1 Introduction

Agricultural commodities drive the vast majority of tropical deforestation (Pendrill et al., 2022). Major commodity traders have adopted zero-deforestation commitments in response to consumer and regulatory pressure, yet evidence on the effectiveness and feasibility of these commitments in low-income settings remains limited (Lambin et al., 2018; Lambin and Furumo, 2023). West African cocoa exemplifies the implementation challenge: Ghana and Côte d'Ivoire supply over 70% of global cocoa through millions of smallholder farmers, and cocoa expansion drives substantial deforestation across the region (Kalischek et al., 2023). Cocoa farmers lack technology to credibly demonstrate compliance with deforestation-free standards, reducing access to premium markets where sustainable production is rewarded (Bold et al., 2022). Consequently, farmers lack incentives to adopt sustainable production practices, perpetuating environmental degradation and rural poverty (de Janvry and Sadoulet, 2020; Barbier, 2010; Barrett, 2008).

The European Union Deforestation Regulation (EUDR), which takes effect between December 2026 and June 2027, requires importers to verify that cocoa and six other tropical commodities were not produced on land deforested after December 2020 (European Union, 2023). Compliance requires property-level traceability systems capable of proving deforestation-free status—a formidable challenge in low-income smallholder contexts. We develop a mobile application that addresses this technology gap by digitalizing the cocoa supply chain and integrating satellite-based deforestation monitoring. The app records cocoa purchases, links transactions to georeferenced farm boundaries, and automatically verifies compliance using weekly high-resolution deforestation alerts from Global Forest Watch (2026).

We evaluate this digital traceability technology through a randomized controlled trial in partnership with Kuapa Kokoo Farmers Union (KKFU), a co-op representing over 100,000 cocoa farmers in Ghana. KKFU operates a network of clerks who buy cocoa directly from farmers at designated sheds. We randomize 90 sheds to three arms: control, monitoring with visible certification (T1), or monitoring with deforestation-free premiums (T2). In T1, the mobile app prints traceable bag tags certifying deforestation-free status, creating transparency without financial incentives. In T2, farmers receive a $5-per-bag premium for deforestation-free cocoa in addition to certification tags. We measure deforestation at three spatial scales—on mapped properties, inside 200-meter buffers, and within village boundaries—providing experimental estimates of spatial leakage. We also measure additional outcomes including cocoa quantity, quality, and co-op recruitment.

Beyond measuring deforestation outcomes, we assess implementation feasibility from both supply and demand sides. Point-of-sale surveys with approximately 3,600 farmers elicit willingness to participate in certification under alternative contract designs, including variable premiums and enforcement regimes, revealing the conditions under which smallholders would accept deforestation monitoring and certification. Purchasing clerk surveys and administrative data identify operational bottlenecks to improve scalability and organizational buy-in, and cost effectiveness analyses assess costs per additional hectare of deforestation averted and costs per additional farmer obtaining deforestation-free certification. These findings will directly inform EUDR implementation in low-income countries and provide rigorous evidence on whether satellite-based certification can deliver environmental benefits while improving rural livelihoods. Data collection will occur between October and December 2026 during the cocoa harvesting season, with no data on implementation or outcomes collected prior to this period.

1.1 Related Literature and Contributions

This paper contributes to four strands of literature. First, we contribute to research on *supply-chain governance and deforestation-free commitments*. Private-sector zero-deforestation commitments (ZDCs), which are voluntary pledges by companies to exclude commodities from recently deforested land, have proliferated across global supply chains. A well-studied example is Brazil's Amazon Soy Moratorium, under which grain traders agreed not to purchase soy from recently deforested land. Econometric evidence suggests the Moratorium prevented approximately 18,000 km^2 of forest clearing over its first decade (Heilmayr et al., 2020), though effectiveness depends on consistent monitoring and enforcement and credible exclusion of violators (Gibbs et al., 2015). However, gaps in ZDC adoption limit efficacy even for well-monitored commodities: traders source over 40% of tropical agricultural commodities indirectly through local intermediaries, leaving blind spots (Zu Ermgassen et al., 2022; Gollnow et al., 2022). Furthermore, ZDCs covering Brazilian cattle and Indonesian palm oil achieved compliance on certified properties but generated substantial leakage to unmonitored areas (Gibbs et al., 2015; Carlson et al., 2018; Heilmayr et al., 2020), potentially offsetting 43–50% of avoided deforestation (Villoria et al., 2022).

The European Union Deforestation Regulation (EUDR) (European Union, 2023), which requires importers to verify that cocoa and six other commodities were not produced on land deforested after December 2020, increases the policy relevance and urgency of research focused on implementation of ZDCs at scale. The EUDR takes effect in December 2026 for large and medium

operators, and in June 2027 for micro and small operators, requiring traceability systems capable of proving deforestation-free status for cattle, cocoa, coffee, palm oil, rubber, soy, and wood fiber.[1] Existing traceability platforms rely on field agent reports or proximity-based risk indicators rather than automated satellite verification (Fripp et al., 2023), and implementation challenges remain substantial for smallholder-dominated supply chains where property-level mapping and monitoring infrastructure are largely absent.

We make three contributions to this literature. First, we provide pre-registered experimental evidence on whether property-level satellite monitoring reduces deforestation in commodity supply chains, addressing selection and endogeneity concerns inherent in observational studies of ZDC effectiveness. Second, whereas existing research has focused primarily on large-scale commercial agriculture (e.g., soy, beef) in middle-income countries, we test whether satellite traceability is feasible for smallholder farms in a low-income setting. Our findings will directly inform how the EUDR can be implemented for West African cocoa production, which accounts for over 70% of global supply. Third, we measure deforestation at three nested spatial scales (on-property, 200-meter buffers, and village boundaries), enabling experimental estimation of displacement effects, which are a major concern in this literature.

Second, we contribute to the literature on *information, transparency, and incentives in sustainable supply chains*. Information provision can drive environmental compliance through multiple channels. Satellite-based monitoring enables targeted enforcement: Brazil's DETER system curbs Amazon deforestation (Assunção et al., 2023), and government subscription to deforestation alerts reduced forest clearing by 18% in Africa (Moffette et al., 2021). Beyond formal enforcement, supply chain transparency can activate social norms and reputational pressures that change behavior even absent sanctions (Gardner et al., 2019; Nyborg et al., 2016). Social norms influence farmers' environmental practices through value cognition, risk perceptions, and peer effects (Simmons et al., 2021; Qiu et al., 2020). Relational contracts in agricultural supply chains create informal enforcement mechanisms (Macchiavello and Morjaria, 2015). However, transparency alone may be insufficient. Adoption of sustainable practices increases with perceived economic benefits (Piñeiro et al., 2020; Trujillo-Barrera et al., 2016), suggesting financial incentives may be necessary alongside information provision.

[1] These seven commodities were collectively responsible for 57% of agriculture-related deforestation between 2001-2015 (Goldman and Weisse, 2024). The EUDR was originally scheduled to take effect in December 2024, but was delayed due to implementation and compliance challenges in complex supply chains, including those for smallholder-dominated cocoa (Igini, 2025).

We make two contributions to this area. First, we experimentally unbundle the effects of information and financial incentives on supply chain sustainability: Treatment 1 provides satellite monitoring with visible certification, creating transparency without financial rewards, while Treatment 2 adds a $5 per-bag premium. Second, our survey module elicits farmers' willingness to accept premiums under alternative contracts, informing incentive-compatible certification design.

Third, we contribute to the literature on *conservation incentives and payments for ecosystem services (PES)*. Experimental evidence from Uganda shows that PES reduced tree cover loss with a benefit-cost ratio exceeding 2.4 and no evidence of spatial leakage to nearby land (Jayachandran et al., 2017). However, evaluations of Mexico's national PES program document two forms of leakage: increased deforestation on other properties owned by program recipients and within high-participation markets (Alix-Garcia et al., 2012). PES design also matters: up-front payments increase compliance (Jack et al., 2025), individual payments outperform group payments (Kaczan et al., 2013), and effectiveness depends on spatial targeting and payment levels (Alix-Garcia et al., 2015; Börner et al., 2020). Self-selection into PES programs can affect additionality (i.e., conservation beyond what would have occurred without payment) (Jack and Jayachandran, 2019).

We make two contributions to this literature. First, while existing PES programs operate as standalone conservation interventions, we embed conditional payments within an existing agricultural supply chain. Farmers receive deforestation-free premiums when and where they sell their cocoa, reflecting how sustainability premiums operate in commodity markets. Our survey module tests whether farmers would accept variable premiums that fluctuate with buyer demand, informing whether market-based certification can sustain farmer participation without donor subsidies. Second, we measure leakage at three spatial scales to distinguish on-farm compliance from displacement to adjacent land and broader village-level spillovers, indicating whether farm-level monitoring is sufficient or broader communal interventions are necessary.

Fourth, we contribute to literature on *agricultural certification and smallholder welfare*. Sustainability certifications can raise producer welfare through price premiums, market access, and cooperative organization (Dragusanu et al., 2014, 2022). In cocoa, Fairtrade certification increases yields, prices, and living standards (Sellare et al., 2020; Karki et al., 2016), with over 20% of global cocoa area now VSS-certified (Kemper et al., 2023). However, existing certification schemes rely on periodic audits, often at the co-op level, rather than plot-level geolocation and continuous land-use monitoring, limiting their ability to ensure deforestation-free compliance for smallholders (Romano et al., 2026; Verma, 2026). Without credible verification technology, farmers cannot

access markets where sustainable production commands a premium (Bold et al., 2022). Consequently, farmers lack incentives to adopt sustainable practices, perpetuating poverty (de Janvry and Sadoulet, 2020; Barbier, 2010). Digital traceability systems can strengthen certification credibility (Kraft and Kellner, 2022; Steinke et al., 2024), but self-reported data creates risks of inaccurate reporting, and consumers value traceability only when the certifier is credible (Bai et al., 2013).

We contribute to this literature by testing whether property-level, satellite-based certification of deforestation-free status is feasible for smallholder cocoa, addressing the verification gap that undermines existing certification systems. We also examine implementation from both supply-side and demand-side perspectives: farmer surveys reveal participation constraints, while district surveys and administrative data identify operational bottlenecks that affect scalability. These insights will directly speak to EUDR implementation in low-income contexts and provide evidence on whether satellite-based digital certification can connect smallholder farmers to premium markets while delivering environmental benefits.

Finally, we consider external validity and how our study may provide broader insights for traceability and deforestation monitoring in tropical agriculture. First, cocoa is not an outlier among EUDR-regulated crops in its reliance on smallholder production. Celik et al. (2026) find that small-scale farms (under 2 hectares) account for 60% of forest-linked cocoa production globally, comparable to 53% for coffee, 81% for palm oil, and 91% for rubber. In contrast, soybean is produced predominantly by large-scale farms ($\geq$ 200 hectares), suggesting our findings generalize more readily to coffee, palm oil, and rubber than to soy. Our experimental sample is representative of KKFU's operating area, which spans Ghana's cocoa belt. Beyond Ghana, similar smallholder traceability challenges characterize cocoa production across West Africa (Moluh Njoya et al., 2025), suggesting our findings could extend regionally. More broadly, our approach to property-level monitoring and traceability through a mobile app linked with satellite-based deforestation alerts could be adapted to other cooperatives, countries, or crops where smallholder sales pass through intermediary organizations capable of mapping their farmers' property boundaries.

2 Background

2.1 Ghana's Cocoa Sector

Ghana is the world's second-largest cocoa producer, contributing 15% of global supply in 2024-2025 (Ghana Cocoa Board, 2026; Shahbandeh, 2025). Cocoa cultivation spans 1.3 million hectares,

employs 800,000 farm households, and generates $2 billion in annual foreign exchange (Taylor et al., 2025). Despite this scale, Ghana's participation in the global chocolate value chain is largely limited to cultivation and export, capturing only 18.6% of total value added (FAO, 2020). In 2012-2013, 27% of Ghana's cocoa farmers lived below the national poverty line, with cocoa sales accounting for 61% of average household income (Vigneri and Kolavalli, 2018; Bymolt et al., 2018).

Low farmer incomes create major sustainability challenges. First, 55% of children aged 5–17 in Ghana's cocoa-growing areas engage in child labor, with 51% performing hazardous tasks including handling agrochemicals, carrying heavy loads, and land clearing (Sadhu et al., 2020). Second, insufficient funds for inputs incentivize farmers to clear new forest when plantation productivity begins to decline (Kongor et al., 2018; Binam et al., 2008; Amanor et al., 2022). Between 2001 and 2015, cocoa expansion caused 230,000 hectares of deforestation in Ghana—one-third of total forest loss (Goldman and Weisse, 2024; Kalischek et al., 2023).

The state-owned Ghana Cocoa Board (COCOBOD) controls all cocoa purchases, exports, and quality control, setting farm-gate prices at the start of each harvest season. Farmers sell to Licensed Buying Companies (LBCs), including farmer-owned cooperatives like KKFU and commercial firms. LBCs can pay farmers additional premiums beyond the COCOBOD base price for compliance with certifications such as Fair Trade or Organic. The Cocoa Marketing Company, a COCOBOD subsidiary, holds exclusive export rights (Boysen et al., 2021).[2]

2.2 Kuapa Kokoo Farmers Union

Kuapa Kokoo Farmers Union (KKFU) is a farmer-led cooperative that organizes cocoa producers. The cooperative comprises over 100,000 member farmers and purchased 6% of Ghana's total cocoa output in 2021 (Ghana Cocoa Board, 2021; KKFU, 2026). KKFU organizes farmers into zones (generally corresponding with villages) based on geographic proximity, with each zone operating a purchasing shed (SHED) where a purchasing clerk buys bags of cocoa from farmers and coordinates storage and transport of bags to district warehouses. At warehouses, district managers measure moisture content, and overly damp bags are opened, dried, and re-bagged. KKFU holds Fairtrade and UTZ Rainforest Alliance certifications and provides farmer training and extension services. As part of its supply chain traceability efforts, KKFU has mapped over 41,000 individual farm properties across 1,052 zones using GPS. Mapping is conducted by trained tech-

[2]This centralized model contrasts with neighboring Côte d'Ivoire, where the Conseil du Café-Cacao sets minimum floor prices but allows independent commercial export (Yao et al., 2025).

nicians who walk property boundaries with farmers to record the coordinates (KKFU, 2026). The co-op currently relies on paper-based transaction recording and record-keeping, which prevents headquarters staff from accessing real-time administrative data to monitor operations and makes farm-level traceability difficult to verify.

KKFU serves as the primary implementation partner for this project under a Memorandum of Understanding with the research team (reproduced in Appendix A). KKFU provided the research team with shapefiles of all mapped farms to enable satellite-based deforestation monitoring, and will implement the experiment by integrating data collection through the mobile app at purchasing sheds. KKFU will also facilitate training of purchasing clerks in app usage and communication of treatment assignment to farmers as part of the experimental information intervention. This partnership leverages the co-op's established relationships with farming communities and local coordination infrastructure. Figure 1 illustrates KKFU operations from farm to depot.

2.3 Digital Traceability and Deforestation Monitoring App

Several digital tools for cocoa traceability have emerged in recent years, including global platforms (e.g., Connected Cacao, Farmtracker, KoltiTrace) and systems implemented by specific companies (e.g., Barry Callebout, Cargill) (Comunicaffe, 2025; Koltiva, 2024; Selby, 2017; Cargill, 2021). In Ghana, COCOBOD recently piloted the Ghana Cocoa Traceability System (GCTS), which maps farms and digitizes transaction records (SASI, 2025; Ghana Cocoa Board, 2024). The system aims to track cocoa from farm to port, though full implementation timelines remain uncertain. These platforms all share a major limitation: deforestation verification relies on field agent reports, self-reported information, or proximity-based risk indicators rather than automated, real-time satellite monitoring (Fripp et al., 2023).

