Sustainability Initiatives in West Africa. *Sustainability*, **10**, Article 4249. https://doi.org/10.3390/su10114249

[6] Kroeger, A., Koenig, S., Thomson, A., Streck, C., Weiner, P.-H. and Bakhtary, H. (2017) Forest- and Climate-Smart Cocoa in Côte d'Ivoire and Ghana, Aligning Stakeholders to Support Smallholders in Deforestation-Free Cocoa. World Bank.

[7] Asare, R. (2019) The Nexus between Cocoa Production and Deforestation. *Grain de Sel*, **78**, 26-27.

[8] Gockowski, J. and Sonwa, D. (2010) Cocoa Intensification Scenarios and Their Predicted Impact on CO_2 Emissions, Biodiversity Conservation, and Rural Livelihoods in the Guinea Rain Forest of West Africa. *Environmental Management*, **48**, 307-321. https://doi.org/10.1007/s00267-010-9602-3

[9] Kolavalli, S. and Vigneri, M. (2017) The Cocoa Coast: The Board-Managed Cocoa Sector in Ghana. International Food Policy Research Institute.

[10] Wessel, M. and Quist-Wessel, P.M.F. (2015) Cocoa Production in West Africa, a Review and Analysis of Recent Developments. *NJAS*: *Wageningen Journal of Life Sciences*, **74**, 1-7. https://doi.org/10.1016/j.njas.2015.09.001

[11] Afriyie-Kraft, L., Zabel, A. and Damnyag, L. (2020) Adaptation Strategies of Ghanaian Cocoa Farmers under a Changing Climate. *Forest Policy and Economics*, **113**, Article 102115. https://doi.org/10.1016/j.forpol.2020.102115

[12] Gockowski, J. (2019) The Tree Crop Farming System: Stagnation, Innovation and Forest Degradation. In: Dixon, J., Garrity, D., Boffa, J.-M., Williams, T., Amede, T., et al., Eds., *Farming Systems and Food Security in Africa*, Routledge, 282-317. https://doi.org/10.4324/9781315658841-9

[13] Patterson, W. (2024) Astonishingly High Cocoa Prices Set to Continue as Deficit Concerns Grow. THINK Economic and Financial Analysis, ING Bank N.V.

[14] Voora, V., Bermúdez, S. and Larrea, C. (2019) Global Market Report: Cocoa. Sustainable Commodities Marketplace Series 2019. International Institute of Sustainable Development (IISD).

[15] Asare, R., Afari-Sefa, V., Gyamfi, I., Okafor, C. and Mva J.M. (2010) Cocoa Seed Multiplication: An Assessment of Seed Gardens in Cameroon, Ghana and Nigeria. STCP Working Paper Series Issue 11, The Sustainable Tree Crops Program, International Institute of Tropical Agriculture (IITA).

[16] Asare, R., Afari-Sefa, V. and Muilerman, S. (2016) Access to Improved Hybrid Seeds

in Ghana: Implications for Establishment and Rehabilitation of Cocoa Farms. *Experimental Agriculture*, **54**, 273-285. https://doi.org/10.1017/s0014479716000247

[17] Baby, J., Minimol, J.S., Santhoshkumar, A.V., Joseph, J., Abd-ElGawad, A.M. and Ullah, F. (2025) Identification and Development of Drought-Tolerant Cocoa Hybrids: Physiological Insights for Enhanced Water Use Efficiency under Water Stress Conditions. *BMC Plant Biology*, **25**, Article No. 501. https://doi.org/10.1186/s12870-025-06448-3

[18] CacaoNet (2012) A Global Strategy for the Conservation and Use of Cacao Genetic Resources, as the Foundation for a Sustainable Cocoa Economy (Compiled by B. Laliberté). Bioversity International.

[19] Kongor, J.E., Owusu, M. and Oduro-Yeboah, C. (2024) Cocoa Production in the 2020s: Challenges and Solutions. *CABI Agriculture and Bioscience*, **5**, Article 102. https://doi.org/10.1186/s43170-024-00310-6

[20] Rubiano, F., Talsma, T. and Nguyen-Duy, N. (2018) CSA Practices for Sustainable Cocoa Farming Systems. International Center for Tropical Agriculture (CIAT).

