IMPROVING CAPACITY BUILDING AND KNOWLEDGE SHARING TO SUPPORT MANAGEMENT OF CADMIUM LEVELS IN LATIN AMERICA AND THE CARIBBEAN

STDF/PG/577

END OF PROJECT REPORT

Report Date : 24 Oct 2025

PROJECT INFORMATION

STDF/PG/577

Title

Improving Capacity Building and Knowledge Sharing to Support Management of Cadmium Levels in Latin America and The Caribbean

Implementing agency

Inter-American Institute for Cooperation on Agriculture (IICA)

Partners

Cocoa Research Centre (CRC) in Trinidad and Tobago, Colombian Agricultural Research Corporation (AGROSAVIA), The Ministry of Agriculture and Irrigation (MINAGRI), currently The Ministry of Agricultural Development and Irrigation of Peru (MIDAGRI), Instituto Nacional de Investigaciones Agropecuarias of Ecuador (INIAP)

Start date

01/02/2022

End date

30/09/2025
Extension from 31/01/2024 to 30/09/2025

Beneficiary/ies

Colombia, Ecuador, Peru and Trinidad and Tobago

Budget

Project Total Value: Contract USD 550,948 | Actual total project value USD 814,119

STDF contribution: USD 381,946

Other contribution: Total in-kind contribution – Contract USD 103,748 | Actual USD 368,743
Total co-financing from EU – Contract USD 65,254 | Actual USD 63,430.02

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LIST OF ABBREVIATIONS

AEZ – Agro-Ecological Zone (Trinidad and Tobago)

CALMAG – Plant nutrient supplement that provides calcium and magnesium

Cd – Cadmium

CDCTTL – Cocoa Development Company of Trinidad and Tobago Limited

CGC – Cocoa Growing Community (Trinidad and Tobago)

CV - Coefficient of Variation

11th EDF – 11th cycle of the European Development Fund

E-max – Equipment used for cadmium and heavy metal analysis

EU – European Union

FEDECACAO – Federación Nacional de Cacaoteros (Colombia)

GFAAS - Graphite Furnace Atomic Absorption Spectroscopy

ICCO – International Cocoa Organization

ICENS - International Center for Environmental and Nuclear Sciences (Jamaica)

ICP-MS - Inductively coupled plasma mass spectrometry

ICP-OES - Inductively coupled plasma mass spectrometry

IICA – Inter-American Institute for Cooperation on Agriculture

INIA – Instituto Nacional de Innovación Agraria (Peru)

INIAP – Instituto Nacional de Investigaciones Agropecuarias (Ecuador)

ISBN - International Standard Book Number

ISO - International Organization for Standardization

MALF – Ministry of Agriculture Lands and Fisheries (Trinidad and Tobago)

MEL – Monitoring, Evaluation, and Learning

NPIA – National Project Implementation Agency

PEA – Project Executing Agency

pH – Potential of Hydrogen (soil acidity/alkalinity measure)

PMU – Project Management Unit

PTA – Project Technical Annex – Recommendations for improvement of and inclusion in National Cocoa Sector Plans

r – Pearson correlation coefficient

SD – Standard Deviation

LIST OF ABBREVIATIONS CONTINUED

SENASA – Servicio Nacional de Sanidad Agraria (Peru)

SOP – Standard Operating Procedure

SPS – Sanitary and Phytosanitary

STDF - Standards and Trade Development Facility

T&T – Trinidad and Tobago

UWI-CRC – University of the West Indies – Cocoa Research Centre

XRF - X-ray Fluorescence

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1. EXECUTIVE SUMMARY

The project titled "Improving Capacity Building and Knowledge Sharing to Support Management of Cadmium Levels in Latin America and the Caribbean" (STDF/PG/577) was launched in response to the European Union's 2019 enforcement of Maximum Residue Limits (MRLs) for cadmium in cocoa and chocolate products. These new regulations posed a direct threat to market access for Latin American and Caribbean (LAC) countries, which supply 20% of the world's cocoa and over 80% of its fine flavour production. The project enabled Colombia, Ecuador, Peru, and Trinidad & Tobago to build on the scientific evidence, tools, and capacity needed to manage cadmium in cocoa, comply with international standards, safeguard market access, protect farmer livelihoods, and reduce health risks from cadmium exposure.

The project was approved on 19 January 2022 and officially implemented from 1 February 2022, with an original end date of 31 January 2024. Due to political and administrative delays particularly, extensions were granted, moving the final reporting deadline to 30 September 2025. The total project budget was USD 814,119, with contributions from STDF (USD 381,946), in-kind support (USD 368,743), and EU co-financing (USD 63,430).

Implemented by the Inter-American Institute for Cooperation on Agriculture (IICA) in partnership with the cadmium in cocoa national scientific institutions AGROSAVIA (Colombia), MIDAGRI (Peru), INIAP (Ecuador), and the Cocoa Research Centre at UWI (Trinidad and Tobago), the project established harmonized, quality-assured cadmium testing protocols for LAC, developed a Master Trainers' curriculum and webinar series to share knowledge across the cocoa value chain, and delivered tailored mitigation strategies formally integrated into national cocoa sector plans.

Among the most significant achievements was the training of 80 (26 women and 54 men) laboratory technicians across all four project countries, far exceeding the original target. These individuals were trained in standardized cadmium testing techniques using advanced tools such as ICP-MS and the E-max analyzer, a low-cost, rapid XRF-based technology validated under the project and now officially applied by the Ministry of Agriculture in Trinidad and Tobago. Additionally, 173 Master Trainers (51 women and 122 men) were trained across the four countries and cascaded their knowledge to more than 2,300 cocoa farmers proving the efficacy of the method to promote broad uptake of cadmium mitigation strategies.

Cadmium hotspot maps for cocoa beans and soils were developed for Colombia. Over 1,000 samples identified Arauca and Santander, located in the northeast of the country, as critical hotspots, with cocoa bean cadmium levels exceeding 15 mg/kg. In contrast, Nariño and Meta, located in the southwest and central regions, were found to be low-cadmium areas, making them suitable for cocoa expansion. A total of 1,010 soil samples and 120 bean samples were analysed from cadmium hotspots in Piura, San Martín, and Huánuco the main cocoa regions of Peru. In addition, data from 100 farms in Trinidad and Tobago, water and fertilizer analyses provided valuable insights into region-specific contamination drivers, including soil acidity, low calcium levels, geological characteristics, and fertilizer use. These data guide targeted interventions based on environmental and soil conditions.

In Trinidad and Tobago, researchers at the Cocoa Research Centre used the higher-resolution cadmium data to create a Farm Categorization Model, grouping farms into four categories based on bean Cd levels and agro-ecological factors to guide targeted mitigation:

- Category 1: >0.8 mg/kg (high risk)
- Category 2: 0.6–0.8 mg/kg (moderate risk)
- Category 3: 0.5–0.6 mg/kg (low risk)
- Category 4: <0.5 mg/kg (very low risk)

Each category was linked to tailored mitigation actions, such as lime application, use of low-Cd rootstock, organic matter amendment, flood control, and blending of beans from lower-Cd zones.

This categorization model not only guides national interventions but also serves as a blueprint for adaptation in other LAC countries with similar production systems.