To address these limitations, we develop a mobile application integrating real-time satellite-based property-level deforestation monitoring, supply chain digitalization, and survey administration at point-of-sale. This technology reduces data collection costs, eliminates the need for separate field enumeration, and allows researchers and KKFU managers to update survey questions dynamically (though only pre-registered survey questions will be analyzed in this study). The app operates through three portals:

- **SHED Portal (Purchasing Clerk):** When a purchasing clerk initiates a transaction at a purchasing shed, they enter the farmer's name and zone into a tablet to locate the farmer's

Figure 1: KKFU Operations from Farm to Depot

(a) Cocoa farm

(b) Cocoa purchasing SHED

(c) Quality inspection at SHED

(d) Transport to depot

(e) Depot warehouse

(f) Drying area at depot

Note: Photos taken by research team during January 2025 scoping visit and October 2025 pilot fieldwork. Panel (a) shows a typical cocoa plantation with mature trees. On average, each zone contains approximately 40 cocoa plots with mean size of 0.94 hectares. Panel (b) shows a KKFU purchasing SHED. These are typically located in the village center corresponding to a particular zone. SHEDs are where farmers bring their cocoa bags to sell to KKFU purchasing clerks, and will serve as the location of survey administration. Panel (c) illustrates the initial quality inspection undertaken by purchasing clerks at the SHED, including checks for contaminants and excess moisture. In experimental zones, the purchasing clerk will seal each bag with a QR-coded sticker affixed to a color-coded zip tie to achieve property-level traceability for each bag. Panel (d) shows a light transport vehicle used to move cocoa bags from SHEDs to KKFU district warehouses. On average, one warehouse supports 15 SHEDs, and warehouses are typically located in larger towns within each district. Panel (e) shows cocoa bags stored at a district warehouse. At the warehouse, district managers test each bag's moisture content using portable probe devices. Bags with excess moisture must be opened, dried (as shown in panel f), and re-bagged. This re-bagging process destroys property-level traceability and will be recorded as our main quality outcome. From district warehouses, cocoa bags are transferred to the national COCOBOD for export.

unique KKFU ID. Once this ID is located, the app displays the real-time deforestation status (updated weekly) for any mapped plots held by that farmer, based on 10×10m resolution, high-confidence deforestation alerts from Global Forest Watch (2026). See Section 3.3 for more detailed discussion of these data. In the app, the clerk logs transaction details including number of bags purchased and payment amount. The clerk also administers a survey module that adjusts dynamically based on the farmer's treatment assignment and survey

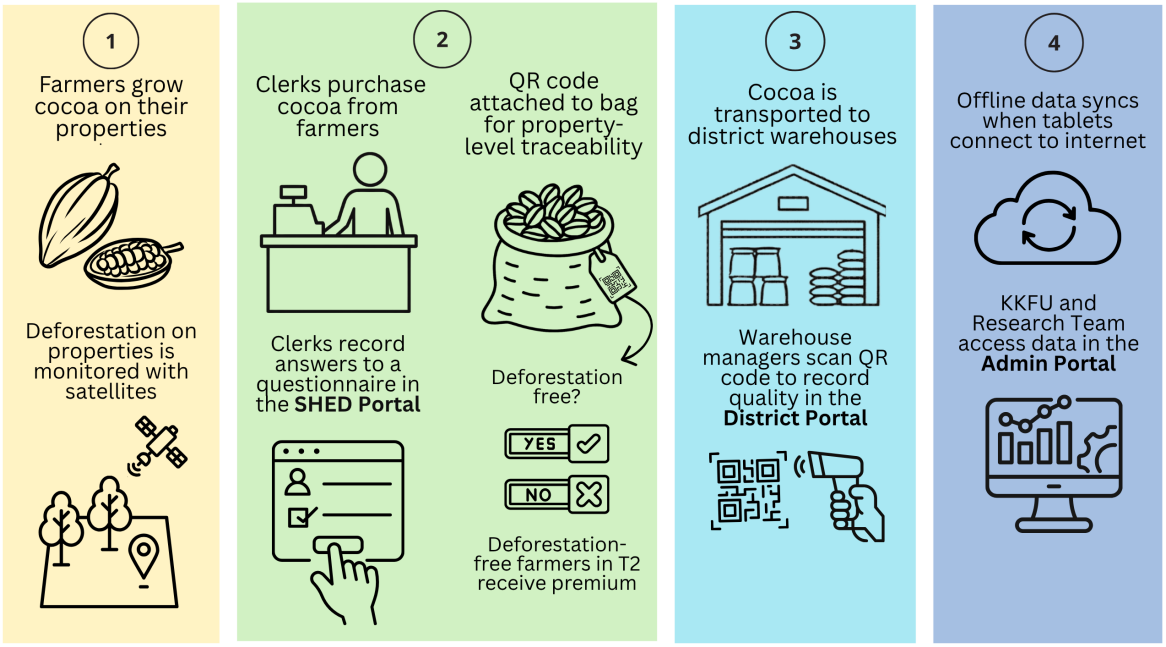
completion history. Upon completing the transaction, the app triggers a sticker printer that produces QR-coded labels for each cocoa bag indicating deforestation status. The clerk attaches these stickers to colored zip ties (green for deforestation-free, red for non-compliant, or white for unmapped properties) that seal cocoa bags, creating tamper-evident certification markers that travel with bags through the supply chain. All data store locally on the tablet and automatically sync to cloud servers when the device comes online, which typically occurs when the clerk delivers cocoa to the district warehouse. The farmer survey is reproduced in Appendix B.

- **District Portal (Warehouse Manager):** At district warehouses, KKFU managers use tablets to scan QR codes on each cocoa bag and record quality outcomes using the district-level survey, which is reproduced in Appendix C. For each bag, the manager measures moisture content using a handheld sensor and records whether re-bagging is required due to excessive dampness. These quality metrics link to the original farmer transaction through the bag's unique identifier, enabling traceability of quality issues back to specific farmers and SHEDs

- **Admin Portal (Research Team and KKFU Management):** Researchers and KKFU managers access an administrative portal to download transaction records, survey responses, quality control data, and deforestation monitoring results. The portal provides dashboards showing purchasing volumes by zone, deforestation compliance rates, and quality metrics. Administrators can use the portal to remotely update survey modules, enabling the cooperative to collect information from farmers as operational needs evolve.

The offline-first design with automatic cloud synchronization enables deforestation verification at point-of-sale despite unreliable internet access in rural Ghana, where SHEDS often lack connectivity. Figure 2 summarizes the mobile app's user portals and functionality.

Figure 2: Mobile App Portal Summary



3 Research Design

3.1 Overview

Deforestation-free certification programs rely on two mechanisms to influence farmer behavior: monitoring and financial incentives. Monitoring creates transparency by detecting non-compliance, potentially generating reputational costs or social pressure. Financial incentives, in the form of price premiums for deforestation-free cocoa, provide economic rewards for compliance, compensating farmers for foregone profits from forest clearing.[3]

Our experimental design unbundles these mechanisms through a three-arm randomized controlled trial (RCT) across 90 purchasing zones (typically corresponding to villages) in Ghana's cocoa belt. In all zones, purchasing clerks record transaction data and administer farmer surveys through the mobile app when farmers bring cocoa to purchasing sheds. The control group (C) receives only this baseline data collection without deforestation monitoring. Treatment 1 (T1) adds satellite-based deforestation monitoring with visible certification stickers affixed to cocoa bags,

[3]Punitive enforcement actions (e.g., fines, blacklists, asset confiscations) represent a third mechanism for influencing farmer behavior, and have been used extensively to combat deforestation in the Amazon (Nunes et al., 2024). We do not incorporate punitive sanctions in this experiment for ethical reasons and because limited enforcement capacity and organizational constraints would undermine the incentive compatibility and scalability of this approach.

creating transparency without financial incentives to test whether monitoring alone affects behavior through reputational or informational channels.[4] Treatment 2 (T2) combines monitoring with a $5 per bag premium for farmers verified as deforestation-free, testing the joint effect of monitoring and economic incentives.[5]

Beyond direct compliance effects, the experiment tests for a potential unintended side effect of property-level monitoring: spatial leakage, where deforestation shifts to areas outside monitored property boundaries. The study will also assess program feasibility and sustainability through survey questions measuring farmer valuations of certification, purchasing clerk experience surveys, and KKFU management feedback. These program implementation outcomes are critical for understanding whether property-level deforestation monitoring can scale to other smallholder cooperatives in low-income countries.

The experiment leverages KKFU's ongoing property mapping efforts. Since 2023, KKFU has georeferenced approximately 41,000 of its 100,000+ member farmers. Prior to randomization, we will select 9 districts spanning KKFU's operating area in Ghana's cocoa belt. Within each district, we will randomly select approximately 10 zones from those with at least 20 georeferenced farm properties, resulting in 90 experimental zones in total. Within each zone, we will work with the existing mix of mapped and unmapped farmers. On average, 40 farmers per zone have georeferenced properties, yielding approximately 3,600 mapped farmers across the 90 experimental zones. Mapped KKFU members in treatment zones (T1 and T2) receive property-level deforestation monitoring and certification, while unmapped farmers—including both KKFU members and non-members selling at KKFU purchasing sheds—participate in surveys and transaction recording but cannot be monitored.

There are often multiple LBCs like KKFU operating in a village, and while these organizations cannot compete on price (COCOBOD sets uniform prices), they can compete through value-added services such as extension training, certification premiums (e.g., Organic, Fairtrade), and now

[4]The EUDR requires deforestation-free verification for cocoa entering the EU market but does not guarantee that compliance will be rewarded with a price premium. T1 thus approximates the scenario in which monitoring exists without any accompanying financial incentive.

[5]The $5 per bag premium level is based on two considerations. First, it is broadly consistent with existing Fairtrade and Organic premiums paid by KKFU, making it comprehensible to farmers accustomed to these other premiums. Second, it represents the maximum feasible premium given our budget constraint: larger premiums would require a smaller sample and thus reduced statistical power. As context, COCOBOD set the 2025/26 farm-gate price at approximately $224 per 64kg bag (COCOBOD, 2026), so our premium represents roughly 2.2% of the standard bag price. Despite this modest share, cocoa farming households in Ghana earn 53% below the Living Income Benchmark on average (Manu et al., 2024), suggesting even a small, guaranteed premium may be behaviorally meaningful for liquidity-constrained smallholders. Summing across an expected 10 bags per cocoa farming household yields $50 dollars in additional earnings from deforestation-free certification.

potentially deforestation-free premiums. Treatment 2 villages offering $5 per bag premiums for verified farmers may attract new KKFU members or retain existing ones who might otherwise sell to competing LBCs, making cooperative enrollment an important secondary outcome.

The experimental timeline follows Ghana's cocoa season. In May 2026, at the onset of land preparation and planting, purchasing clerks will deliver an information intervention to farmers in their zone, conveying treatment status and potentially inducing changes in land-use and other farmer behaviors. Sticker printers and tablets pre-loaded with the app will be distributed to purchasing clerks immediately prior to the cocoa harvest, which begins around October 1st. Data on program outcomes and implementation will be collected during cocoa transactions at SHEDs between October and December 2026.

Figure 3 illustrates the study region and spatial structure of our experimental design. Panel (a) maps forest loss in Ghana between 2000-2025, showing the concentration of deforestation in cocoa-producing regions where KKFU operates. This figure motivates our focus on this major sustainability challenge. Panel (b) plots KKFU zone boundaries constructed using Voronoi tessellations around village centroids. From these, we will select the 90 experimental zones for randomization to control, T1, and T2. Panel (c) shows an example zone with mapped property boundaries and 200-meter buffers, illustrating the three spatial scales at which we measure deforestation: on-property, buffer zone leakage, and zone-level leakage.

3.2 Treatment Arms

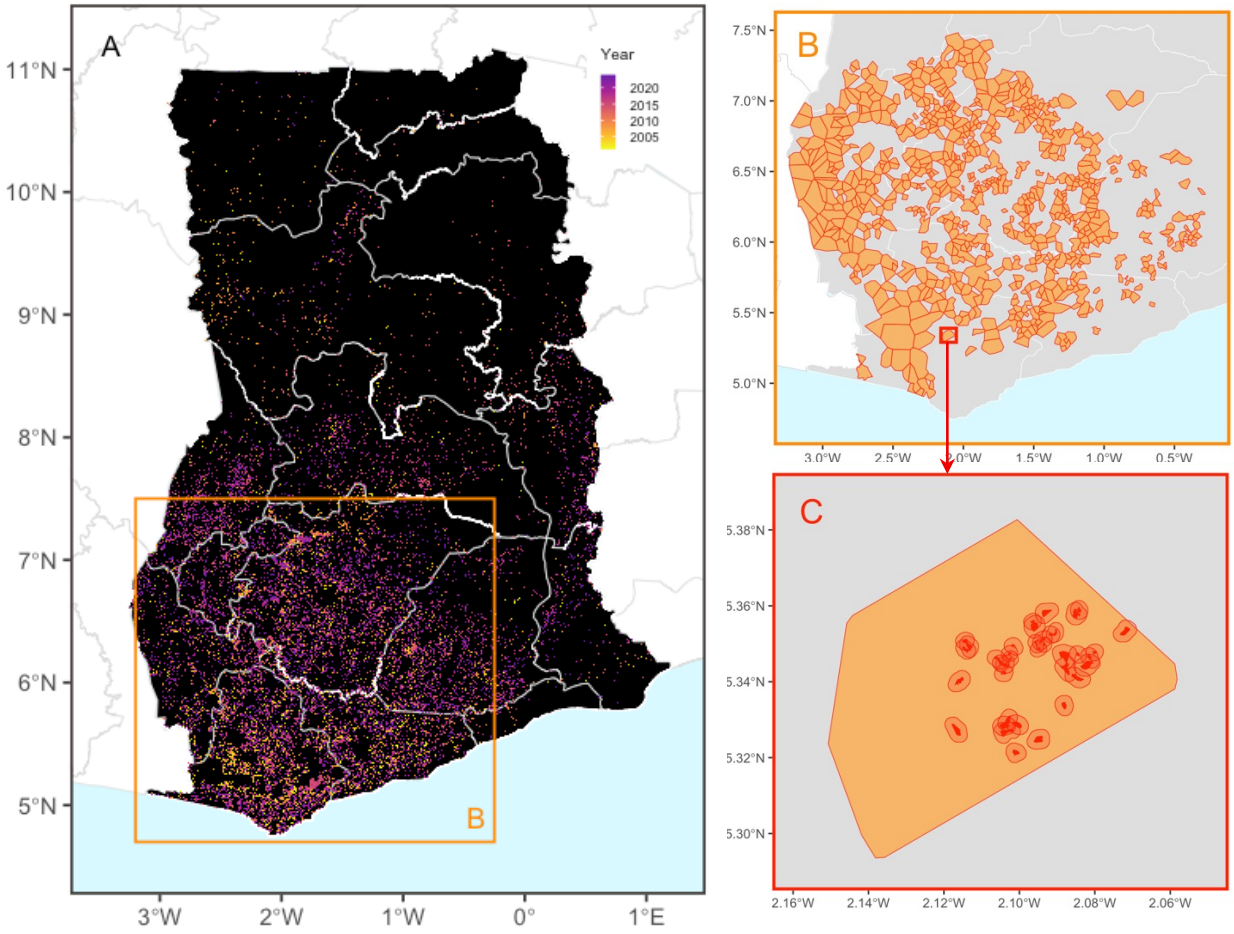
Control

In control zones, purchasing clerks will use the mobile app to administer surveys during cocoa transactions, collecting data on farmer demographics, farm characteristics, land use practices, deforestation awareness, and valuation questions designed to assess farmers' willingness to accept varying hypothetical levels of premium payment for deforestation monitoring and certification. Farmers will receive standard KKFU pricing with no deforestation monitoring. This group establishes baseline levels of deforestation, cocoa quantity and quality, and co-op participation.

Treatment 1: Monitoring and Visible Certification

In Treatment 1 zones, the mobile app will display mapped farmers' deforestation status based on weekly satellite alerts. Purchasing clerks will affix color-coded zip ties with QR-coded stickers

Figure 3: Sample Region, KKFU Zones, and Cocoa Plots with Buffers



Note: Panel (A) maps tree cover loss in Ghana using data from Global Forest Watch (2026), with colors indicating the year of forest loss from 2000 to 2025. Purple shades represent recent deforestation. The map illustrates the concentration of forest clearing in Ghana's southwest cocoa-growing regions. Panel (B) plots Voronoi tessellations constructed around village centroids corresponding to KKFU zones. Voronoi tessellations partition space such that each point within a tessellation is closer to that village's centroid than to any other village centroid. These boundaries allow measurement of spatial deforestation leakage beyond mapped properties. Panel (C) shows an example zone with individual cocoa plots, each surrounded by a 200-meter buffer zone (shown in lighter shading).

to each of the farmers' cocoa bags: green for bags sourced from deforestation-free farms, red for bags sourced from farms with detected deforestation, and white for bags sourced from unmapped properties. Each QR code contains a unique transaction identifier that links the physical bag to the corresponding digital transaction record. These visible markers create transparency about compliance status throughout the supply chain. Farmers in this group will receive no premium payment, isolating the effects of monitoring, information provision, and potential reputational

mechanisms from financial incentives.[6]

Given the possibility of measurement error in deforestation alerts leading to false positives, a farmer identified as having deforestation alerts on their property may either accept this status or challenge it. If challenged, the purchasing clerk will visit the property together with the farmer to visually inspect the plot and determine whether the alert appears to reflect an accurate detection of deforestation. If the clerk judges the alert to be mistaken (e.g., due to a satellite detection error), the clerk can overrule the flag, and the farmer's eligibility for deforestation-free certification and, in Treatment 2, the deforestation-free premium, is restored. Clerks will receive training on this protocol as part of the broader purchasing clerk training described in Appendix E.[7]

Treatment 2: Monitoring with Premium Payments

Treatment 2 is identical to Treatment 1, with the addition that farmers with green certification (no deforestation detected) will receive a $5 per bag deforestation-free premium payment. Premiums will be distributed at the end of the season alongside other KKFU certification premiums (Organic, Fairtrade), following standard co-op payment practices. This treatment combines monitoring with explicit financial rewards for compliance.

3.3 Outcomes

This section presents four blocks of outcomes: (i) deforestation, (ii) farmer outcomes, (iii) valuation and willingness-to-accept monitoring, and (iv) descriptive outcomes. The ordering of these blocks does not imply a prioritization or ranking of their relative importance or interpretive weight. Direct and spillover effects of treatment on deforestation are of central interest given the intervention's stated goals. However, mature cocoa farms retain little remaining native vegetation to clear and baseline on-property deforestation rates are low, leaving limited scope for on-property outcomes to register substantial declines. Similarly, the study timeline spans a single

[6] A market-based deforestation-free premium is not guaranteed under EUDR, for three main reasons. First, the EU absorbed about 75% of Ghana's cocoa exports in 2024 (USDA, 2025), leaving a substantial non-EU outside option that could grow further if producers or intermediaries route non-compliant cocoa away from the EU to avoid verification costs. Second, even for cocoa that continues to flow to the EU, buyers may simply treat verification as a baseline requirement for market access rather than a quality attribute worth paying for, in which case compliance compresses producer margins rather than generating a premium. Third, EUDR-induced premiums could be captured by intermediaries such as cocoa buyers, exporters, or traders, leaving farmers with additional compliance costs but no monetary reward. T1 therefore provides a lower bound on the effects of the EUDR in the scenario where it does not generate a market-based farm-gate premium for deforestation-free cocoa.