[21] Glover, D., Sumberg, J. and Andersson, J.A. (2016) The Adoption Problem; or Why We Still Understand So Little about Technological Change in African Agriculture. *Outlook on Agriculture*, **45**, 3-6. https://doi.org/10.5367/oa.2016.0235

[22] Binswanger-Mkhize, H.P. and Savastano, S. (2017) Agricultural Intensification: The Status in Six African Countries. *Food Policy*, **67**, 26-40. https://doi.org/10.1016/j.foodpol.2016.09.021

[23] Adu-Acheampong, R., Jiggins, J., Quartey, E.T., Karikari, N.M., Jonfia-Essien, W., Quarshie, E., *et al.* (2017) An Innovation Platform for Institutional Change in Ghana's Cocoa Sector. *Cahiers Agricultures*, **26**, Article 35002. https://doi.org/10.1051/cagri/2017016

[24] Anim-Kwapong, G.J. and Frimpong, E.B. (2010) Vulnerability and Adaptation Assessment under the Netherlands Climate Change Studies Assistance Programme Phase 2 (NCCSAP2) Vulnerability of Agriculture to Climate Change—Impact of Climate Change on Cocoa Production. Annual ICCO Report.

[25] Muilerman, S. and Vellema, S. (2017) Scaling Service Delivery in a Failed State: Cocoa Smallholders, Farmer Field Schools, Persistent Bureaucrats and Institutional Work in Côte d'Ivoire. *International Journal of Agricultural Sustainability*, **15**, 83-98. https://doi.org/10.1080/14735903.2016.1246274

[26] Lillesø, J.B.L., Graudal, L., Moestrup, S., Kjær, E.D., Kindt, R., Mbora, A., *et al.* (2011) Innovation in Input Supply Systems in Smallholder Agroforestry: Seed Sources, Supply Chains and Support Systems. *Agroforestry Systems*, **83**, 347-359. https://doi.org/10.1007/s10457-011-9412-5

[27] Acheampong, M., Appiah, P., Tham-Agyekum, E.K., Bakang, J.-A., Jones, E.O., Osei, C., *et al.* (2023) Farmers' Accessibility and Use of Hybrid Cocoa Seedlings for Cocoa Rehabilitation: Empirical Results from Amenfi Central District, Ghana. *Russian Journal of Agricultural and Socio-Economic Sciences*, **137**, 129-140. https://doi.org/10.18551/rjoas.2023-05.13

[28] Binam, J.N., Gockowski, J. and Nkamleu, G.B. (2008) Technical Efficiency and Productivity Potential of Cocoa Farmers in West African Countries. *The Developing Economies*, **46**, 242-263. https://doi.org/10.1111/j.1746-1049.2008.00065.x

[29] Cordaro, F. and Desdoigts, A. (2021) Bounded Rationality, Social Capital and Technology Adoption in Family Farming: Evidence from Cocoa-Tree Crops in Ivory Coast. *Sustainability*, **13**, Article 7483. https://doi.org/10.3390/su13137483

[30] Nieves-Orduña, H.E., Müller, M., Krutovsky, K.V. and Gailing, O. (2024) Genotyping

of Cacao (*Theobroma cacao* L.) Germplasm Resources with SNP Markers Linked to Agronomic Traits Reveals Signs of Selection. *Tree Genetics & Genomes*, **20**, Article No. 13. https://doi.org/10.1007/s11295-024-01646-w

[31] Ribeyre, F., Sounigo, O., Argout, X., Cilas, C., Efombagn, M.I.B., Denis, M., Bouvet, J.M., Fouet, O. and Lanaud, C. (2017) The Genomic Selection of *Theobroma cacao*: A New Strategy of Marker-Assisted Selection to Improve Breeding Efficiency and Predict Useful Traits in New Populations. *ICCO Proceedings of the International Symposium on Cocoa Research*, Lima, 13-17 November 2017.

[32] Schnell, R.J., Kuhn, D.N., Brown, J.S., Olano, C.T., Phillips-Mora, W., Amores, F.M., *et al.* (2007) Development of a Marker Assisted Selection Program for Cacao. *Phytopathology®*, **97**, 1664-1669. https://doi.org/10.1094/phyto-97-12-1664

[33] Bekele, F.L., Bidaisee, G.G., Allegre, M., Argout, X., Fouet, O., Boccara, M., *et al.* (2022) Genome-Wide Association Studies and Genomic Selection Assays Made in a Large Sample of Cacao (*Theobroma cacao* L.) Germplasm Reveal Significant Marker-Trait Associations and Good Predictive Value for Improving Yield Potential. *PLOS ONE*, **17**, e0260907. https://doi.org/10.1371/journal.pone.0260907

[34] Wickramasuriya, A.M. and Dunwell, J.M. (2018) Cacao Biotechnology: Current Status and Future Prospects. *Plant Biotechnology Journal*, **16**, 4-17. https://doi.org/10.1111/pbi.12848

[35] Gockowski, J., Robiglio, V., Muilerman, S. and Agyeman, N.F. (2011) Agricultural Intensification as a Strategy for Climate Mitigation in Ghana. An Evaluative Study of the COCOBOD Hi Tech Program, Rural Incomes, and Forestry Resources in the Bia (Juaboso) District of Ghana. Sustainable Tree Crops Program. IITA.