Importantly, the project uncovered that both organic and synthetic fertilizers are a major source of cadmium contamination. In Colombia, several products were found with cadmium levels up to 40 mg/kg, while in Ecuador and Peru, more than 13% of tested fertilizers exceeded regulatory limits. These findings highlight the need for improved fertilizer regulation, monitoring, and farmer awareness.

The project produced key technical resources to strengthen regional capacity on cadmium management in cocoa. These include two bilingual manuals: a **Standard Operating Procedure (SOP) Manual for Cadmium Testing** (English ISBN: 978-92-9273-152-6; Spanish ISBN: 978-92-9273-151-9) and a **Curriculum for Training Extension Specialists** (English/French and Spanish editions; ISBN: 978-99-4222-605-1). In addition, a **Pocketbook Glossary** (English ISBNs: 978-92-9273-158-8 digital / 978-92-9273-159-5 print; Spanish ISBNs: 978-92-9273-160-1 digital / 978-92-9273-161-8 print) was developed to harmonize cocoa sector terminology across Latin America and the Caribbean. All resources are freely available in both print and digital formats.

Dissemination products included eight informational bulletins, six training videos, and a comprehensive training curriculum adopted across all project countries and hosted on IICA's Agriperfiles platform. Five webinars, which together reached a diverse global audience of 216 (99 women and 107 men) consistent participants from 32 countries in the five continents. Findings were also disseminated through scientific publications, including three peer-reviewed articles documenting the first national mapping of cadmium in Colombian cocoa https://doi.org/10.1016/j.scitotenv.2024.176398, cadmium levels in fertilizers used in cocoa production in Colombia https://doi.org/10.1080/19440049.2025.2537872 and assessing X-ray fluorescence as a reliable method to measure cadmium in cacao https://doi.org/10.1016/j.sab.2025.107352, Inception, Midterm and End of Project workshops.

Long-term sustainability is supported through nine mitigation strategies including targeted blending which have been consolidated into national cocoa sector plans in Colombia, Ecuador, and Peru. In Trinidad and Tobago, the updated plan is under governmental review, but proactive steps, including procurement of the E-max analyser and training of technicians from the Ministry of Agriculture Land and Fisheries, have already been taken.

Recommendations to maintain momentum and expand impact at targeted stakeholders include the following actions;

- Governments should enforce cadmium limits in fertilizers and cocoa, and support localized mitigation planning.
- National authorities should institutionalize SOPs and training materials into extension and laboratory systems.
- Laboratories should regularly participate in inter-lab quality control exercises analysing the same samples and comparing results or ring tests to verify accuracy and maintain compliance with international quality standards.
- Donors and STDF are encouraged to invest in certification schemes and lab infrastructure upgrades across the region.
- Private sector actors should invest in traceability systems, cadmium-compliant sourcing, and farmer capacity building.

The project generated several positive spill overs beyond its core objectives. It fostered stronger institutional collaboration among cocoa stakeholders, improved laboratory capacity applicable to other crops and contaminants, and increased awareness of food safety standards across the agricultural sector. The cadmium training materials and mitigation strategies are now being adapted for broader use. Importantly, the project also supported the development of human capital contributing to two graduate degrees (one MSc and one PhD) in Peru and Ecuador respectively, both of which were directly informed by project activities, data and findings. Regional partnerships established through the project have also laid a foundation for future collaboration in food safety and trade compliance. The project has built a strong foundation for cadmium risk management in cocoa and represents a regional model for tackling emerging food safety challenges through coordinated science, training, and policy reform.

2. OVERVIEW

The project addressed SPS compliance issues by building human laboratory capacity, updating cadmium hotspots maps, training Master Trainers and farmers in mitigation practices, and creating a regional platform for consensus on harmonized cadmium testing protocols, leading to improved compliance with international cadmium MRLs for cocoa products and securing export markets.

Project background and Context:

Improving Capacity Building and Knowledge Sharing to Support Management of Cadmium Levels in Cocoa in Latin America and the Caribbean responded to an urgent SPS (Sanitary and Phytosanitary) challenge in Latin America and the Caribbean by equipping cocoa-producing countries with the science-based evidence, tools, and capacity to manage cadmium. This science-driven approach safeguards international market access, protects farmer livelihoods, and reduces health risks from cadmium exposure, ensuring cocoa remains a safe, viable, and competitive export.

Objective:

Countries (Colombia, Ecuador, Peru, and Trinidad & Tobago) comply with international standards and import requirements for cadmium limits in cocoa and cocoa-derived products.

Background and Rationale:

In January 2019, the EU enforced regulations setting strict cadmium limits for chocolate and cocoa products. Other countries, including the USA (California Proposition 65), are following with similar standards. The LAC region supplies nearly 20% of the world's cocoa and over 80% of fine flavour and organic cocoa, mainly to the EU and USA. High cadmium levels in cocoa threaten market access, rural employment, and farmer livelihoods. Cocoa beans can absorb cadmium naturally from soils with geological or anthropogenic cadmium deposits. Bioavailability depends on factors like soil pH, organic matter, and cocoa variety genetics. Loss of cocoa markets would adversely impact the livelihoods of over 200,000 cocoa farming families in Colombia, Ecuador, Peru and Trinidad and Tobago and could push farmers back to illicit crop production, particularly in Colombia.

Key Issues Identified by the STDF PPG/577 conducted by the ICCO:

The PPG assessed research and practices on cadmium mitigation in cocoa beans across Latin America and the Caribbean, identified knowledge gaps, and consulted stakeholders to develop a regional strategy framework. This framework provided recommendations and informed the PG/577 project proposal aimed at supporting coordinated regional action, improving cocoa quality, and ensuring compliance with international standards in cocoa and cocoa products. Some of the key findings of PPG/577 include;

- Lack of harmonized cadmium testing protocols and terminology across countries.
- Limited knowledge sharing and coordination among LAC countries.
- Knowledge gaps in mitigation strategies for farmers and extension workers.
- Complexity of cadmium uptake due to soil, plant genetics, and management factors.
- Low awareness among farmers and stakeholders about cadmium issues.
- Socioeconomic risks for smallholder farmers and rural communities.

PG/577 Project Approach:

- Create a regional platform/network to coordinate cadmium research and build consensus on harmonized testing protocols among NPIAs.
- Standardize sampling, cadmium testing methods, and glossary for better comparability across NPIA laboratories in LAC.
- Update cadmium hotspot maps in cocoa-producing regions to guide mitigation efforts.
- Develop a Master Trainer curriculum to scale farmer training on cadmium mitigation practices.
- Disseminate best practices for soil management, varietal selection, and post-harvest handling.

Context in Relation to National/Regional Policies:

- The project aligns with national cocoa development plans and food safety initiatives in Colombia, Ecuador, Peru, and Trinidad & Tobago.
- It supports alternative livelihood strategies (e.g., post-conflict rural development in Colombia) and regional agricultural sustainability goals.

Thus, the project directly supported SPS compliance by giving countries the scientific, technical, and operational tools to meet international cadmium limits securing market access for their cocoa exports.

PROJECT THEORY OF CHANGE

SPS Problem:

- The EU implemented Regulation No. 488/2014 and CF/12 INF/1 from the Codex Alimentarius Commission established strict Maximum Residue Limits (MRLs) for cadmium (Cd) in cocoa and cocoa products.
- If countries like Colombia, Ecuador, Peru, and Trinidad & Tobago could not comply, they risked losing export markets, damaging farmers' livelihoods and national economies.