[7] Overruling a flag changes only the farmer's compliance status used for certification and premium eligibility. It does not alter the underlying satellite alert data used to construct our primary research outcomes. Overrule decisions are recorded to assess false positive rates.

growing season, which may be too short for behavioral responses and land use investments to manifest. Farmers' stated land use plans and willingness-to-accept monitoring and certification are thus of equal interest.

Block I: Deforestation

We measure deforestation at three spatial scales to distinguish direct compliance effects from spatial leakage:

1. **On-Property Deforestation**: Our first outcome is a binary indicator for whether any high-confidence deforestation alert occurred on a farmer's mapped property during the intervention period, i.e., after May 2026 (see Project Timeline in Section 3.9).[8] We use 10×10m resolution weekly deforestation alerts from Global Forest Watch (2026), which processes Landsat and Sentinel 1 and 2 imagery to detect tree cover loss.[9] For each mapped farm, we overlay property shapefiles with the global deforestation alert dataset and flag any property containing one or more alert pixels. This measures direct compliance: whether monitoring and premiums reduce deforestation on monitored parcels. Because farmers often operate multiple plots, we aggregate plot-level alerts to the farmer level, flagging cocoa bags as non-compliant if they are associated with a farmer ID linked to any plot registering a deforestation alert. As a robustness check, we will use the share of pixels within property boundaries registering

[8]While we will push weekly deforestation alert updates to the mobile app during the study period, purchasing clerks in the field will only receive updates when they connect to Wi-Fi. The alerts displayed on their devices may therefore be several weeks outdated, though typically not more than one month, given clerks' frequent warehouse visits during harvest season. For our primary deforestation outcomes, we use alerts generated during the study period (following the May 2026 information intervention). For determining farmers' deforestation-free status and Treatment 2 premium eligibility, we use all alerts recorded since January 1, 2021, in line with EUDR criteria. Among mapped parcels in our sample, only 0.51% carry a pre-existing alert registered between January 1, 2021 and the onset of our information intervention in May 2026, making them ex ante ineligible for Treatment 2 premiums regardless of behavior during the study period. Given how small this share is, we do not expect it to meaningfully dilute the Treatment 2 contrast, and our primary analysis includes all mapped farmers. As a robustness check, we will also re-estimate H2 restricting the sample to farmers who were ex ante premium-eligible as of May 2026 (i.e., with no alert between January 2021), to confirm that our headline estimate is not sensitive to this ineligible share.

[9]We use Global Forest Watch's integrated disturbance alerts, which synthesize four independent satellite-based monitoring systems to detect forest and vegetation disturbances in near real-time. The integrated layer includes: (1) GLAD-L alerts (University of Maryland Global Land Analysis and Discovery lab) using NASA Landsat imagery at 30-meter resolution; (2) GLAD-S2 alerts (University of Maryland) using European Space Agency Sentinel-2 imagery at 10-meter resolution; (3) RADD (Radar for Detecting Deforestation) alerts (Wageningen University) using Sentinel-1 radar at 10-meter resolution, which can penetrate cloud cover; and (4) DIST-ALERT (University of Maryland and NASA) combining Landsat and Sentinel-2 data at 30-meter resolution to monitor all vegetation types globally. The platform resamples all data to 10-meter resolution and assigns confidence levels based on how many independent systems detect disturbance in the same pixel: low confidence (single system), high confidence (single system with multiple observations, our primary measure), and highest confidence (multiple systems, used as a robustness check). Optical systems (GLAD-L, GLAD-S2, DIST-ALERT) update every 1–4 days, while the radar system (RADD) updates every 12 days (Berger et al., 2026).

deforestation alerts as a continuous alternative to our main binary outcome.[10]

While no satellite-based deforestation measure is free of error, several features of our design mitigate this concern. First, our primary measure relies on high-confidence alerts, which require agreement across multiple observations (Berger et al., 2026). Second, independent validation of the component alert systems in tropical, humid forest settings comparable to Ghana's cocoa belt has found strong accuracy: RADD alerts, validated in the Congo Basin, achieve a user's accuracy of 97.6% and a producer's accuracy of 95% for disturbances of 0.2 hectares or larger, with confirmation of nearly all alerts within a few weeks of first detection (Reiche et al., 2021). Integrating RADD with the optical GLAD-S2 and GLAD-L alerts raises the average detection rate to 97% and results in no false detections at the highest confidence level (Reiche et al., 2024). Third, our design provides a source of farmer-initiated ground-truth data: when a mapped farmer's property is flagged, the farmer may challenge the flag and prompt a clerk to visually inspect the property in person. The resulting overrule rate, which we pre-register as a descriptive outcome, gives us direct evidence on the incidence of false positives in our specific study context.

Despite the high quality and reliability of Global Forest Watch's deforestation alerts, we acknowledge that detecting real-time deforestation on smallholder parcels in our setting is a non-trivial challenge. On larger properties, requiring a threshold of multiple pixel alerts to identify deforestation can guard against pixel-level noise. On sub-hectare farmers in our study area, however, meaningful clearing can affect just a few pixels, and a higher threshold could miss real deforestation. We therefore rely on single high-confidence pixel alerts to assign deforestation status. We believe that testing the feasibility of deforestation monitoring at this level is one of our study's contributions.

2. **Buffer Zone Deforestation (200m)**: To test for spatial leakage immediately around monitored properties, we construct 200-meter buffers around each mapped property boundary and create a binary indicator for whether any deforestation alert occurred within the buffer zone, excluding the property itself. If certification creates incentives to shift forest clearing

[10] We acknowledge here an important limitation in our study design regarding timing: land-use decisions to clear forest for cocoa expansion are typically multi-year investments, shaped by tree-stock age, soil fertility, and price expectations over horizons considerably longer than the seven-month window between our May 2026 information intervention and the close of the October–December 2026 harvest season. It is possible that our design shifts farmers' underlying land-use intentions without that shift yet being expressed in the harvest-season satellite alert record. For this reason, we view farmers' stated-intention outcomes (i.e., hypothesis H7 below) as important complements to realized land use outcomes, since they may capture emerging behavioral responses that have not yet manifested within a single season.

from monitored to adjacent unmonitored areas, we expect higher buffer-zone deforestation in Treatment 2 relative to Control. Similarly to on-property deforestation, we will use the share of pixels inside buffers with alerts as a robustness check.

3. **Zone-Level Deforestation**: We measure deforestation at the zone-level to capture broader spatial leakage or potential spillovers onto unmapped farmers. Because administrative village boundary shapefiles are not available, we construct spatial boundaries for KKFU zones using Voronoi tessellations around zone centroids.[11] We then divide each zone into 1-hectare grid cells (each containing 100 10x10m pixels) and count the number of deforestation alerts occurring within each grid cell over the study period. We exclude KKFU properties and their buffer zones from this count, isolating broader deforestation spillovers. This outcome tests whether monitoring and certification programs reduce overall deforestation within village boundaries or merely displace it spatially from monitored to unmonitored areas[12]

Block II: Farmer Outcomes

1. **Cocoa Quality:** Cocoa quality is measured at the district warehouse, where district managers measure moisture content using handheld sensors and decide whether bags require re-bagging. The re-bagging procedure destroys property-level traceability by mixing cocoa from the affected bag with other farmers' cocoa during drying and re-sealing. Re-bagging outcomes are recorded and linked back to the originating farmer and SHED using unique transaction IDs. Re-bagged bags become ineligible for deforestation-free premiums, since premiums are paid cumulatively at season's end conditional on maintaining traceability from SHED to handoff from KKFU to COCOBOD. This creates additional motivation for farmers in Treatment 2 to ensure proper drying and post-harvest handling to avoid re-

[11] Voronoi tessellations partition space into polygons where each polygon contains all points closer to a given village centroid than to any other centroid. We obtain village centroid coordinates from CIESIN (2021) and match these 1:1 to KKFU zones. We use this approach because authoritative administrative boundary shapefiles for Ghana, such as GADM, are only available down to the district (ADM2) level. We acknowledge that Voronoi tessellations are an analytic convenience rather than a representation of the boundaries that actually govern where displaced deforestation occurs, and that our zone-level leakage estimates may be sensitive to this construction. As a robustness check, we will re-estimate zone-level outcomes using fixed-radius buffers of 5km and 10km around village centroids as an alternative to Voronoi tessellations. We do not adopt fixed radii as our primary specification because, unlike Voronoi tessellations, they generate substantial overlap and omitted areas between neighboring zones and do not capture variations in zone size (see Figure 3, Panel B).

[12] We consider long-distance travel by farmers to deforest land outside their own zone as unlikely, since monitoring and incentives operate exclusively at the property level. Farmers are neither rewarded nor penalized based on deforestation elsewhere, and are not informed that we separately track buffer- or zone-level deforestation as research outcomes.

bagging. The quality outcome tests whether monitoring or premiums induce complementary improvements in cocoa quality.

2. **KKFU Recruitment, Retention, and Sales Volume:** We measure KKFU membership status and total bags sold to KKFU over the season for each farmer. While all LBCs pay identical farmgate prices set by COCOBOD, they compete on value-added services such as extension training and certification premiums (Fairtrade, Organic). Treatment 2's deforestation-free premiums may attract new KKFU members or increase sales from existing members who might otherwise sell to competing buyers. Conversely, Treatment 1's monitoring without premiums could deter farmers who wish to avoid reputational costs. These outcomes test whether deforestation-free certification serves as a recruitment tool and whether farmers value the premium enough to consolidate their sales with a single buyer.

3. **Adaptive Responses:** We measure farmer adaptation strategies that may emerge in response to deforestation monitoring and premiums, including likelihood of household members working off-farm, planting new cocoa trees, practicing agroforestry by maintaining shade trees on properties, and stated intentions to reduce or exit cocoa farming. These outcomes capture whether certification leads households to shift toward alternative livelihoods or adopt less deforestation-intensive production practices.

Block III: Valuation

1. **Willingness-to-Accept:** The survey implements discrete choice experiments to elicit farmer willingness to accept deforestation monitoring under alternative contract structures. The valuation module varies systematically by treatment group and mapping status to present appropriate questions to each group. For all farmers, we elicit willingness to participate in (or continue) deforestation monitoring by randomly assigning hypothetical deforestation-free premium offers drawn from a uniform distribution of integers between \$0 to \$15 per bag. Unmapped farmers are asked whether they would agree to have their farms mapped and monitored at the assigned premium. Mapped farmers are asked about their willingness to participate in (control) or continue (T1 and T2) monitoring at the assigned premium. These questions provide willingness-to-accept estimates across different information states: hypothetical participation (unmapped farmers), no monitoring experience (mapped control farmers), monitoring experience without payment (mapped T1 farmers), and monitoring

experience with premium payments (mapped T2 farmers).

2. **Risk Tolerance:** We next follow up with a risk tolerance question: Would you participate in monitoring and certification if the premium averaged the same amount (i.e., the randomly assigned value the farmer was presented with in the previous question) but varied between \$0 and twice that amount? For example, a farmer randomly offered a hypothetical premium of \$7 would then be asked about a variable premium averaging \$7 but ranging from \$0 to \$14. These questions test whether farmers discount uncertain payments relative to fixed premiums of equal expected value, revealing risk preferences that determine the feasibility of market-based certification contract designs.[13]

3. **Tolerance for Enforcement:** Finally, for Treatment 2 farmers, we measure tolerance for stronger enforcement by asking the minimum premium they would be willing to accept if the penalty for detected deforestation changed from loss of premium only to exclusion from selling to KKFU for the remainder of the season. Response options range from \$0 to \$20+ or unwillingness to participate at any premium. This elicits the compensating differential farmers require for bearing exclusion risk, informing whether cooperatives can implement credible sanctions without damaging supplier relationships.

These valuation outcomes inform the design of scalable certification programs by identifying which contract features farmers value most and what premium levels are necessary to maintain participation under different monitoring regimes.

We note two limitations of our valuation module. First, as in any stated-preference exercise, responses are hypothetical, and may not reflect farmers' true valuations, given the lack of any real payment tied to the farmer's answer. Second, because the same purchasing clerk who administers treatment also elicits WTA responses, farmers may feel pressure to respond in a manner they perceive to be favorable to the clerk or KKFU. This concern is somewhat mitigated by the fact that

[13] Risk tolerance questions address a key dimension of program scalability. While our experiment offers guaranteed stable premiums, market-based certification programs could tie premiums to variable factors such as global commodity prices, consumer demand for sustainable cocoa, or regulatory stringency in importer countries. Understanding farmers' willingness to accept variable premiums informs whether market-based certification can achieve widespread participation without permanent donor subsidies. The survey asks: "This deforestation-free premium might vary with the market price of cocoa. Would you still be willing to participate if the premium averages \$[X] per bag, but could vary from \$0 to \$2[X]?" We elect to present this uncertainty range in the simplest form possible (stating minimum, maximum, and average values) without describing the underlying probability distribution to ensure the question remains comprehensible for farmers with varying levels of education and numeracy. Because we do not specify the shape of this distribution to farmers, the elicited object is not a clean mean-preserving spread, and farmers' subjective beliefs about the distribution's shape may vary. We therefore interpret declines in stated acceptance under the variable premium as suggestive evidence of risk aversion, rather than as a precisely estimated measure of risk preferences.

Treatment 2 premiums are not paid out on the spot, but rather logged and disbursed at the end of the season alongside other certification premiums (Organic, Fairtrade), reducing the likelihood of immediate reciprocity effects. We do not attempt to fully resolve either concern, since doing so would require an incentive-compatible elicitation mechanism (e.g., a Becker-DeGroot-Marschak procedure) that is impractical to implement at the point of sale in this setting. We will report our WTA results with a clear discussion of these caveats in the final paper, interpreting differences in stated acceptance across premium levels (H8) and risk framings (H9) as informative about the relative shape of demand and risk preferences, and treating differences across treatment arms (H10) with appropriate caution.

Block IV: Descriptive Outcomes

Beyond formal hypothesis testing, we will collect descriptive data on farm characteristics, farmer understanding of deforestation monitoring, and purchasing clerk experiences with the app, which will provide descriptive evidence on cocoa production in the study region and inform policy design. Descriptive outcomes will be reported separately by treatment arm to assess correlates of treatment effects.

Farm characteristics: We measure total farmed land and land dedicated to cocoa cultivation, number of plots managed, and labor sources (family, hired, or communal).

Deforestation and sustainability awareness: We assess farmers' awareness of nearby forest boundaries, understanding of "deforestation-free cocoa," and familiarity with monitoring and traceability. We also measure farmers' ranking of deforestation relative to other challenges they face, e.g., low cocoa prices, cocoa pests/diseases, droughts or floods, artisanal mining, and access to inputs like fertilizers and pesticides.

Treatment awareness and comprehension: We measure whether purchasing clerks explained the experiment and treatment assignment to farmers. For mapped farmers, we will also assess their understanding of monitoring technology and whether farmers correctly understand that clearing unmapped land does not disqualify them from premium eligibility.

Purchasing clerk feedback: In January 2027, after data collection concludes, we will administer a survey to all purchasing clerks who participated in the experiment, via the mobile app. The survey will assess practical implementation challenges including tablet and printer reliability, time burden per transaction, and hassles or problems in the workflow (e.g., premium calculation errors, offline functionality). We will also measure purchasing clerks' perceptions of how well farmers

understood the monitoring system and whether farmers asked strategic questions about which land would be monitored or how to maintain premium eligibility. For T2 clerks, we will assess difficulties explaining the premiums to farmers and processing payments. Open-ended questions will solicit suggestions for improving the app. Responses will provide insight into whether and how digital traceability systems can scale beyond donor-funded pilots. The purchasing clerk survey is reproduced in Appendix D.

Zone-level compliance: To assess implementation fidelity, we measure the share of cocoa bags recorded through the app with a valid QR-coded sticker (green, red, or white) relative to total bags received at the district warehouse, by zone and by week. Even with the compensation, training, and monitoring safeguards described in Section 3.8, purchasing clerks may not fully comply with the app protocol in practice. Tagging rates thus provide valuable information on whether a digital traceability system of this kind can be implemented reliably by frontline staff under realistic operating conditions— informing scalability.

Alert overrule rate: For mapped farmers in Treatment 1 and Treatment 2 who receive a red (deforestation-detected) flag, we record whether the farmer challenged the flag, whether the purchasing clerk conducted a property visit, and whether the flag was ultimately overruled. This provides descriptive evidence on how often satellite-detected alerts are contested and how often field verification leads clerks to conclude the alert was mistaken, offering a farmer-initiated, field-based check on alert accuracy. In addition, KKFU monitoring and evaluation staff, who already circulate through experimental zones for compliance monitoring, will opportunistically visit red-flagged properties they encounter during their rounds, whether or not the farmer challenged the flag, and record whether visible evidence of recent clearing is present. We will report the resulting confirmation rate descriptively as a supplementary check on alert accuracy.

Cost-Effectiveness Analysis

To assess the practical scalability of property-level, satellite-based deforestation monitoring in a low-income, smallholder context, we will conduct a cost-effectiveness analysis comparing implementation costs to program outcomes.

