CocoaSoils

# Annual Report 2022

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## Acronyms and Abbreviations

| | |
|---|---|
| AE | agronomic efficiency |
| AEZ | Agroecological zone |
| BMP | best management practices |
| CASE2 | Cocoa Crop Model |
| CIAT | International Centre for Tropical Agriculture |
| CMIP6 | Coupled Model Intercomparison Project Phase 6 |
| CSA | climate-smart agriculture |
| CSC | climate-smart cocoa |
| CT | Core Trials |
| CFP | current farmer practice |
| EA | extension agent |
| EiA | Excellence in Agronomy |
| GAPs | good agricultural practices |
| GCM | global climate model |

| | |
|---|---|
| IDH | The Sustainable Trade Initiative |
| IITA | International Institute of Tropical Agriculture |
| ISFM | Integrated Soil Fertility Management |
| KABP | knowledge, attitude, behavior, and practices |
| KNUST | Kwame Nkrumah University of Science and Technology |
| MEL | monitoring, evaluation, and learning |
| NARS | national agricultural research systems |
| NO | no fertilizer |
| NGO | non-governmental organization |
| NORAD | Norwegian Agency for Development Cooperation |
| ODK | open data kit |
| OF | off-take model |
| P4D | Partnership for Delivery |
| R4D | Research for Development |
| ROI | return on investments |
| SIPs | Stepwise investment pathways |
| ST | Satellite Trials |
| ToR | terms of reference |
| ToT | training of trainers |
| UNEP-WCMC | United Nations Environmental Program—World Conservation Monitoring Centre |
| WENR | Wageningen Environmental Research |
| WUR | Wageningen University and Research |

## 1 Key messages and challenges

The projects' two field trials, commonly referred to as CT and ST, are being managed in collaboration with national research institutes and private sector partners. Currently, 11 CTs are being implemented in Cameroon, Côte dÍvoire, Ghana, Nigeria, Ecuador, and Indonesia. The design for the CTs are factorial combinations of N, P, K plus Ca, Mg, and micronutrients on a single field measuring at least 2 ha. The design for the STs is an additive approach of four plots (T1-T4) representing increased intensities of management on 389 cocoa plantations across in Cameroon, Côte d'Ivoire, Ghana, and Nigeria. The experimental plots in the ST measure 21m × 21m. The T1 (control) is managed by the participating farmer, while T2 entails applying all the GAPs, except fertilizer application. T3 includes all GAPs as in T2, plus the application of the nationally recommended fertilizer in Ghana (GAP+NF). In T4, GAPs are applied plus fertilizer based on the estimation by an OF, which calculates the nutrient requirements of the cocoa trees, using nutrient uptake data and allometric relations from empirical measurements (GAP+OF).

With a current database of over 180 000 farmers available through CocoaSoils partner dissemination networks and the engagement with digital dissemination partners, the project is delivering recommended options on ISFM to smallholder farmers in West and Central Africa through EA-led farmer training sessions organized in all the four countries. In this summary, highlights of the progress on the R4D, P4D, and project management for 2022 are described and further detailed in the main body of the report.

***Progress on R4D Outputs***

With regards to generating ISFM options, 11 Core Trials hosted by 9 partners including 4 private sector companies (including Mondelez, Barry Callebaut, Nestle and Mars) are being implemented in Cameroon (2), Côte d'Ivoire (3), Ghana (2), Nigeria (2), Ecuador (1), and Indonesia (1). Analysis of data from the CTs shows that by assuming a specific nutrient response function, it is possible to estimate key parameters that can be used to calculate important measures such as maximum and minimum agronomic efficiency,

available soil nutrients, economically optimal rates, and water limited yields. Computer simulations show that inference of multi-dimensional nutrient responses is possible, with estimations obtained for all parameters, albeit with considerable uncertainty. A first analysis of yield data from one of the trials demonstrated that the experimental design was successful in accounting for within-field heterogeneity, but effects of nutrient application are not observable as the trials are in their early stages.

The Satellite Trials (STs) are managed by 8 private sector company partners (including Olam, Mondelez, Cargill, Kuapa Kooko, Sucden, Olatunde International, Climate 42 and Tulip Cocoa) hosting a total of 389 ST sites. The current distribution of the ST sites is as follows: 132 in Côte d'Ivoire; 64 in Cameroon; 127 in Ghana and 66 in Nigeria. Analyses of current data Satellite Trials have validated the 'STEPWISE Approach'. Data show that intensifying management including improving fertilizer management results in additional yield benefits, and such an approach may provide a pathway to assist poorly resourced farmers to intensify and maintain cocoa productivity. Data from most of the explanatory variables collected in the field are being analysed to fully understand the yield change drivers in cocoa fields under real farmer conditions.

An API and user management system that allows downloading cocoa datasets has also been developed for partners to access their data.

The second draft of the decision-support app (STEPWISE) has been developed to include a segmentation module to understand farm diversity and a Good Agronomic Practices (GAP) module.

Various scenarios regarding cocoa intensification and the impact on the forest have been accessed. A cocoa specific soil-constraint map has been developed.

On deforestation monitoring, the deforestation rates within the cocoa growing areas of Côte d'Ivoire, Ghana, Nigeria, and Cameroon decreased in 2019 and 2021. This has been largely mirrored in the landscapes surrounding the Satellite Trials, with deforestation rates decreasing in all four countries during the periods.

A guiding framework to help target cocoa system design for national to local level deforestation risks and social, economic, and environmental objectives in cocoa growing regions has also been developed.

A report on Identifying opportunity areas for cocoa agroforestry in Ghana to meet policy objectives has been published. Here, different policy goals were analyzed and guiding principles that were developed for integrated decision making for sustainable intensification of cocoa, carbon sequestration, and biodiversity conservation for Ghana were implemented. Several scenarios for agroforestry development were mapped and can serve as input to spatial planning to prioritize interventions to achieve these multiple objectives. The study found that there are opportunities to increase tree cover across almost 2 million hectares of low-shade cocoa growing areas in Ghana.

A biodiversity assessment and protocol were developed and applied to the Satellite Trial plots setup. An analysis of this was documented in the report entitled "Identifying opportunity areas for cocoa agroforestry in Ghana to meet policy objectives", published in 2022. It sought to identify where different national forest-related policy objectives that look to cocoa agroforestry to achieving their targets, including supporting climate change adaptation with different shade level recommendations across the country could be achieved and for which co-benefits, including applying the results of the biodiversity vs cocoa-related land use modelling work.

On identifying areas of vulnerability for natural capital and ecosystem services under shifting suitability ranges, the paper on "mapping biodiversity and ecosystem services at risk in cocoa growing areas of West Africa" submitted to Agriculture, Ecosystems & Environment early 2021 was revised and resubmitted to

the publication, Land Policy in April 2022 as “Patterns of environmental risks from cocoa expansion and intensification in West Africa call for context specific responses.

The draft spatially explicit decision-tree and guidance document to help target cocoa system design considering national to local level deforestation risks and opportunities to maintain or improve biodiversity and ecosystem services in cocoa growing areas was finalized. A toolkit to support planning for ecosystem services in cocoa landscapes has been published on the CocoaSoils website.

Four PhD peer reviewed articles have been published (1) ‘Unravelling drivers of high variability of on-farm cocoa yields across environmental gradients in Ghana' in Agricultural Systems Journal; (2) ‘How nutrients rich are decaying cocoa pod husks?’ in Plant and Soil Journal; and (3) Farmers’ Perception as a Driver of Agricultural Practices: Understanding Soil Fertility Management Practices in Cocoa Agroforestry Systems in Cameroon’ (4) ‘The cocoa yield gap in Ghana: A quantification and an analysis of factors that could narrow the gap’. Ten MSc theses have been published.

The project shared initial results from the CTs and STs with private sector and public sector partners at a Science Committee Meeting held in December 2022 in Montpellier.

***Challenges with the R4D Outputs***

Fertilizer application in the CTs was delayed in some countries due to difficulties in acquiring fertilizers. Alternatives were proposed, including adjusting formulations.

Although four PhD and 10 MSc papers have been published, a few are in the writing stages. Others have been submitted for publication. All four PhD candidates received a six-month extension to their scholarships funded by Wageningen University. All candidates are on track to submit by mid-2023. The five MSc are still working on their thesis and are on track to complete them in 2023.

***Progress with P4D Outputs***

Eleven private sector partners (Barry Callebaut, Kuapa Kokoo, Cargill, Mars, Mondelez, Nestlé, Olam, Olatunde International, Rockwinds, Sucden, and Tulip Cocoa) have signed agreements either through the Cooperation Agreement or later through the Participation Statement. In addition, 13 dissemination agreements have been signed including 2 digital scaling partners (VIAMO and ANADER).

Copies of the training manual on ISFM have been handed over to relevant authorities in Cameroon, Ghana, and Nigeria. 165 Extension Agents (EAs) were trained in 2022. This has increased the number of EAs trained by the project to 700 (11% female).

6249 famers were trained in 2022, increasing the number of farmers reached with ISFM recommendation and GAPs to 69503 (25% female). This represents 50 percent of the 2022 target of 140 000 farmers.

***P4D component—challenges***

The project’s efforts to reach 140 000 farmers with ISFM recommendations was restricted by the COVID-19 outbreak and conflicting schedules for EAs. EAs commitment has improved, and more farmers will be trained in 2023 under the CocoaSoils use case.

An endline survey by the MEL team to collect information on the adoption or use of ISFM recommendations by EAs and farmers has concluded. Data is currently being analyzed.

Version 3 of the training manual will be developed when new recommendations from research activities are available.

***Progress with project coordination***

The project shared its achievements and learnings with the wider public through its Annual Forum held virtually on May 3, 2022, and physically on May 12, 2022, in Ibadan, Nigeria. The physical meeting was attended by more than 80 regional and global stakeholders.

Under MEL, data from an endline survey to capture the knowledge and practices of EAs and farmers after physical training sessions is being analyzed.

Tweets about the program's activities were seen 18911 times by Twitter users between January 2022 and December 2022. Six newsletters were published in 2022.

The total estimated amount for the year was $2,886,378, out of which 98% was used for planned activities leaving a variance of 2% which was earmarked for 2022 audit and Project endline review in quarter 2 of 2023.

***Project coordination—challenges***

Data from the project's endline survey is being analyzed by the MEL team. The final report will be available in 2023.

# 2 Progress narrative

## 2.1 Introduction

The CocoaSoils Annual Report 2022 presents progress on the 2022 workplan. Results and progress were evaluated against the 2022 targets for outcomes and outputs, as well as the set milestones for coordination-related activities, and the R4D, and P4D components. Delays experienced were explained and mitigation plans were presented with timelines. Progress against specific outcomes and outputs is presented in APPENDIX 1—Status of Project Results with Mitigation Plans. The milestones are evaluated under the respective outputs in the report itself.

## 2.2 Project coordination

### 2.2.1 Project coordination team established

Achievement of the following milestones is expected at the time of reporting: (1) interviews based on specific ToR organized; (2) negotiations and signing of contracts completed; (3) list of required capital items assembled; and (4) capital items procured and delivered. Table 1 provides details on progress in the milestones for 2022.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 1. Status of milestones under project coordination team established**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Coordination-related** | | | | | | | | | | | | | | | | | | | | |
| **Project coordination team established** | | | | | | | | | | | | | | | | | | | | |
| Recruitment of project staff | | | | | | | | | | | | | | | | | | | | |
| Milestone: Interviews based on specific ToR organized | | | | | | | | | X | X | | | | | | | | | | |
| Milestone: Negotiations and signing of contracts completed | | | | | | | | | X | X | | | | | | | | | | |
| Procurement of capital equipment | | | | | | | | | | | | | | | | | | | | |
| Milestone: List of required capital items assembled | | | | | | | | | | | | | | | | | | | | |
| Milestone: Capital items procured and delivered | | | | | | | | | | | | | | | | | | | | |

***Progress on milestones:*** The project retained all its staff in 2022.

### 2.2.2 Project management and administration functional

Achievement of the following milestones is expected at the time of reporting: (1) timely reports by the applicants and its partners submitted; (2) annual planning and evaluation meetings organized; (3) effective communication using various tools facilitated; and (4) three quarterly newsletters produced. Table 2 and the subsequent information provide details on the progress of the milestones for 2021.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 2. Status of milestones under project management and administration functional**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Coordination-related** | | | | | | | | | | | | | | | | | | | | |
| **Project management and administration functional** | | | | | | | | | | | | | | | | | | | | |
| Agreement on a reporting framework | | | | | | | | | | | | | | | | | | | | |
| Milestone: A reporting framework established | | | | | | | | | | | | | | | | | | | | |
| Milestone: Timely reports by the application and its partners submitted | | | | | | | | | | | | | | | | | | | | |

| Agreement on a meeting and communication strategy | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milestone: Annual planning and evaluation meetings organized | | | | | | | | | | | | | | | | | | | |
| Milestone: Effective communication using various tools facilitated | | | | | | | | | | | | | | | | | | | |
| Milestone: three monthly newsletters produced | | | | | | | | | | | | | | | | | | | |

***Progress on milestones:*** All contractual reports (progress on financial and technical reports for 2021 and workplan for 2022) were submitted on the agreed dates. See here for the final approved annual report by NORAD for 2021. All contractual reports have been submitted by partners for the current progress report. The reporting framework for 2022 was used for this report. See here for a sample.

The Annual CocoaSoils Week was held from 9 to12 May 2022 at IITA Headquarters in Ibadan. The week's activities commenced with the P4D meeting on 9 May 2022 under the theme 'Enabling policy environment in various countries for public-private partnership within CocoaSoils Program.' The P4D meeting brought together representatives of national and international research institutions and private companies to discuss the achievements under P4D, the challenges with partnerships and scaling recommendations, and how to improve engagement with partners. The R4D meeting was held on 10 May 2022 under the theme 'Closing the loop: learning from field trials, stakeholder feedback, and facing the future!'. Discussions focused on 'preliminary results from the CTs and the general progress towards recommendations.' See here for the report on R4D and P4D meetings.

The fourth edition of the CocoaSoils Forum was held virtually on 3 May 2022 and physically on 12 May 2022 in Ibadan Nigeria. The virtual meeting brought together global stakeholders of the program while the physical meeting in Ibadan targeted regional stakeholders. The forum in Ibadan was attended by more than 80 participants from private sector companies, research institutes, and public institutions. Held under the theme "Looking back and moving forward: closing knowledge gaps to create a sustainable cocoa sector", stakeholders discussed the project's achievements and challenges since 2018, and looked into new areas for further research as the project transitioned into EiA initiative. See here for the agenda for the 2020 Annual Forum. See here for the report on the forum.

Various tools and platforms were used to support both internal and external communication. The project's website is updated regularly with information on various activities under the project. Between January and December 2022, the website was used by 2199 (2179 new users). The website received a total of 3091 sessions and 5376-page views. The top countries for users were the Netherlands, United States, Ghana, Nigeria Cameroon, and United Kingdom. See here for detailed analytics on the website turnout overview in terms of audience, location of users, and language.

Monthly and quarterly newsletters were produced to provide update on activities, new research papers, and even to all partners, including the NARS and private sector companies. Six newsletters distributed to stakeholders were opened 863 times. See here for detailed analytics on readership for the newsletters. In addition, a brochure on the key achievements of the project was translated into French for francophone partners and stakeholders. View the brochure here.

### 2.2.3 Convening mechanisms in place

At the time of reporting, the milestone "regular meetings with industry partners facilitated" should have been realized. Table 3 and the subsequent information provide details on the progress towards the milestones for 2022.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline according to the implementation plan in the proposal.

**Table 3. Status of milestones under convening mechanisms in place**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Coordination-related** | | | | | | | | | | | | | | | | | | | | |
| **Convening mechanisms in place** | | | | | | | | | | | | | | | | | | | | |
| Organization of regular meetings with the industry | | | | | | | | | | | | | | | | | | | | |
| Milestone: Meeting schedules agreed upon | | | | | | | | | | | | | | | | | | | | |
| Milestone: Regular meetings with industry partners facilitated | | | | | | | | | | | | | | | | | | | | |

***Progress on milestones:*** IDH continued facilitating monthly meetings (online) with CocoaSoils private sector partners. Since the beginning of 2021, each meeting has included a thematic deep dive on a specific topic or output related to the CocoaSoils program. Four of such meetings were organized:

- February 2022: P4D achievements and learning;
- March 2022: ISFM in cocoa: Investment costs, profitability, and access to capital;
- April 2022: How crop nutrition impacts the carbon footprint of crops such as cocoa and coffee; and
- May 2022: Closing reflections on the CocoaSoils program.

### 2.2.4 Appropriate MEL tools and processes

Achievement of the following milestones is expected at the time of reporting: (1) users of the MEL framework trained; (2) MEL framework continuously updated; and (3) learning from the MEL framework fed back into other activities (refer to **APPENDIX 1—Status of Project Results with Mitigation Plans for milestone-specific details**). Table 4 and the subsequent information provide details on the progress of the milestones for 2022.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 4. Status of milestones under appropriate MEL tools and processes**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Coordination-related** | | | | | | | | | | | | | | | | | | | | |
| **Appropriate MEL tools and processes** | | | | | | | | | | | | | | | | | | | | |
| Development of a participatory MEL framework | | | | | | | | | | | | | | | | | | | | |
| Milestone: Key outcome and impact indicators identified | | | | | | | | | | | | | | | | | | | | |
| Milestone: MEL tools and processes agreed upon | | | | | | | | | | | | | | | | | | | | |
| Facilitation of the use of the MEL framework by all project partners | | | | | | | | | | | | | | | | | | | | |
| Milestone: Users of the MEL framework trained | | | | | | X | X | X | X | X | X | X | X | X | X | X | | | | |
| Milestone: MEL framework continuously updated | | | | | | | | | | | | | | | | | | | | |
| Milestone: Learning from the MEL framework fed back into other activities | | | | | | | | | | | | | | | | | | | | |
| Implementation of baseline and end-line studies | | | | | | | | | | | | | | | | | | | | |
| Milestone: Baseline study documented for the four target countries | | | | | | | X | X | | | | | | | | | | | | |
| Milestone: End-line study documented for the four target countries | | | | | | | | | | | | | | | | | | | | |

***Progress on milestones:*** The project trained 165 EAs between Q1 and Q4 of 2022, increasing the number of EAs trained on the CocoaSoils MEL framework and dissemination data collection tools in the four countries in 2022 to 700 (11 percent female). The 700 EAs trained represent 112 percent of the target for 2022 (625) to be trained. The MEL framework is continuously updated using data from project interventions. The farmer and EA baselines established the reference point for impact and most outcome indicators. Data from EA and farmer engagements (dissemination of ISFM knowledge through various events) have been captured and used in updating selected outputs under P4D.

The updated results framework provides learning for the project cycle, serving as a basis for appraisal and renewed planning. Recommendations from the evaluations of the initial EA training were used to improve content and methodology of subsequent trainings. EA learning areas have been made more practical as compared to initial trainings. The events registration tool also provides information on the content of farmer training. This helps the project to know areas where farmers are being trained, the anticipated feedback, and benefits thereafter.