Project Approach:

- **Regional Cooperation:** Established a platform for knowledge sharing among participating countries to coordinate cadmium research and build consensus to harmonize protocols.
- **Testing and Standards:** Created a standardized cadmium testing manual, used by NPIAs and adoptable by LAC laboratories, to deliver consistent, quality-assured results compliant with international standards.
- **Mapping and Risk Identification:** Updated cadmium hotspots maps to identify high-risk growing areas, allowing targeted intervention.
- **Knowledge Transfer:** Developed manuals, glossaries, and training programs for lab staff, extension officers, and farmers to promote best practices in reducing cadmium uptake.
- **Capacity Building:** Trained lab technicians, Master Trainers and farmers to strengthen practices that reduce cadmium levels in cocoa and cocoa products at the source.
- **Awareness Raising:** Produced materials and conducted public campaigns to help farmers and stakeholders understand the risks of Cd contamination and best mitigation practices according to current scientific knowledge.

Global Impact

- Sustainable market access maintained for cocoa and cocoa-derived products from Colombia, Ecuador, Peru, and Trinidad & Tobago.

Long term Outcomes

- Countries comply with international standards (Codex and EU MRLs for cadmium).
- Decrease in rejections of cocoa shipments due to Cadmium levels.
- Increased value of cocoa exports.

Intermediate Outcomes

- Laboratories use standardized cadmium testing protocols.
- Farmers in hotspot regions apply mitigation best practices.
- National authorities implement cadmium mitigation strategies.

Project Outputs

- One bilingual SOP manual with standardized and harmonized Cd testing protocols with 80 lab technicians trained.
- Created cadmium soil and bean maps for COL and detailed risk profiles for PER's key cocoa-producing areas. Improved the granularity of cadmium hotspot soil and bean maps for Ecuador and Trinidad and Tobago.
- 173 Master trainers trained, delivering outreach to 2,300 farmers.
- Developed and disseminated a Master Trainers' curriculum with training aids in ENG, FRE, and SPN; a glossary of cocoa-sector terms in ENG and SPN; and video summaries with Q&As from a five-part webinar series called 'Cd Talks' designed to simplify the science and key issues of cadmium in cocoa.
- Three peer-reviewed publications on; the first national Cd hot spot map for Colombia; cadmium levels in fertilizers used in cocoa production in Colombia; assessing X-ray fluorescence as a reliable method to measure cadmium in cacao
- National authorities endorsed the recommended nine cadmium mitigation strategies for implementation in national cocoa sector plans.
- Developed a Farm Categorization Model that integrates environmental factors, production practices, and soil and heavy metal analysis results to design targeted cadmium mitigation strategies for cocoa farms in Cd hotspots in TTO.

Project Activities

- Developed a Platform to derive standardized Cd testing protocols and manuals.
- Trained lab technicians and master trainers.
- Conducted coordinated cadmium testing on cocoa beans, soils, water, and both inorganic and organic fertilizers used in cocoa production to identify contamination sources and update cadmium hot spot maps.
- Raised awareness among farmers and cocoa value chain actors.
- Hosted inception, midterm, and final workshops
- Shared results and promoted regional dialogue intra and inter projects with STDF/PG/681.

3. PROJECT IMPLEMENTATION

The Inter-American Institute for Cooperation on Agriculture (IICA) and the Standards and Trade Development Facility (STDF) fully executed the project implementation agreement on 19 January 2022, with the official implementation period spanning 1 February 2022 to 31 January 2024. As the Project Executing Agency (PEA), IICA was responsible for establishing formal agreements with the National Project Implementing Agencies (NPIAs) in each of the four participating countries Colombia, Ecuador, Peru, and Trinidad and Tobago. These NPIAs, recognized as the leading national scientific institutions engaged in cadmium research in cocoa, were granted access to project funds through these agreements, enabling them to initiate country-level activities in alignment with the regional project objectives.

The Cocoa Research Centre (CRC) at the University of the West Indies (UWI), St. Augustine, Trinidad and Tobago, was the first NPIA to sign its agreement with IICA Barbados under the 11th EDF SPS project funded by the EU, on 23 June 2022. Dr. Gideon Ramtahal was appointed as focal point. Agrosavia in Colombia signed next on 11 August 2022, naming Dr. Daniel Bravo as focal point. MIDAGRI in Peru followed on 31 August 2022, appointing Ms. Carmen Rosa Chavez (SENASA) as NPIA Lead. However, political transitions in Peru led to rapid administrative changes, with Mr. Javier Zapata (SENASA) eventually assuming the role of focal point and the Ministry's name reverting to MINAGRI in 2023. INIAP in Ecuador experienced the most complex conditions in finalizing its agreement with IICA, reflecting broader political and security challenges in 2022–2023. The agreement was successfully signed on 31 January 2023, with Dr. Manuel Carrillo appointed as focal point on 25 April 2023. Project implementation across all countries formally commenced in May 2023, following a 15-month delay. As a result, STDF granted a project extension to 31 Mar 2025 and a further extension was granted to 30 Sep 2025 for the completion of the End of Project Assessment and submission of the final report.

The project was managed from the IICA Delegation in Jamaica, led by Dr. Elizabeth Johnson, who oversaw the Project Management Unit (PMU), comprising an Assistant Project Manager, a Platform Lead Consultant, an Information Specialist, and a Budget Monitor. Following the conclusion of Mr. Nelson Laville's tenure as Project Administrator on 12 May 2023, Dr. Caleb Lewis was appointed as Assistant to the Project Lead, serving from 28 August 2023 to 31 January 2024, with a subsequent extension through 31 March 2025. The Platform Lead Consultant, Ms. Sarah Bharath, and the Information Specialist, Mr. Chavez Creary, were initially contracted from 1 June 2022 to 31 January 2023, with two extensions: first to 30 June 2023 and then to 31 January 2024, to accommodate the timelines for deliverables requiring inputs from all four NPIAs.

Dr. Lewis, Ms. Bharath, and Mr. Creary demonstrated strong commitment to the project and satisfactorily completed their contract terms. They also continued to support the project team with additional small requests beyond their formal duties. Notably, Ms. Bharath, reflecting her dedication to the project's goals, self-funded her participation to the End-of-Project Workshop held in Guayaquil, Ecuador in November 2024.

The PMU's Budget Monitor, Mr. Ainsworth Riley, an Agribusiness Specialist at IICA Jamaica, worked closely with the project administrators in each country: Mrs. Donna Halstead-Perry (IICA Jamaica), Mr. Pedro Sicacha (IICA Colombia), Mr. Alejandro Calle (IICA Ecuador), Mr. Ricardo Lopez (IICA Peru), and Ms. Salisha Estrada (IICA Trinidad and Tobago). Additionally, IICA designated a technical focal point in each project country: Ms. Viviana Maria Borda (Colombia), Mr. Julio Escobar, assisted by intern Christian Sobrevilla (Ecuador), Ms. Erica Soto, assisted by intern Rosario Alarcón (Peru), and Mr. Richard Rampersaud (Trinidad and Tobago). Together with the PMU and NPIAs, these individuals formed the project's administrative and technical teams.