Costs: We calculate per-zone implementation costs separately for Treatment 1 and Treatment 2, including tablets, sticker printers, purchasing clerk training and compensation, and KKFU monitoring and evaluation staff time, using realized program expenditures. For Treatment 2, we additionally include realized premium payments to certified farmers. We exclude the fixed cost of

mobile app development and the marginal cost (in time and effort) of accessing satellite deforestation alerts, since both scale to additional zones at negligible incremental cost.

Effectiveness measures: We report two cost-effectiveness ratios. First, cost per additional hectare of deforestation averted, using the estimated treatment effects on on-property, buffer-level, and zone-level deforestation to translate alert reductions into hectare-equivalent units. Second, cost per additional farmer achieving deforestation-free certification, using the share of mapped farmers certified as deforestation-free by treatment arm. This second measure captures the value of property-level monitoring even absent a statistically detectable reduction in deforestation, since certification itself may have value to farmers and KKFU independent of realized environmental impact—for example by supporting eligibility for certifications or market-based premiums.

3.4 Hypotheses

We organize hypotheses into four groups: (i) environmental compliance and leakage, (ii) farmer responses, (iii) farmer valuation of certification designs, and (iv) heterogeneous treatment effects.

Environmental Compliance and Spatial Leakage

- *H1 (Monitoring effect):* On-property deforestation is lower in Treatment 1 than Control. Satellite monitoring with visible certification creates reputational incentives even without financial rewards.[14]

- *H2 (Premium effect):* On-property deforestation is lower in Treatment 2 than Treatment 1. Financial incentives amplify monitoring effects by compensating foregone profits from forest clearing.

- *H3 (Direct leakage):* Buffer-zone deforestation is higher in both Treatment 1 and Treatment 2 relative to Control. Monitoring without compensation (T1) may generate stronger displacement as farmers avoid reputational costs while maintaining production. Premium payments (T2) may reduce displacement by compensating for foregone clearing, though the net effect on leakage relative to T1 is ambiguous.

[14] A visible red tag makes an individual farmer's non-compliance observable to purchasing clerks and other farmers who are present at the SHED. We hypothesize that farmers may perceive this visibility as consequential because widespread non-compliance could jeopardize KKFU's certifications (e.g., Fairtrade, Rainforest Alliance), which benefit all farmers in the co-op through premium payments.

- *H4a (Net zone-level effect):* Total zone-level deforestation is lower in Treatment 2 than Control. Direct compliance effects on mapped properties dominate spatial leakage to unmapped areas, generating net forest conservation.
- *H4b (Broader spatial leakage):* Zone-level deforestation excluding KKFU mapped properties and their 200m buffers is higher in Treatment 2 than Control. Monitoring displaces deforestation to unmapped areas within zone boundaries.[15]

Farmer Responses

- *H5 (Quality complementarity):* Re-bagging rates are lower in Treatment 2 than Control. Premiums increase the value of avoiding re-bagging, inducing greater farmer effort in cocoa preparation and handling.
- *H6a (Recruitment – monitoring without premiums):* KKFU membership and per-farmer sales volumes are lower in Treatment 1 than Control. Farmers avoid selling to KKFU to avoid monitoring and potential reputational costs when not compensated.
- *H6b (Recruitment – monitoring with premiums):* KKFU membership and per-farmer sales volumes are higher in Treatment 2 than Control. Deforestation-free premiums make cooperative membership more attractive relative to alternative buyers, dominating any deterrence effect of monitoring.
- *H7 (Behavioral changes):* Farmers in Treatment 2 are more likely than Control to report plans to replant existing areas, adopt agroforestry practices, and diversify income through off-farm work, and less likely to report plans to expand or clear new land. Premiums incentivize farmers to adopt compliant production strategies.

Farmer Valuation and Program Design

- *H8 (Premium sensitivity):* Stated willingness to participate in monitoring and certification declines as hypothetical premiums decrease from $15 to $0 per bag. Demand for certification

[15] We interpret the four possible configurations of H4a and H4b as follows. If both are confirmed, direct compliance effects exceed leakage, producing net conservation despite displacement to unmapped areas. If H4a is confirmed and H4b is not, we find no evidence of leakage, the most favorable outcome for the policy's scalability. If H4a is rejected and H4b is confirmed, leakage fully offsets on-property gains, indicating displacement rather than net conservation. If neither is confirmed, we find no evidence of a net effect or leakage, though we note that because mapped properties constitute a small share of total zone area, a real but spatially concentrated effect on mapped land could be too small in absolute terms to move total zone-level deforestation measurably, independent of whether leakage occurs.

is price-elastic.

- *H9 (Risk aversion):* Stated willingness to participate declines when farmers are offered a variable premium averaging the same randomly assigned amount but ranging from $0 to twice that amount. Farmers are risk-averse over premium income streams and discount variable payments relative to fixed premiums of equal expected value (though we interpret this evidence as suggestive given that the elicited premium range is not a precisely specified mean-preserving spread). Steep drops in acceptance would indicate that variable premiums tied to commodity prices may struggle to achieve widespread farmer buy-in.

- *H10 (Experience effect):* For any given hypothetical premium level, acceptance rates are higher among Treatment 2 farmers than Treatment 1 or Control. Experiencing premium payments increases perceived value of certification.

- *H11 (Penalty tolerance):* Among Treatment 2 farmers, the stated minimum premium required to accept hypothetical KKFU exclusion penalties for deforestation exceeds $5 (the baseline premium without exclusion risk). The difference between this threshold and $5 reveals farmers' valuation of exclusion risk.

Heterogeneity and Mechanisms

- *H12 (Baseline deforestation risk):* Treatment effects on property-level deforestation increase with baseline zone-level deforestation rates (measured between 2020-2025, prior to intervention). Monitoring and premiums are more effective where deforestation pressure is higher.

- *H13 (Information transmission):* Farmers in T1 and T2 zones report higher rates of discussing deforestation with other farmers compared to Control. Visible certification stickers and premiums increase salience of deforestation.

- *H14 (Awareness and compliance):* Farmers who recall hearing about satellite monitoring show larger treatment effects on on-property deforestation. Program awareness is necessary for monitoring to affect behavior.

- *H15 (Understanding and strategic behavior):* T2 Farmers who correctly understand that clearing unmapped land does not disqualify them from premiums show higher buffer-zone leakage. Comprehension of monitoring scope enables strategic displacement.

- *H16 (Reputational concern):* T1 farmers who report believing other farmers or KKFU staff would be upset if deforestation were detected on their property show larger treatment effects on on-property deforestation. Responsiveness to monitoring is concentrated among farmers who feel social pressure to comply.

3.5 Regression Specifications

3.5.1 Farmer-Level

For outcomes measured at the farmer level (e.g., on-property deforestation, buffer deforestation, cocoa volume and quality, production practices) we will estimate:

$$Y_{fzd} = \alpha + \beta_1 T1_z + \beta_2 T2_z + \mathbf{X}'_{fz}\gamma_1 + \delta_d + \epsilon_{fzd} \tag{1}$$

where Y_{fzd} is the outcome for farmer f in zone z belonging to district d. Transaction-level data collected during the harvest season (October–December 2026) will be aggregated to the farmer level to construct season totals for cocoa sales volumes and quality measures. End-line deforestation outcomes will be measured using satellite data in January 2027 after the harvest season concludes. $T1_z$ and $T2_z$ are indicators for Treatment 1 (monitoring with visible certification) and Treatment 2 (monitoring with premiums), with control zones as the omitted category. $\mathbf{X}_{fz}$ is a vector of baseline zone-level covariates (zone size, baseline deforestation rate, average farmer age, sex, and cocoa sales volume) to adjust for potential randomization imbalances. Our preferred specification omits $\mathbf{X}_{fz}$ for simplicity. We will report the covariate-adjusted specification as a robustness check. δ_d are district fixed effects, which account for stratification of the randomization by district. Standard errors will be clustered at the zone level, which is the level of randomization. Coefficients β_1 and β_2 estimate the average treatment effect (ATE) of Treatment 1 and Treatment 2 relative to control.

3.5.2 Grid-Cell Specification for Zone-Level Deforestation

For zone-level deforestation, we will analyze spatial leakage beyond mapped properties and buffers. The unit of observation is a grid cell g within zone z. We construct zone boundaries using Voronoi tessellations around zone centroids and overlay a grid of uniform 100×100m cells, each containing 100 10×10m pixels within which weekly satellite deforestation alerts can be reported.

Outcome Y_{gzd} is the count of high-confidence deforestation alerts within cell g in zone z and district d during the study period, excluding cells that intersect mapped properties or 200-meter buffers. We estimate:

$$Y_{gzd} = \alpha + \beta_3 T1_z + \beta_4 T2_z + \mathbf{X}_z' \gamma_2 + \delta_d + \epsilon_{gzd} \tag{2}$$

where notation follows equation (1). Standard errors will be clustered at the zone level. Coefficients β_3 and β_4 identify the ATE of monitoring (T1) and monitoring with premiums (T2) on deforestation in unmapped areas within zone boundaries, capturing spatial leakage. Given that Y_{gzd} is a sparse count outcome, we will report results from both linear and Poisson regressions.

3.5.3 Farmer Valuations

To assess premium sensitivity (H8), we randomize the hypothetical deforestation-free premium level shown to each farmer, drawn from a uniform distribution of integers between \$0-\$15 per bag, and estimate:

$$\mathbb{1}(\text{Accept})_{fz} = \alpha + \beta_5 \text{Premium}_{fz} + \mathbf{X}_{fz}' \gamma_3 + \delta_z + \epsilon_{fz} \tag{3}$$

where $\mathbb{1}(\text{Accept})_{fz}$ is an indicator for farmer f's willingness to participate in monitoring and certification, Premium_{fz} is the randomly assigned hypothetical premium, $\mathbf{X}_{fz}$ includes basic baseline farmer covariates (age, sex, education, number of children, cocoa area cultivated), and δ_z are zone fixed effects that absorb treatment assignment. We test whether $\beta_5 > 0$.

To assess risk aversion (H9), we next offer farmers a variable premium with the same expected value but ranging from \$0 to twice that amount, and estimate:

$$\mathbb{1}(\text{Accept})_{fz} = \alpha + \beta_6 \mathbb{1}(\text{Variable})_{fz} + \theta \text{Premium}_{fz} + \mathbf{X}_{fz}' \gamma_4 + \delta_z + \epsilon_{fz} \tag{4}$$

where $\mathbb{1}(\text{Variable})_{fz}$ indicates the variable premium was offered instead of the fixed premium, and Premium_{fz} is the expected value of the premium. We test whether $\beta_6 < 0$ (farmers discount variable premiums relative to fixed premiums of equal expected value).

To test experience effects (H10), we use the main specification from Equation (1), augmented with a control for the randomly assigned premium level, with $\mathbb{1}(\text{Accept})_{fz}$ as the outcome. We test whether $\beta_2 > \beta_1 \geq 0$, indicating that Treatment 2 farmers exhibit higher acceptance rates than Treatment 1 or Control for any given premium level. Finally, to assess penalty tolerance (H11),

among Treatment 2 farmers we compare the mean minimum premium required to accept KKFU exclusion penalties against the baseline $5 premium using a one-sample t-test.

3.5.4 Heterogeneity Analysis

We explore treatment effect heterogeneity using interaction specifications. For baseline deforestation intensity (H12), we estimate:

$$Y_{fzd} = \alpha + \beta_7 T1_z + \beta_8 T2_z + \beta_9 T1_z \times Baseline\_Defor_z + \beta_{10} T2_z \times Baseline\_Defor_z + \beta_{11} Baseline\_Defor_z + \mathbf{X}'_{fz}\gamma_5 + \delta_d + \epsilon_{fzd} \quad (5)$$

where $Baseline\_Defor_z$ is the number of deforestation alerts per mapped hectare in zone z from January 2020 through December 2025. Coefficients β_9 and β_{10} identify how treatment effects vary with baseline deforestation intensity. Positive coefficients indicate treatments are more effective in zones with higher baseline deforestation pressure.

For information diffusion (H13), we estimate equation (1) with the outcome being an indicator for whether the farmer reports discussing deforestation with other farmers, testing whether $\beta_1 > 0$ or $\beta_2 > 0$. For awareness (H14, H15) and reputational concern (H16) mechanisms, we interact treatment indicators with farmer recall of satellite monitoring, understanding that clearing unmapped land does not disqualify premiums, and reported expectation of social disapproval following detected deforestation, respectively, following the specification in equation (5) with the relevant indicator replacing $Baseline\_Defor_z$. All heterogeneity analyses will report both main effects and interaction coefficients, with standard errors clustered at the zone level. As with our primary specifications, our preferred heterogeneity specifications omit the baseline covariate vector $\mathbf{X}_{fz}$, with covariate-adjusted estimates reported as a robustness check.

3.6 Multiple Hypothesis Testing

This pre-registration specifies multiple primary, secondary, and tertiary hypotheses. Recent work argues that pre-registration may reduce the need for stringent corrections (Viviano et al., 2026). We will nevertheless adopt a cautious approach and report both unadjusted and adjusted p-values. We will report unadjusted p-values for all pre-registered outcomes as our primary inference. We will also report Romano-Wolf stepdown adjusted p-values (Romano and Wolf, 2005; Clarke et al., 2020), which control the family-wise error rate while accounting for correlations

among outcomes. Following McKenzie (2024), we apply Romano-Wolf corrections separately within conceptually distinct outcome families: (i) deforestation outcomes (on-property, buffer, zone-level), (ii) secondary farmer outcomes (quality, membership, sales volumes, production practices), and (iii) farmer valuation outcomes (willingness-to-accept, risk and penalty tolerance).

For heterogeneity analyses (Hypotheses H12-H16), we will report unadjusted p-values and acknowledge that while pre-specifying heterogeneity tests reduces researcher degrees of freedom, it does not eliminate multiple testing concerns. We will report all pre-specified heterogeneity tests regardless of statistical significance and interpret results as exploratory evidence on treatment effect variation rather than causal tests of specific mechanisms.

3.7 Sampling and Randomization

Prior to randomization, we will select 9 districts representative of KKFU's operating area, which is roughly equivalent to Ghana's cocoa producing region as a whole. Within each district, we will randomly select approximately 10 zones from the set of zones with at least 20 georeferenced farm properties (to ensure a sufficient number of farms can be monitored), resulting in 90 experimental zones in total.[16] On average, zones contain 40 farmers with georeferenced property boundaries, yielding approximately 3,600 mapped farmers across the experiment. By randomly sampling zones within each district, we ensure the experimental sample is broadly representative of KKFU's operating area, increasing external validity.

The sample size is determined by budget constraints, accounting for costs of field operations, purchasing clerk training, tablets and printers, and premium payments to T2 farmers. Randomization into treatment will occur at the zone level to avoid contamination from within-zone information spillovers and simplify program implementation.[17] We will stratify by district to ensure balance across KKFU's geographic regions, then randomly assign the 90 zones to three arms: 30 Control, 30 T1, and 30 T2. We will report baseline balance statistics comparing experimental zones to all KKFU zones to assess external validity for the broader cocoa-producing region.

[16] At least 63% percent of KKFU zones meet the threshold of 20+ mapped properties. KKFU's mapping rollout has been idiosyncratic and based on field agent availability rather than systematic targeting, mitigating selection concerns.

[17] A farmer's treatment status is determined by their KKFU zone of registration, not by the physical location where they sell cocoa. Since purchasing clerks locate a farmer's unique KKFU ID by entering their name and registered zone, a farmer who sells at a SHED outside their home zone is still treated according to their registered zone's assignment. This eliminates any incentive for farmers to shop around for a more favorable SHED, since doing so would not change their monitoring or premium status.

3.7.1 Balance Testing

We will assess the effectiveness of zone-level randomization using balance tests. These will compare treatment and control groups across pre-treatment outcomes and covariates, measured using satellite data and KKFU administrative records. Satellite-based measures include the frequency of high-confidence deforestation alerts inside mapped properties and buffer zones between January 2020 and December 2025, as well as average zone size, latitude, longitude, urbanized area, and distance to nearest town. Administrative data from KKFU include zone-level cocoa sales volumes, number of active farmers, and average farmer age and sex. We will test for balance by comparing means across treatment arms using t-tests for pairwise comparisons (Control vs. T1, Control vs. T2, T1 vs. T2). We will also report a joint F-test across all covariates to test the null hypothesis that treatment assignment is uncorrelated with baseline characteristics. While our preferred specification always omits covariates for simplicity, we will report covariate-adjusted specifications of all tests as a robustness check.

3.8 Attrition and Compliance

Zone-level attrition (i.e., failure of purchasing clerks to use the mobile app or implement treatments as assigned) is a central implementation risk for any technology-dependent intervention, and we address it through four complementary safeguards. First, purchasing clerks are KKFU employees, and app usage and survey administration are a required part of their job responsibilities inside experimental zones. Second, we budget compensation payments to purchasing clerks to offset the additional time and hassle of learning and operating the app, addressing the concern that clerks may under-comply if not paid for their effort. Third, we build in monitoring and support at two levels: district managers are trained to assist purchasing clerks within their districts, reinforcing correct app usage and troubleshooting problems whenever clerks bring cocoa to the district warehouse, and KKFU monitoring and evaluation staff, funded through the project budget, circulate through experimental zones throughout the harvest season to observe clerk practices directly and reinforce compliance in real time. Fourth, the app allows us to directly detect non-compliance: we measure, near real-time, the share of cocoa bags recorded through the app with a valid QR-coded sticker relative to total bags received at district warehouses, by zone and by week. Zones with low or declining tagging rates can be identified and flagged for additional support while data collection is ongoing.