Updating the results framework has also provided opportunities for adaptive management of the project. New strategies were developed with partners where gaps were identified in achieving specific output targets (e.g., some partners are engaging cooperative leaders to reach out to more farmers in the dissemination of ISFM).

***Challenges and proposed changes in milestone timelines*:** No challenges

## 2.3 Key impacts and outcomes of CocoaSoils

The project has three main outcomes: (1) new cocoa ISFM-related research products are used by private and public stakeholder partners; (2) recommendations generated through research products are used by target households; and (3) decision-makers (public and private) are using tools and knowledge to avoid increased deforestation and child labor while promoting cocoa intensification.

The achievement of these outcomes will ultimately impact cocoa production through increased productivity and incomes of smallholder cocoa farmers and help to reduce pressure on forests. The impact indicators will be measured through the project endline to ascertain the changes against the baseline figures. The status of the outcomes is presented below. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for status of indicator targets under impact, outcomes, and outputs.

*I.* ***Outcome 1: New cocoa ISFM-related research products are used by private and public stakeholder partners***

Outcome 1 is related to the development of the research products and their ultimate use by the extension networks of both private and public organizations. The targets for this reporting period are: (1) at least six research products validated and used by private and/or public stakeholders; and (2) at least 450 EAs using the new research products.

The following outputs contribute to the achievement of this Outcome: (1.1.) a set of ISFM options generated; (1.2.) documented evidence for understanding the physiological basis of cocoa nutrient uptake and use; (1.3.) decision-support system developed for intensifying cocoa production; (1.4) recommendation domains and forest dynamics; (1.5) sustainability assessment tools; (1.6.) operational open knowledge and data sharing portal for the storage, management, and dissemination of cocoa intensification research results; and (1.7) a new cadre of cocoa scientists having PhD/MSc with knowledge on new cocoa intensification. See Section 2.4 for updates on these outputs.

Validated training manual continued to be used to train partner EAs and farmers. **Refer to report on details of EA activities.**

Regarding knowledge gained and its use, 700 EAs (11 percent female) have been trained across the project's partner organizations in the four countries using the content of the manual. The use of the knowledge gained by EAs has been documented through the KABP survey.

The analysis of this data shows knowledge gained in areas such as recommended periods of fertilizer application. Results show that most EAs across the four countries subscribed to fertilizer application between March and May, which differs from the recommendations assembled in the manual. In Côte d'Ivoire, for example, 75 percent of EAs stated in the baseline that fertilizer is applied between March and April, which is contrary to the recommendation that it is best applied between March/April and July/August. The KABP survey after the training shows that 90 percent of EAs now accept the recommended timings.

In terms of EA attitude towards the use of ISFM content, the baseline shows that 33 percent of EAs were aware of the ISFM content but had limited access to content and materials. Analysis of farmers' training data from EAs shows that all the 212 EAs who have uploaded such data (40 percent of the EAs trained)

have integrated the new knowledge they have gained. These include productivity without deforestation, soil fertility management, pruning to enhance soil fertility, weeding, mulch and compost, inorganic fertilizers, pest and disease management, shade management, and seedling management. See here for the EA KABP survey report.

***Outcome 2: Recommendations generated through research products are used by target households***

Under this Outcome, smallholder farmers are expected to acquire knowledge and use the intensification recommendations for cocoa production. The targets for this reporting period are: (i) at least 30 000 cocoa farmers using the new recommendations/new knowledge; (ii) at least 60 000 cocoa farmers using the existing recommendations/new knowledge; (iii) at least three new recommendations are being used; and (iv) at least five existing (old) recommendations are being used.

The outputs of this Outcome include the following: (2.1) agreements with private and/or governmental scaling partners; (2.2) appropriate extension tools for integration in partner-led scaling; (2.3) appropriate ToT manuals for use in the training sessions for EAs; and (2.4) engagement in policy action in support of cocoa intensification. Outputs 1.4 and 1.5 under R4D also contribute to the achievement of this Outcome, directly linked to output 2.3. See Section 2.5 for updates on the outputs.

A total of 69 503 farmers were trained physically and through digital platforms (Viamo and ANADER) since 2018. An endline survey was conducted by Viamo and ANADER to assess knowledge and practices after farmer training through the digital platforms. The analysis of the survey shows that farmers have gained knowledge and have started using such knowledge. For example, in Nigeria, out of a sample of 250 farmers, between 52 and 64 percent of farmers had already weeded and pruned their farms according to the recommendations. In addition, most farmers applied chemical fertilizers and implemented GAPs (e.g., most farmers pruned their farms twice by the end of August 2021) as against the baseline, where most farmers opted to clear forest lands to plant more cocoa to increase productivity. There is appreciation of good farm maintenance such as timely and yearly pruning of cocoa trees and weeding of farms. See here for endline reports. A second survey to assess knowledge, practices, and benefits (yield) of farmers who participated in physical trainings by EAs will be conducted by the end of Q2, 2022.

***II. Outcome 3: Decision-makers (public and private) are using tools and knowledge to avoid increased deforestation and child labor while promoting cocoa intensification***

Under this Outcome, policymakers, and other organizations (including the private sector) are expected to integrate intensification recommendations in (country) policies and support the use of feedback from applying tools developed for sustainability assessment and deforestation monitoring. This outcome is related to the "sustainability" dimension of the project's impact through reducing the risk of deforestation.

The target for this reporting period is the production of final maps of land-use patterns and ecosystem services in target countries. The main output related to this Outcome is (2.4) engagement in policy action in support of cocoa intensification. However, Outputs 1.4 and 1.5 also contribute to the achievement of this outcome. See sections 2.4.4 and 2.4.5 for updates on these outputs.

## 2.4 R4D-related outputs

### 2.4.1 Output 1.1. A set of integrated soil fertility management options generated

The target for this output in 2022 is to generate a final set of ISFM recommendations generated, including feedback from scaling and the physiology work. Achievement of the following milestones is expected at the time of reporting. Table 5 and the subsequent information provide details on the progress of the

milestones for 2022. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 5. Status of milestones for Output 1.1**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **R4D (Research-for-Development)-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 1.1. A set of ISFM options** | | | | | | | | | | | | | | | | | | | | |
| Activity 1.1.1. Agreement on the design of the Core and STs | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.1.1.1. Literature on cocoa agronomy reviewed | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.1.1.2. The design of the CTs and STs finalized | | | | X | X | X | X | X | X | | | | | | | | | | | |
| Activity 1.1.2. Implementation of the Core and STs | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.1.2.1. Sites selected, pending contributions from the industry | | | | X | X | X | X | X | X | X | | | | | | | | | | |
| Milestone 1.1.2.2. Trials installed following the approved protocols | | | | | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| Milestone 1.1.2.3. Trials managed following agreed practices | | | | | | | | | | | | | | | | | | | | |
| Activity 1.1.3. Data collection and analysis on the trial data | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.1.3.1. Data collection protocols finalized | | | | X | X | X | X | X | X | | | | | | | | | | | |
| Milestone 1.1.3.2. Trial data collected | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.1.3.3. Collected data analyzed | | | | | | | | | | | | | | | | | | | | |
| Activity 1.1.4. Development of a set of site-specific ISFM recommendations | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.1.4.1. A prototype ISFM decision-support tool developed | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milestone 1.1.4.2. Version 1 of an ISFM decision-support tool developed | | | | | | | | | | | | | | | | | | | |
| Milestone 1.1.4.3. Version 2 of an ISFM decision-support tool developed | | | | | | | | | | | | | | | | | | | |

***Progress on milestones*** Eleven (11) CTs are being implemented in Cameroon, Côte d'Ivoire, Ghana, and Nigeria. Based on developed protocols, activities have been carried out through 2022. Protocols are organized based on the cocoa trees' growth stages: (i) Early-Stage Evaluation: evaluation done during the first year after planting; (ii) Advanced Stage Evaluation: evaluation done after a year of planting); and (iii) Mature Stage Evaluation: includes several evaluations as pod production, litterfall, and the data collection is trial-specific based on productivity. Overview of data collection and general activities can be observed in Table 1. Early pod production has been observed and recorded in several CTs (Figure 1).

**Table 6. General status of CTs per activities**

| Country | Cameroon | Cameroon | Cote d'Ivoire | Cote d'Ivoire | Cote d'Ivoire | Ghana | Ghana | Nigeria | Nigeria | Ecuador | Indonesia |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Trial Manager | Didier Begoude | Hailemariam Giweta Mekonnen | Jacques Alain | AKA ROMAIN | Arthur Tapi | Amos Quaye | Amos Quaye | Moses Ogunlade | Stefan Hauser | Eduardo Chavez | Niken |
| Date of Cocoa Planting | 1-5-2020 | 1-10-2020 | 1-5-2020 | 1-11-2020 | 25-11-2020 | 23-10-2019 | 1-6-2022 | 5-1-2020 | 20-6-2019 | 1-11-2020 | 1-8-2020 |
| Trial ID | C0CA001 | C0CA002 | C0CI001 | C0CI002 | C0CI003 | C0GH001 | C0GH002 | C0NI001 | C0NI002 | C0EC001 | C0IN001 |
| Map field | | | | | | | | | | | |
| Maize data or Plantain data | | | | | | | | | | | |
| Field preparation | | | | | | | | | | | |
| Soil data | | | | | | | | | | | |
| Blocking design | | | | | | | | | | | |
| Fertiliser formulations and protocol | | | | | | | | | | | |
| Early evaluation 4 MAP | | | | | feb-21 | | Mar-22 | | | | |
| Early evaluation 8 MAP | | set-21 | | jul-21 | apr-21 | | | | | | |
| Early evaluation 12 MAP | nov-22 | dec-21 | | nov-21 | aug-21 | | | | | | |
| First fertilizer application: Split 1 | 2023 | | sep-21 | sep-21 | Oct-21 | jul-21 | | May-22 | 2-jul-20 | aug-22 | apr-22 |
| First fertilizer application: Split 2 | | | apr-22 | apr-22 | apr-22 | sep-21 | | | 22-sep-20 | | Nov-Dec 22 |
| Advance evaluation 1 | dec-21 | Oct-22 | | jul-22 | aug-22 | jul-22 | | jul-21 | jul-21 | | |
| Advance evaluation 2 | nov-22 | | | nov-22 | nov-22 | | | Oct-21 | Oct-21 | | |
| Second fertilizer application: Split 1 | | | sep-22 | sep-22 | apr-23 | May-22 | | | 11-jul-21 | | |
| Second fertilizer application: Split 2 | | | | | | | | | 9-sep-21 | | |
| Advance evaluation 3 | | | | | | | | jan-22 | jan-22 | | |
| Advance evaluation 4 | | | | | | | | apr-22 | apr-22 | | |
| Advance evaluation 5 | | | | | | | | Oct-22 | aug-22 | | |
| Third fertilizer application: Split 1 | | | | | | | | | 01-May-22 | | |
| Third fertilizer application: Split 2 | | | | | | | | | | | |
| Advance evaluation 6 | | | | | | | | | Oct-22 | | |
| | | | | | | | | | | | |
| activities submitted/completed | | | | | | | | | | | |

**Figure 1. Pod production at CT site in Mbalmayo, Cameroon**

**Figure 2. Pod production at CT site in Tiassale, Côte d'Ivoire**

Analysis of data from the CTs show that by assuming a specific nutrient response function, it is possible to estimate key parameters that can be used to calculate important measures such as maximum and

minimum AE, available soil nutrients, economically optimal rates, and water limited yields. Using computer simulations, we show that inference of multi-dimensional nutrient responses is possible, with estimations obtained for all parameters, albeit with considerable uncertainty. An initial analysis of yield data from one of the trials demonstrated that the experimental design was successful in accounting for within-field heterogeneity. However, the effects of nutrient application are not observable at this early stage.

Analysis of the bean yield data with the quadratic mixed model yielded substantial variance components for replicate and block, with standard deviations of 26 and 34 kg/ha, compared to a residual (plot-level) standard deviation of 66 kg/ha and a mean yield of 120 kg/ha. This confirms that blocking contributed to decreasing residual variation and increasing statistical power. Nonetheless, no evidence of nutrient responses was found. Visual inspection of the treatment showed no effects of increasing nutrient levels (Figure 3) and none of the estimates of initial AE was significantly larger than 0 (Figure 4).

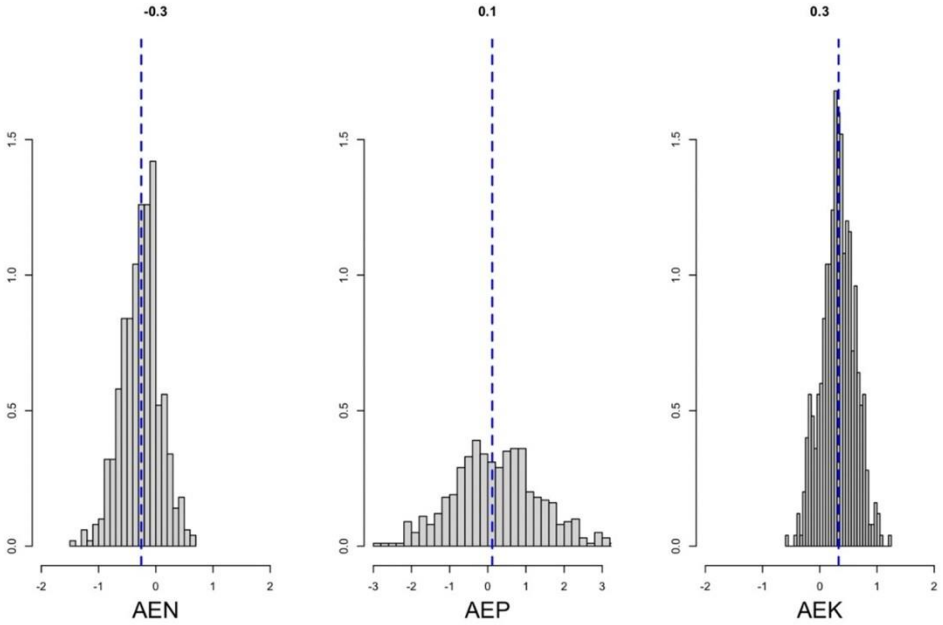



**Figure 3. Parametric bootstrap results showing the uncertainty around estimates (shown in blue) of initial AE for the three nutrients, obtained by the quadratic linear mixed model on the real experimental data**

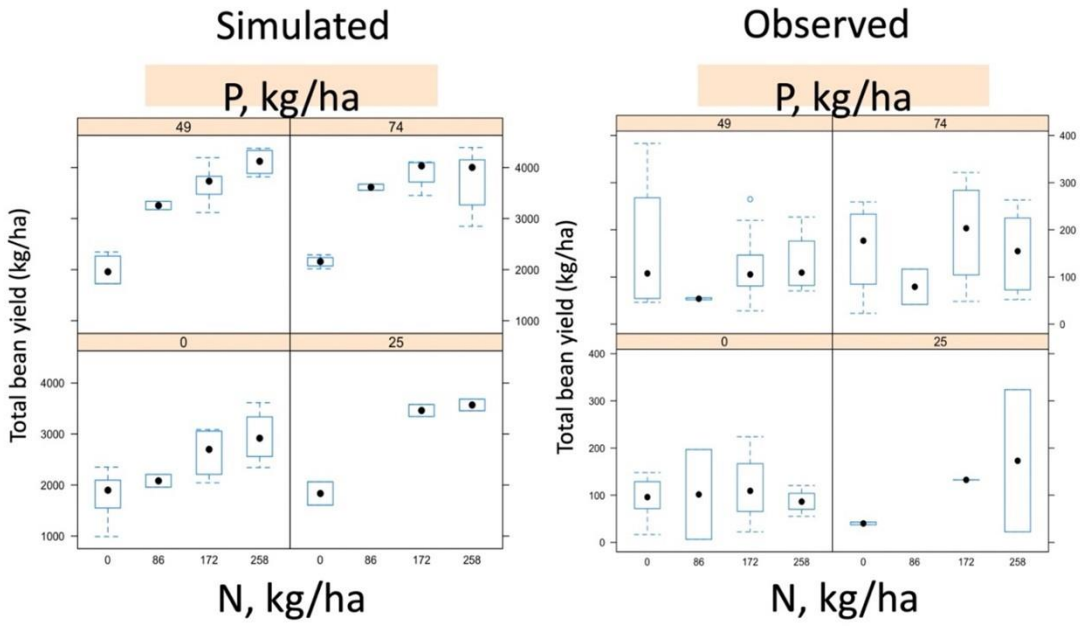



**Figure 4. Boxplots showing the total yield at different levels of N (x-axes) and P (different sections of each plot). The real data is shown on the right while simulated data is presented on the left for comparison**

For the STs, activities and data collection were conducted through 2022 based on protocols and calendar activities per country. Data collection tools were constantly monitored based on technicians' performance and feedback and updated when required (Figures 5 & 6). The project has 389 ST sites across the four countries. The current distribution of the ST sites is as follows: 64 in Cameroon, 132 in Côte d'Ivoire, 127 in Ghana, and 66 in Nigeria. Analyses of current STs data have validated the 'Stepwise Approach'. That is intensifying management including improving fertilizer management results in additional yield benefits. Such an approach may provide a pathway to assist poorly resourced farmers to intensify and maintain cocoa productivity. Data from most of the explanatory variables collected in the field are being analyzed to fully understand the yield change drivers in cocoa fields under real farmer conditions.

The project has been sharing these results directly with the private companies and national partners. Companies have started to login directly into the portal and download the set of data they were involved in and analyses for their use. The 2022 Annual CocoaSoils Forum held in hybrid mode (with the in-person component held in Ibadan) in May 2022, and Science Committee Meeting held in Montpellier in December 2022 presented opportunities for the project to present and discuss early results from the CTs and STs.