[36] Lillesø, J.P.B., Harwood, C., Derero, A., Graudal, L., Roshetko, J.M., Kindt, R., *et al.* (2017) Why Institutional Environments for Agroforestry Seed Systems Matter. *Development Policy Review*, **36**, O89-O112. https://doi.org/10.1111/dpr.12233

[37] Ghana News Agency (2015) Tree Global Distributes Cocoa Seedlings to Farmers. Ghana News Agency (GNA) Business and Finance News. https://www.ghanaweb.com/GhanaHomePage/business/Tree-Global-distributes-cocoa-seedlings-to-farmers-359894#:~:text=Tree%20Global%2C%20a%20trade%20organisation,Bosuso%20to%20boost%20their%20production

[38] Fosu, S. (2021) Tree Global Ghana Ltd Awarded as Agricultural Nursery Service Provider of the Year. GhanaWeb. https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Tree-Global-Ghana-Ltd-awarded-as-Agricultural-nursery-service-provider-of-the-Year-1249123

[39] Wätzold, M.Y.L., Abdulai, I., Cooke, A., Krumbiegel, K., Ocampo-Ariza, C., Wenzel, A., *et al.* (2025) Do Voluntary Sustainability Standards Improve Socioeconomic and Ecological Outcomes? Evidence from Ghana's Cocoa Sector. *Ecological Economics*, **229**, Article 108474. https://doi.org/10.1016/j.ecolecon.2024.108474

[40] World Cocoa Foundation (2019) Cocoa Action 2019 Data Narrative. World Cocoa Foundation.

[41] Oladeji, J.O., Abimbola, O.A., Ademola, A.O. and Adedeji, T.O. (2018) Effect of Communication Channels on the Use of Tree Crops Development Units' Services among Cocoa Farmers in Oyo State, Nigeria. *Journal of Scientific Research and Reports*, **20**, 1-10. https://doi.org/10.9734/jsrr/2018/7810

[42] Olwig, M.F., Bosselmann, A.S. and Owusu, K. (2024) Agroforestry as Climate Adaptation: The Case of Cocoa Farming in Ghana. Palgrave MacMillan.

[43] Tropenbos International, Tropenbos Ghana and Nitidae (2023) Cocoa Agroforestry

in West Africa. Experiences from the Private Sector and Opportunities for Collaborative Action. Tropenbos International, Tropenbos Ghana and Nitidae.

[44] Cocoa and Forests Initiative National Secretariat, IDH and World Cocoa Foundation (2023) Annual Report Cocoa and Forests Initiative 2023. Landscape Approach and Collective Action for the Protection of Forests and the Sustainable Production of Coco. https://www.idhsustainabletrade.com/uploaded/2024/09/CFI-Annual-Report-2023-Cote-DIoire_EN.pdf

[45] Cocoa and Forests Initiative National Secretariat, IDH and World Cocoa Foundation (2023) Cocoa and Forests Initiative Annual Report Ghana 2023. https://www.idhsustainabletrade.com/uploaded/2024/09/CFI-Annual-Report-2023-Ghana_EN.pdf

[46] Mondelēz International (2024) Cocoa Life 2024 Progress Report. Cocoa and Forests Initiative. Progress and Partnership in a Changing Cocoa Landscape. https://downloads.ctfassets.net/qggsjlmpzfmx/793XtA6QMbWZKMdWTIBAwm/4471471f32dcf0c5b76ae3bc4e5af973/MDLZ_Cocoa_Life_Cocoa___Forests_Initiative_2024_Progress_Report_June_2025__1_.pdf

[47] Asante, W.A., Ahoma, G., Gyampoh, B.A., Kyereh, B. and Asare, R. (2021) Upper Canopy Tree Crown Architecture and Its Implications for Shade in Cocoa Agroforestry Systems in the Western Region of Ghana. *Trees*, *Forests and People*, **5**, Article 100100. https://doi.org/10.1016/j.tfp.2021.100100