The project was guided by a Steering Committee composed of senior decision-makers from the national cocoa sectors of each project country, Dr. Omar Dominguez, Director of Research FEDECACAO Colombia, Dr. Manuel Danilo Carrillo Zenteno, Head of the Soil and Water Department, INIAP Ecuador, Christian Alejandro Garay Torres, Deputy Minister of MINAGRI Peru with alternate Dr. Jorge Figueroa Rojas, MIDAGRI Focal Point Peru and Dr. Simone Titus, Chief Technical Officer, with alternates Mr. Ian Mohammed, Research Director and Mr. Amel Baksh, Deputy Research Director of the Ministry of Agriculture, Land and Fisheries (MALF) Trinidad and Tobago. These individuals played a key role in facilitating the endorsement and integration of consensus recommendations, generated by the NPIAs, into their respective National Cocoa Sector Plans. Their leadership ensured that project outcomes could be translated into actionable strategies at the national level, thereby strengthening the sustainability and policy alignment of project interventions.

Last but by no means least, Dr. Johnson greatly appreciated the guidance and support provided by Mr. Simon Padilla (Economic Affairs Officer), Ms. Ezinne Anyanwu former MEL Specialist, and Ms. Aichetou Ba (Monitoring, Evaluation and Learning Specialist) from the Standards and Trade Development Facility (STDF); Mr. Michel Arrion (Executive Director), Mr. Yunusa Abubakar (Program Officer) and Mr. Michele Nardella (Director of Economics and Statistics Division) from the International Cocoa Organization (ICCO); throughout the course of project implementation.

4. ACHIEVEMENT OF RESULTS

This project successfully strengthened the scientific, technical, and operational tools of Colombia, Ecuador, Peru, and Trinidad and Tobago to comply with regulatory limits on cadmium in cocoa and chocolate products, ensuring continued access to the EU market. These results were achieved through the completion of the following key deliverables:

- **Outcome 1** - Standardized testing protocols and best practices applied by laboratories in project countries.

1.1. Output: Regional platform established for consensus on standardized testing protocols *by lead research agencies from Colombia, Ecuador, Peru and Trinidad and Tobago*:-

The National Project Implementing Agencies (NPIAs) and IICA Technical Staff in Colombia, Ecuador, Peru, and Trinidad & Tobago formed dedicated committees to source and review publications, agency reports, and gray literature on cadmium (Cd) in cocoa. Their goals were to:

- gather and systematize relevant knowledge to establish consensus on standard Cd testing protocols for the region.
- train technicians from Colombia, Ecuador, Peru and Trinidad and Tobago in agreed standardized and harmonized Cd testing protocols.
- based on agreed Cd testing protocols, identify effective strategies for mitigating Cd levels in cocoa and cocoa products for inclusion and implementation in National Cocoa strategies for endorsement by relevant national cocoa authorities.
- derive a glossary to standardize terms used among cocoa actors across the project countries.

The committees were coordinated by Platform Technical Lead, Ms. Sarah Bharath, and Information Specialist, Mr. Chavez Creary, who were part of the Project Management Unit (PMU) in Jamaica. Ms. Bharath, with extensive experience in the cocoa private sector including work with companies, farmers, NGOs, and academia played a key role in engaging industry experts. Her efforts brought valuable insights from various stakeholders, enriching the technical discussions on Cd mitigation strategies and adoption challenges.

As part of the efforts to identify appropriate strategies to mitigate Cd levels in cocoa and cocoa products, a total of five seminars from the private sector were organized with lessons learned summarized below:

- **Chocolate makers' at origin (Casa Luker - by (Maria Jose Chica – Research Lead, Casa Luker) – (4 Oct 2022).** Heavy metal contamination in food extends beyond cacao, with common foods like salad greens and fruits containing higher levels of arsenic, cadmium, lead, and mercury. Exposure risk increases when low-contaminated foods are consumed in large quantities.
  Field mitigation strategies include using low-cadmium fertilizers, high-quality irrigation water, lime, organic matter, zinc amendments, suitable cultivars, and planting in clayey neutral soils. Casa Luker is addressing cadmium regulations through knowledge-building, mapping contamination, and implementing mitigation strategies at agronomy, postharvest, production, and product levels.
  Key findings include cadmium accumulation in cacao (highest in dry leaves, lowest in soil), the volcanic origin of Latin American soils, and collaborations to tackle the issue. Microorganisms show promise in reducing cadmium during fermentation, and nanotechnology is being tested at the lab scale to remove cadmium from cacao liquor. Casa Luker is also adjusting its product portfolio and training staff and clients to manage the cadmium situation.

- **Farmer perspectives and potential factors influencing their adoption of cadmium mitigation strategies by (Alejandro Gil, Penn State University & National Chocolate Company, Colombia) – (04 Oct 2022)**- A Penn State PhD study explored factors influencing the adoption of cadmium mitigation practices in cacao farming using a mixed-methods approach. Adoption of mitigation methods remains low, risking their effectiveness, and the factors influencing adoption are not well understood. Two mitigation technologies soil amendments and improved cacao varieties (clonal) were studied. Key factors influencing adoption included:
    - For clonal cacao: Farmer beliefs about its impact on productivity and bean flavor and quality, as well as the personality trait of conscientious planning.
    - For soil amendments: Belief in their impact on productivity, access to extension services, conscientious planning, and perceived need to control soil pH.

  Notably, the perceived need to control cadmium contamination did not influence farmer decisions for either technology. Donations of soil amendments also did not drive adoption.

  Conclusions:
    - Cadmium concerns were irrelevant to farmer adoption behavior.
    - Adoption is highly location-specific and depends on socioeconomic and environmental conditions.
    - Different innovations follow different adoption processes.
    - Extension services play a crucial role in soil amendment adoption.
    - Farmers' beliefs and conscientious planning significantly influence technology adoption.

- **Buyers at European destination** - **by (Cacao Latitudes/ECOM) by (Kate Cavallin, Cacao Latitudes/ECOM) – 14 Feb 2023.** Cocoa producers face significant challenges in managing on-farm cadmium (Cd) contamination, with limited knowledge of risk factors, reduction methods, costs, and timelines. High cocoa content chocolate and cocoa powder are most at risk. Industry buyers struggle with reliable Cd quantification, lacking standardized sampling methods, representative sample sizes, and widely accessible certified labs. Multiple testing episodes across the supply chain increase costs and complexity. There is no definitive list of EU-approved labs for Cd testing, leading buyers to select those yielding the lowest results. A science-based approach is suggested to determine acceptable Cd levels for cocoa beans from specific origins, aiding trade in countries like Colombia, Ecuador, Peru, and Trinidad & Tobago.

- **European academic research & validation (KU Leuven University) by Jesse Dekeyrel – 26 Apr 2023** - KU Leuven University conducted a quality-control exercise, an STDF-funded (PG/681) Ring Test under the CLima LoCa project, in which analyses on the same KU Leuven–prepared cocoa soil and bean (KUL) samples were performed to compare results and assess the accuracy, consistency, and overall proficiency of cadmium testing protocols across 34 participating labs in Ecuador and Colombia. Each lab used its own protocols and equipment to analyze 6 reference materials (KUL samples), five powdered cacao liquor samples (two from Colombia and three from Ecuador) and one commercial cacao powder sample from Belgium, provided by KU Leuven. Labs are required to complete a questionnaire on the specifics of their protocols used and if their results exceed two z'-scores (ISO 17043(2010) and ISO 13528(2015)) which provides guidance on the use of statistical methods in proficiency testing. Protocols were reviewed and feedback given to improve accuracy as needed. The results identified which labs met acceptable standards and which needed to improve their quality control developing a quality assurance method using the Ring Test method as a cost effective equivalent to standardized lab certification processes.