**Figure 5. Pruning activities in Ghana**


**Figure 6. Pod harvest measurement activities in Ghana**

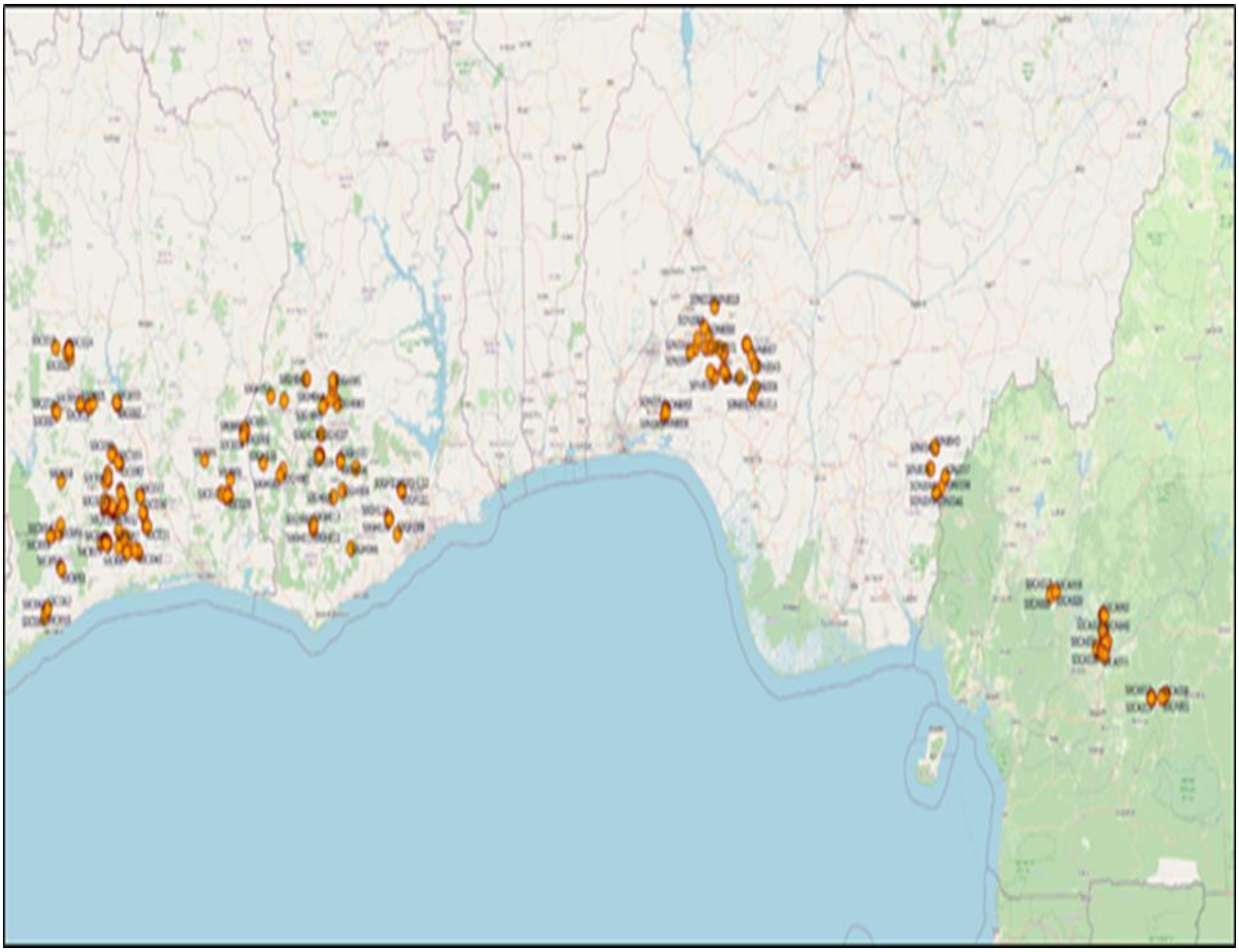


**Figure 7. Distribution of ST sites in Cameroon, Côte d'Ivoire, Ghana, and Nigeria**

***Challenges and proposed changes in milestone timelines****:* Some CTs reported difficulties in getting fertilizer products. To address this, alternatives were proposed, including adjusting formulations. The project is conducting a logistics survey to evaluate the performance of each of the 369 ST sites. This will inform the decision to reduce or maintain the number of ST sites across the four countries. This has become necessary because of issues with data quality from some of the trial sites.

### 2.4.2 Output 1.2. Documented evidence for understanding the physiological basis of cocoa nutrient uptake and use

The target for this Output in 2022 is to have at least six papers on cocoa ISFM/physiology accepted. Achievement of the following milestones is expected at the time of reporting. Table 7 and the subsequent information provide details on the progress of the milestones for 2022. Refer to **APPENDIX 1 – Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 7. Status of milestones for Output 1.2**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **R4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 1.2. Understanding the physiological basis of cocoa nutrient uptake and use** | | | | | | | | | | | | | | | | | | | | |
| Activity 1.2.1. Identification of factors determining high yield/quality in a range of genotypes/environments | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.2.1.1. Protocols developed | | | X | X | X | X | X | X | | | | | | | | | | | | |
| Milestone 1.2.1.2. Protocols implemented | | | | | | | | | X | X | X | X | X | X | X | X | | | | |
| Milestone 1.2.1.3. Data analyzed and fed back into other activities | | | | | | | | | | | | | X | X | X | X | X | | | |
| Activity 1.2.2. Assessment of interactions between water, light, nutrient status, and growth efficiency | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.2.2.1. Protocols developed | | | X | X | X | X | X | X | X | | | | | | | | | | | |
| Milestone 1.2.2.2. Protocols implemented | | | | | | | | | | | X | X | X | X | X | X | X | | | |
| Milestone 1.2.2.3. Data analyzed and fed back into other activities | | | | | | | | | | | | | | | | | X | | | |
| Activity 1.2.3. Development of foliar norms for cocoa | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.2.3.1. Protocols developed | | | X | X | X | X | | | | | | | | | | | | | | |
| Milestone 1.2.3.2. Protocols implemented | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.2.3.3. Data analyzed and fed back into other activities | | | | | | | | | | | | | | | | | | | | |
| Activity 1.2.4. Assessment of interactions between potassium nutrition and drought stress | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.2.4.1. Protocols developed | | | X | X | X | X | | | | | | | | | | | | | | |
| Milestone 1.2.4.2. Protocols implemented | | | | | | | | | | | | | | | X | X | X | | | |
| Milestone 1.2.4.3. Data analyzed and fed back into other activities | | | | | | | | | | | | | | | | | | | | |

***Progress on milestones:*** The PhD Student from Ghana, Paulina Asante, is still undertaking her study on the identification of factors determining high yield/quality in a range of genotypes/environments. Paper 2 titled "The cocoa yield gap in Ghana: A quantification and an analysis of factors that could narrow the

gap" have been completed and published in Agricultural Systems 201 (2022) 103473. https://doi.org/10.1016/j.agsy.2022.103473

In this paper, cocoa yield gap in Ghana was quantified and the factors that can contribute to narrowing the gap were identified. Researchers calculated the cocoa yield gap as the difference between potential yield: (i) water-limited potential (Yw) quantified using a crop model; (ii) attainable yield in high-input systems (YE); and (iii) attainable yield in low-input systems (YF) and actual farmer yield. Both absolute and relative yield gaps were calculated and identified as a function of environment and management variables using mixed-effects models.

Researchers found considerable yield gaps on all cocoa farms. Maximum water-limited yield gaps (YGW) were very large with a mean absolute gap of 4577 kg/ha representing 86% of Yw (Figure 1). Attainable yield gap in high input (YGE) was lower with mean absolute gap of 1930 kg/ha representing 73 percent of YE. The yield gap in low input (YGF) was even lower with mean absolute gap of 469 kg/ha representing 42 percent of YF. Mixed-effects models showed that absolute YGW were larger at sites with higher precipitation in the minor wet and minimum temperature in the minor dry season explaining 22 percent of the variability in YGW. These same factors and cocoa planting density explained 28 percent of variability in absolute YGE. Regardless of climate, absolute YGF and relative YGW, YGE, and YGF were reduced by increasing cocoa planting density and application of fungicide against black pod. The models explained 25 percent of the variability in absolute YGF, and 33, 33, and 25 percent in relative YGW, YGE, and YGF, respectively.

In conclusion, climate determined absolute YGW in Ghana while absolute YGE were determined by both climate and management. In contrast, absolute YGF and relative YGW, YGE, and YGF can be reduced by agronomic management practices.

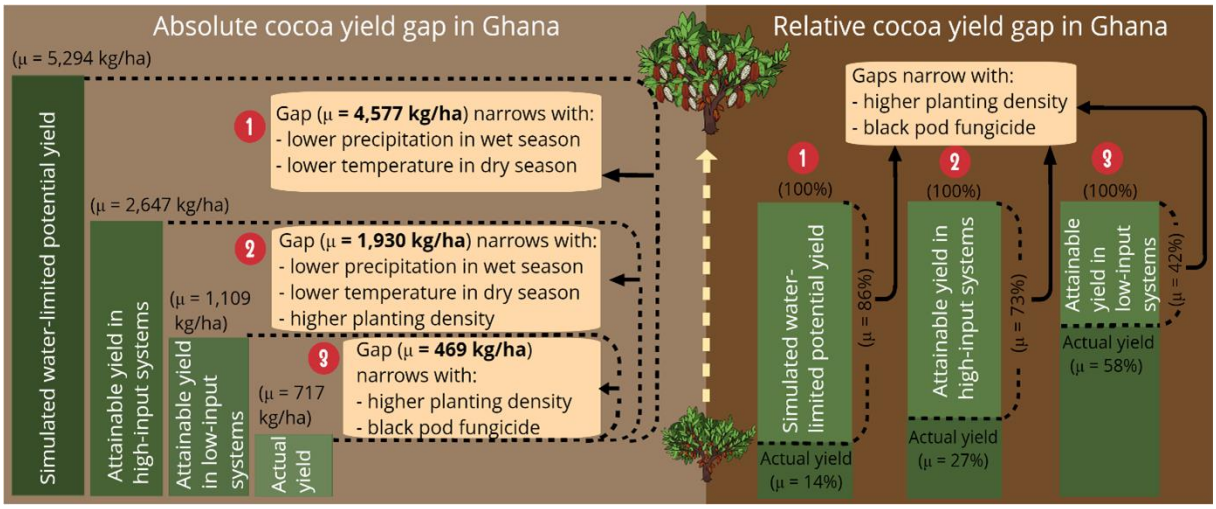



**Figure 8. The absolute and relative cocoa yield gaps across farms in Ghana based on the maximum yield attainable in rain-fed system (simulated water-limited potential yield) and the attainable yields in high and low input systems (Asante et al 2022)**

Her third manuscript, which is on climate change impacts on cocoa production in the major producing countries of West and Central Africa, is in preparation to be submitted. The aim of this paper is to advance understanding of potential cocoa productivity responses to climate change projected by global climate models (GCMs in the major cocoa-producing countries of West and Central Africa up to the mid-century. Researchers simulated potential Yw using a physiology-based crop model to simulate the effects of warming and changes in precipitation based on five plausible future climate scenarios projected by GCMs,

with and without $CO_2$ fertilization effects. The extent to which variation in current and projected-future yields was associated with variation in individual climate variables using mixed-effects models was examined. Researchers also quantified how much cocoa could be produced in the future on the current planted area without expansion under low-input business-as-usual and high-input scenarios.

With some notable exceptions, it was discovered that future climate increases in Yw and gains in a suitable area for production are expected, particularly when the $CO_2$ fertilization effect is accounted for and in the wetter climate-change scenarios (Figure 9). There was a clear (south) east–west gradient with projections being most positive for Cameroon where increases in yield (~39-59 percent) suitable area for cocoa (11-12 Mha) were the strongest, followed by Nigeria, where the largest increase in suitability (~17-20 Mha) was seen, and Ghana. Projections were least positive for Côte d'Ivoire where yield reductions were strong (up to 12 percent) and losses of current suitable area (6-11 Mha) are expected by 2060. Inter-annual yield variability is expected to be higher in areas with lower yields, being strongest in northwest Côte d'Ivoire. Nonetheless, current country-level production is expected to be maintained within current cocoa-growing areas of Côte d'Ivoire and Ghana by mid-century. Predicted increases in water-limited potential yields were mostly associated with projected increases in dry season precipitation while reduction in a consecutive number of months with precipitation below 100 mm reduced yield variability.

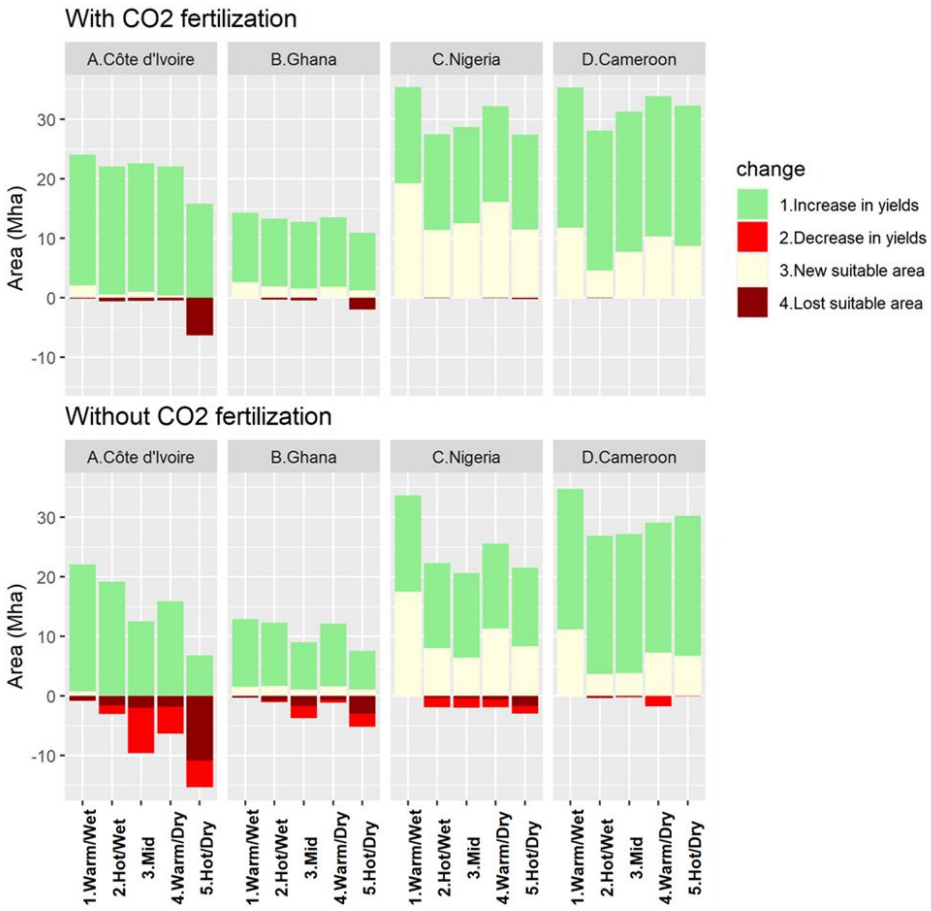



**Figure 9. Predicted changes in total area in each country where simulated water-limited potential yield is expected to change with and without $CO_2$ fertilization**

Luccette Adet's research to assess the interactions between potassium nutrition and drought stress is progressing. Data analysis and writing of the first chapter is ongoing. Different outputs were derived from preliminary collected data, including leaf water potential, expressing how sensitive genotypes respond to drought (Figures 10 & 11). Further results revealed that, in addition to cocoa physiology, bean yield and quality varied depending on the response of cocoa genotypes to drought, and potassium input did not show any consistent effect on mitigating the effects of drought on adult trees.

Early results show significant irrigation, potassium, genotype, and seasonal effects on cocoa physiological traits (Figure 10). Genotypes responded differently to water stress and dry seasons. At the phenological level, drought-sensitive cocoa trees adapted themselves by inducing changes in canopy leaf size, color, senescence, and leaf fall (Figure 11). Leaf fall was related to cocoa leaf area index, canopy transpiration, and the overall water uptake of the tree. Results revealed a clear difference among genotypes for each variable across seasons. These responses are genotype specific. Further analysis will give more insight into how these genotypes respond to stress. More detailed information will be provided in the article when it is published.

For her second manuscript, data has been organized and prepared for the next step of statistical analyses. This chapter addresses the effects of soil water deficit and potassium treatments on cocoa yield criteria. Therefore, the relationship between physiological traits, climate, tree morphology, yield, and bean properties were investigated using correlation analysis and mixed-effects models. Further steps are needed to be done to fully understand this relationship. Fertilizer trials (treatments with and without potassium) have been established and are ongoing. At the two chosen sites in Côte d'Ivoire, most of the planned experiments and protocols have been implemented. Data is being analyzed to understand stories contained in each dataset. To date, most of the monitored variables have been measured. Laboratory analysis was undertaken to determine physical and chemical properties on bean samples.

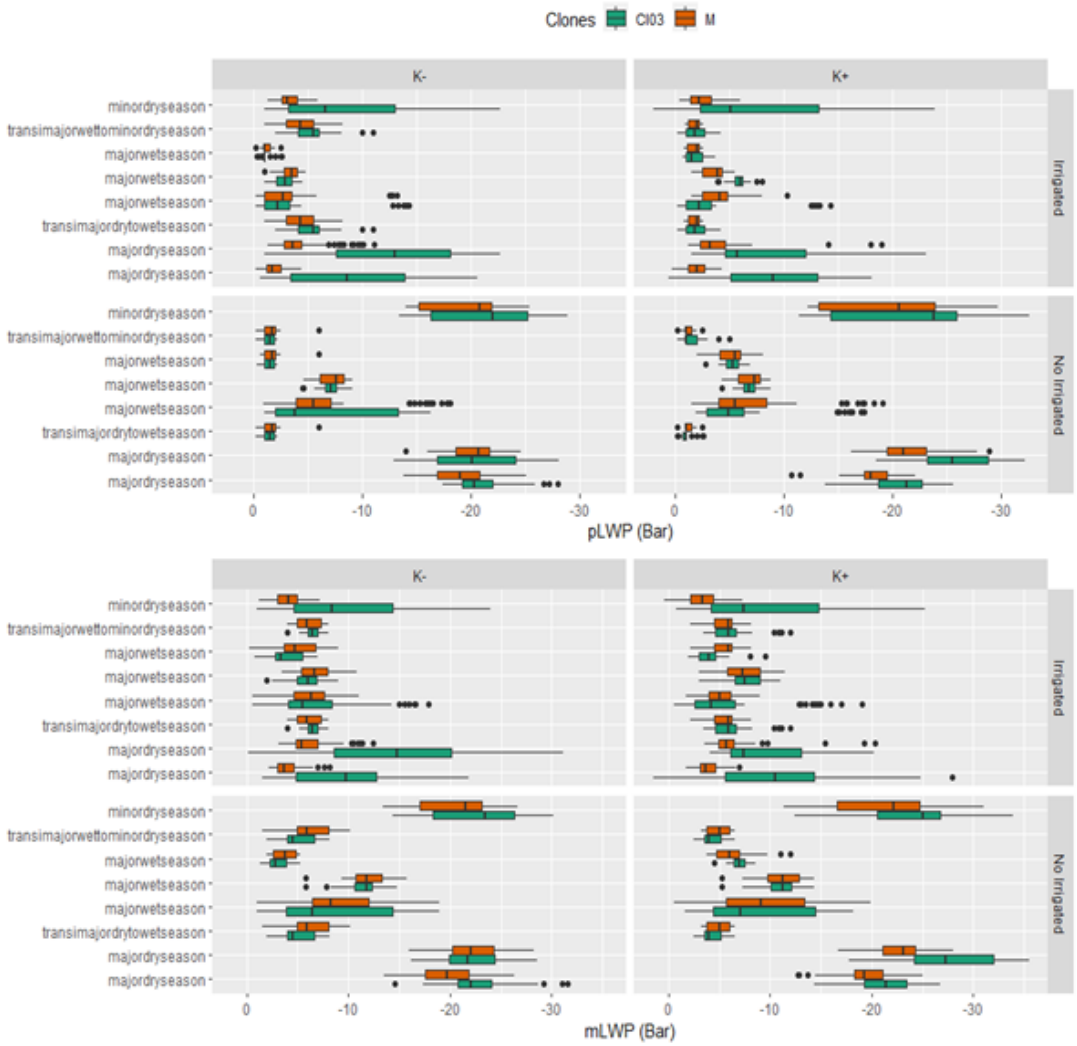



**Figure 10. Seasonal progression leaf water potential at predawn pLWP -8.891±0.128 Bar and at midday mLWP -11.26± 0.121 for two genotype cocoa trees: a clone CI03 (a) and a hybrid M (b) during 2020 and 2021, respectively, across all the measurement periods using cocoa leaf trees subjected to: (a) non-irrigated without potassium treatment; (b) non-irrigated with potassium treatment; (c) non-irrigated without potassium treatment; and (d) irrigated with potassium treatment. A linear model effects analysis was used to examine if the effects of treatments (withholding irrigation /potassium and their interaction), time and genotype were statistically significant. Values represent means ± S.E. Vertical bars indicate standard error at 95% confidence interval.**