Farmer-level attrition (i.e., farmers not selling to KKFU or declining surveys) is itself an outcome of interest (H6a, H6b) rather than a source of bias. Deforestation outcomes can be measured remotely via satellite monitoring on all mapped properties regardless of survey completion or sales activity, ensuring outcome data are available even for farmers who attrit from KKFU or decline surveys. Our preferred specification omits covariate adjustment and our covariate-adjusted robustness specification uses zone-level covariates rather than individual farmer-level covariates, so farmer-level regressions for satellite-based outcomes can include all mapped farmers regardless of survey completion.

3.9 Project Timeline

The research team has conducted two preliminary field visits to prepare for the upcoming experiment. In **January 2025**, the team visited KKFU headquarters, purchasing sheds, district warehouses, and cocoa farms, conducting focus groups with farmers, purchasing clerks, and district warehouse personnel to gather input on program design, operational constraints, and farmer priorities. In **November 2025**, the team piloted the mobile app and survey instrument in three KKFU zones, each representing a different treatment arm (one control, one Treatment 1, one Treatment 2). This pilot tested app functionality, survey design, and data collection procedures, generating feedback that informed refinements to the questionnaire and app interface. Following the pilot, the research team worked with native Twi speakers with knowledge of the local context to translate the survey instrument and app interface into Twi, the predominant language in Ghana's cocoa-growing regions. The Twi interface enables purchasing clerks and farmers to respond accurately to questions in their native language, improving data collection quality.

In early **May 2026**, purchasing clerks will receive remote training via SMS messages, audio messages, and individualized phone calls in their local language. This training will focus on how to deliver a treatment-specific information intervention to farmers in their assigned zone, explaining how monitoring, certification, and premium payments will operate. Early May timing allows farmers to receive and process this information before the main cocoa season begins, enabling behavioral adjustments to planting and land management decisions. The training protocol and information intervention scripts are reported in Appendix E.

In **September 2026**, the research team and KKFU staff will conduct in-person training sessions for purchasing clerks and district warehouse managers, focusing on mobile app usage and data collection protocols. Training sessions will be conducted separately by treatment assignment to

provide treatment-specific instruction: Control clerks receive training on transaction recording, survey administration, and QR-coded sticker printing (white stickers only, for warehouse tracking); Treatment 1 clerks additionally learn deforestation status display and color-coded sticker application (green for deforestation-free, red for detected deforestation, white for unmapped); Treatment 2 clerks receive all Treatment 1 training plus premium payment procedures. Clerks will bring tablets and printers back to their assigned zones at the conclusion of this training.

The main harvest season, corresponding with experimental data collection, runs from October through December 2026. No data on program implementation or outcomes, derived from the app or any other source, will be collected prior to October 2026—ensuring a clean pre-registration. During October-December, farmers bring cocoa to purchasing sheds for sale and purchasing clerks record transactions, display deforestation status for mapped farmers in treatment villages, administer surveys, and (in Treatment 2) calculate premium payments to be distributed at the end of the season. District warehouse managers receive cocoa deliveries from SHEDs, scan bag QR codes, measure moisture content, and record re-bagging outcomes. End-line deforestation analysis and purchasing clerk surveys will occur in **January 2027** after the harvest season concludes.

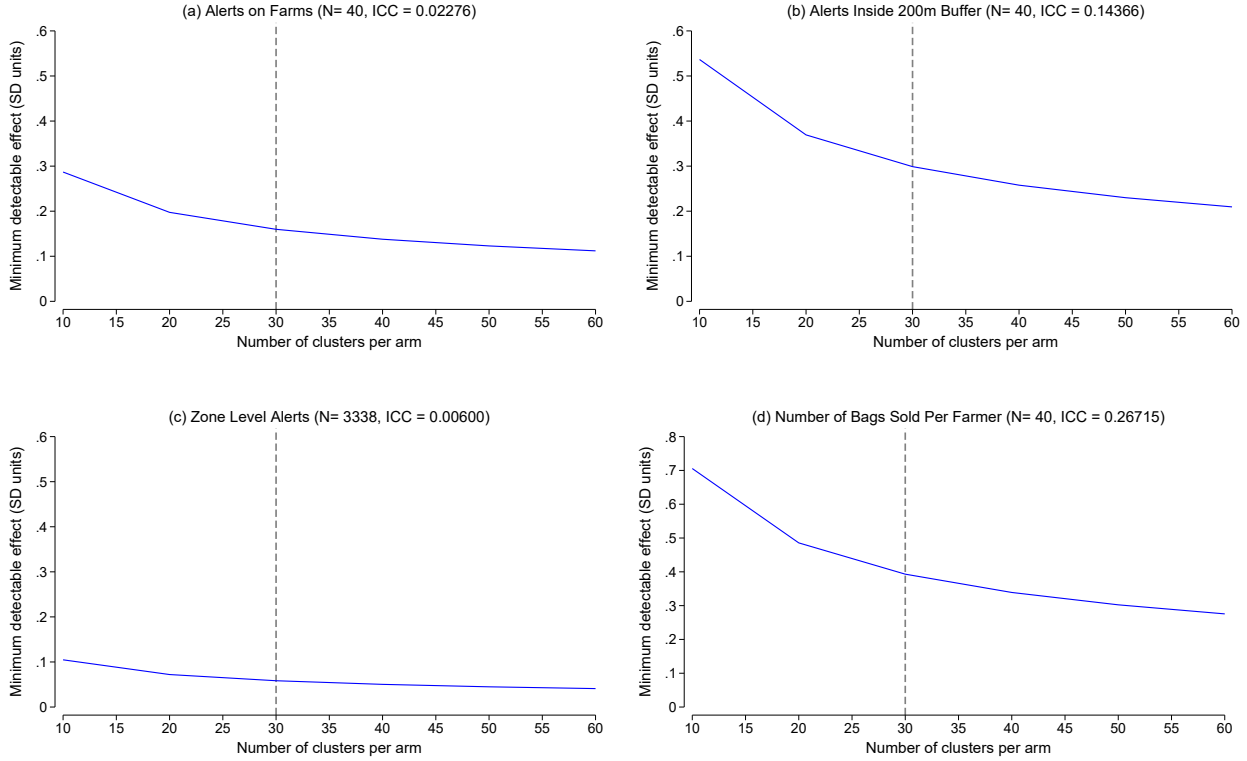
4 Statistical Power and Minimum Detectable Effects

We conduct power calculations to determine minimum detectable effects (MDEs) for key outcomes based on pre-experimental data. With clustered random assignment at the zone level, statistical power depends on the number of clusters and the intra-cluster correlation (ICC) of each outcome. We calculate ICCs and MDEs for four outcomes for which pre-intervention data are available: (1) deforestation alerts on mapped properties, (2) alerts inside 200-meter buffers around mapped properties, (3) alerts at the zone level, and (4) number of cocoa bags sold per farmer. For deforestation outcomes, we use historical satellite alerts from 2021-2025. For sales, we use transaction records from KKFU's 2024/2025 season.

ICCs vary substantially across outcomes. On-property alerts exhibit low clustering (ICC = 0.02276). Buffer-zone alerts show somewhat higher clustering (ICC = 0.14366). Zone-level (grid-cell) alerts have the lowest ICC (0.00600) and the largest sample size (averaging 3,338 1ha grid-cell observations per cluster after excluding mapped properties and buffers). Number of bags sold per farmer shows the highest within-cluster correlation (ICC = 0.26715), reflecting similarity in farm sizes and production among smallholders within zones.

Figure 4 plots MDEs in standard deviation units as a function of clusters per treatment arm for all four outcomes, with the vertical dashed line indicating our budget-constrained maximum of 30 clusters per arm—determined by the costs of supplying tablets and sticker printers, providing training, monitoring, and logistics support, and paying premiums to T2 farmers. Sample sizes per cluster are 40 for on-property and buffer-zone outcomes (reflecting an average of 40 mapped farmers per zone), 3,338 for zone-level outcomes (reflecting the average number of unmapped hectares per zone), and 40 for number of bags sold (again reflecting an average 40 mapped farmers per zone). At 30 clusters per arm, on-property alerts (panel a) has an MDE of 0.15982 SD, buffer-zone alerts (panel b) has an MDE of 0.29892 SD, zone-level alerts (panel c) has an MDE of 0.05837 SD, and number of bags sold per farmer (panel d) has an MDE of 0.39310 SD.

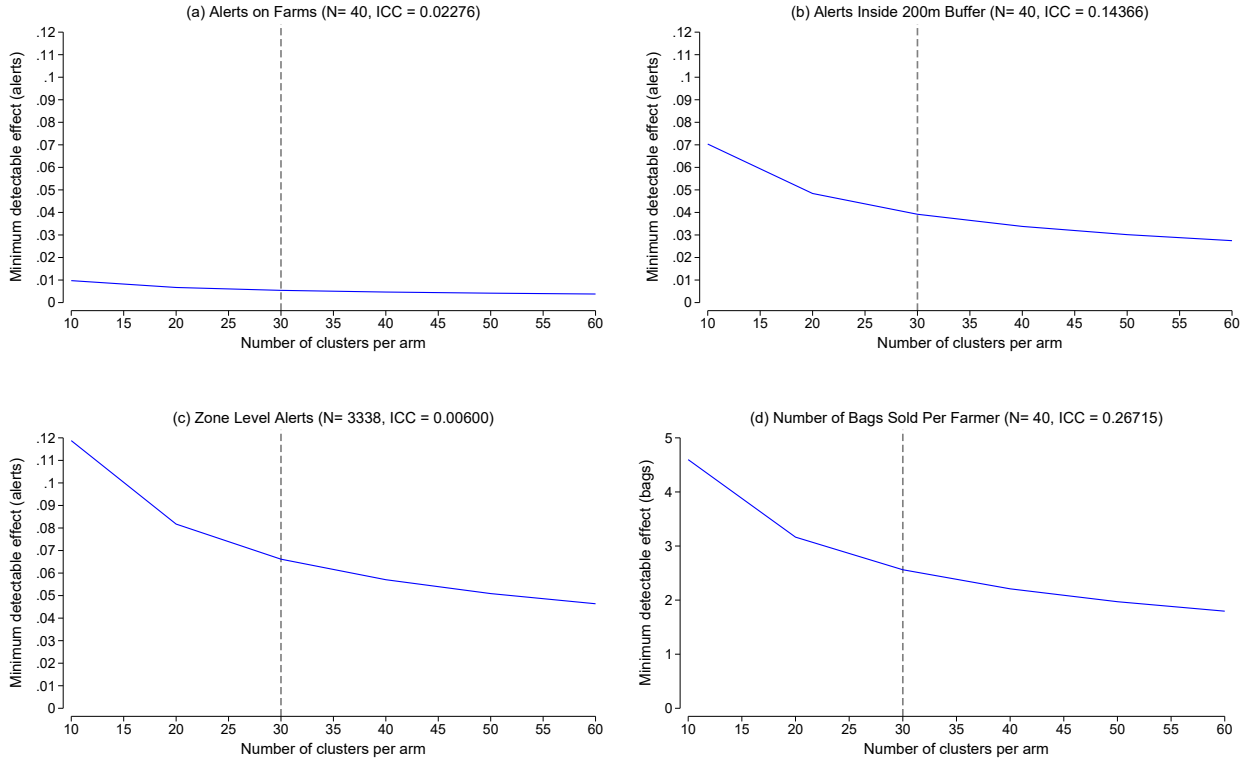
Figure 4: Minimum Detectable Effects (Standard Deviation Units)



Note: Each panel plots the minimum detectable effect (MDE) in standard deviation units as a function of clusters per treatment arm, with the vertical dashed line indicating the budget-constrained maximum of 30 clusters per arm. Panel (a) shows MDEs for alerts for mapped cocoa farms. Panel (b) shows MDEs for alerts inside 200-meter buffers around a farmer's mapped properties. Panel (c) shows MDEs for alerts at the zone level, measured in 1ha grid cells, excluding properties and buffers. Panel (d) shows MDEs for the number of cocoa bags sold per farmer. Sample sizes and ICCs are calculated from five years of historical satellite alert data (2021-2025) for panels (a)-(c) and from KKFU transaction records from the 2024/25 season for panel (d). Panels (a)-(c) share a common y-axis to facilitate direct comparison across deforestation outcomes; panel (d) is shown on its own axis, since bags sold is a distinct outcome measured in different units.

While standardized MDEs are useful for comparing precision across outcomes measured on different scales, they can obscure how large an effect actually needs to be in absolute terms, particularly for rare events. We therefore also report MDEs in levels, i.e., in the natural units of each outcome (number of alerts or number of bags), in Figure 5. At 30 clusters per arm, the MDE in levels is 0.00543 alerts for on-property deforestation, 0.03919 alerts for buffer-zone deforestation, 0.06617 alerts per grid cell for zone-level deforestation, and 2.56135 bags for bags sold per farmer.

Figure 5: Minimum Detectable Effects (Levels)



Note: Each panel plots the minimum detectable effect (MDE) in levels as a function of clusters per treatment arm, with the vertical dashed line indicating the budget-constrained maximum of 30 clusters per arm. Panel (a) shows MDEs for alerts on mapped cocoa farms. Panel (b) shows MDEs for alerts inside 200-meter buffers around a farmer's mapped properties. Panel (c) shows MDEs for alerts at the zone level, measured in 1ha grid cells, excluding properties and buffers. Panel (d) shows MDEs for the number of cocoa bags sold per farmer. Sample sizes and ICCs are calculated from five years of historical satellite alert data (2021-2025) for panels (a)-(c) and from KKFU transaction records from the 2024/25 season for panel (d). Panels (a)-(c) share a common y-axis, since all three outcomes are measured in alerts; panel (d) is shown on its own axis, since bags sold is measured in different units.

To interpret these MDEs in context, Table 1 reports the baseline incidence of each outcome over the 2021–2025 pre-intervention period. Only 0.167% of mapped farmers recorded any on-property alert over the five-year window, with a mean of 0.01528 alerts per farmer. Buffer-zone deforestation is more common: 1.722% of buffer zones recorded any alert, with a mean of 0.86111 alerts per farmer. At the grid-cell level underlying our zone-level outcome, 0.1% of grid cells recorded any alert, with a mean of 0.02605 alerts per cell. Low alert rates on mapped properties and within zones more broadly reflect how established farms retain little residual forest to clear, as well as efforts by KKFU to exclude active deforestation areas from their sourcing, in line with Fairtrade and Rainforest Alliance requirements (which rely on region-level risk assessments rather than property-level traceability).

Table 1: Baseline Incidence and Minimum Detectable Effects, 2021–2025

Outcome	Unit	N	Share w/ ≥ 1 alert	Mean # Alerts/Bags	SD	ICC	MDE (SD Units)	MDE (Levels)
On-property deforestation	Farmer	3,600	0.00167	0.01528	0.03395	0.02276	0.15982	0.00543
Buffer-zone deforestation	Farmer	3,600	0.01722	0.86111	0.13111	0.14366	0.29892	0.03919
Zone deforestation (grid cell)	Grid cell	252,726	0.00100	0.02605	1.13349	0.00600	0.05837	0.06617
Bags sold per farmer	Farmer	3,600	n/a	6.80205	6.51585	0.26715	0.39310	2.56135

Note: Share w/ $\geq$1 alert reports the share of farmers or grid cells with at least one high-confidence deforestation alert between 2021–2025, and is not applicable for the bags-sold row. Mean and SD report the baseline mean and standard deviation of each outcome at its unit of analysis: a binary indicator (any alert) for on-property and buffer-zone outcomes, a count of alerts per 1-hectare grid cells for the zone-level (grid cell) outcome, and bags sold per farmer over the 2024/25 season. For on-property and buffer-zone outcomes, a farmer's total alert count is summed across all of their mapped farms before constructing the binary indicator, since a single farmer may own multiple mapped properties and the deforestation check at point of sale evaluates all of a farmer's farms jointly. N, Share w/ $\geq$1 alert, and Mean for on-property, buffer-zone, and bags-sold outcomes are computed using a random sample of 3,600 farmers from KKFU's broader population, approximating our expected experimental sample size. SD and ICC are computed using the full KKFU sample. MDE (SD units) reports the minimum detectable effect at 30 clusters per treatment arm. MDE (levels) reports the same MDE converted to the outcome's natural units.

Summing up, the experiment may be underpowered to detect low-frequency deforestation alerts in levels, particularly for the on-property outcome. It is important to note, however, that deforestation outcomes are only one of four blocks of pre-registered outcomes in this study, alongside farmer-level outcomes, valuation and willingness-to-pay measures, and descriptive and cost-effectiveness outcomes, including cost per farmer certified as deforestation-free, false positive and challenge rates, and user experience feedback from purchasing clerks. Collectively, these findings will provide policy-relevant and timely evidence on whether property-level, satellite-based deforestation monitoring is feasible in a smallholder context.

Moreover, while low baseline deforestation rates create challenges for statistical power, they

also suggest that over 98% of farm households should be able to comply with property-level monitoring requirements at no cost, giving them deforestation-free traceability that could be valuable in obtaining EUDR premiums. For the small tail of farmers accounting for most detected activity (up to 37 on-property and 752 buffer-zone deforestation alerts at the 99th percentile), property-level monitoring offers a mechanism for exclusion from the certified supply chain that was missed by region-level risk assessments.

5 Ethics and Data Management

This experiment received institutional review board approval through the University of Geneva's University Commission for Ethical Research in Geneva (CUREG) on February 6th, 2026 (Decision Form CUREG-2025-08-133), with the approval form reproduced in Appendix F. The research adheres to strict ethical standards governing data protection, informed consent procedures, and community engagement, ensuring that participant welfare and local benefit remain central to all research activities.