Given political-delayed start of our ECU and PER agencies, it was agreed that our project lead research labs will participate in the KU Leuven Ring Test to quickly reach agreed consensus standardized protocols.

- **Technological advances in heavy metal analysis (AGROSAVIA presentation by Dr. S. Chen) – 29 Nov 2022** - A new analytical tool using X-ray fluorescence (XRF), the E-Max analyzer, developed by Dr. Seuw Chen, offers a next-generation solution for rapid and accurate cadmium and heavy metal quantification. It measures multiple elements in a single run, significantly enhancing analysis value for producers.

  Key advantages:

  - Minimal sample preparation, reducing errors
  - Less technical training required
  - Faster processing, increasing daily sample throughput
  - High accuracy, comparable to ICP-OES
  - Lower cost per sample compared to traditional methods
  - Portable and compact, unlike bulky ICP-OES machines
  - Affordable at $57,000 per unit (~10% of ICP-OES machine costs)
  - Rental options available, making it accessible for mass testing in short timeframes

  This technology could provide immediate solutions to the cadmium project by improving efficiency, affordability, and accessibility to heavy metal testing eqiuipment.

The new X-ray fluorescence (XRF) analytical instrument, the E-max, was evaluated using agreed standardized testing protocol for its effectiveness in cadmium (Cd) testing in cocoa and soil samples. Its ability to analyze dry samples significantly reduces both cost and processing time, making it a promising alternative to conventional methods. Results from the E-max closely matched those obtained from the industry-standard inductively coupled plasma mass spectrometry (ICP-MS)**,** confirming its accuracy and reliability. Furthermore, its performance in testing KU Leuven KUL ring test samples fell within the consensus-accepted range. This initiative was spearheaded by NPIA Agrosavia in Colombia under our project and findings published in Spectrochimica Acta Part B: Atomic Spectroscopy-235: https://doi.org/10.1016/j.sab.2025.107352. Both the E-max and ICP-MS instruments were used to analyze KUL ring test samples prepared by the KU Leuven team under STDF/PG/681. The results demonstrated strong correlations between cocoa bean consensus values and measurements obtained using both instruments:

Table 1: Cd concentrations of the (KUL) cocoa bean ring test samples prepared under the STDF/PG/681 project. The samples were analysed by our NPIA Agrosavia Colombia using the E-max and ICP-MS instruments. The consensus (accepted true Cd content in each KUL sample) values are highlighted in red. There were significant correlations between the cocoa bean consensus values and the ICP-MS values (r^2 = 0.9995), as well as between the cocoa bean consensus values and the E-max values (r^2 = 0.9954).

Code	E-max Cd (mg kg^{-1})	ICP-MS Cd (mg kg^{-1})	Consensus Cd (mg kg^{-1})
KUL 1	0.868	0.807	0.81
KUL 2	0.095	0.102	0.09
KUL 4	1.333	1.205	1.19
KUL 5	0.549	0.461	0.45
KUL 6	0.306	0.294	0.3

Agrosavia also compared the accuracy and efficiency of the E-max against the ICP-MS in analysing cocoa bean samples collected in the Santander region of Colombia. The E-max was found to be a high-throughput instrument, with results obtained in minutes rather than days with the ICP-MS, for the non-destructive analysis of Cd in samples. A significant correlation (r^2 = 0.985) between both analytical techniques was observed

(Figure 1). Notably, the correlation improved when Cd concentrations were below 0.8 mg/kg, making the E-max particularly suitable for testing low-Cd containing cocoa beans to ensure compliance with international food safety standards for cocoa and chocolate products. Additionally, the reagent cost per analysis with the E-max is ten-folds cheaper than that of the ICP-MS.

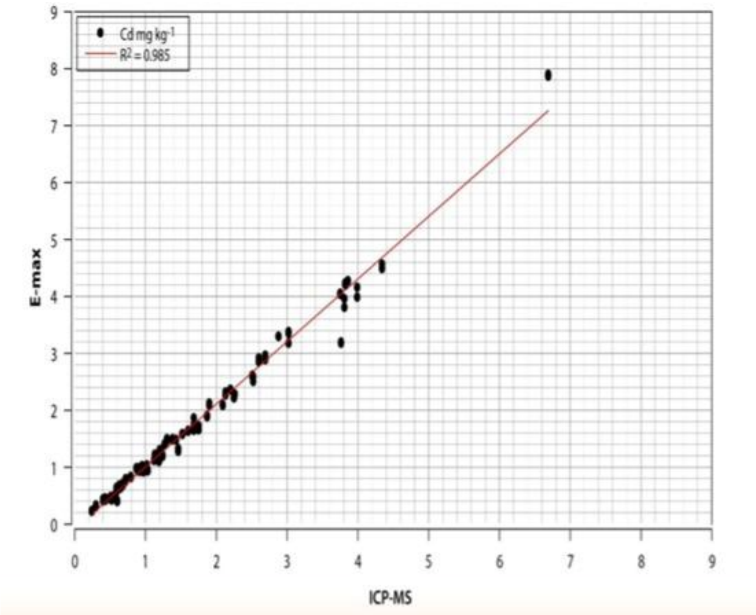


Figure 1: Relationship demonstrated between the Cd concentrations of cocoa bean samples analysed by Agrosavia using the E-max and ICP-MS instruments.

Knowledge Systemization from the Platform

A searchable database containing 140 curated entries on cadmium in cocoa including protocols, research papers, and reports from partner countries was created by Mr. Creary, using the Koha open-source library system. Hosted on IICA's website, it is currently for internal use by NPIAs only, allowing project members to openly share published and unpublished research and gray literature to support consensus-building. The database serves as a valuable resource to project countries for decision-making on cadmium testing protocols and facilitates information sharing through project meeting notes, videos, and other media. A user manual for the Koha database is available in English and Spanish, in both written and video formats for NPIAs.

1.2 Output: 80 (32 in COL, 10 in ECU, 18 in PER, and 20 in TTO), 26 women and 54 men) *Technical staff trained in agreed standardized and harmonized protocols to analyze Cadmium Levels in cocoa and cocoa products*

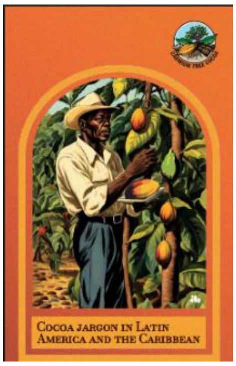
The E-max analyzer was acquired by Agrosavia under a temporary rental agreement. Currently, all lead research agencies involved in the project have access to established Cd determination technologies, including Graphite Furnace Atomic Absorption Spectroscopy (GFAAS), Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), and Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

The project initially set out to train eight technicians across the four participating countries under Activity 2.2, "Training technical staff within and between project partners in the use of standard methodologies." However, this cross-country exchange became unnecessary once consensus was reached to adopt the protocols developed and used by the NPIA laboratories that met or exceeded the quality assurance benchmarks established under STDF/PG/681. As a result, funds originally allocated for travel were redirected toward expanding the scope of training. This strategic reallocation allowed the project to train 80 technicians (32 in COL, 10 in ECU, 18 in PER, and 20 in TTO), 26 women and 54 men, in standardized cadmium testing protocols for cocoa soils, plant tissues, and final products, exceeding the original target by more than 1,000%.