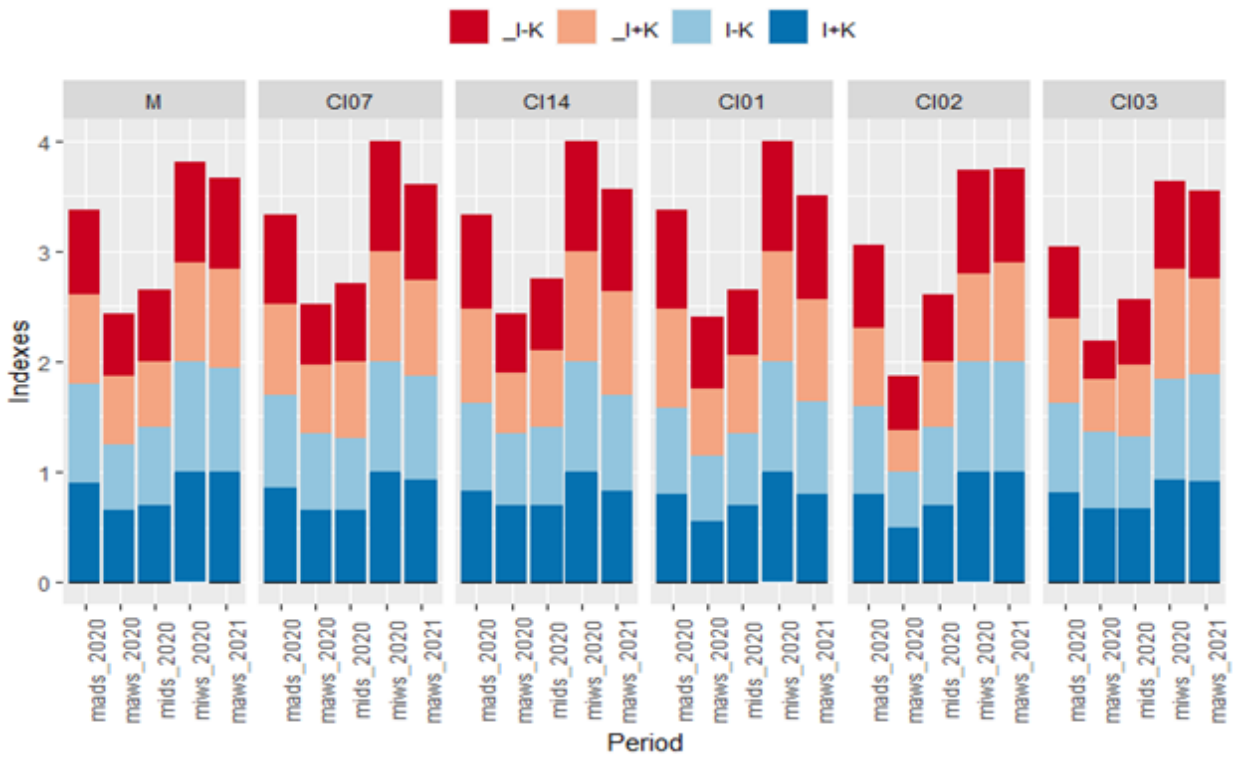



**Figure 11. Indexes represent a reference for leaf canopy phenology dynamic assessment; Water stress indexes related to phenological events occurring across measurements periods (major and minor dry/wet seasons) in different cocoa genotypes trees subjected to withholding irrigation and potassium treatments: (a) non-irrigated without potassium treatment; (b) non-irrigated with potassium treatment; (c) non-irrigated without potassium treatment; and (d) irrigated with potassium treatment. For the overall genotypes, the average index value was 3.698 ±0.049.**

On the assessment of interactions between water, light, nutrient status, and growth efficiency, PhD student, Déo-Gratias Hougni monitored litterfall and cocoa leaf decomposition in low shade agroforestry systems. The objective was to understand the spatial variability of litterfall and to assess the importance of macrofauna in the nutrient release. It was found that with planting density set at 1000 trees/ha, there was no gradient in litterfall from the stem of cocoa trees to the area under the dripline of the canopy. This is probably due to uncontrolled branch inter-locking. It was also observed that over one year, the presence of macrofauna (especially that of termites) was associated with faster cocoa leaf litter decomposition, increased N release, and reduced P immobilization.

Also, to test the relevance of N fertilizer application, a trial was established in 10 low shade plantations in Ondo state, Nigeria with two groups of farms (Figure 10): (1) those that are responsive to N and not to PK; and (2) those that are responsive to PK and not to N. Three rates of N (0, 50, and 100 kg N/ha) were compared, while P and K were supplied at recommended rates to reduce the probability of nutrient co-limitation. Pruning, weeding, and pest control were evaluated monthly. The dynamics of cocoa leaf biomass and early cocoa bean yield response were assessed in the first year. First-hand analysis suggests that:

1. among evaluated management practices, only timely pruning was associated with cocoa yield increase;

2. fertilizer application reduced leaf shedding consecutive to early drought but did not significantly increase cocoa leaf production; and
3. results from the fertilizer trial will require additional data since it is a long-term experiment

A paper titled 'How nutrients rich are decaying cocoa pod husks? The kinetics of nutrient leaching' has been published. Two manuscripts are almost finalized and will soon be submitted.

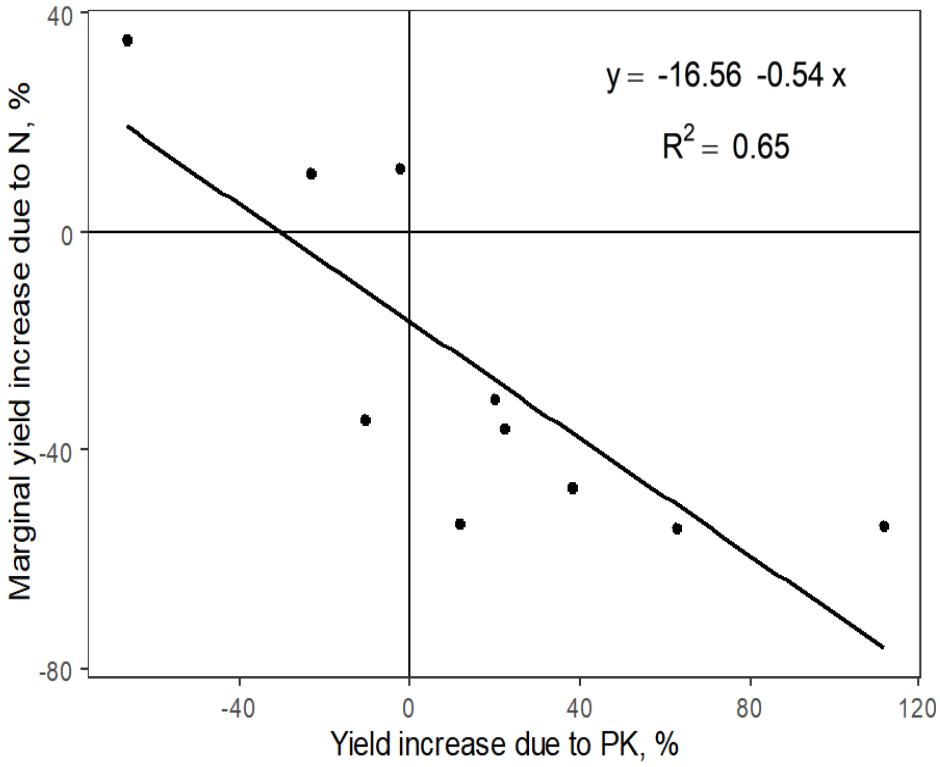



**Figure 12. Yield increase of PK vs control and marginal yield increase of N vs PK application only**

Figure 12 shows the relationship between the yield increase of PK compared to control and marginal yield increase of N compared to PK application only. Yields were recorded in the main season of Year 1 upon fertilizer application on 20-year-old cocoa trees.

***Challenges and proposed changes in milestone timelines***

Delays in the completion of Chapter 2 of the thesis on identifying factors that determine high yield/quality in a range of genotypes/environments due to model simulation errors for dry areas in CASE2 affected the completion of Chapter 3, which has now been extended to February 2023.

The COVID-19 pandemic and some failure in the functioning of the equipment led to delays in the completion of key components of the thesis on "Assessment of interactions between potassium nutrition and drought stress." Delays in implementing the experiments did not allow the expected results to be achieved on time. To address this, a decision was made to extend fieldwork and data collection to Q2 2022. Data analysis commenced in Q3 2022 and is currently ongoing.

### 2.4.3 Output 1.3. A decision-support system developed for intensifying cocoa production

As a target for this Output for 2022, the project will adapt tools for farmer segmentation and Stepwise intensification for cocoa producing areas, with a final set of decision support tools ready for scaling. Achievement of the following milestones is expected at the time of reporting. Table 8 and the subsequent information provide details on the progress of the milestones for 2022. Refer to **APPENDIX 1 – Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 8. Status of milestones for Output 1.3**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **R4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 1.3. A decision-support system for intensifying cocoa production** | | | | | | | | | | | | | | | | | | | | |
| Activity 1.3.1. Development of a decision-support framework for cocoa intensification | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.3.1.1. Prototype decision-support framework developed | | | | | | | X | X | X | | | | | | | | | | | |
| Milestone 1.3.1.2. Decision-support tool populated | | | | | | | | | X | X | X | X | X | X | X | X | | | X | X |
| Milestone 1.3.1.3. Version 1 of a decision-support tool available | | | | | | | | | | | X | X | X | X | X | X | | | X | |
| Activity 1.3.2. Validation of the decision-support framework with target user groups | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.3.2.1. Feedback on version 1 assembled | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.3.2.2. Version 2 available and evaluated | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.3.2.3. Final version delivered for scaling | | | | | | | | | | | | | | | | | | | | |
| Activity 1.3.3. Production and multiplication of a handbook on cocoa intensification | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.3.3.1. Draft concept available | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.3.3.2. First draft available and validated | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milestone 1.3.3.3. Handbook multiplied and available to the cocoa community | | | | | | | | | | | | | | | | | | | | |

***Progress on milestones:*** The CSC Implementer is a mobile application tool that combines the farmer segmentation tool (clustering) and stepwise investment pathways (SIP) in GAP for improved productivity. Based on emerging new insights, several changes and additions have been proposed and incorporated into the current version of the decision support application (CSC Implementer). The current version of the CSC app includes a segmentation module to understand farm diversity in the broader sense (e.g. farmers who use fertilizer and those who do not) and a GAP module. Farmer segmentation module profiles cocoa farmers into groups/clusters based on their socio-economic indicators/resource endowments and generates the most suitable CSA practices for farmer improved adoption.

Due to the project's emphasis on community empowerment, especially the need for rural communities to be able to identify and articulate their interests, a participatory co-development approach is being used to incorporate the contributions of women and youth and other stakeholders in the design and validation of the knowledge product. Co-development is expected to lead to greater adoption and diffusion of the new technologies, changed farming practices, and changes in institutions or management regimes. The innovation makes use of the SIPs. This approach breaks down the investment burden of one 'basket of GAP' into smaller or component practices for farmers to gradually increase their investments in cocoa agronomy and reduce the management gap following a defined set of steps based on initial farm conditions (see Figure 13). The breakdown of GAP bundles takes care of resource-constrained farmers, particularly women, and increases their participation. CocoaSoils deliberately focuses on increasing the participation of women in local level institutions and improving their capacity to take advantage of opportunities and assumes that women will be willing to and free to participate in institutions and capacity building initiatives.

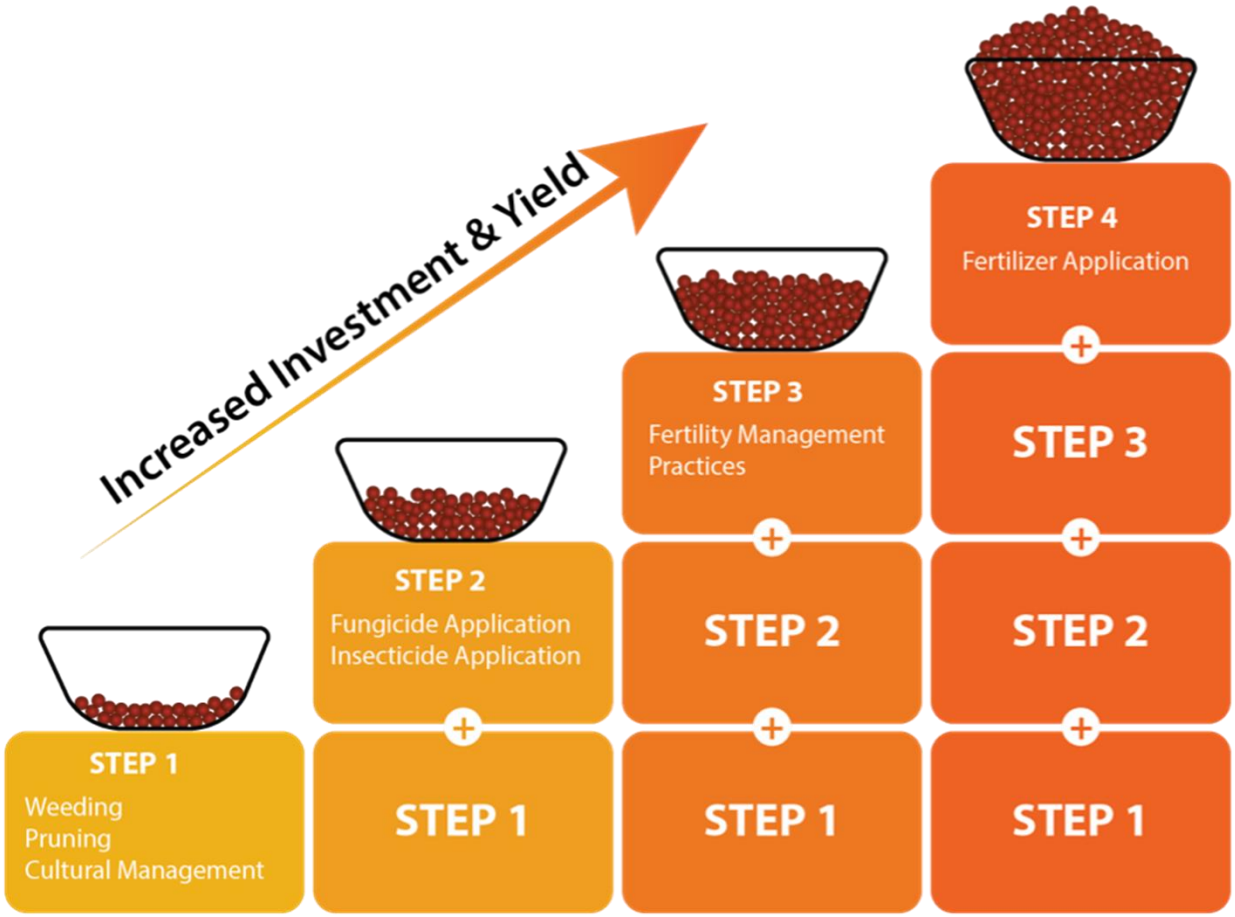



**Figure 13. The Stepwise pathway outlining the necessary steps needed to achieve BMPs, the sequencing of practice through carefully crafted steps is incorporated into the app to help farmers achieve climate-smart cocoa production**

Although the prototype of decision-support tool (Stepwise) is under development, the partners who support the development of the tool, and will integrate the solutions into their system, are directly engaged in the various steps of development. In the four countries, there are cocoa platforms that have been established as an advisory machinery between the CTs and STs and active dissemination of recommendation. This is done through a mediating process between research and governments. These platforms are constituted by private and public sector organizations. The tool will be completed, validated, and ready for use under the CocoaSoils Use Case in EiA.

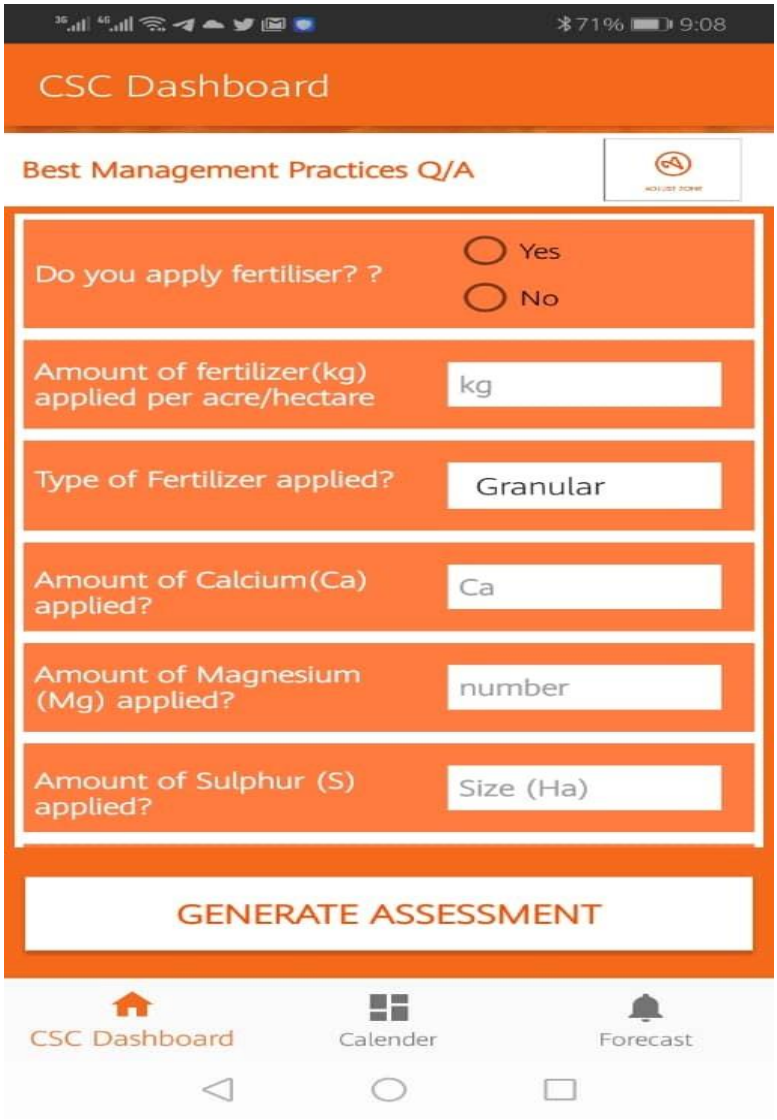



**Figure 14. BMP module of the current prototype of application**


**Figure 15. The activity calendar module of the current prototype of the application showing the date of activity and detailed guidelines**

***Challenges and proposed changes in milestone timelines:*** The current version of the CSC app is inadequate and requires further development and alignment to the standard decision support tools in EiA. The analytical framework for the yield and ROI has been set-up (Figure 16) but requires experimental data from the STs and CTs to reliably calibrate CASE2 to simulate actual farm yields. It is important that each suggested step for any farm (by geolocation) can be simulated not only in terms of productivity but also in terms of the costs and economic benefit. This process will take considerable time than anticipated due to these required capabilities. It is expected that for a fully functional application with spatial yield and profit prediction, the activity will go beyond 2022.