Data protection is taken seriously in the research design. The mobile app implements a three-portal structure with password-protected access. The SHED portal (for purchasing clerks), District portal (for warehouse managers), and Admin portal (for researchers and KKFU management) operate independently with role-based permissions, ensuring that purchasing clerks cannot access administrative data and researchers cannot access data without the proper credentials. The Admin portal is hosted on the secure transpath.eu domain under European Union data protection regulations (GDPR). Farmer names and personally identifiable information are used only during data collection to link farmers with KKFU IDs, and will be destroyed after the collection period concludes, with all analysis conducted using anonymized farmer IDs. Research data are archived on Yareta, the University of Geneva's certified long-term digital preservation platform, which provides encrypted storage and controlled access rights compliant with Swiss and European data protection standards. We will never report individually identifiable information.

Informed consent procedures respect local context and literacy constraints. Before data collection begins, research team members will train KKFU purchasing clerks on informed consent procedures alongside KKFU officials to ensure clerks understand the project objectives and can accurately communicate them to farmers. Given that many participating farmers have limited experience with written communication, purchasing clerks will administer consent verbally in the

local language, using standardized language that explains voluntary participation, data confidentiality, and the right to withdraw without penalty. Farmers who decline participation will not experience any reduction in access to KKFU membership benefits. Likewise, farmers identified as deforestation non-compliant will not experience any penalties, explicit shaming, or loss of KKFU membership benefits beyond exclusion from deforestation-free premiums. The consent form and survey instruments were translated into Twi by native speakers with knowledge of the local context to ensure accurate communication and data collection quality. The informed consent script is reproduced on page 2 of the SHED-level survey in Appendix B.

Our project addresses genuine sustainability challenges facing cocoa farmers in Ghana: 27% live below the national poverty line, and cocoa-driven deforestation threatens long-term farm productivity. The experimental design prioritizes farmer welfare: no treatment imposes penalties or restrictions, and participation can only benefit farmers through premium payments and enhanced access to deforestation-free certification markets. The project builds local capacity through partnership with KKFU, Ghana's largest farmer-led cocoa cooperative, providing technology that digitalizes administrative data collection and enables operational decisions to be informed by real-time information. The research team includes members from Ghana's cocoa-growing regions who understand the local context and speak Twi, ensuring culturally appropriate research design and implementation. Findings will be communicated to participating farmers and KKFU management through feedback sessions, ensuring research benefits flow back to participating communities. The project operates under a Memorandum of Understanding with KKFU (reproduced in Appendix A), with no conflicts of interest between research and co-op objectives.[18]

The research team retains full independence and freedom to publish all findings from this study regardless of results. The Memorandum of Understanding with KKFU explicitly guarantees that publication decisions rest solely with the research team and require no approval from KKFU, funding agencies, or other institutional partners. This independence ensures unbiased reporting of treatment effects, null results, and any unintended consequences of the intervention.

[18]One potential ethical concern arises at the conclusion of the experiment, when premium payments to Treatment 2 farmers will cease. Farmers who have received $5 per bag premiums may experience discontinuation as a loss, potentially generating dissatisfaction with KKFU or the research team. To mitigate this, purchasing clerks will communicate clearly at the outset that premiums are tied to the research program and not guaranteed beyond the experimental period. Importantly, participating in the experiment positions farmers and KKFU favorably to capture market-based deforestation-free premiums that are expected to emerge as the EUDR takes effect and international buyers increasingly reward verified deforestation-free supply chains. End-of-season feedback sessions will communicate this framing to participating farmers.

5.1 Data Management and Access

All research data will be stored on secure, password-protected servers. Raw data collected via the mobile app will be hosted on the transpath.eu domain under European Union data protection regulations, with access restricted to approved KKFU officials and core research team members through role-based credentials. Long-term archiving will use Yareta, the University of Geneva's certified digital preservation platform, which provides encrypted storage and controlled access compliant with Swiss and European data protection standards (GDPR).

Upon acceptance of this research for publication, we will provide a complete replication package including all analysis code and de-identified experimental data on a public repository such as Zenodo. The replication package will include: (i) cleaned datasets with anonymized farmer identifiers, (ii) code for all tables, figures, and statistical analyses reported in the paper, and (iii) a detailed README file.

5.2 Deviations from Pre-Registration

This pre-registration specifies our research design, hypotheses, and analytical approach prior to viewing experimental data. We commit to transparently document any deviations from this plan in published papers and replication materials. We may deviate under the following circumstances: (i) unforeseen data quality issues requiring alternative measurement approaches or (ii) implementation challenges preventing delivery of treatments as designed. Deviations will be clearly highlighted in published work, with separate reporting of pre-registered analyses and post-hoc exploratory analyses. We commit to reporting all pre-registered outcomes and tests regardless of statistical significance or consistency with theoretical predictions.

6 Conclusion

The European Union Deforestation Regulation (EUDR) takes effect between December 2026 and June 2027, yet fundamental questions about the feasibility and effectiveness of deforestation-free requirements in low-income settings remain unanswered. Existing evidence on supply-chain governance comes predominantly from large-scale commercial agriculture in middle-income countries (e.g., soy and beef in Brazil, palm oil in Indonesia), where monitoring is comparatively straightforward. Whether satellite-based traceability can achieve deforestation-free compliance and organizational buy-in in smallholder supply chains is less clear.

Our experimental design addresses this gap by testing property-level monitoring in a context where farms average less than one hectare and government enforcement capacity is limited. Because land-use decisions of this kind typically unfold over multiple years, a single harvest season may capture only the earliest stage of behavioral change, a limitation we weigh against the immediate and binding EUDR timeline motivating this study. Results will directly inform EUDR implementation in West Africa and provide experimental evidence on spatial leakage, transparency versus financial incentives, and farmer demand for certification. These contributions are essential for designing scalable deforestation-free supply chains for tropical commodities.

Declaration of Generative AI in the Manuscript Preparation Process

During the preparation of this work, the authors used Claude (Anthropic) to assist with text revision, LaTeX formatting, and proofreading. All substantive content and research design are the authors' original work.

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Supplementary Materials

Contents

A KKFU Memorandum of Understanding

Memorandum of Understanding (MoU)

For Collaborative Research on Sustainable Cocoa Production between the University of Geneva, the University of Ghana, and Kuapa Kokoo Cooperative Cocoa Farmers and Marketing Union Limited (KKFU)

Date: November 7th, 2024

1. Introduction

Cocoa is well known as a cash crop for countries that produce it and is the main ingredient in the production of chocolate. In Ghana, the cocoa sector employs close to 6 million people, including approximately 800,000 smallholder farmers that rely on cocoa for at least 90% of their household income (Waarts et al.,2019). Income from cocoa makes significant contributions to household food consumption, nutrition, health, and education, as this income is used mainly in purchasing food, paying schools, and accessing better health care services (Belsky and Siebert, 2003; Bentley and Boa, 2004; Schmitz and Shapiro, 2012). However, among these benefits there are many challenges, such as pest and disease attacks, declining soil fertility, aging cocoa farms, rising input prices, climate change effects, and low incomes, which contribute to low and declining cocoa production (Fountain and Hütz-Adams, 2020). These problems often push smallholder farmers with limited resources to expand their farming into forests to capitalize on the recent increases in cocoa prices worldwide, which has harmful effects on the environment and human welfare by increasing greenhouse gas emissions, reducing biodiversity, and depleting household food and income sources. There are also social issues such as child labor and poverty that are obstacles to fair trade and sustainable development.

Recognizing these challenges, the government and its institutions such as COCOBOD and private sector organizations such as the Kuapa Cocoa Farmers Union (KKFU) have begun implementing grassroot approaches and interventions to help improve the sustainability and transparency of Ghana's cocoa supply chain. From our interviews with KKFU it appears that quite some success has been achieved so far, for instance, in mapping out the property boundaries of cocoa farms. These efforts laid the groundwork for improved land use and land management and efficient traceability of cocoa beans. In addition, KKFU plans to introduce innovative sustainability practices, efficient data acquisition and credible quality control mechanisms, necessary for sourcing traceable cocoa of such quality that it will be fully compliant with the requirements of certifying entities (Fairtrade, Rainforest Alliance) as well as with the standards for the procurement of deforestation-free cocoa by the European Union with its new Zero Deforestation regulation (EUDR). KKFU has taken strong initiatives to complete the mapping of assets of all its members to achieve this target by end 2024 or latest by mid-2025 with fund requirement.

As researchers we have a strong motivation for the mission of KKFU – and to accomplish that we think we can provide necessary support during the partial and complete mapping for which their workplan allows. We will work together to generate research output that will help the Union in its decision making on fair trade and sustainable cocoa supply chain issues and through our partnership we hope to contribute to a sustainable and transparent cocoa industry in Ghana that is of benefit to farmers, the environment and the wider world.

- **Parties Involved:**
  - Institute of Economics and Econometrics, University of Geneva (Geneva, Switzerland)
  - Institute of Statistical, Social and Economic Research, University of Ghana (Accra, Ghana)
  - Kuapa Kokoo Cooperative Cocoa Farmers and Marketing Union Limited (KKFU) (Ghana)

- **Purpose of the MoU:**
  - To establish a framework for cooperation on a field experiment focused on sustainable supply chain policies for cocoa production in Ghana.

2. Objectives

- **Research Goals:**
  - To develop a lasting research partnership between involved parties to contribute to useful knowledge and capacity-building for the development of Ghana's cocoa sector.
  - To understand the impacts of property boundary mapping, point-of-purchase quality screening, and other interventions, such as traceability and participatory forest monitoring on deforestation reduction, sustainable cocoa production practices, cocoa quality, cocoa producers' wellbeing, and operational outcomes for the cooperative.

- **Expected Outcomes:**
  - Substantial increase in mapping of property boundaries for KKFU members.
  - Improved sustainability practices, data collection processes, and quality screening for cocoa production within KKFU.
  - Improved cocoa production and effective reduction in deforestation.
  - Improved compliance with Certifiers' (e.g., Fair Trade) and European Union's (EU) Deforestation-Free supply chain requirements.
  - Research outputs including, but not limited to, research briefs and internal reports to KKFU directors, academic research publication(s), and a policy brief for EU policymakers focused on deforestation-free supply chain governance.

3. Scope of Collaboration

This research project will be implemented in selected districts of KKFU in Ghana.

- **Field Experiment Details:**
  - See Appendix I (Research Design) for a detailed description of the proposed research project. This design will continue to evolve based on collaborative discussions between involved parties.

- **Duration of the Project:**
  - This MoU will take effect on DATE, and will continue in effect until DATE, at which point it may be renewed in its existing form, amended subject to discussion and approval between the involved parties, or terminated, subject to the terms of termination described below.

4. Roles and Responsibilities

- **University of Geneva and University of Ghana**
  - Design and implementation of the research project
  - Coordination of research project implementation in collaboration with KKFU field staff.
  - Drafting, publication, and dissemination of findings. Joint publication is encouraged, with both parties agreeing to mutually decide on authorship criteria, the manuscript development process, choice of publication outlets, and acknowledgments to ensure a fair and transparent process.

- **KKFU:**
  - Facilitation of access to cocoa farmers and collection points for the research team.
  - Support in logistics and local coordination.
  - Collection and sharing of data on farmers' properties and collection points, subject to the Data Use Agreement discussed below and presented in Appendix II (Data Use Agreement).
  - Implementation of property boundary mapping, mapping trainings with farmers, and other sustainability-related engagement with farmers.
  - Broader engagement with the cocoa farming community and other stakeholders.

5. Data Management

- **Data Collection:**
  - Types of data to be collected include mapped properties boundaries (shapefiles) for KKFU farmers' properties, farmer characteristics, satellite data on deforestation, point-of-sale data on cocoa production volume, quality characteristics, and self-reported farming practices, and administrative data on cocoa purchases and sales. The quality of cocoa beans will be assessed based on criteria established by two main sources:

1. Ghana Cocoa Board (COCOBOD)

2. Internal standard protocols of KKFU Marketing Wing. Overall, the quality criteria will ensure compliance with international market requirements for cocoa.

- Methods and tools for data collection include (i) mapping of property boundaries using GPS-enabled tablets or smartphones provided by the University of Geneva team, (ii) collection of point-of-sale data at collection points using surveys designed by the University of Geneva and University of Ghana teams in collaboration with KKFU researchers and field staff, and (iii) intersection of mapped property boundaries and areas around collection points with satellite data on deforestation (e.g., Global Forest Watch), to be implemented by the University of Geneva and University of Ghana research teams.

- **Data Use Agreement (Annex II):**
  - Refer to Annex II (Data Use Agreement) for further details regarding data collection, sharing, and use.

6. Ethical Considerations

- **Institutional Review Board Approval:**
  - The research project detailed in Appendix I (Research Design) will be submitted for approval by the Institutional Review Boards of the University of Geneva and the University of Ghana prior to implementation by KKFU. This process will ensure that the research design complies with international and country-specific standards for ethical research.
  - Research teams will obtain informed consent from all research subjects, including KKFU farmers and staff at collection points, prior to their participation in the project.

- **Confidentiality:**
  - Adequate measures will be taken to ensure confidentiality of research subjects' data and participation, including, but not limited to, storage of all project data on a password-protected, encrypted cloud folder with access restricted to approved research project staff, anonymization of research records whenever possible, and commitment by research teams to never publish or otherwise release identifiable information on research subjects.

7. Financial Arrangements

- **Funding Sources:**
  - Funding for this project will be provided through the University of Geneva from Horizon Europe Grant No. 101081984, to the amount of €125,000 (one hundred and twenty-five thousand euros).

- **Budget Allocation:**
  - The University of Geneva research team will commit to use the abovementioned research funding for project-specific activities/items:
    - Purchase of tablet computers or smartphones for property boundary mapping,
    - Farmer training and information interventions conducted by KKFU field staff
    - Surveying of farmers at collection points by KKFU field staff,
    - Other logistics of program implementation including, but not limited to, transportation and local sustenance of field staff
    - Data analysis and publication components involved in the research project.
    - Any activities outside the scope of the project but deemed essential for its success may be included in the project budget, provided both parties agree in writing.

  - KKFU will commit to funding all activities or items that are not specified as project-specific tasks for the University of Geneva research team but are already part of KKFU's regular operations. KKFU will not use the research funding to finance:
    - Internal research inputs from their team that are unrelated to the project and have not been explicitly included in the project budget, as agreed upon in writing by both parties.
    - Components of field operations that are part and parcel of their normal operations, such as field extension services, farmer visits, interactions with farmers at collection points, and regular data collection and sharing, unless these activities have demonstrably contributed to specific project outcomes. We acknowledge that such situations may arise due to administrative and technical challenges within KKFU, as well as macroeconomic factors (e.g., inflation) beyond its control. For such activities to be included in the project budget and receive funding, they must be documented in writing and supported by tangible evidence of their execution for the project.

8. Monitoring and Evaluation

- **Progress Monitoring:**
  - Either the University of Geneva or the University of Ghana will submit a progress report quarterly to KKFU, specifying progress made to that point on implementation of the research project, discussing upcoming next steps, and highlighting any outstanding challenges or obstacles that must be addressed to ensure continued progress on the research project. KKFU will also prepare a quarterly report specifying similar information, to be submitted to the University of Geneva and University of Ghana research teams, including progress made to that point, next steps and milestones, and outstanding obstacles and challenges to be addressed. Research team leaders and KKFU staff will meet quarterly, within one month after the sharing of these reports, to discuss their findings and coordinate next steps to ensure mission alignment and continued progress.

- **Evaluation Metrics:**
    - Criteria for evaluating the success of the project will include (i) the quarterly progress reports described above, (ii) property mapping metrics to be defined in Annex I (Research Design), other data collection metrics at collection points to be defined in Annex I (Research Design), research outputs including internal reports to KKFU directors, policy briefs, and academic research publications, and sustainable supply chain and traceability metrics defined by Certifiers and the European Union's Deforestation-Free supply chain initiatives.

9. Dispute Resolution

- **Conflict Resolution Mechanisms:**
    - Any conflicts that arise during the implementation of this collaborative project will first be raised in prompt communications with other involved parties, with the aim of rapidly and amicably resolving issues to ensure continued and mutually beneficial progress on the research project. Conflicts or disputes that cannot be resolved through informal discussions will be raised in written quarterly reports submitted to other involved parties and discussed subsequently by respective research team leaders.

10.Termination Clause

- **Conditions for Termination:**
    - This Memorandum will automatically terminate upon successful completion of the research project described in Appendix I (Research Design), or upon the date of termination defined at the beginning of the document, with both of these cases leaving open the possibility of renewing or extending the agreement in its present or amended form to enable further mutually beneficial collaborations between involved parties. In the case of irreconcilable disputes that have previously been documented in quarterly reports and thoroughly discussed by research team leaders, all involved parties have the unilateral right to terminate this MoU at any time.

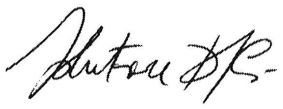
- **Notice Period:**
    - Any party wishing to terminate this MoU at a date other than that defined above must notify other involved parties in writing at least two months prior to this date.

- **Amendments:**
    - This MoU represents a living document that may be amended based on collaborative inputs, discussions, and learning throughout the course of the research project. As such, any of the involved parties may propose amendments to the MoU at any time by sharing the amendments in writing with other involved parties. Amendments will be adopted and incorporated into a new version of the MoU based on discussions between research team leaders.

- **Governing Law:**
  - This MoU shall be governed by and interpreted in accordance with the laws of Switzerland/Ghana. This clause will help prevent potential disputes by establishing which laws will apply in case of any issues.