1

1.2 Activity: *Standardized terminology and methodologies for measurement and management of cadmium in cocoa*

A Glossary to standardize terminologies used in cocoa sectors across LAC was developed and endorsed by the national project partners. An excerpt of relevant terminologies used specifically by laboratory technicians in the conduct of Cd



analyses is included in the training SOP manual/curriculum (Activity 2.1). The English glossary '**Cocoa Jargon in Latin America and the Caribbean**'[1] and the Spanish version '**Glosario del Cacao en América Latina y el Caribe**'[1] were published under the following IICA ISBNs and are freely available at https://agriperfiles.agri-d.net/display/n181861 :

English – Digital: 978-92-9273-158-8; Print: 978-92-9273-159-5
Spanish – Digital: 978-92-9273-160-1; Print: 978-92-9273-161-8

Strategy adopted to establish consensus, quality-assured, standardized, and harmonized protocols for measuring cadmium in cocoa soils and tissues.

Ecuador joined the project in March 2023, which naturally delayed the NPIA's early participation and affected the pace of regional alignment on key deliverables. In combination with delays in receiving information from partner institutions, this led to a revised timeline for Activity 1, which serves as the foundation for several subsequent actions.

Despite these challenges, the project team used this period to reassess the feasibility of developing a single standardized cadmium testing protocol for the entire LAC region. This option proved impractical due to the high cost and long lead times for equipping labs with the same new equipment, the need for cross-lab calibration, and the extensive training required. While KU Leuven has identified the E-max analyzer as a faster, cost-effective alternative to current equipment in use; its cost exceeded the project budget for regional adoption. However, Agrosavia has chosen to pursue alternative options independently to test the Emax analyser.

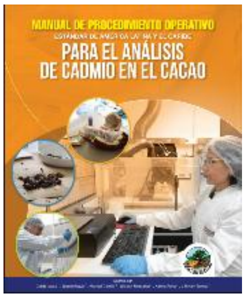
[1] To access the link, copy and paste it into your web browser if it is not launched from the document.

Each NPIA has at least one laboratory equipped to measure cadmium in cocoa soils and tissues. The project collaborated with PG/681 to conduct the KU Leuven's quality assurance ring test previously described, which uses shared cocoa soil and tissue samples prepared by KU Leuven called 'KUL samples' to verify the accuracy and consistency of laboratory protocols. Reagents and all other costs were funded by PG/577.

It was agreed that the protocols developed and routinely used by NPIA laboratories with acceptable z´-scores (the quality-assurance benchmark) will serve as the regional consensus for cadmium testing. These protocols will be incorporated into the technician training curriculum under Activity 1.2.1 and ideally compiled into a Standard Operating Procedures (SOP) manual. Full participation and successful completion of the assessment by all NPIA labs were critical to the effectiveness of this strategy.

1.3 **Activity:** *User appropriate manual and Official endorsement of updated national strategies and* **Activity 2.1:** *Curriculum and Technical manual with agreed standards and reference materials for sampling and analysis methodologies*

A Standard Operating Procedure (SOP) manual for cadmium (Cd) analysis in soils and cocoa bean samples was developed through collaboration among lead research agencies in the project countries. This SOP outlines rigorous protocols that met the z´-score quality assurance standards of STDF/PG/681, covering all stages from sample reception and preparation to Cd quantification in cocoa tissues and soils. It covers the laboratory technologies and equipment most commonly used across Latin America and the Caribbean. The 76-page manual, titled **"Latin America and the Caribbean Standard Operating Procedure for the Analysis of Cadmium in Cocoa**," is freely available in **English-ISBN: 978-92-9273-152-6** and **Spanish-ISBN: 978-92-9273-151-9** on IICA's Agriperfiles platform https://agriperfiles.agri-d.net/display/n255230.



"Research on effective mitigation strategies for managing cadmium in cocoa beans is ongoing, as multiple factors affect its accumulation. However, the project reached consensus on nine recommended strategies, published in PTA-1-112023 (Annex 1). National authorities in Colombia, Ecuador, and Peru have reviewed the recommendations and their National Cocoa Sector Plans to confirm that these strategies will be implemented and have formally endorsed them (Annex 2). In Trinidad and Tobago, the Ministry of Agriculture has begun implementing the nine recommended strategies as the updated National Cocoa Sector Plan progresses through parliamentary approval. Notably, PG/577 findings on the E-max analyser were formally recognized as Recommendation #4 in PTA-1-112023 (Annex 1). Consequently, the Ministry of Agriculture, Lands, and Fisheries (MALF) has adopted this innovation, procuring the E-max analyzer for its laboratories to enable rapid, affordable, and accurate cadmium testing for farmers.

Number of labs adopting the new standardized testing protocols

The NPIAs in all four project countries have now adopted the SOP manual of standardized testing protocols for cadmium analysis in cocoa soils and tissues. Further, support was extended to Ecotox (Trinidad and Tobago) and (the International Center for Environmental and Nuclear Sciences (ICENS) in Jamaica) to extend the same standards in the Caribbean. However, neither completed the quality assurance process due to limited market demand for certified Cd testing at Ecotox and staffing constraints at ICENS.

Recommendation:

A notable gap remains: EU laboratories involved in testing cocoa bean and product shipments, particularly those reporting to the Rapid Alert System for Food and Feed (RASFF), have not yet participated in the KU Leuven–led quality-assurance ring-test initiative developed for LAC laboratories. Joint participation of EU and LAC labs in the quality-assurance ring tests would build trust in comparable results and advance the standardization required for EU cocoa market access.

- Adopt consensus-based protocols for rapid, cost-effective Cd analysis using advanced technologies like E-max's XRF.
- Improve laboratory competence through scheduled ring-tests, capacity-building, infrastructure upgrades, and equipment enhancements.
- Continuously update Cd hotspot maps using the latest analytical techniques and establish an international database for precise geographic tracking.

- **A Call to Action**

These advancements empower cocoa producers, policymakers, and industry stakeholders to tackle the cadmium challenge, ensuring market access, farmer livelihoods, and sustainability. Next steps include support implementing integrated project recommendations in national cocoa sector plans to increase the supply of industry-compliant cocoa from LAC.

Outcome 2 – Knowledge on best practices to mitigate cadmium levels transferred to farmers from master trainers

Output 2.1: *Improved knowledge of countries on possible sources for cadmium presence in the cocoa growing areas through analysis and mapping of hotspots and* ***Activity*** 3.1 *Updating maps of cadmium contamination in identified hotspots*

The project facilitated Cd quantification in water, soil, fertilizer, and cocoa bean samples across major cocoa-producing regions in participating countries. These analyses informed the development and refinement of Cd concentration zones in Peru or hotspot maps for Colombia and Trinidad and Tobago, augmenting information on critical known environmental determinants. These insights enabled the formulation of region-specific mitigation strategies in Trinidad and Tobago to reduce Cd levels in cocoa beans and guide the establishment of new farms in areas with naturally lower Cd accumulation. A comprehensive Cd hotspot bean map for Ecuador had already been produced through a five-year initiative (2013–2017) led by the Ministerio de Agricultura y Ganadería (MAG). PG/577 improved the detail and resolution of cocoa for the bean cadmium hotspot map across 21 of Ecuador's 24 provinces.