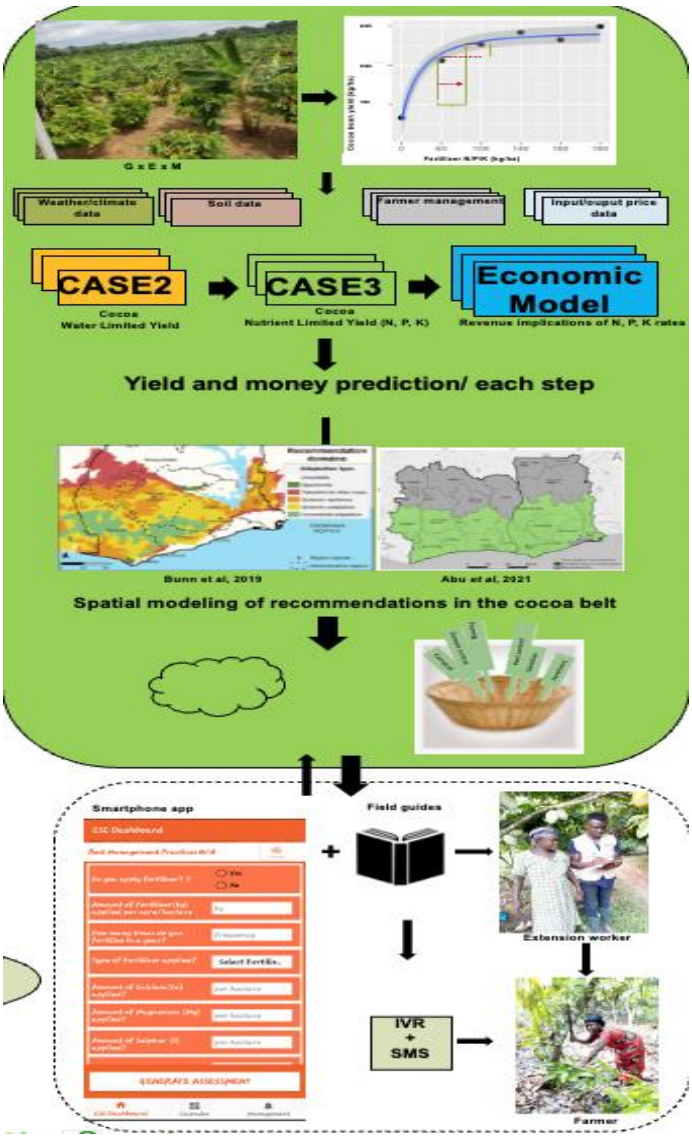



**Figure 16. The analytical framework to support the SIPs**

The CASE2 model will be developed for spatial yield prediction loosely coupled to an economic model to generate a basket of production options at each farm and the economic implications. These options can be passed on to the farm in the form of an app, field guide, interactive voice messages (IVR), or short message services (SMS).

### 2.4.4 Output 1.4: Recommendation domains and impact of sustainable intensification on forest pressure identified

The target in 2022 for Output 1.4 was to develop final cocoa suitability maps and deforestation scenarios. Achievement of the following milestones is expected at the time of reporting. Table 9 and the subsequent information provide details on the progress of the milestones for 2022. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 9. Status of milestone for Output 1.4**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **R4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 1.4. Identification of recommendation domains and impact of sustainable intensification on forest pressure** | | | | | | | | | | | | | | | | | | | | |
| Activity 1.4.1. Identification of representative trial sites under current and future climates | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.1.1. Historical climate data compiled | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.1.2. Future climates for the target regions down-scaled | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.1.3. AEZ for site selection assessed | | | | | X | X | X | X | | | | | | | | | | | | |
| Activity 1.4.2. Scale indicators and recommendations of trials to spatial domains | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.2.1. Spatial proxies of key CSA packages and indicators identified | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.2.2. Scaling spatial domains mapped | | | | | | | | | | | | | X | X | X | X | | | | |
| Milestone 1.4.2.3. Suitability of domains discussed/validated with stakeholders | | | | | | | | | | | | | | | X | X | | | | |
| Activity 1.4.3. Ex-ante assessment of cocoa intensification packages and interventions on cocoa suitability | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.3.1. Adaptation potential of CSA packages quantified | | | | | | | | | | | | | X | X | X | X | | | | |
| Milestone 1.4.3.2. Cocoa suitability models based on 3.1 re-run | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.3.3. Intensification potential for each intervention spatially quantified | | | | | | | | | | | | | | | | | | | | |
| Activity 1.4.4. Quantification of the impact of intensification scenarios on forest protection/deforestation | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.4.1. Historical deforestation baseline built using Terra-I | | | | | X | X | X | X | X | X | X | X | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milestone 1.4.4.2. Cocoa intensification with deforestation scenarios combined | | | | | | | | | | | | | | | | | | |
| Milestone 1.4.4.3. Impact of different intensification scenarios on forest protection/deforestation assessed | | | | | | | | | | | | | | | | | | |

***Progress on milestones***: With regards to assessing cocoa intensification packages and interventions on cocoa suitability, two different approaches were used to assess the adaptation potential of cocoa: (1) the statistical environmental niche modeling, which relates current growing areas to current climate based on statistically inferred relationships and extrapolates these into new areas and future climates; and (2) the process-based crop modeling, which simulates water-limited and potential yield, assuming best agronomic management without limitations by nutrients, pests and diseases or weeds.

The statistical environmental niche modeling assumes that cocoa best thrives under climatic conditions where it is currently grown and assumes no adaptation to changing conditions. It compares climates according to key differential characteristics to score the climate similarity in space and/or time. The process-based crop modeling allows for assessing effects on cocoa yields, instead of climate suitability, while also enabling the assessment of the effect of elevated atmospheric $CO_2$ concentration on yield. Because there may be various adaptation mechanisms, which are currently not fully known, CO2 effects were modeled with and without elevated atmospheric $CO_2$ concentration to account for this uncertainty.

Similarly, to acknowledge the uncertainty of future climates, five potential future climates were selected based on a classification of global climate models (GCMs) from the Coupled Model Intercomparison Project Phase 6 (CMIP6 using the Shared Socioeconomic Pathway SSP5-8.5 (high greenhouse gas emissions scenario) representative of 2050. The adaptation package corresponds to the adoption of best agronomic practices that minimizes most of the limitations from nutrients and reduce factors, such as weeds and pests and diseases, unlike business-as-usual practices (i.e., no changes in current management). These scenarios were defined based on the yield gap assessment conducted in Ghana and published in Agricultural Systems (Asante et al. 2022)[1]. Additional adaptation practices, such as the use of optimal shading have not been implemented in the model because there are several modeling challenges to be resolved. To tackle these challenges, a literature review was conducted on how cocoa modeling can be improved to better represent shading in a process-based cocoa model. The review manuscript was submitted to Agricultural Systems (Tosto et al.)

The results are currently in preparation for submission (Asante et al. in prep) and show that the climate change adaptation potential depends strongly on the five selected plausible future climates (i.e.; warm/wet, hot/wet, mid, warm/dry, and hot/dry) and realized effect of elevated atmospheric CO2 on cocoa yield. The dry scenarios had more negative effects on production areas than wet scenarios, particularly in the northern areas of Côte d'Ivoire and Ghana. While the northern part of Cameroon and Nigeria might experience improvements in climate suitability, changes in rainfall distribution appear to

[1] Asante el al. (2022) The cocoa yield gap in Ghana: A quantification and an analysis of factors that could narrow the gap https://doi.org/10.1016/j.agsy.2022.103473

strongly determine the future of cocoa in West and Central Africa, more so than the expected increases in temperature. However, the more limiting water will be, the more sensitive the cocoa yield is to increasing temperature, due to its indirect effect on evapotranspiration. Surprisingly, these modeling results indicate that despite the increases in temperature and changes in rainfall distribution, many areas where cocoa is currently grown will remain equally productive or even increase in potential productivity.

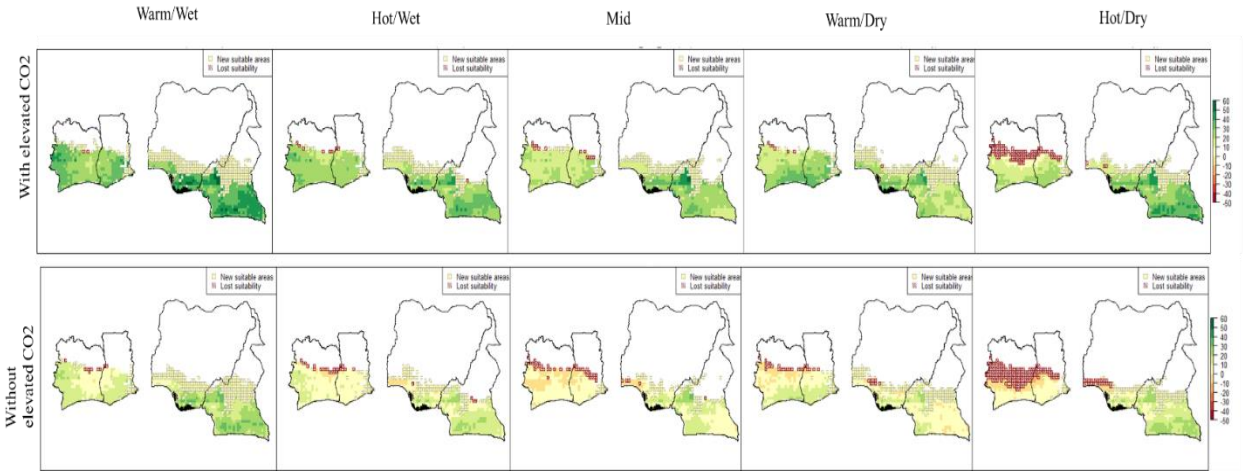
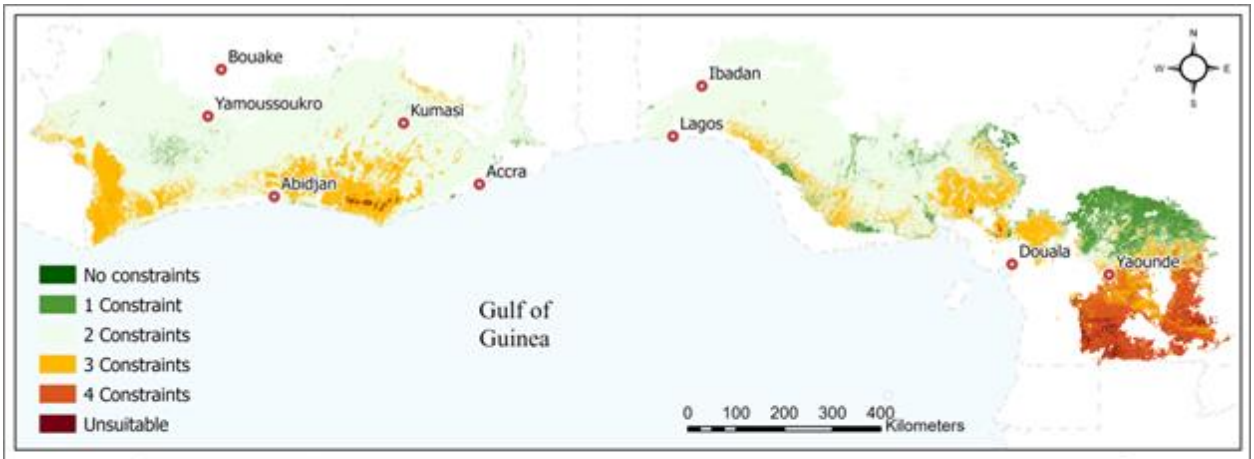



**Figure 17. Effect of different plausible future climate scenarios on cocoa yield (yield change in percentage**

To assess the impact of the intensification scenarios (no intensification vs intensification) on forest protection/deforestation, the potential future cocoa production was calculated without expansion of cocoa. The results indicated that if cocoa is sustainably intensified through the adoption of best agricultural practices, cocoa production could double in Côte d'Ivoire and Ghana in a future climate. For this study, only the mid climate scenario was used, representing the average change in temperature and precipitation among the GCMs. The analysis was only conducted for Côte d'Ivoire and Ghana, as spatial datasets only exist for these two countries.

When comparing risks of forest conversion due to cocoa across all countries, major risks are identified in Cameroon. The increase in cocoa production potential in Cameroon, particularly in the southern area, in combination with potential production losses in Côte d'Ivoire and Ghana under a dry future climate scenario, might pose additional risks for forest conversion in southern Cameroon. This area is where much of the forested areas remain, as most forests in the cocoa growing areas of Côte d'Ivoire and Ghana have already been lost. On the other hand, increases in production potential in the Cameroonian forest-savannah transition zone, could be a potential for afforestation of savannah with cocoa agroforestry systems (Jagoret et al. 2012). Soil conditions also seem optimal under these new conditions of the forest-savannah transition zone (Figure 18). In Côte d'Ivoire and Ghana, risk of continued forest loss is particularly high under the hot/dry future climate scenarios in the northern areas.




| Soil property | Unsuitable | Severe constraints | Moderate constraints | No constraints |
|---|---|---|---|---|
| pH H2O | <4.6 & >7.5 | 4.6 – 5.1 & 7 – 7.5 | 5.1 – 6 | 6 – 7 |
| Clay % | > 50 | 0 – 5 & 40 – 50 | 5 – 17.5 & 30 – 40 | 17.5 – 30 |
| CEC (me/100 g) | 0 | 1 – 12 | 12 – 20 | > 20 |
| C org (%) | 0 | 0.1 – 1.7 | 1.7 – 2 | > 2 |
| Soil depth (cm) | <20 | 20 – 100 | 100 – 150 | >150 |

**Figure 18. Soil constraints in currently climatically suitable cocoa growing areas**

Another study undertaken together with UNEP-WCMC focused on where different types of cocoa systems, with respect to vegetation structure (i.e., from monocropping to complex agroforestry systems), should be prioritized. Here, different policy goals were analyzed and guiding principles that were developed for integrated decision making for sustainable intensification of cocoa, carbon sequestration, and biodiversity conservation for Ghana were implemented. Several scenarios for agroforestry development were mapped and can serve as input to spatial planning to prioritize interventions to achieve these multiple objectives. The study found that there are opportunities to increase tree coverage across almost 2 million hectares of low-shade cocoa growing areas in Ghana. However, if low shade and monoculture systems are prioritized across the country, this could lead to a loss of almost 6.5 million tons of carbon. On the other hand, implementing recommendations by the Rainforest Alliance on climate smart cocoa, in combination with forest reserve restoration, could increase the carbon stored by up to 52 million tons.

On deforestation monitoring, the deforestation rates within the cocoa growing areas of Côte d'Ivoire, Ghana, Nigeria, and Cameroon have decreased in 2021, after a marked increase in 2020 (Table 10). This has been largely mirrored in the landscapes surrounding the ST, with deforestation rates decreasing in 2019 in all four countries and increasing in 2020 in all countries except Côte d'Ivoire and decreasing again in 2021. However, care must be taken when interpreting these results. This large-scale assessment is based on 30 m resolution Landsat data (Hansen et al. 2013) using the primary tropical humid forests (Turubanova et al. 2018) as baseline. However, when comparing with higher resolution Sentinel (10m resolution) land-use classification from 2019 — provided by KNUST — many of the 2020 deforestation events occurred on already deforested sites. More detailed analyses will be needed to compare the different data sets to get a better understanding of deforestation close to ST sites. Additionally, continued efforts from field staff to help verify the actual conditions on the ground are crucial.

**Table 10. Deforestation rate in cocoa area and surrounding landscapes of Sate Trials. Data based on 30 m resolution Landsat data (Hansen et al. 2013) and Primary Humid Tropical Forests (Turubanova et al. 2018).**

| | Entire cocoa area (%) | | | | 4 km radius around STs (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2018 | 2019 | 2020 | 2021 | 2018 | 2019 | 2020 | 2021 |
| Côte d'Ivoire | 2.42 | 1.11 | 1.26 | 0.65 | 0.41 | 0.15 | 0.11 | 0.09 |
| Ghana | 1.28 | 0.60 | 1.48 | 1.11 | 1.23 | 0.74 | 1.14 | 0.83 |
| Nigeria | 1.14 | 0.91 | 1.11 | 0.84 | 0.44 | 0.35 | 0.80 | 0.28 |
| Cameroon | 0.41 | 0.33 | 0.75 | 0.51 | 0.47 | 0.42 | 1.72 | 1.18 |

### 2.4.5 Output 1.5: Sustainability assessment tools developed and validated to support the sustainable development of cocoa production in relation to biodiversity and the ecosystem services at the landscape level

Target for this Output for 2022 is to produce the final draft of sustainability assessment tools. Achievement of the following milestones is expected at the time of reporting. Table 11 and the subsequent information provide details on the progress of the milestones for 2022. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 11. Status of milestones for Output 1.5.**

| **Activities and milestones** | **2018** | | | | **2019** | | | | **2020** | | | | **2021** | | | | **2022** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Q1** | **Q2** | **Q3** | **Q4** | **Q1** | **Q2** | **Q3** | **Q4** | **Q1** | **Q2** | **Q3** | **Q4** | **Q1** | **Q2** | **Q3** | **Q4** | **Q1** | **Q2** | **Q3** | **Q4** |
| **R4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 1.5. Sustainability assessment tools** | | | | | | | | | | | | | | | | | | | | |
| Activity 1.5.1. Assessment of climate-smart cocoa scenarios and impacts on biodiversity and ecosystem services | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.5.1.1. Baseline of natural capital and ecosystem functions produced | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.5.1.2. Implications for biodiversity and ecosystem services of potential shifts in cocoa suitability areas mapped | | | | | | | X | X | X | X | | | | | | X | | | | |
| Milestone 1.5.1.3. Potential impacts on biodiversity and | | | | | | | | X | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ecosystem services of intensification scenarios assessed | | | | | | | | | | | | | | | | | | | | |
| Activity 1.5.2. Assessment of landscape vulnerability and potential co-benefits of climate-smart cocoa | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.5.2.1. Areas of vulnerability for natural capital and ecosystem services under shifting suitability ranges identified | | | | | | | | | **X** | **X** | **X** | **X** | **X** | | | | | | | |
| Milestone 1.5.2.2. Areas where climate-smart cocoa may help mitigate such impacts identified and mapped | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.5.2.3. Guidance materials produced | | | | | | | **X** | **X** | **X** | **X** | **X** | **X** | | | | | | | | |
| Activity 1.5.3. Review of potential synergies among industry and national commitments regarding forests supported by sustainable cocoa intensification | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.5.3.1. Synergies and trade-offs among industry and national commitments supported by intensification scenarios reviewed | | | | | | | | | | | | | | | | | | | | |
| Activity 1.5.4. Validation of results and stakeholder engagement | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.5.4.1. multi-stakeholder workshops organized | | | | | | | | | | | | | | | | X | | | | |
| Milestone 1.5.4.2. Scientific papers submitted and policy briefs on workshop recommendations finalized | | | | | | | | | | | | **X** | **X** | X | **X** | X | X | X | | |

***Progress on milestones***: The results on the potential implication for biodiversity and ecosystem services of shifts in cocoa areas due to climate change was presented at various meetings, including CocoaSoils public forum and Global Land Project Open Science meeting in 2019. The results were published in a paper, two reports, and a storymap (https://arcg.is/0Lvfa4) that brings together most of the spatial analysis that was conducted under Output 1.5. UNEP-WCMC planned to collaborate with CIAT to refine the analyses to include climate change impact gradients rather than zones, using new downscaled climate data (CMIP6) and climate extremes. However, the new climate data has taken longer to produce than anticipated. A related study supported by another project at UNEP-WCMC was developed to extend the analysis of potential risks from expansion and intensification of cocoa (Sassen et al. 2022) to the Congo

Basin, including Cameroon, as the area is seen as susceptible to deforestation due to national policies promoting cocoa production.