11. Signatures

- **Signatories:**



  - Dr. Salvatore di Falco, Institute of Economics and Econometrics, University of Geneva

  - Dr. Fred Mawunyo Dzanku, Institute of Statistical, Social and Economic Research, University of Ghana

  - Representatives of KKFU. Boateng Solomon
    Executive Secretary.

Annexes

Annex I: Research Design

- **Research Questions:**
  - How do (1) mapping of cocoa farmers' property boundaries, (2) information interventions that raise awareness of traceability requirements, and (3) traceability and quality checks of cocoa beans at collection points affect outcomes of interest, including (a) deforestation on farmers' properties or deforestation in the catchment area of a collection point, (b) farmers' self-reported sustainability practices, (c) quality of cocoa beans delivered to collection points, (d) prices paid to farmers at collection points, and (e) prices received by KKFU for cocoa beans when they are sold onwards to exporters?
- **Methodology:**
  - The primary methodology employed in this study is a randomized controlled field experiment, wherein farmers from KKFU's pool of member farmers are randomly selected to be treated by one or more of several interventions, which are numbered in the research questions above and described in detail below, while other KKFU farmers are randomly allocated into control groups for comparison.

    Experimental Interventions:

    1) **Mapping of property boundaries:** randomly selected farmers could have their property boundaries mapped, and follow-up outcomes on their properties related to unmapped properties could be measured through surveys conducted at collection points. Alternatively, certain collection points could have properties within their catchment area mapped, and satellite data plus surveys conducted at collection points could measure outcomes on properties in these areas relative to areas around control collection points where property boundaries were not mapped.
    2) **Information on traceability requirements:** within a sample of properties whose boundaries were mapped, some farmers could be randomly selected to participate in a training session led by field extension agents explaining traceability and deforestation-free requirements versus participatory forest monitoring. Outcomes from satellite data on deforestation and surveys conducted at collection points for farmers treated by this information intervention could be compared to outcomes for control farmers who were not treated by the information intervention.
    3) **Traceability and quality checks:** collection points with high versus low levels of property boundary mapping within their catchment area could conduct surveys of farmers at the point-of-sale to measure how property mapping affects quality and self-reported production practices. High- and low-mapping collection points could also be compared in terms of total deforestation observed within their catchment areas. Potentially, catchment areas could be given "deforestation scores" based on deforestation measured from satellite data on the properties of member farmers within their catchment areas, and information provided about these scores to collection point

staff or extension agents could constitute another treatment, where outcomes would be measured using subsequent deforestation rates or survey outcomes at point-of-sale.

- **Sampling Plan:**
  - Randomization may occur at either the individual (farmer or property) level or collection point level, depending on feasibility and the nature of the specific treatment intervention.

- **Data Collection Instruments:**
  - A variety of data collection procedures will be used to evaluate outcomes among treated and control farmers, including satellite data to measure deforestation, survey data of farmers' production practices, and administrative data shared by KKFU on quality of farmers' cocoa beans delivered to collection points, prices paid to farmers at collection points, and prices received by KKFU during sales to exporters.
    - Satellite data on deforestation will be downloaded and analyzed by research team staff from the University of Geneva or University of Ghana and will be combined with shapefiles of member farmers' property boundaries shared with the research team by KKFU.
    - Point-of-sale surveys of farmers will be developed by research team members and administered by KKFU field staff at the point of sale.
  - Administrative data internal to KKFU will be collected by KKFU through normal or adapted data collection channels, as needed, prepared by KKFU research personnel, and shared with the research team.
  - KKFU shall facilitate access to qualified Quality Control Officers to help assess the quality of cocoa beans at the following critical points along the supply chain:
    1. Farmer-level: Farmer-village purchasing clerk (PC) transactions.
    2. District warehouse-level: Transfer from PC to district warehouse.
    3. Port-level: Haulage-CMC (COCOBOD) at port, prior to export.
    4. Buyer-level: Handover from port to buyers.

- **Analysis Plan:**
  - Data collected as part of this project will be combined with standard administrative data shared by KKFU and satellite data on deforestation (which is publicly available) to conduct statistical analyses to estimate treatment effects of experimental interventions described above. Both parties will establish a Data Management Policy to ensure mutual access to relevant data. This policy will define protocols for data sharing, storage, security, quality control, and intellectual property rights. It will be reviewed and updated regularly to maintain compliance with regulatory requirements and adhere to best practices. All relevant data will be accessible to both parties according to the terms outlined in the policy.

- **Timeline:**
  - Experimental interventions and data collection efforts will begin promptly after the date of signing of this MoU, following practical and logistical considerations regarding the timing of cocoa production seasons in Ghana. Based on these on-the-ground considerations, the following (approximate) timeline for different steps of the project will be followed:

- [Date]: Purchase and distribute GPS-enabled tablets to KKFU field staff and conduct training for field staff and other personnel on property boundary mapping.
- [Date]: Design and pilot surveys for farmers at point-of-sale, to be conducted by KKFU field staff at collection points.
- [Date]: Begin property mapping efforts following randomized experimental protocol (e.g., mapping intensively in the catchment areas of certain collection points and not in others).
- [Date]: Implement information interventions for farmers through KKFU field extension staff, and continue efforts to map property boundaries, both in line with experimental protocols regarding treatment and control areas.
- [Date]: Administer surveys to farmers at the point-of-sale, to be conducted by KKFU field staff at collection points, and report data back to KKFU internal research team.
- [Date]: Research teams will collaborate to coordinate with KKFU collection point staff to implement quality and traceability checks for farmers at the point of sale, in line with experimental protocols.
- [Date]: Compile and begin analysis of survey data, satellite data on deforestation, and administrative data shared by KKFU, to be undertaken by University of Geneva and University of Ghana research teams.
- [Date]: Deliver specified project outputs, including research brief for KKFU directors, academic research paper, and EU policy brief.

Annex II: Data Use Agreement

- **Types of Data Covered by the Agreement:**
  1. Mapped property boundaries of KKFU member farmers' properties (shapefiles), including farmer attributes where available
  2. Point-of-sale data from collection points, including basic data on date and volume of sale, price paid, farmer ID/property ID (to allow linking back to property boundary shapefiles), and collection point ID, as well as survey data (survey to be designed by research teams) conducted with farmers at the point-of-sale, including information on farmer characteristics (e.g., age, education, gender) and self-reported information on production practices and outputs. In cases where collection points screen for quality checks, point-of-sale data will include data on the quality of farmers' beans.
  3. KKFU administrative data on volumes and (where available) quality of beans for each collection point involved in the study (treatment and control), dates and numbers of purchases, prices paid, volumes destined for export, and collection point geolocations (latitude/longitude points).
  4. Satellite data on pixel-level forest cover and land use, from Global Forest Watch database or a similar source, available annually for all of Ghana. These data are publicly available

and will be downloaded, intersected with KKFU member farmers' property boundaries, and analyzed by research team staff.

- **Data Access and Sharing:**
  - Data types 1, 2, and 3 belong to KKFU and will be shared in accessible formats with the University of Geneva and University of Ghana research teams and regularly updated with newly available data, for the duration of the project described in this MoU, for the exclusive purpose of the research project described in Appendix I (Research Design). Data sharing will be undertaken using a shared, password-protected Google Drive folder (or similar software).
  - Data type 4 is publicly available and will be downloaded, analyzed, and intersected with KKFU farmers' property boundaries by the University of Geneva and University of Ghana research teams.
  - The final combined dataset of property boundaries and annual deforestation values, as well as codes and procedures used to download and combine these data, will be shared by the research teams with KKFU, which will have the right to incorporate these codes and data into its internal operations if desired.
- **Confidentiality and Security:**
  - All data containing personally identifiable information will be anonymized wherever possible, including, but not limited to, removing farmers' names. Auto-generated ID numbers to identify farmers, properties, and sales will be used to link property boundaries to cocoa sales at collection points. These anonymization procedures may be implemented either internally by KKFU staff prior to data sharing, or by research team staff upon receipt of the shared data.
  - All data will be stored in a secure, encrypted, password-protected cloud-based folder such as Google Drive, with two-factor authentication activated to ensure maximum security. Only approved KKFU staff and approved research team members at the University of Geneva and University of Ghana will be granted access to this folder. For research team staff at the University of Geneva and University of Ghana, full access to this raw data folder will only be allowed from the date of project initiation until the date of project termination, and staff that leave the project will lose access.
  - Research outputs including academic publications, reports, briefs, and other media will never report individually identifiable information about farmers or collection points, and will never reveal sensitive proprietary information about KKFU.
- **Intellectual Property:**
  - KKFU retains ultimate ownership over all raw data shared with the University of Geneva and University of Ghana research teams. Access to these raw data will be revoked and terminated at the end of the project, as specified in this MoU, or upon termination of the project according to the procedures for termination outlined above.

- Research teams at the University of Geneva and University of Ghana will have the right to create an anonymized version of the dataset that omits individually identifiable information but contains sufficient information to perform all empirical analyses involved in all research outputs. This final dataset will be retained by the research teams in perpetuity for the purposes of publication, replicability, and (to extents agreed upon by the research team and KKFU) open data sharing for academic research purposes.

B Farmer Survey

Survey for Ghana Cocoa Traceability RCT Design

Transaction Details (regardless of the experiment)

Section 1: SHED information (pre-loaded by the SHED Purchasing Clerk)

1	Region	Dropdown/list of Ghana regions
2	Society/District/Depot name	Dropdown/list of districts
3	Zone/Village/SHED name	Dropdown/list of SHEDs in that district

Section 2: Identification

#	Question	Response Type / Options
4	Farmer ID	Assigned by App system/pulled from our database by searching
5	Sex of farmer	☐ Male ☐ Female ☐ Other

Section 3: Transaction data

6	How many full bags have been brought?	Numeric input
7	How many bags are not full (i.e. less than 64 kg)?	Numeric input
7a	Weight of the produce brought today for non-full bags (kg) [This question appears only if Q7 > 0]	Numeric input
8	KKFU member?	☐ Yes ☐ No
9	Part of any certification scheme? [Multiple options correct]	☐ FairTrade ☐ Rainfall Alliance/UTZ ☐ Organic ☐ Other ☐ No Certification
10	Total payment received for all bags of cocoa in this transaction (Amount in GHS)	Numeric input

STOP SURVEY HERE if farmer has previously responded to Experimental Section.
This is to accommodate multiple SHED visits per farmer:
[STOP if system-defined Q14 = Yes]

Experiment

[This prompt should appear for the PC: "Explain the information below to the farmer and obtain their informed consent before proceeding with the rest of the survey."]

Traceability and Sustainability in Cocoa Supply Chains: Experimental Evidence from Ghana

This project, together with University of Geneva, University of Ghana, and Kuapa Kokoo Farmers' Union, collaborative research to target traceability and measure deforestation compliance through digital innovation, as part of project TRANSPATH. Researchers from the two universities are aiming to digitalize the cocoa supply chain with the introduction of an app-based system for cocoa transactions (developed in collaboration with Pensoft Publishers). We are testing out this new app to manage KKFU's cocoa purchases and keep track of what is happening on plots where cocoa is bought from.

We are also using the app to conduct a research experiment about deforestation associated with cocoa production. The researchers have created alerts to check farm-level deforestation status using geo-mapping and satellite alerts, and cocoa bags will be labelled accordingly to create a certification of "deforestation-free cocoa". This experiment will provide policy-relevant evidence on the feasibility and impact of this type of program. Expected results include reduced deforestation, improved farmer income, increased operational efficiency for cooperatives, and actionable recommendations for scaling digital traceability systems. These objectives have direct applications in evaluation, operational improvement, and sustainability certification readiness.

No personal data like video-image, audio-voice, address, surname, first name, date of birth, telephone number, email addresses, IP addresses, etc., are processed. We will collect individual data like Sex, Age (years), Education, Family size, Geolocation of work, Village, District, Farm practices, Land ownership, and Deforestation and sustainability awareness. All of these responses are anonymised under a numeric farmer id. Farmer names are used only during the collection of data and destroyed after the data collection process is over.

At the end of the experiment, you will receive communication about the outcome of the study. The researchers from the universities, along with KKFU officials, will inform you of the results, either through the PC channel or by hosting a meeting session.

Do you consent for us to record your information in the app and use it for this research experiment and to improve our operations and services?

Your participation is entirely by choice, and there is no penalty if you choose not to take part. All answers will be kept strictly confidential, stored securely on password-protected devices, and accessed only by the authorized research team for agreed research purposes. There is no risk for you in terms of access to membership benefits and certification premiums. Rather, if your farm is found to be deforestation free, you would be eligible to a deforestation-free marker for your cocoa, upon satisfying all related conditions.

Consent:

Does the farmer agree to take part in the survey?	☐ **Yes** ☐ **No**

[Only if "Yes", the next part of the survey is activated. If "No", stop the survey.]

Section 4: Experiment Identification (All system-defined information)

11	Intervention group	☐ Control (C) ☐ Treatment 1 (T1) ☐ Treatment 2 (T2)
12	Farmer's plots mapped	☐ Yes ☐ No
13	Deforestation status	☐ Green ☐ Red ☐ Not assigned
13a	Is the farmer challenging this deforestation status? * *(Instruction for PC pops up beside this question): This question is not to be asked directly, but only to note the response in case of a disagreement from the farmer [The survey is completed following its natural course. If "Yes" is the response to this question, a notification gets sent to the app under this PC's account, as a "Pending Check". Refer to Block A at the end of the survey for more details.]	☐ No ☐ Yes
14	Survey already completed	☐ Yes ☐ No

Section 5: Introductory Questions

#	Question	Response Type / Options
15	How old are you?	Numeric input (years)
16	Number of adult household members (18+)	Numeric input
17	Number of children in household (<18)	Numeric input
18	What is your level of education?	☐ None ☐ Primary ☐ JHS ☐ SHS ☐ Tertiary ☐ Other
19	What made you choose to sell your cocoa to KKFU? [Multiple options allowed]	☐ Convenient location ☐ Good price ☐ Services/training ☐ Premium payments ☐ Interested in joining KKFU ☐ Other
20	Besides KKFU, how many other cocoa buyers can you easily reach from your farm?	☐ None - KKFU is my only realistic option ☐ 1 other buyer ☐ 2-3 other buyers ☐ 4 or more buyers

21	From this list, choose what you think are the TWO most serious challenges facing cocoa farmers in your community: [Two options allowed]	☐ Low cocoa prices ☐ Cocoa pests/diseases ☐ Droughts or floods ☐ Artisanal mining ☐ Deforestation ☐ Access to inputs like fertilizers and pesticides ☐ Other

Section 6: Farm Characteristics

A. Land and Crop Production		
22	How much total land do you farm? (all crops, all plots)	Numeric input (acres)
23	How much land do you farm for **cocoa** (all plots)	Numeric input (acres)
24	How many different cocoa plots do you manage?	Numeric input
B. Labour Use		
25	What is the main source of labor on your farm? [Multiple options allowed]	☐ Family ☐ Hired (casual) ☐ Hired (permanent) ☐ Communal/shared ☐ Other
26	Have you or any member of your household worked outside of your farm for pay any time this season?	☐ Yes ☐ No
C. Farm Practices		
27	Have you planted new cocoa trees in the last 5 years?	☐ Yes ☐ No
28	Have you cleared new land for cocoa in last 5 years?	☐ Yes ☐ No
29	What do you plan to do with your cocoa farm over the next 5 years?	☐ Clear new land to expand cocoa ☐ Keep same area but replant old trees ☐ Keep same area with the same trees ☐ Reduce cocoa area ☐ Stop cocoa farming entirely ☐ Not sure / Haven't decided
30	Have you replanted old cocoa trees this season?	☐ Yes ☐ No
31	Do you have shade trees on your cocoa farm?	☐ Yes ☐ No

Section 7: Deforestation Awareness

32	Do you know what “deforestation-free” cocoa means?	☐ Yes ☐ No
32a	Explain to farmer: “deforestation-free” means that you have not cleared forest on or nearby your cocoa farm. If your property is mapped, KKFU can verify this using satellite technology. [This prompt appears only if Q32 = “No”]	
33	Do you recall hearing about how KKFU will be monitoring deforestation on farmers’ properties this season using satellites? [This question appears only if Q11 = T1 or T2]	☐ Yes ☐ No
34	Do you believe your farm is deforestation free?	☐ Yes ☐ No
35	Have you discussed deforestation with other farmers in your village?	☐ Yes ☐ No
36	If deforestation were detected on your property, do you think other farmers or KKFU staff would be upset?	☐ Yes ☐ No
37	Suppose a farmer's mapped cocoa farm is deforestation-free, but the farmer clears forest on other land they own to plant cocoa. Do you think they would still get the deforestation-free premium? [This question appears only if Q11 = T2]	☐ Yes ☐ No