Cd Hotspot mapping in Colombia

Cocoa bean and soil samples were collected from Colombia's top cocoa-producing regions Antioquia, Arauca, Bolívar, Boyacá, Córdoba, Guaviare, Huila, Meta, Nariño, Norte de Santander, Santander, and Tolima. Sampling focused on farms with an average production age of 15 years, covering 70% of the country's cocoa-growing areas. A total of 1,093 cocoa bean and soil samples were analysed in this project. Soil analyses indicate Cd hotspots primarily in northern Arauca, south-central Santander, and western Boyacá (central-eastern mountain range). Bean Cd concentrations ranged from below the ICP-MS detection limit (<0.043 mg/kg) to a maximum of 15.2 mg/kg (**Table 2**).

Table 2: Mean Cd concentration (mg kg^{-1}) of beans from seven departments in Colombia. For each department, the standard deviation (SD), coefficient of variation (CV), minimum, and maximum values are shown. 'BDL' signifies that the Cd concentration was lower than the detection limit of the ICP-MS (0.043 mg kg^{-1}).

Department	Mean Cd	SD	CV	Minimum Cd	Maximum Cd
Antioquia	1.69	1.4	0.81	0.17	5.94
Arauca	3.81	1.6	0.41	0.1	9.79
Meta	0.84	1	0.87	0.19	5.36
Nariño	0.66	0.3	2.27	0.1	1.33
Norte de Santander	1.74	1.9	0.94	0.21	7.65
Santander	2.71	3.5	1.29	BDL	15.2
Tolima	1.47	1.7	0.89	0.17	7.97

The proportion of farms producing cocoa beans with Cd concentrations exceeding 0.8 mg/kg varied across regions. In Santander, Arauca, Antioquia, Nariño, Tolima, Meta, and Norte de Santander, the percentages of high-Cd beans were 60%, 99%, 67%, 30%, 55%, 27%, and 40.9%**,** respectively (**Figure 2**).
The departments of Nariño and Meta produced the highest proportion of cocoa beans with Cd concentrations below 0.8 mg/kg, making them ideal for expanding cocoa production, especially as output in these regions is projected to increase by 10% over the next two years.

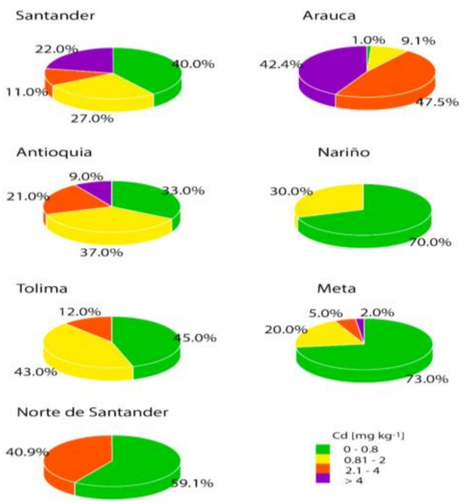


Figure 2: Proportion of beans produced within each department that contained Cd concentrations between 0–0.8 mg kg^{-1} (green), 0.81–0.2 mg kg^{-1} (yellow), 2.1–4 mg kg^{-1} (red), and more than 4 mg kg^{-1} (purple).

In contrast, Santander, Arauca, and Antioquia had the lowest proportion of beans below 0.8 mg/kg Cd, posing a challenge particularly for Santander (34.4%) and Arauca (16.2%), the country's largest cocoa-producing regions. However, within Santander, bean blending could reduce overall Cd levels by 62%, offering a short-term mitigation strategy. In Arauca, where only 1% of beans fall below the 0.8 mg/kg threshold, more aggressive mitigation measures, such as soil amendments, are necessary to manage Cd contamination effectively.

Two maps were developed under this project to illustrate Cd distribution in Colombian soils and cocoa beans (**Figure 3**). The first map (**Figure 3A**) displays bean Cd concentrations across sampled farms, highlighting regional variations within each department. The second map (**Figure 3B**) identifies Cd hotspots and cold spots, where hotspots represent areas with statistically high Cd levels surrounded by similar high-Cd samples, while cold spots indicate areas with consistently low Cd concentrations. Cd hotspots and cold spots are color-coded based on the likelihood of detecting similar Cd concentrations within an average radius of 9.3 km. The highest number of hotspots were found in Santander (222) and Arauca (80), while cold spots were most prevalent in Santander (101), Huila (60), and Nariño (53). The mean Cd concentrations in hotspot areas were 4.3 ± 3.6 mg/kg, compared to 0.52 ± 0.42 mg/kg in cold spots.

Cd accumulation in hotspot areas was linked to aged soils, high Cd availability, low pH, calcium content, mining activities, and hydrocarbon exploitation. These findings reinforce that Nariño and Meta are optimal for expanding low-Cd cocoa cultivation in Colombia. Based on this analysis, the study "The First National Mapping of Cd in Cacao Beans in Colombia" (Bravo et al., 2024) was published in Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2024.176398

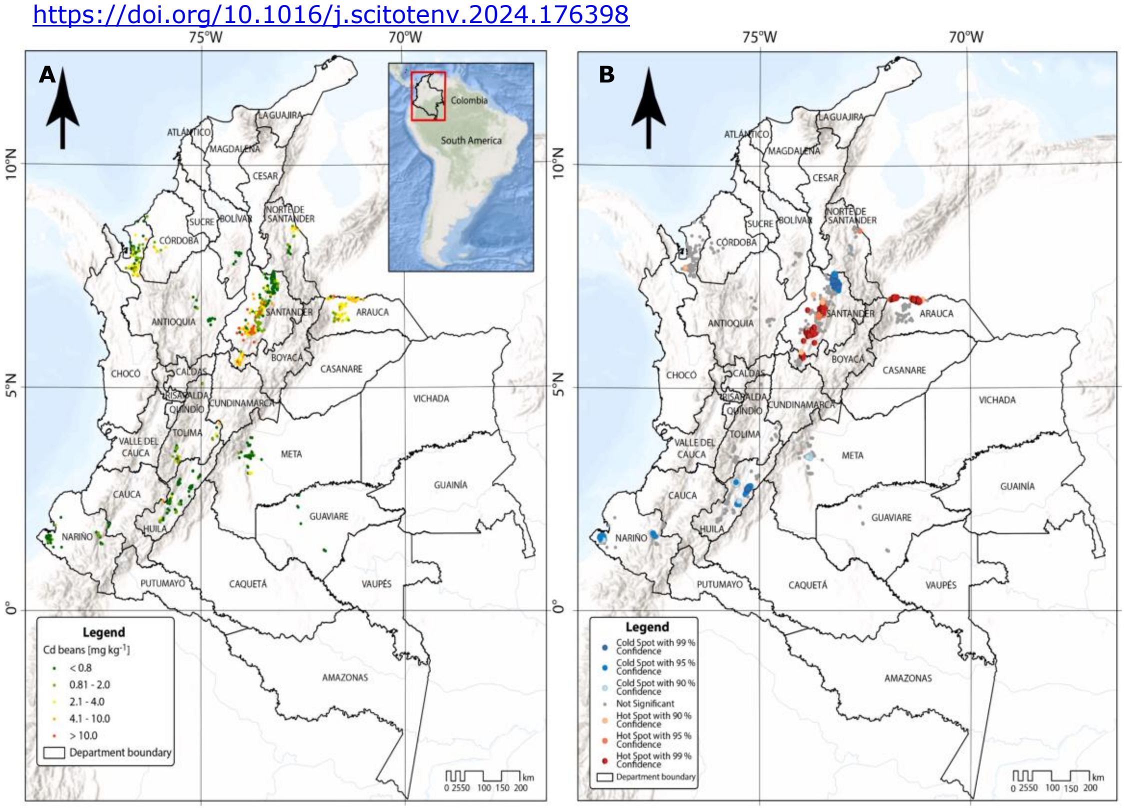


Figure 3: Cd Distribution in Colombian Cocoa
(A) Bean Cd concentrations across sampled farms in Antioquia, Arauca, Bolívar, Boyacá, Córdoba, Guaviare, Huila, Meta, Nariño, Norte de Santander, Santander, and Tolima, highlighting regional variations.
(B) Cd hotspots (red dots) and cold spots (blue dots), color-coded to indicate the statistical likelihood of high or low Cd levels within a 9.3 km radius.