On identifying areas of vulnerability for natural capital and ecosystem services under shifting suitability ranges, the paper on "Mapping biodiversity and ecosystem services at risk in cocoa growing areas of West Africa" submitted to Agriculture, Ecosystems & Environment in early 2021 was revised and resubmitted to the publication Land Policy in April 2022 as "Patterns of environmental risks from cocoa expansion and intensification in West Africa call for context specific responses".

On assessing the potential impacts on biodiversity and ecosystem services of intensification scenarios, data was collected on biodiversity in Ghana and Cameroon to test and improve the published biodiversity impact model (Maney et al. 2021) and further understanding of the relationship between biodiversity, management practices, and cocoa yields. These will also be implemented in Côte d'Ivoire and Nigeria in 2023 under the next phase of CocoaSoils. A biodiversity assessment and protocol were developed and applied to the ST plot setup. An analysis of this can be found in the report titled "Identifying opportunity areas for cocoa agroforestry in Ghana to meet policy objectives", which was published in 2022. It sought to identify where different national forest-related policy objectives that look to cocoa agroforestry as a means to achieving their targets, including supporting climate change adaptation with different shade level recommendations across the country, could be achieved and for which co-benefits, including applying the results of biodiversity vs cocoa-related land-use modeling work (Maney et al. 2022/online in 2021). This work was done in collaboration with CIAT and KNUST in Ghana.

The report on mapping potential areas to implement cocoa agroforestry in Côte d'Ivoire, which was finalized in 2021 was the subject of a blog on the World Cocoa Foundation in 2022 https://www.worldcocoafoundation.org/blog/research-shows-cote-divoire-can-restore-20-of-its-forest-cover-by-2030/ and a news story on the UNEP-WCMC website https://www.unep-wcmc.org/en/news/cocoa-agroforestry-could-help-cote-divoire-achieve-20-forest-cover-target.

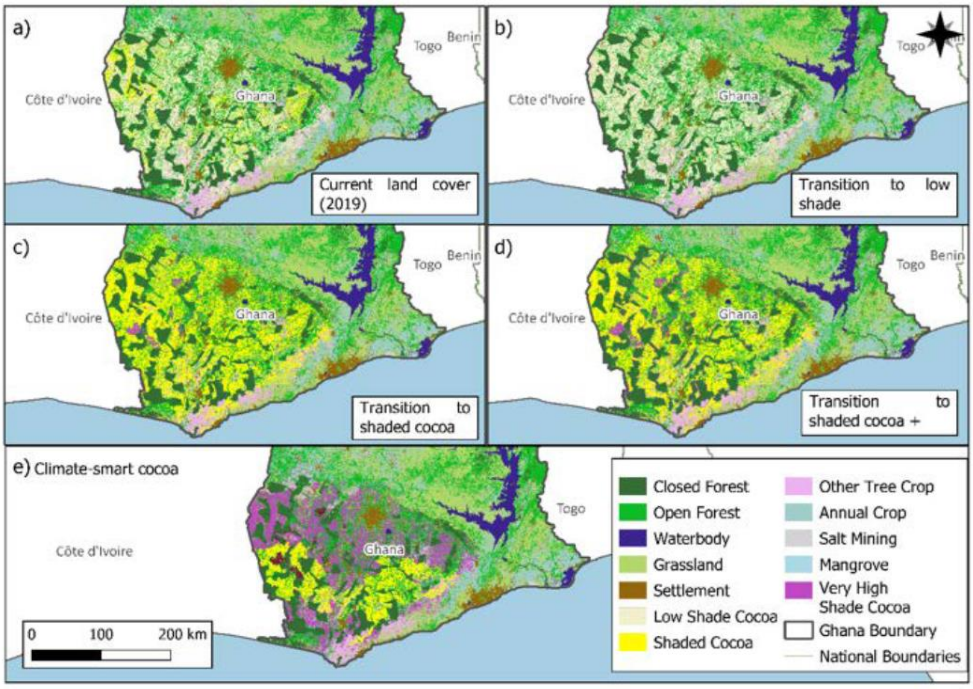


**Figure 19. Map of land cover in Ghana (a) in 2019 (Source: RMSC-FC 2020); (b) under the transition to low shade scenario; (c) under the transition to shaded cocoa scenario, where monoculture cocoa transitions to shaded cocoa, and high-shade cocoa is implemented in forest reserves where cocoa is currently planted; (d) transition to shaded cocoa +scenario, implementing high-shade cocoa in 1 km buffers around forest reserves as well; and e) the climate-smart cocoa scenario**

All guidance materials aim to support the consideration and balancing of trade-offs and synergies with forests, biodiversity, and ecosystem services when planning for sustainable cocoa production into the future. The draft spatially explicit decision-tree and guidance document to help target cocoa system design that take into account national to local level deforestation risks and opportunities to maintain or improve biodiversity and ecosystem services in cocoa-growing areas was finalized and presented at the CocoaSoils Annual Forum, internal meetings, meetings and workshops with private sector partners in Wageningen, European Cocoa Forum, Round Table Cocoa, International Symposium on Cocoa Research, and INCOCOA groups workshop. A suitable publication outlet for the framework and its supporting document is being considered. This work integrates R4D components of the project in support of Outcomes 1-3.

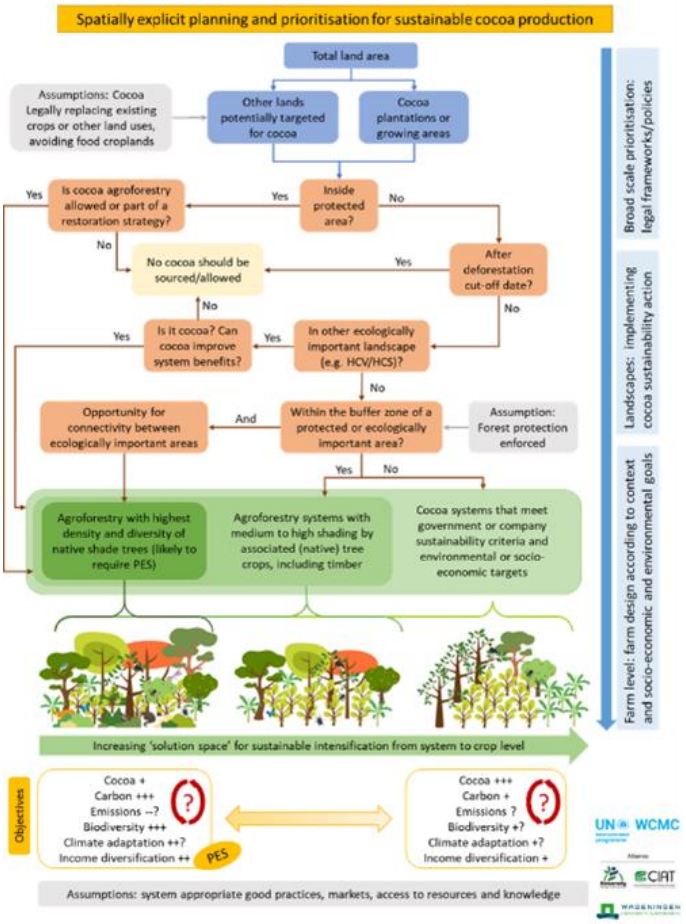



**Figure 20. Draft guidance tree**

The toolkit to support planning for ecosystem services in cocoa landscapes has been published on the CocoaSoils website and will be the subject of a blog on the WCMC website in early 2023. The toolkit helps users navigate tools that can support considering ecosystem services in cocoa-

related land-use planning and system design, including the tools used in various analyses conducted under this Output.


**Figure 21. Introduction page in Excel**

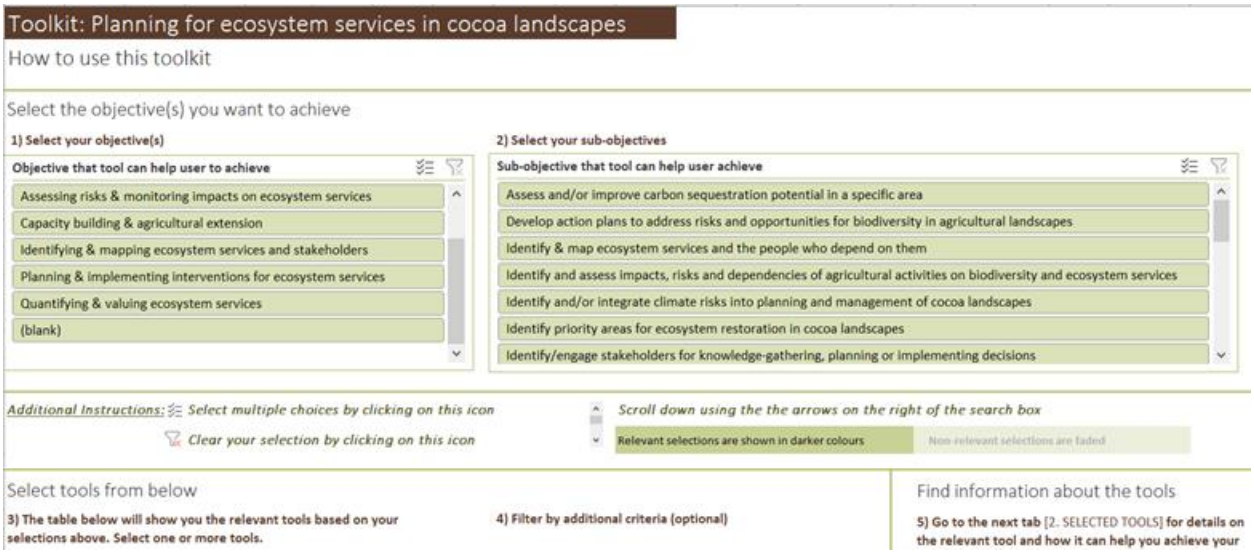



**Figure 22. User interface in Excel**

On exploring how to further support synergies among industry and national commitments through smart planning of sustainable intensification of cocoa, new initiatives, and entry points for the work of CocoaSoils to support synergies on cocoa production, forests, biodiversity, and ecosystem services are being monitored. Individual companies are increasingly expressing interest in this topic. Products are being tailored to meet their needs and increase the impact of the project. This is reflected in the interaction with different stakeholders and the development of a follow-up project (see Activity 1.5.4.). These activities feed into Output 2.4 and Outcome 3.

One stakeholder consultation was held in Côte d'Ivoire in support of Output 1.5.2.2 to discuss results and gather feedback from stakeholders at various meetings. A multi-stakeholder workshop for experts from research, civil society, and policy sectors was held in Accra in April 2022 to discuss progress and challenges

on reconciling economic, social, and environmental objectives in cocoa landscapes, and research priorities to support better outcomes.

The multi-stakeholder workshop held in Accra in April under the theme "Reconciling economic, social, and environmental sustainability objectives within cocoa landscapes in Africa: Identifying research needs" was attended by participants from Ghana, Côte d'Ivoire and Cameroon, from diverse fields including academia, civil society, farmer organization, government and research institutes within disciplines such as social, economic, agronomic, and environmental sciences. Agro Eco used results from the workshop in their guidance "Towards better Livelihoods and Climate Smart Cocoa".

The following meetings and stakeholder interactions took place in 2022 under this output:

- Online meeting with Nestlé (January 2022) to discuss options and opportunities for indicators to monitor biodiversity (at farm level) in perennial crops.
- CocoaSoils annual meeting in Ibadan (May 2022);
- CocoaSoils coordination team (March 2022): present Cote d'Ivoire analysis.
- World Biodiversity Forum (June 2022) Modeling biodiversity impacts cocoa land-use change (Poster, Maney et al. 2022);
- World Biodiversity Forum (June 2022) Identifying biodiversity risk areas from potential cocoa expansion in the Congo Basin (Presentation, Kamath, 2022).
- Science committee meeting (March 22): planning and prioritizing for sustainable cocoa production under climate change Meeting production, biodiversity, and ecosystem services objectives, with Eric Rahn (CIAT), Output 1.4.
- Mid-2022: provide data of Cote d'Ivoire analysis to SIAT company to support their management planning for a highly degraded classified forest;
- Multi-stakeholder workshop: Reconciling economic, social, and environmental sustainability objectives within cocoa landscapes in Africa: Identifying research needs (April 2022);
- Meeting advisor to the Prime Minister of Cote d'Ivoire in Wageningen: shared report and other publications (August 2022);
- Dutch government top sector proposal development workshop with Cargill, Nestle, Mondelez, Mars, Barry Callebaut (September 2022);
- Project planning workshop with Nestle and Olam (September 2022);
- Meeting with representatives of the Dutch Ministry of Foreign Affairs, Netherlands Enterprise Agency and embassies of the Netherlands in Ghana and Cote d'Ivoire (November 2022): present our work on cocoa, including the framework but also the data infrastructure (Arun Pratihast), work on living income (Yuca Waarts) among others;
- International Symposium on Cocoa Research, Montpellier (December 2022): presentation and poster; and
- INCOCOA group workshop (December 2022): presentation on cocoa as a driver of deforestation and the role of sustainable intensification as a mitigation factor.

***Challenges and proposed changes in milestone timelines***

Work on the two policy briefs was delayed due to the need to organize stakeholder engagements in 2022 whose outcomes would inform the development of the policy briefs. The briefs will be finalized in 2023 in collaboration with CIAT and IITA. Also planned for 2023 is the development of blogs and news stories for various outputs.

### 2.4.6 Output 1.6. Operational open knowledge and data sharing portal for the storage, management, and dissemination of cocoa intensification research results

As a target for this Output in 2022, a final version of the data portal will be available, and all datasets will be submitted. Achievement of the following milestones is expected at the time of reporting. Table 12 and the subsequent information provide details on the progress of the milestones for 2022. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 12. Status of milestones for Output 1.6.**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **R4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 1.6. Operational open knowledge and data sharing portal** | | | | | | | | | | | | | | | | | | | | |
| Activity 1.6.1. Development of data capture, structure, and publication mechanisms, and user requirements analysis | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.6.1.1. Data structure for all functions in AgroSTAC implemented | | | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| Milestone 1.6.1.2. Overall architecture and publication mechanism designed | | | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| Milestone 1.6.1.3. Data capture app developed | | | | X | X | X | X | X | X | X | | | | | | | | | | |
| Milestone 1.6.1.4. User requirements analysis completed | | | | X | X | X | X | X | X | X | X | X | | | | | | | | |
| Activity 1.6.2. Development of outward-facing parts of the knowledge and data-sharing portal | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.6.2.1. Public-facing portal and data visualization platform, prototype 1 developed | | | | | | | | | | | | X | X | X | X | X | | | | |
| Milestone 1.6.2.2. Public-facing portal and data visualization platform, beta release available | | | | | | | | | | | | | | | | X | X | | | |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milestone 1.6.2.3. Public-facing portal and data visualization platform, final release available | | | | | | | | | | | | | | | | | | | | | | |
| Activity 1.6.3. Development of consortium-dedicated parts of the knowledge and data-sharing portal | | | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.6.3.1. Scientific analysis facility and data publication facility, prototype 1 developed | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | |
| Milestone 1.6.3.2. Scientific analysis facility and data publication facility, beta release available | | | | | | | | | | | | X | X | X | | | | | | | | |
| Milestone 1.6.3.3. Scientific analysis facility and data publication facility, final release available | | | | | | | | | | | | | | | | X | X | | | | | |
| Activity 1.6.4. Maintenance, user testing, and targeted improvements of knowledge and data-sharing portal | | | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.6.4.1. Data and knowledge sharing portal maintained | | | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.6.4.2. Testing and targeted improvements used | | | | | | | | | | | | | | | | | X | X | | | | |

*Progress on milestones:* The Wageningen Environmental Research (WENR data team has developed a new PostgreSQL database (curated data storage) with user management roles and granted general privileges to users. This database stores all quality-checked databases and associated credentials for each partner. Within this database, the privacy-sensitive data and non-privacy-sensitive data have been separated. Privacy-sensitive data were accessed for consortium partners only. The non-privacy-sensitive data were available for download. In addition, a Knowledge Portal for data visualization and sharing, and an API to assess the harmonized data sets were developed.

The Cocoa Ontology report has been finalized. The report describes properties, processes, management practices concepts and their hierarchical structure. It aims to facilitate cross-database querying. It consists of standardized vocabulary, concepts, and relations between cocoa agronomy and production processes.

To summarize key achievements under this output: Outward-facing parts of the knowledge and data-sharing portal was developed. An API and user management system that allows downloading cocoa datasets has also been developed. The team at WENR is leading an ongoing mobile data collection, and training on cocoa trial experiments and ODK data harmonization work. The Cocoa Oncology for

FAIRization of data and metadata interoperability was also finalized. Some of these achievements were presented at conferences including:

- "Innovative digital data collection in collaborative cocoa fertilizer trials", 2022 International Symposium on Cocoa Research (ISCR), Montpellier, France; and
- "Digital tools and ontology: A Collaborative Pathway for Managing & Sharing Cocoa Data", 2022 International Symposium on Cocoa Research (ISCR), Montpellier, France.