Section 8: Valuation

38	In this program, some farmers have had their cocoa farms mapped and monitored for deforestation using satellite technology. Suppose buyers offered you a premium of **$[X1] per bag** for deforestation-free cocoa if you had your farm mapped and monitored. Would you be willing to participate? [This question appears only if Q12 = No] [X1 is randomly generated integer from uniform distribution of range $0 to $15]	☐ Yes, I would participate ☐ No, I would not participate
38a	This deforestation-free premium might vary with the market price of cocoa. Would you still be willing to participate if the premium varies between **$0 to $2[X1]**? In some seasons it could be $0, other seasons up to $2[X1], or in between. [This question appears only if Q12 = No] [X1 is the same integer used in Q38]	☐ Yes, I would participate ☐ No, I would not participate
39	In this program, some farms are being monitored for deforestation using satellite technology. Suppose buyers offered you a premium of **$[X2] per bag** for deforestation-free cocoa if you agreed to have your property monitored. Would you be willing to participate? [This question appears only if Q12 = Yes & Q11 = Control] [X2 is randomly generated integer from uniform distribution of range $0 to $15]	☐ Yes, I would participate ☐ No, I would not participate
39a	This deforestation-free premium might vary with the market price of cocoa. Would you still be willing to participate if the premium varies between **$0 to $2[X2]**? In some seasons it could be $0, other seasons up to $2[X2], or in between. [This question appears only if Q12 = Yes & Q11 = Control] [X2 is the same integer used in Q39]	☐ Yes, I would participate ☐ No, I would not participate
40	In this program, your farm's deforestation status is being monitored, and you receive stickers on your cocoa bags showing this status. After this experiment ends, suppose buyers offered you a premium of **$[X3] per bag** for deforestation-free cocoa if you continued monitoring. Would you be willing to participate? [This question appears only if Q12 = Yes & Q11 = T1] [X3 is randomly generated integer from uniform distribution of range $0 to $15]	☐ Yes, I would participate ☐ No, I would not participate
40a	This deforestation-free premium might vary with the market price of cocoa. Would you still be willing to participate if the premium varies between **$0 to $2[X3]**? In some seasons it could be $0, other seasons up to $2[X3], or in between. [This question appears only if Q12 = Yes & Q11 = T1] [X3 is the same integer used in Q40]	☐ Yes, I would participate ☐ No, I would not participate

41	After this program ends, the deforestation-free premium payment might work differently. Suppose buyers offered you a premium of **$[X4] per bag** for deforestation-free cocoa if you continued monitoring. Would you be willing to participate? [This question appears only if Q12 = Yes & Q11 = T2] [X4 is randomly generated integer from uniform distribution of range $0 to $15]	☐ Yes, I would participate ☐ No, I would not participate
41a	This deforestation-free premium might vary with the market price of cocoa. Would you still be willing to participate if the premium varies between **$0 to $2[X4]**? In some seasons it could be $0, other seasons up to $2[X4], or in between. [This question appears only if Q12 = Yes & Q11 = T2] [X4 is the same integer used in Q41]	☐ Yes, I would participate ☐ No, I would not participate
42	Currently, if deforestation is detected on your farm, you lose the premium for that season but can continue selling to KKFU at the regular price. Suppose the rules changed: if deforestation is detected, you cannot sell to KKFU for the rest of the season and must sell to other buyers instead. What is the **minimum** premium per bag you would need to participate in this case? [This question appears only if Q12 = Yes & Q11 = T2]	☐ I would participate even with $0 premium ☐ At least $2 per bag ☐ At least $5 per bag (current level) ☐ At least $7 per bag ☐ At least $10 per bag ☐ At least $15 per bag ☐ At least $20 per bag ☐ No premium would be enough

Block A: Pending Checks (Activated only if "Yes" to Q13a):

Transaction number: <>, Farmer ID: <>, Farmer name: <>

A	Have you visited the farm with the farmer to check for deforestation?	☐ Yes ☐ No
B	Have you found any deforestation in that farm?	☐ Yes ☐ No

[These checks disappear from the Notification Centre when they are completed. The results are logged as a mini response into an Excel sheet. The deforestation alerts are then manually modified by the researchers, in the main dataset, if applicable.]

C District Warehouse Survey

Survey for Ghana Cocoa Traceability RCT Design

For District Manager or IMS Officer - bag level survey after shipment arrives at the depot

Section 1: Depot information (preloaded by the DM or the IMSO)

1	Region	Dropdown/list of Ghana regions
2	Society/District/Depot name	Dropdown/list of districts

Section 2: Scanned information (scanning the sticker on the bag preloads this information)

3	Zone/Village/SHED name	Dropdown/list of SHEDs in that district
4	Farmer ID	Automatically pulled from database
5	Transaction ID	Numeric input
6	Intervention group	☐ Control (C) ☐ Treatment 1 (T1) ☐ Treatment 2 (T2)
7	Deforestation status	☐ Green ☐ Red ☐ Not assigned
8	Farmer is a KKFU member?	☐ Yes ☐ No
9	Part of any certification scheme?	☐ FairTrade ☐ Rainfall Alliance/UTZ ☐ Organic ☐ Other ☐ No Certification

Section 3: Bag information

#	Question	Response Type
10	Is it a full bag (62.5 kg)?	☐ Yes ☐ No
10a	Weight if not a full bag (appears only if 'No' in previous question)	Numeric input

Section 4: Bean quality (KKFU)

11	Does this bag meet the KKFU standard for quality? (bean quality, dryness, presence of twigs and other material)	☐ Yes ☐ No
11a	Is this bag going to be re-dried or reconditioned, and rebagged? (appears only if 'No' in previous question)	☐ Yes ☐ No
11b	If rebagging is done, is the bag kept in a separate pile for easy identification? (appears only if 'Yes' in previous question)	☐ Yes ☐ No

D Purchasing Clerk Feedback Survey

Purchasing Clerks' End-of-Season Survey

Administered: January 2027 (via mobile app)

SHED information (pre-loaded)

Region	Dropdown/list of Ghana regions
Society/District/Depot name	Dropdown/list of districts
Zone/Village/SHED name	Dropdown/list of SHEDs in that district
Intervention group	☐ Control (C) ☐ Treatment 1 (T1) ☐ Treatment 2 (T2)

Section 1: OVERALL EXPERIENCE

1	How would you rate your overall experience using the mobile app this season?	☐ Very difficult ☐ Difficult ☐ Neutral ☐ Easy ☐ Very easy
2	Compared to previous seasons without the app, how much additional time did transactions take on average to digitally record them instead of manually?	☐ Much less time ☐ Slightly less time ☐ About the same time ☐ Slightly more time ☐ Much more time
3	Did using the app improve any aspects of your work? (Select all that apply)	☐ Faster record-keeping ☐ Fewer errors in records ☐ Better tracking of purchases ☐ Easier communication with district warehouse ☐ Other: [text field] ☐ No improvements

Section 2: TECHNOLOGY PERFORMANCE

4	Which parts of the app worked well? (Select all that apply)	☐ Recording transactions ☐ Searching for farmer IDs ☐ Administering surveys ☐ Printing stickers ☐ Checking deforestation status [T1/T2 only] ☐ Offline functionality ☐ All parts worked well

5	Which parts of the app caused problems or frustration? (Select all that apply)	☐ Slow loading times ☐ App crashes ☐ Printer malfunctions ☐ Difficulty finding farmer records ☐ Survey questions too long ☐ Poor internet connectivity ☐ Battery drain on tablet ☐ Other: [text field] ☐ No problems
6	How could the app be improved?	[Open text field]

Section 3: FARMER RESPONSES [Treatment-specific versions]

[For T1 & T2 clerks only]

7	How well did farmers understand the deforestation monitoring system?	☐ Not at all ☐ Slightly ☐ Moderately ☐ Well ☐ Very well
8	What was farmers' general attitude towards the monitoring?	☐ Very negative ☐ Negative ☐ Neutral ☐ Positive ☐ Very positive
9	Did farmers ask questions about which land would be monitored?	☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Very often

[For T2 clerks only]

10	How much difficulty did you have explaining the premium system to farmers?	☐ No difficulty ☐ Slight difficulty ☐ Moderate difficulty ☐ High difficulty ☐ Very high difficulty
11	How much additional time did processing no-deforestation rewards add to transactions?	☐ No additional time ☐ 1 minute ☐ 2-5 minutes ☐ 5-10 minutes ☐ More than 10 minutes

12	Were there any problems with premium payments? (Select all that apply)	☐ Calculating correct amounts ☐ Farmers disputing eligibility ☐ Payment processing delays ☐ Record-keeping complications ☐ Other: [text field] ☐ No problems

[For T1 clerks only]

13	Did farmers ask why some bags received different colored stickers?	☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Very often

Section 4: WORKFLOW IMPACT

14	Which part of using the app created the most hassle or took the most time?	☐ Transaction recording ☐ Survey administration ☐ Sticker printing ☐ Premium calculations [T2 only] ☐ Tablet/printer setup ☐ Technical problems ☐ Other: [text field]
15	If KKFU continues using this system, what is the most important improvement needed?	[Open text field]
16	How adequate was the training you received before using the app?	☐ Very inadequate ☐ Inadequate ☐ Adequate ☐ More than adequate ☐ Very thorough

Section 5: OPTIONAL COMMENTS

17	Any other feedback about the program, app, or monitoring system?	[Open text field]

E Training Protocols

Training of KKFU purchasing clerks will occur in two phases. In May 2026, clerks will receive remote training on how to deliver an information intervention to farmers at the beginning of the cocoa season, when farmers are making land-use decisions. In September 2026, clerks will receive in-person technical training on mobile app usage specific to their treatment assignment. District manager training will also take place in September 2026.

Phase 1: Training for the Information Intervention (May 2026)
Purchasing clerk training will be conducted remotely via (i) SMS messages, (ii) audio messages, and (iii) individualized phone calls in the local language. Clerks will receive all three of these communications sequentially to ensure maximum comprehension, impact, and retention, with the final phone call resolving any doubts or questions. Each clerk will receive instruction on the farmer information intervention specific to their zone's treatment assignment.

Control Group Remote Training: Purchasing clerks in control zones will receive training on how to inform farmers that KKFU is introducing a mobile application to collect data on cocoa purchases, improve operations, and support research on sustainable supply chains. Training will focus on obtaining informed consent, with emphasis on explaining the research purpose and data use in terms farmers can understand.

Control Group Information Script for Farmers: Clerks will deliver the following script to all farmers in their zone through group or individual meetings, by the end of May 2026:

"KKFU is introducing a new mobile app to record cocoa purchases and help us improve our operations. The app is also being used for research about sustainable cocoa supply chains. When you sell cocoa to me, I will use this app to record information about your transaction, just as I have always done, but now digitally instead of on paper. I will also ask you survey questions about your farm and your experience selling cocoa. Your participation is voluntary, and whether or not you participate will not affect your ability to sell cocoa to KKFU or the price you receive. The information you provide will be kept confidential and used only for research purposes."

Treatment 1 Remote Training: Purchasing clerks in T1 zones will receive training on how to: (1) explain the satellite-based deforestation monitoring system to farmers, (2) inform farmers about

the certification tags they will receive for deforestation-free cocoa, and (3) respond to common farmer questions about how alerts are generated, what constitutes deforestation, and how certification status is determined.

Treatment 1 Information Script for Farmers: Clerks will deliver the following script to all farmers in their zone through group or individual meetings, by the end of May 2026:

"KKFU is introducing a new mobile app to record cocoa purchases and help us improve our operations. The app is also being used for research about sustainable cocoa supply chains. We are using satellite images—pictures taken from space—to monitor forest clearing on cocoa farms in this area. When you sell cocoa to me, I will use the app to check whether satellites have detected forest clearing on your mapped farm plots. If your plots show no recent forest clearing, you will receive a special tag on your cocoa bags that certifies your cocoa as deforestation-free. This tag proves to buyers that your cocoa was produced sustainably. This could help KKFU access better markets for our cocoa in the future. When you come to sell, I will also ask you survey questions about your farm and your experience selling cocoa. Your participation is voluntary, and whether or not you participate will not affect your ability to sell cocoa to KKFU or the price you receive. The information you provide will be kept confidential and used only for research purposes."

Treatment 2 Remote Training: Purchasing clerks in T2 zones will receive the same training as T1 clerks, plus instruction on: (1) explaining the $5-per-bag premium for deforestation-free cocoa, (2) clarifying premium eligibility criteria to farmers, and (3) explaining what happens if deforestation is detected on farmers' plots during the season.

Treatment 2 Information Script for Farmers: Clerks will deliver the following script to all farmers in their zone through group or individual meetings, by the end of May 2026:

"KKFU is introducing a new mobile app to record cocoa purchases and help us improve our operations. The app is also being used for research about sustainable cocoa supply chains. We are using satellite images—pictures taken from space—to monitor forest clearing on cocoa farms in this area. When you sell cocoa to me, I will use the app to check whether satellites have detected forest clearing on your mapped farm plots. If your plots show no recent forest clearing, you will receive a special tag on your cocoa bags that certifies your cocoa as deforestation-free. For each bag that receives this certification tag, you will also receive an extra payment of $5, at the end of the season. This premium rewards you for preserving forest on your land. If forest clearing is detected on your farm plots, you will not receive the premium for any of your cocoa, but you can still sell it at the regular price. When you come to sell, I will also ask you survey questions

about your farm and your experience selling cocoa. Your participation is voluntary, and whether or not you participate will not affect your ability to sell cocoa to KKFU or the price you receive. The information you provide will be kept confidential and used only for research purposes."

Phase 2: In-Person Technical Training (September 2026)

In-person training sessions will take place at KKFU district offices in September 2026, immediately prior to the October harvest season. Training sessions will be conducted separately by treatment group to maintain protocol fidelity and prevent cross-contamination. Each clerk training session will include: (1) technical training on the mobile app and data collection procedures, (2) practice sessions using tablets and printers, and (3) review of treatment-specific protocols for interacting with farmers during cocoa transactions.

Control Group Technical Training: Purchasing clerks in control zones will receive training on basic mobile app functionality for recording cocoa transactions and administering surveys. The app will not display any information about farmers' deforestation status to clerks in control zones. Training will emphasize data collection accuracy, consistent app use, and regular app syncing at district warehouses.

Treatment 1 Technical Training: Purchasing clerks in T1 zones will receive the same training on the mobile app as control zone clerks, as well as training on how to: (1) access and interpret deforestation status alerts, (2) print bag tags displaying farmers' deforestation-free certification status, and (3) explain the monitoring system to farmers during transactions. Clerks will practice using tablets and printers and responding to farmer questions about certification status.

Treatment 2 Technical Training: Purchasing clerks in T2 zones will receive the same technical training as T1 clerks, plus additional instruction on: (1) calculating and distributing $5-per-bag premiums for deforestation-free cocoa, (2) recording premium payments in the mobile app, and (3) managing end-of-season premium payouts. Clerks will practice the full transaction workflow including premium calculations.

Handling Deforestation Alert Challenges. Purchasing clerks in Treatment 1 and 2 zones will also receive specific training on how to respond when a mapped farmer challenges a red (deforestation-detected) flag. If a farmer disputes the flag, the clerk will accompany the farmer to the property to

conduct a visual inspection. Clerks will be trained to look for physical evidence consistent with recent forest disturbance, including freshly felled or downed trees, visibly cleared ground, damaged vegetation, evidence of burning, and fresh cutting or clearing tools or debris. If the clerk observes clear physical evidence of recent deforestation consistent with the alert, the clerk will not overrule the flag, regardless of the farmer's objections or requests. Clerks will be explicitly instructed to remain firm in these cases: the purpose of the property visit is to check for satellite measurement error, not to provide farmers a route to dispute legitimate detections, and clerks acquiescing to pressure to overlook clear evidence of deforestation undermines the integrity of the monitoring system for all participating farmers. All challenges and outcomes (challenged/not challenged, visited/not visited, overruled/upheld) will be logged in the app, allowing KKFU monitoring and evaluation staff and the research team to review overrule patterns for consistency across clerks and zones.

District Manager Technical Training: District managers will receive in-person training in September 2026 on using the district portal of the mobile app to maintain traceability throughout KKFU's supply chain. Training will focus on how to: (1) scan bag tags when cocoa arrives at district warehouses, (2) record quality inspection results for each tagged bag, and (3) document re-bagging outcomes when damp or damaged bags must be consolidated or replaced. Training will emphasize the importance of scanning every tagged bag to preserve the chain of custody for deforestation-free certification. District managers will practice using the scanning interface and troubleshooting common issues such as damaged tags.

F Ethics Approval

UNIVERSITÉ DE GENÈVE

CUREG 2.0

COMMISSION UNIVERSITAIRE POUR UNE RECHERCHE ETHIQUE A GENEVE (CUREG)

DECISION FORM: CUREG-2025-08-133

CUREG DECISION: Certification of Ethical Compliance*

- ☐ **PROCEDURE APPLIED TO MASTER'S PROJECT OR MASTER OF ADVANCED STUDIES (MAS)**
- ☒ **FAST TRACK PROCEDURE APPLIED TO RESEARCH PROJECT**
- ☐ **IN-DEPTH PROCEDURE APPLIED TO RESEARCH PROJECT**
- ☐ **MODIFICATION OF A PREVIOUSLY APPROUVED PROJECT**

1. Title of the research project	Traceability and Sustainability in Cocoa Supply Chains: Experimental Evidence from Ghana
2. Responsible researcher(s)	Salvatore Di Falco Utsoree Das
3. Funding	Horizon Europe (HORIZON) Project: 101081984 — TRANSPATH
4. Faculty / Interfaculty center	GSEM

Date of submission to the Commission	22.08.2025
Decision of ethical compliance	yes ☒ no ☐
Date of acceptance (sent by e-mail)	06.02.2026
Expected completion date of the project	31.10.2028
Signature of CUREG President:	 Sébastien Castelltort Date: 17.02.2026

**** This authorization is valid only until the date of completion of the project and conditional to the binding recommendations of the commission (available on your personal space on the platform or, in the case of a Master's project, in the validation email) if applicable.***

Any changes to the project (title, number of participants, duration of the research, etc.) must be reported to the CUREG before the completion date.
Please contact us at "commission-ethique@unige.ch".

Commission Universitaire pour une Recherche Ethique à l'Université de Genève
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