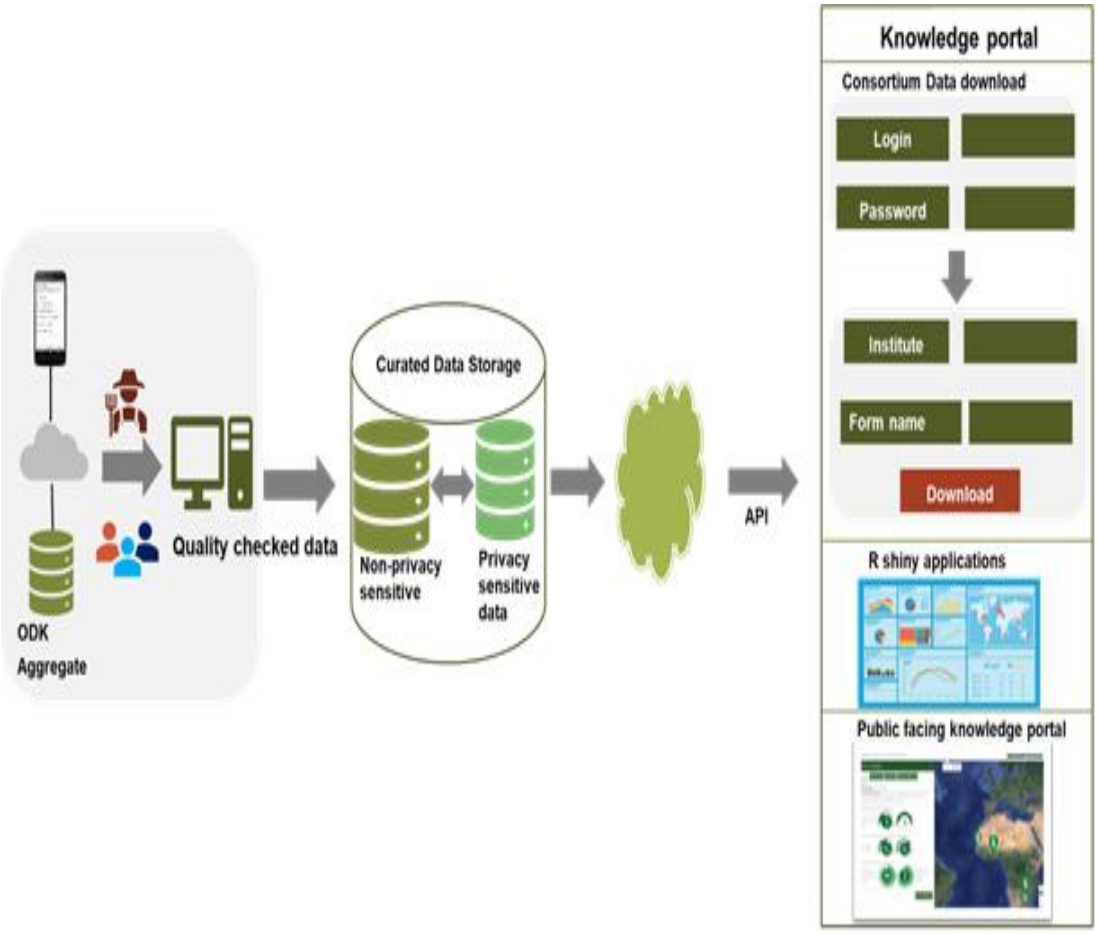



**Figure 23. Plans for steps of data curation and sharing within the consortium**

***Challenges and proposed changes in milestone timelines***

Since CocoaSoils is still ongoing, data is still being collected. The data server continuously needs updating and maintenance. The ODK aggregate server is no longer updated by the open-source community. ODK Central is the new version. Hence, data and service will be migrated to ODK Central in 2023. An important step in the future is to educate the community on ontologies in general, and Cocoa Ontology in particular. This way, it will be promoted more broadly and enable uniformity in data sharing. Lastly, continuous updates to integrate growing vocabulary and classes are crucial to ensure a sustainable long-term ontology.

### 2.4.7 Output 1.7. A new cadre of PhD and MSc-holding cocoa scientists with knowledge in new cocoa intensification options (including Output 1.2 results)

As target for this Output in 2022, the project will approve at least four PhD theses and at least six MSc theses. Achievement of the following milestones is expected at the time of reporting. Table 13 and the subsequent information provide details on the progress of the milestones for 2022. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 13. Status of milestones for Output 1.7**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **R4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 1.7. A new cadre of PhD and MSc-holding cocoa scientists** | | | | | | | | | | | | | | | | | | | | |
| Activity 1.7.1. Identification of PhD and MSc topics | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.7.1.1. Agreements with universities hosting the students finalized | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.7.1.2. Research proposals approved | | | | X | X | X | X | X | X | | | | | | | | | | | |
| Activity 1.7.2. Implementation of the PhD and MSc projects | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.7.2.1. Best candidates identified | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.7.2.2. Regular discussions with the supervisory committees held | | | | | | | | | | | | | | | | | | | | |
| Activity 1.7.3. Submission and approval of the PhD and MSc theses | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.7.3.1. Papers in relation to thesis chapters drafted and reviewed | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.7.3.2. Theses submitted | | | | | | | | | | | | | | | | | | | | |
| Milestone 1.7.3.3. Theses defended | | | | | | | | | | | | | | | | | | | | |

***Progress on milestones***: Four PhD thesis and ten MSc thesis have been published. The following is a summary of the activities of the PhD students: Deo-Gratias Hougni, the PhD student working on ISFM in Nigeria has published one paper on nutrient release from cocoa pod husks under simulated watering

regime. Two manuscripts are almost finalized and will soon be submitted. Results from the fertilizer trial will require additional data since it is a long-term experiment.

Paulina Asante, the PhD student stationed in Ghana at CRIG has completed and published Chapter 1 of her thesis titled 'Unravelling drivers of high variability of on-farm cocoa yields across environmental gradients in Ghana ( https://doi.org/10.1016/j.agsy.2021.103214 ). Chapter 2 titled "The cocoa yield gap in Ghana: A quantification and an analysis of factors that could narrow the gap" is published in Agricultural Systems (https://doi.org/10.1016/j.agsy.2022.103473). Chapter 3, which focuses on 'climate change effects on cocoa production and the potential cocoa-forest 'conflicts' in West Africa is under development.

Urcil Kenfack, the PhD student based in Cameroon, presented two posters on sustainable cocoa intensification through ISFM adoption at the Annual CocoaSoils Forum in 2022. A manuscript titled "Farmers' perceptions as a driver of agricultural practices: Understanding soil fertility management practices in cocoa agroforestry systems in Cameroon" has been published in Human Ecology.
Urcil also presented two abstracts at a conference, initiated two manuscripts and an MSc manuscript, and contributed two book chapters, one of which has been published.
The following abstract were presented at the International Symposium on Cocoa Research in Montpellier:

1. Using decision support tools to foster GAPs among cocoa farmers, what is needed for success? A case study from Cameroon; and
2. Determinants of the adoption of good cocoa farming practices and opportunities for increasing their uptake in the Centre region of Cameroon.

The PhD thesis on "Farmers' access, demand and satisfaction with diverse services and their determinants: The case of the Cocoa sector in Central Cameroon (With Slingerland M., Mathe S., Giller K., Leeuwis C.) is undergoing internal revision and will be submitted to the Journal of Agricultural Education and Extension in Q1 of 2023. The PhD thesis on "The influence of farmers' motivations and participation in support programs GAP adoption, Yields and Net returns (With Arega A., Sika G., Mathe S. and Maja S.) will be submitted to Development in Practices in Q2 of 2023.
An MSc thesis on "Making Decision Support Tools to work for smallholders, what is needed for success? The case of cocoa farmers in Central Cameroon" (With Ebai B. and Fon D.) is undergoing Internal revision and will be submitted to Information Development in Q1 of 2023.
Regarding book chapters, the first chapter titled "Institutional Innovations in Tree Crop Producer Organisations in Africa" has been published[2] and the second one on "Policies to enhance behavioural change towards a sustainable cocoa sector: The case of Cameroon and the Roadmap to deforestation-free cocoa - An ACF analysis" has been submitted to editors for internal review before publication.

Lucette Adet, a PhD student stationed in Côte d'Ivoire, is working on cocoa physiology. Data collection and experimentation ended in May 2022. Chemical and sensory analysis results were received in 2022. Data analysis for Chapter 1 is still ongoing. This will be followed by data analysis for Chapter 2. Statistical analysis for Chapter 3 is also being undertaken. The student is writing the discussion section of manuscript for Article 1. Results related to the effect of drought and potassium on cocoa yield were presented in a poster at the ISRC conference in Montpellier in Q4 of 2022.The student also presented preliminary results of her study at the following conferences:

[2] Institutional Innovations in Tree Crop Producer Organisations in Africa. In: Minang PA, Duguma LA, van Noordwijk M, eds. Tree commodities and resilient green economies in Africa. Nairobi, Kenya: World Agroforestry (ICRAF).

- *Journées Scientifiques de l'Agroforesterie Première édition 2021_ Nutrition du Cacaoyer : Mécanismes Physiologiques face au Stress Hydrique », 12-13 Mars 2021 Université de Daloa* - in Côte d'Ivoire ;
- International Symposium on Cocoa Research (ISCR 2022) titled: «Physiological and yield responses to drought of different cocoa genotypes in Ivory Coast», 5, 6, 7 December 2022 - Montpellier, France; and
- Attendance to the INCOCOA Workshop "Building Cocoa Collaborations to Deliver Research Impact on Climate Change, Deforestation and Living Incomes", 8th December 2022 - Montpellier, France.

Ten (10) out of the 14 MSc students recruited in Nigeria, Cameroon, Ghana, and Côte d'Ivoire have completed and defended their theses. See Table 14 below for details of MSc students' theses.

**Table 14. MSc students recruited under CocoaSoils**

| NAME | THESIS TOPIC | STATUS |
|---|---|---|
| **Nigeria** | | |
| Ajibona Olusade Adeola | Biomass estimation and nutrient partitioning in cocoa trees of different ages | Thesis completed, pending defense |
| Oluwafemi Oyedele | Quantification of litterfall, decomposition, and nutrient release in cocoa plantations | Thesis can be accessed here. |
| **Cameroon** | | |
| Nsong Ngang Andrê | *Agriculture contractuelle et bien-être des producteurs dans les systemes agroforestiers á base de cacao au cameroun* | Thesis can be accessed here. |
| Nsangou Njankouo Abdoulay | *Mapping du système de vente d'intrants pour la cacaoculture dans les localités de Ntui et Makenene, région du centre au Cameroun* | Thesis can be accessed here. |
| Tsouga Manga Milie Lionelle | Influence of management options and some ecological factors on fertility and yields of cocoa in cocoa agroecosystems at Ntui subdivision | Thesis can be accessed here. |
| **Ghana** | | |
| Samuel Yeboah | Response of cocoa seedlings to foliar fertilizer application and fertigation | Thesis can be accessed here. |
| Bernard Darko Quarshie | Characteristics of community-based compost and biochar and their effects on growth of cocoa seedlings | Conducting research in the field |
| Amos Obiri Mornyuie | The response of cocoa seedlings to different growth media | Conducting research in the field |
| ***Côte d'Ivoire*** | | |
| | | |

| NAME | THESIS TOPIC | STATUS |
|---|---|---|
| **Associated students[3]** | | |
| Anne-Juul Welsink | Deforestation in south-west Ghana – Direct drivers, the size of clearings and emerging hotspots | Thesis can be accessed here. |
| Miguel Laitao | Shade trees and cocoa production in western Ghana – A Case Study | Thesis can be accessed here. |
| Marente Lokin | ISFM: Understanding cocoa farmers' motivation and unpacking adoption of ISFM practices | Thesis can be accessed here. |
| Ernestina Quansah | The quality of Cocoa Pod Husk Biochar produced with the Kon-tiki kiln technology, and its effects on soil chemical and physical properties, and the growth rate of cocoa seedlings | Thesis can be accessed here. |
| Mina Fredrikke Bohne | Smallholder cocoa farmers' prospects for social and economic upgrading in global value chains | Thesis can be accessed here. |
| Esther Asare | Morphological characterization of cocoa varieties in different socio-ecological settings in Ghana | Thesis can be accessed here. |

***Challenges and proposed changes in milestone timelines***

Although four PhD and 10 MSc papers have been published, a few more are in the progress of being completed. As a result, the four PhD candidates have received six-month extension to their scholarships with funding from Wageningen University and are expected to complete their thesis by the middle of 2023. The five MSc students are on track to complete their thesis in 2023. The MSc students will not need extra funding. Nevertheless, delays to fieldwork were experienced but all candidates are on track to submit by mid-2023.

## 2.5 P4D-related outputs

The P4D component ensures the transfer of the research products to end-users through existing initiatives for dissemination to partners. The main outcomes of the P4D component are to ensure that the research products and tools are used by target households and policymakers.

### 2.5.1 Output 2.1: Agreements with private (including digital partners) and/or governmental scaling partners developed and signed to disseminate new recommendations/knowledge through their existing structures/ frameworks (HE protocols or ILO protocol)

The target for Output 2.1 for 2022 is to develop and sign at least 10 agreements (at least eight with scaling partners, and at least two with digital partners). The following milestones are expected to be achieved at the time of reporting. Table 15 and the subsequent information provide details on the progress of the

[3] Associated students are students that use the services of the CocoaSoils project but have personal funding.

milestones for 2022. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 15. Status of milestones for Output 2.1**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **P4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 2.1. Agreements with private and/or governmental scaling partners** | | | | | | | | | | | | | | | | | | | | |
| Activity 2.1.1. Identification of relevant dissemination networks | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.1.1.1. Potential scaling partners/initiatives mapped | | | X | X | X | X | X | X | | | | | | | | | | | | |
| Milestone 2.1.1.2. Preliminary agreements with scaling partners established | | | X | X | X | X | X | X | X | X | | | | | | | | | | |
| Activity 2.1.2. Facilitation of agreements with partners having dissemination networks | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.1.2.1. Agreements with scaling partners formalized | | | | | X | X | X | X | X | X | X | X | X | X | X | X | | | | |
| Milestone 2.1.2.2. Agreements updated (as relevant/needed) | | | | | | | | | X | X | | | | | | | | | | |

***Progress on milestones:*** 11 partners (Barry Callebaut, Kuapa Kokoo, Cargill, Mars, Mondelez, Nestlé, Olam, Olatunde International, Rockwinds, Sucden, and Tulip Cocoa) have signed agreements either through the Cooperation Agreement or later through the Participation Statement. In addition, Beyond Beans in Cameroon has signed dissemination agreements, thereby increasing the number of its scaling partners to eight: Olam, Cargill, Mondelez, Kuapa Kooko, Rockwinds/Transroyal, Sucden, and Olatunde International). Table 16 shows the details of scaling partners and the status of agreements.

In all, the 13 signed agreements (11 scaling partners and two digital partners) are well over the 2022 targets of eight scaling partners and two digital dissemination partners. See status on agreements with partners.

**Table 16. Scaling partners and status of agreements**

| Partner | Country | Participation Agreement | Workplan (Dissemination/ Scaling Agreements) |
|---|---|---|---|
| **Olam** | Cameroon | Signed | Signed |
| | Côte d'Ivoire | Signed | Signed |
| | Ghana | Signed | Signed |
| | Nigeria | Signed | In progress |
| **Cargill** | Côte d'Ivoire | Signed | Signed |
| | Ghana | Signed | In progress |
| **Mondelez** | Côte d'Ivoire | Signed | Signed |
| | Ghana | Signed | Signed |
| **Kuapa Kooko** | Ghana | Signed | Signed |
| **Rockwinds/Transroyal** | Ghana | Signed | Signed |
| **Sucden** | Nigeria | Signed | Signed |
| **Olatunde International** | Nigeria | Signed | Signed |
| **Tulip Cocoa** | Nigeria | Signed | In progress |
| **Beyond Beans** | Côte d'Ivoire | | Signed |

***Challenges and proposed changes in milestone timelines:*** New partnerships were not pursued due to CocoaSoils' transition into EiA as a use case. Going forward, the national regulators will oversee the Cocoa Platforms (formerly P4D Committees). The Cocoa Platforms, which comprise public and private sector companies, are mandated to support research activities, validate results, support the development of the Stepwise tool, and coordinate the dissemination of research recommendations to cocoa farmers.

### Output 2.2: Appropriate extension tools assembled and revised for integration in partner-led scaling including integration into digital platforms of new recommendations/tools

As target for this Output in 2022, the project will develop and make available Version 3 of adapted extension tools based on information and feedback from MEL, and Version 2 of adapted digital platform based on secondary ISFM-related information. Table 17 and the subsequent information provide details on the progress of the milestones for 2022. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 17. Status of milestones for Output 2.2**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **P4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 2.2. Appropriate extension tools for integration in partner-led scaling** | | | | | | | | | | | | | | | | | | | | |
| Activity 2.2.1. Assessment of cocoa producers' capacity needs | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.2.1.1. Producer associations identified | | | | | X | X | X | | | | | | | | | | | | | |
| Milestone 2.2.1.2. Training needs assessed | | | | | X | X | X | | | | | | | | | | | | | |
| Activity 2.2.2. Production of extension tools | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.2.2.1. Draft version of the extension tools produced | | | | | X | X | X | X | X | X | | | | | | | | | | |
| Milestone 2.2.2.2. Extension tools validated with cocoa producers' associations | | | | | X | X | X | X | X | X | | | | | | | | | | |
| Milestone 2.2.2.3. Extension tools multiplied | | | | | | | | | | X | X | X | | | | | | | | |
| Activity 2.2.3. Facilitation of feedback sessions with dissemination partners on the extension tools | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.2.3.1. Feedback session schedule organized | | | | | | | | | X | X | X | X | X | X | X | X | x | X | | |
| Milestone 2.2.3.2. Feedback received and analyzed | | | | | | | | | | | | | | | | | | | | |

***Progress on milestones*:** The content of the training manual was used to train 700 EAs of private partners and 69503 farmers. An endline survey to collect data from EAs on the adoption of ISFM knowledge has been conducted and undergoing final analysis. The results from this survey will be provided in the final project report.

As part of EA training sessions, evaluation of the manual content and other aspects (i.e., lessons learned, methodology, and logistics) was conducted. Analysis of this data from an evaluation conducted on EAs with Kuapa Kokoo in Ghana showed a high acceptance rate of the content. Out of 22 EAs trained, 82 percent of participants strongly agreed that the content met their expectations, while 14 percent agreed. See here for the report. Further training sessions will be held for EAs under the CocoaSoils use case.

***Challenges and proposed changes in milestone timelines*:** An endline survey with dissemination partners on the adoption of ISFM recommendation and its integration into their training sessions has been

conducted and undergoing final analysis. The final report will be ready in 2023. Version 3 of the training manual will be developed when new recommendations from research activities are available.

### 2.5.2 Output 2.3: Appropriate ToT manuals developed for use in the training sessions for EAs

The target for Output 2.3 for 2022 is to develop Version 3 of adapted extension tools, at least three digital platforms integrate ISFM knowledge, at least 25 ToT sessions organized (including digital platforms), at least 625 EAs trained including training on digital platform for dissemination, and at least 140 000 cocoa farmers trained on new recommendations and child labor concept.

The following milestones are expected to be achieved at the time of reporting. Table 18 and the subsequent information provide details on the progress of the milestones for 2022. Refer to **APPENDIX 1—Status of Project Results with Mitigation plans** for status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 18 Status of milestones for Output 2.3**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **P4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 2.3. Appropriate ToT manuals for use in the training sessions for extension** | | | | | | | | | | | | | | | | | | | | |
| Activity 2.3.1. Identification of EA for engaging in training-of-trainers' activities | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.3.1.1. Functioning of participating dissemination networks mapped | | | | | X | X | X | | | | | | | | | | | | | |
| Milestone 2.3.1.2. EA identified | | | | | X | X | X | X | X | X | | | | | | | | | | |
| Milestone 2.3.1.3. Training needs assessed | | | | | X | X | X | X | X | | | | | | | | | | | |
| Activity 2.3.2. Implementation of ToT sessions | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.3.2.1. Training schedule organized | | | | | X | X | X | X | X | X | | | | | | | | | | |
| Milestone 2.3.2.2. Training sessions held | | | | | | | | | | | | | | | | | | | | |
| Activity 2.3.3. Collection of feedback on the effectiveness of the ToT sessions and eventual modification of the approach | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.3.3.1. Collection of feedback on the effectiveness of the training | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milestone 2.3.3.2. Continuous improvement of the training modules and processes | | | | | | | | | | | | |

***Progress on milestones:*** 165 EAs were trained in 2022. This increases the number of EAs by the project to 700. A total of 22 training EA training sessions have been organized since 2018. The training sessions focused on ISFM recommendations and BMPs. The total number of EAs trained represents 112 percent of the project target of 625 EAs. The total number of training sessions conducted represents 88 percent of the project target of 25 training sessions. EAs were also trained on: MEL to enhance their knowledge on the use of ODK; tools required to document types of training; location, numbers, and sex of farmers trained; and to capture and upload these farmers' information.

**Table 19. List of EAs submitted by EAs and trained by CocoaSoils**

| Country | Partners | Number of EAs submitted for training | Number of EAs trained in 2022 |
|---|---|---|---|
| **Cameroon** | Olam | 62 | 57 |
| **Côte d'Ivoire** | Olam | 202 | 241 |
| | Cargill/Mondelez | 120 | 67 |
| | Anader | 36 | 36 |
| **Ghana** | Cargill | 32 | 32 |
| | Kuapa Kooko | 62 | 56 |
| | Mondelez | 34 | 35 |
| | Olam | 5 | 26 |
| | Rockwinds | 20 | 16 |
| | CHED | 5 | 5 |
| **Nigeria** | Olam | 77 | 77 |
| | Olatunde International | 18 | 15 |
| | Sucden | 20 | 17 |
| | Tulip Cocoa | 20 | 20 |
| **TOTAL** | | 667 | 700 |

The feedback system developed under the MEL component is being implemented during training sessions for EAs. This includes participant evaluation on content, methodology, master trainers' skills, logistics, and knowledge gained. See report on participants' feedback here.

The total number of farmers trained by EAs on ISFM recommendations and BMPs as of December 2022 is 38 721 (25 percent female). This represents 19 percent increase in the number of farmers trained in 2021. A total number of 30 782 farmers (19 percent female) were trained digitally through Viamo and ANADER dissemination platforms. As a result, the total number of farmers trained by the project is 69 503 (23 percent female). This represents 50 percent of the 2022 target of 140 000 farmers. View reports from Viamo and ANADER here. Details of partners' EA training activities can be seen here.

An endline survey to capture the extent of farmers adoption of the ISFM recommendation has been completed. Data is currently being analyzed and will be compared to the findings of the baseline survey. This information will be included in the final report.

**Figure 24: Training of EAs from Cargill in Ghana**

***Challenges and proposed changes in milestone timelines***: The target of reaching 140 000 farmers with ISFM recommendations by 2022 was not achieved due to COVID-19 restrictions that prevented EAs from interacting with farmers for several months, and EA schedules conflicting with timelines for training activities. The low pick-up rates of the digital dissemination programs in the beginning due to low sensitization also contributed to this. Efforts will be intensified under CocoaSoils Use Case to achieve this target.

### Output 2.4: Engagement in policy action in support of sustainable cocoa intensification ensuring avoidance of deforestation and child labor in applying new recommendations

The targets for Output 2.4 for 2022 are at least two policy briefs, at least four extra interactions with policymakers in at least three countries, and at least 15 public and private sector partners trained on using the developed tools and knowledge. Achievement of the following milestones is expected at the time of reporting. Table 20 and the subsequent information provide details on the progress of the milestones for 202. Refer to **APPENDIX 1—Status of Project Results with Mitigation Plans** for the status of the targets.

Columns with an 'X' indicate new timelines for the milestone. Columns in grey indicate the original timeline for the milestone according to the implementation plan in the proposal.

**Table 20. Status of milestones for Output 2.4**

| Activities and milestones | 2018 | | | | 2019 | | | | 2020 | | | | 2021 | | | | 2022 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **P4D-related** | | | | | | | | | | | | | | | | | | | | |
| **Output 2.4. Engagement in policy action in support of the sustainable intensification of cocoa** | | | | | | | | | | | | | | | | | | | | |
| Activity 2.4.1. Identification of relevant and specific policy briefs | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.4.1.1. Cocoa-related policy environment documented for target countries | | | | | | X | X | X | X | X | X | X | X | X | | | | | | |
| Milestone 2.4.1.2. Policy briefs formulated | | | | | | | | | X | X | X | X | X | X | X | X | X | X | | |
| Activity 2.4.2. Engagement with relevant policymakers | | | | | | | | | | | | | | | | | | | | |
| Milestone 2.4.2.1. Relevant policy-related processes identified and activated | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | |
| Milestone 2.4.2.2. Interactions with policymakers held in relation to products developed under Outputs 1.3, 1.4, and 1.5 | | | | | | | | | | | | | | | | | | | | |

***Progress on milestones*:**

After the handing over of the training manual to Ministry of Agriculture and Rural Development in Cameroon. The training manual was handed to Nigeria's Ministry of Agriculture and Rural Development and Ghana Cocoa Board in 2022.

Since the start of the project, there have been 23 interactions with policymakers. This has been done through the organization of the partnership committees in Cameroon (7), Côte d'Ivoire (4), Ghana (4), and Nigeria (8). In Cameroon, Côte d'Ivoire, Nigeria, and Ghana, a total of 12, 10, 6, and 25 public and private sector partners, respectively, were engaged.

***Challenges and proposed changes in milestone timelines***: The handover of the training manual to authorities in Côte d'Ivoire has been rescheduled to 2023 to allow the project leads and the country's cocoa regulator to agree on a convenient date.

## APPENDIX 1: Status of Project Results with Mitigation Plans

| Project results | 2022 Targets | Status as of December 2022 | Delays experienced and reasons why | Mitigation plans to recover delays |
|---|---|---|---|---|
| Project impact | | | | |
| Impact 1. Smallholder cocoa farmers benefit from sustainably increased cocoa productivity and income generated through cocoa production. | →Yield: 30% increase against baseline<br>→Income: 25% increase against baseline<br>→ At least 90 000 households achieved the yield and income increases<br>→No visible increases in deforestation compared to control sites<br>→No evidence for child labor obtained<br>→No change in carbon stock, water, and biodiversity indexes in cocoa zones of Côte d'Ivoire and Ghana | There is no data yet on the impact indicators. | Training sessions for farmers across the countries took place mainly in 2021. | Effects of the knowledge gained (i.e., yield, incomes) will be assessed in the coming years through farmer surveys. This will give some time for application or otherwise of the knowledge by farmers. |
| **Project outcomes** | | | | |
| Outcome 1<br>New cocoa ISFM-related research products are used by private and public stakeholder partners. | →At least six research products validated and used by private and/or public stakeholders<br><br>→At least 450 EAs are using the new research products | A total of 700 EAs (11% female) have been trained with the content of the training manual. EAs are training farmers with the content of the manual. | | |
| Outcome 2.<br>Recommendations generated through research products are used by target households. | →At least 30 000 cocoa farmers using the new recommendations/new knowledge<br>→At least 60 000 cocoa farmers using the existing recommendations/new knowledge | A total of 69 562 farmers (23% female) have been trained physically by partner EAs and through digital platforms (Viamo and ANADER). An endline survey (to assess knowledge gained and practices) after farmer training through the digital platforms shows that farmers have gained | No new recommendations are being used since the trials are still ongoing | |

| Project results | 2022 Targets | Status as of December 2022 | Delays experienced and reasons why | Mitigation plans to recover delays |
|---|---|---|---|---|
| | →At least three new recommendations are being used<br>→At least five existing (old) recommendations are being used | knowledge, and most have started using new knowledge. For example, in Nigeria, out of a sample of 250 farmers, between 52% and 64% of farmers had already weeded and pruned their farms per the recommendations. There is appreciation of good farm maintenance such as timely and yearly pruning of cocoa trees and weeding of farms.<br><br>Data from an endline survey to assess knowledge gained and practices adopted by farmers through physical training by EAs is being analyzed. | | |
| Outcome 3. Decision-makers (public and private) are using tools and knowledge to avoid increased deforestation and child labor while promoting cocoa intensification. | →Finals maps and assessments available<br>→At least three policy documents of the target countries have integrated into new tools<br>→At least six public and private sector organizations are using new tools and knowledge to promote deforestation free supply chains<br>→All public and private sector organizations engaged in CocoaSoils initiative are | Draft maps of land-use patterns and ecosystem services in target countries have been finalized.<br><br>The documentation of cocoa related policies has been validated within the partnership committees, paving the way for the formulation of policy briefs. | The development of policy briefs was delayed due to late completion of the process to validate the documentation of existing policies. | Formulation of the policy briefs is ongoing. |

| Project results | 2022 Targets | Status as of December 2022 | Delays experienced and reasons why | Mitigation plans to recover delays |
|---|---|---|---|---|
| | enforcing the HE and ILO protocols on child labor-free production to promote new recommendations/ Knowledge. | | | |
| **Project results** | | | | |
| **Project Outputs** | | | | |
| Output 1.1. A set of ISFM options | →A first set of ISFM recommendations generated, ready for integration in scaling | All 11 CTs are being managed, based on agreed protocols.<br><br>A total of 389 ST sites have been installed in accordance with the approved protocols: 64 in Cameroon, 132 in Côte d'Ivoire, 127 in Ghana, and 66 in Nigeria. | Some CTs reported difficulties in getting fertilizer products. To address this, alternatives were proposed, including adjusting formulations. | Alternatives were proposed, including adjusting formulations. |
| Output 1.2. Understanding the physiological basis of cocoa nutrient uptake and use | → At least six papers on cocoa ISFM/physiology accepted | Four papers were accepted and published. The most recent publication is a paper by Paulina Asante titled "The cocoa yield gap in Ghana: A quantification and an analysis of factors that could narrow the gap". It has been completed and published in Agricultural Systems 201 (2022) 103473. https://doi.org/10.1016/j.agsy.2022.103473 | There have been delays in the completion of some of the chapters of students' theses due to model simulation errors in some instances and delays caused by the COVID-19 pandemic.<br><br>To address this, a decision was made to extend fieldwork and data collection to Q2 of 2022. Data Analysis commenced in Q3 of 2022 and is currently ongoing. | All four PhD students have received a six-months extension with funding from WUR. They are on track to finish by mid-2023. |
| Output 1.3. | →Final set of decision support tool ready for scaling | The second draft of the CSC implementer app has been developed to include a | The current version of the CSC app is inadequate and requires further development and | It is important that each suggested step for any farm (by geolocation) can be simulated in |

| Project results | 2022 Targets | Status as of December 2022 | Delays experienced and reasons why | Mitigation plans to recover delays |
|---|---|---|---|---|
| A decision-support system for intensifying cocoa production | | segmentation module to understand farm diversity and a BMP module. | alignment to the standard decision support tools in EiA. The analytical framework for the yield and ROI has been set-up but requires experimental data from the STs and CTs to reliably calibrate the CASE2 to simulate actual farm yields. | terms of productivity but also in terms of the costs and economic benefit. This process will take more time than anticipated due to these required capabilities. It is expected that for a fully functional application with spatial yield and profit prediction, the activity will go beyond 2022. |
| Output 1.4. Recommendation domains and impact of sustainable intensification on forest pressure identified | → Final cocoa suitability maps and deforestation scenarios | Deforestation risks maps were developed to understand past and recent deforestation hotspots. | | |
| Output 1.5. Sustainability assessment tools developed and validated to support the sustainable development of cocoa production in relation to biodiversity and ecosystem services at the landscape level | → Final version of sustainability assessment tools available | - A toolkit on tools to plan for ecosystem services in cocoa landscapes and a storymap on considering risks and opportunities for meeting cocoa sustainability objectives from regional to the national levels were finalized.<br>- The guiding framework to help target cocoa system design considering national to local level deforestation risks and social, economic, and environmental objectives | COVID-19 is thwarting plans for stakeholder consultation and engagement activities, likely into 2022 as well. | Dedicate additional time on communication materials in support of project Output 2.4. and Outcome 3.<br><br>Fieldwork to take place in 2022, though not in all countries (Ghana and Côte d'Ivoire only). Results will be published after the end of this phase of CocoaSoils. |

| Project results | 2022 Targets | Status as of December 2022 | Delays experienced and reasons why | Mitigation plans to recover delays |
|---|---|---|---|---|
| | | in cocoa growing regions was finalized.<br>- Biodiversity assessment protocols were developed and applied in the STs of Ghana and Cameroon. | | |
| Output 1.6. Operational open knowledge and data sharing portal for the storage, management, and dissemination of cocoa intensification research results | →Final version of a portal available<br>→All datasets submitted | - A new PostgreSQL database (curated data storage) with user management roles and granted general privileges to users has been developed. This database stores all quality-checked databases and associated credentials for each partner. Within this database, we also separate the privacy-sensitive data and non-privacy-sensitive data.<br>- A Knowledge Portal for data visualization and sharing has also been developed. | | |

| Project results | 2022 Targets | Status as of December 2022 | Delays experienced and reasons why | Mitigation plans to recover delays |
|---|---|---|---|---|
| | | - A cocoa ontology report has been finalized | | |
| Output 1.7. A new cadre of PhD and MSc-holding cocoa scientists with knowledge on new cocoa intensification options | →At least four PhD theses approved<br>→ At least six MSc theses approved | - All PhD students are currently working on their theses chapters, fieldwork, and manuscripts. Four PhD Papers have been published.<br>- 10 MSc papers have been published. | Some delays in fieldwork and data collection have been observed since some travel restrictions were enforced in some countries due to COVID-19. | Fieldwork is ongoing. Additionally, discussions and meetings with supervisors are constantly held. |
| Output 2.1. Agreements with private and/or governmental scaling partners developed and signed to disseminate new recommendations/ knowledge through their existing structures/frameworks (HE Protocol or ILO Protocol) | →At least eight agreements with scaling partners developed and signed<br>→ At least two agreements with digital partners developed and signed | A total of 11 partners (Barry Callebaut, Kuapa Kokoo, Cargill, Mars, Mondelez, Nestlé, Olam, Olatunde International, Rockwinds, Sucden, Tulip Cocoa) have signed agreements either through the cooperation agreement or later through the Participation Statement. In addition, 11 dissemination agreements have been signed by eight scaling partners (Olam, Cargill, Mondelez, Kuapa Kooko, Rockwinds/Transroyal, Sucden, | Discussions held with new partners to increase reach of dissemination in Cameroon has not progressed as anticipated. This is due to unresolved issues regarding data confidentiality. | Partners are being assured of the confidentiality of their data. |

| Project results | 2022 Targets | Status as of December 2022 | Delays experienced and reasons why | Mitigation plans to recover delays |
|---|---|---|---|---|
| | | Olatunde International, and Beyond Beans).<br><br>Viamo and ANADER completed their pilot work in July 2022. In addition to the two digital dissemination partners, Radio Gognoa in Côte d'Ivoire also completed its broadcasting using the content from the CocoaSoils manual. | | |
| Output 2.2. Appropriate extension tools assembled and revised for integration in partner-led scaling of new recommendations/ tools | →Version 3 of adapted extension tools available, with inclusion of new information and feedback from MEL<br>→Version 2 of adapted digital platforms available, based on secondary ISFM-related information | The training manual and the farmers' handbook were finalized and printed in 2021. Copies have been submitted to private partners and are being used for ToT sessions, farmers' training, and digital dissemination.<br><br>Copies of training manuals were handed over to the authorities in Cameroon, Ghana, and Nigeria.<br><br>The content of the manual was integrated into the digital platform of the two digital partners to serve as Version 1 of the adapted digital platform based on existing information. | Version 3 of adapted extension tools and Version 2 of adapted digital platforms have not been developed because data from the CTs and STs are still being collected. | Data collection is ongoing. |
| Output 2.3. Appropriate ToT manuals developed for use in the training sessions for EAs | →Version 3 of adapted extension tools available<br>→At least two digital platforms integrate ISFM knowledge<br>→At least 20 ToT sessions organized | A total of 700 (11% female) EAs have been trained using the training manual. Also, 22 training sessions were organized. | COVID-19 restrictions on travel, movement, and gatherings delayed the training of EAs and farmers. | To address these delays, training sessions were done in small numbers to comply with COVID-19 protocols. |

| Project results | 2022 Targets | Status as of December 2022 | Delays experienced and reasons why | Mitigation plans to recover delays |
|---|---|---|---|---|
| | →At least 500 EAs trained (gender disaggregated)<br>→At least 140 000 cocoa farmers trained on new recommendations and child labor concept | A total of 38 780 farmers have been trained by partners' EAs. Also, 30 782 farmers have been trained through Viamo and ANADER digital dissemination programs. This gives a total of 69 503 farmers (23% female) trained with the existing ISFM content. | The low pick-up rates of the digital dissemination programs in the beginning were a challenge and these were attributed to low sensitization.<br><br>COVID-19 also hampered physical training sessions with farmers. | More training sessions will be organized under CocoaSoils Use Case |
| Output 2.4. Engagement in policy action in support of sustainable cocoa intensification ensuring avoidance of deforestation and child labor in applying new recommendations | →At least two policy briefs<br><br>→At least four extra interactions with policymakers in at least three countries<br><br>→At least 15 public and private sector partners involved in testing/validating the draft tools and knowledge | The documentation of cocoa-related policies has been completed and validated to pave the way for the formulation of policy briefs<br><br>There have been 16 interactions with policymakers through the organization of the partnership committees for which five were held in Cameroon, two each in Côte d'Ivoire and Ghana, and six in Nigeria. In Cameroon, there were 12 public officials from relevant sectors and private sector companies engaged, 10 in Côte d'Ivoire, 6 in Nigeria, and 3 in Ghana. | The formulation of policy briefs has been delayed because of the late start of the documentation of cocoa-related policies | As the documentation of cocoa-related policies has been validated plans are underway to begin the formulation of policy briefs. |

## APPENDIX 2: Financial Report