Cd Hotspot mapping in Peru

A sampling plan was implemented to assess cadmium (Cd) levels in Peru's top cocoa-producing regions Piura, San Martín, and Huánuco. SENASA and INIA collected and analyzed 370 soil samples, with ten 500 g samples taken from a depth of 0–10 cm per five-hectare cocoa farm. ICP-MS analysis at the INIA laboratory determined that soils exceeding 1.4 mg kg^{-1} Cd were considered contaminated, based on "Suelos de Uso Agrícola" (DS 007-MINAM-2019). In Piura, none of the 150 soil samples exceeded the threshold, indicating no Cd contamination. In Huánuco, 220 samples from 11 districts were assessed, with Castillo Grande (1.72 mg kg^{-1}) and Luyando (3.66 mg kg^{-1}) exceeding the threshold and classified as contaminated. The remaining nine districts had Cd levels below the limit. In San Martín, analysis of 420 soil samples confirmed no contamination.

Cocoa bean samples were collected from farms in San Martín (60 samples), Piura (25 samples), and Huánuco (35 samples). High Cd concentrations were detected in Las Lomas and Tambo Grande (Piura), Nuevo Progreso (San Martín), and Luyando and Castillo Grande (Huánuco). Additional soil and bean samples were taken from these districts to investigate the causes of elevated Cd levels. Soil pits were dug to the bedrock in Piura (5), San Martín (1), and Huánuco (2), and two additional bean samples were collected. Bean Cd concentrations ranged from 0.08 to 14.22 mg kg^{-1}, with an overall mean of 0.83 ± 0.12 mg kg^{-1}. Notably, 33% of samples exceeded the 0.8 mg kg^{-1} threshold, with Piura accounting for 49% of these high-Cd samples.

Piura and Leoncio Prado (Huánuco) had mean and median Cd concentrations above 0.8 mg kg^{-1}, while all other provinces remained below this level (**Figure 4**). Given these findings, Cd mitigation strategies should be prioritized in Piura. In Huánuco and San Martín, blending can be used to ensure beans comply with international Cd regulations. However, in Piura, more intensive mitigation strategies will be necessary to meet export standards.

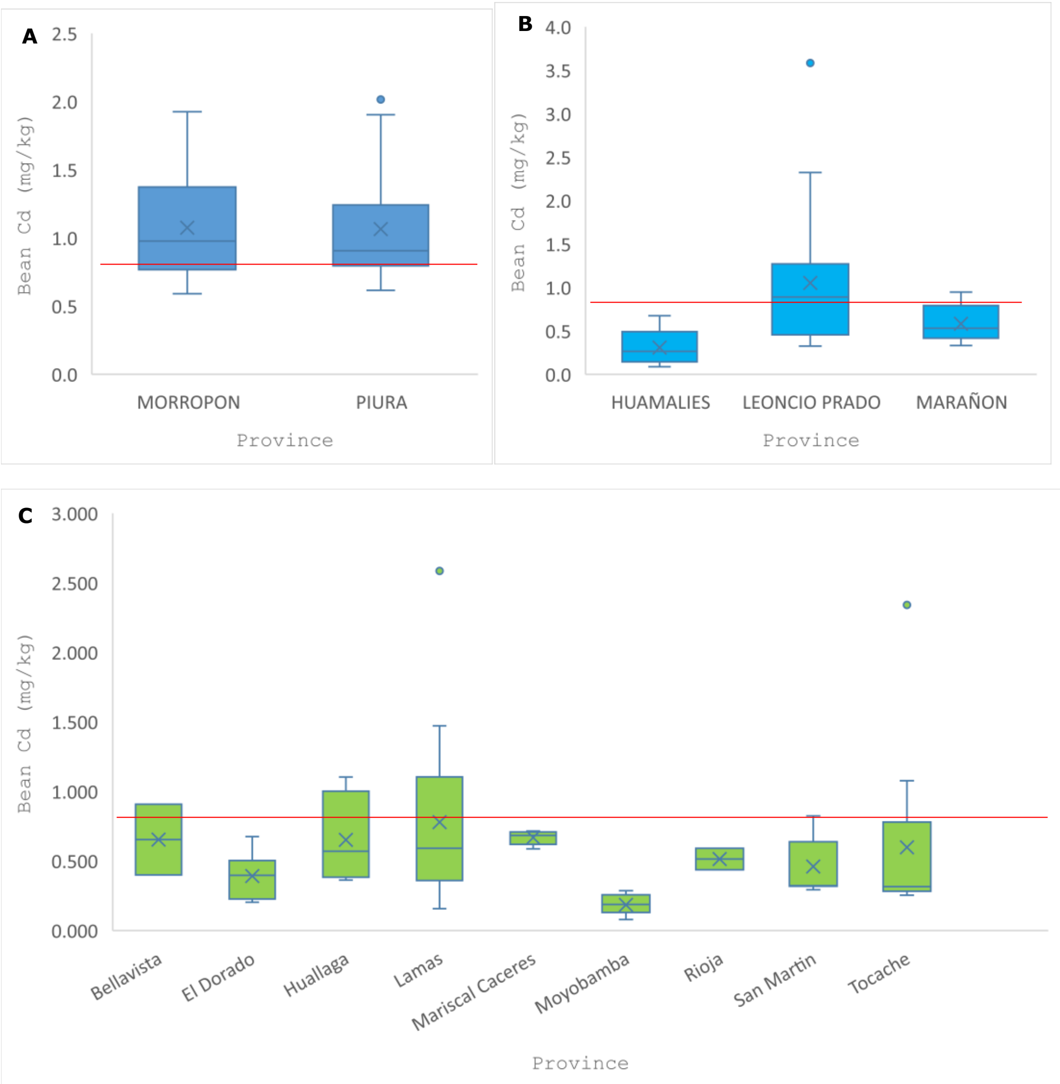


Figure 4: Box and Whisker plots showing the bean Cd concentrations from provinces in the Peruvian regions of (A) Piura, (B) Huánuco, and (C) San Martín. The mean values are marked by an 'X' within the box, and the red line indicates the threshold Cd concentration of 0.8 mg kg-1.

Cd Hotspot mapping in Trinidad and Tobago

Cadmium maps for Trinidad and Tobago were generated from 160 samples analyzed as part of the IMPACTT project (Improving Marketing and Production of Artisanal Cocoa from Trinidad and Tobago, 2015–2019), funded by the IDB-Lab via the Multilateral Investment Fund (MIF). These maps were updated through sampling an additional 100 farms under the current project **(Figure 5)**, providing more details or granularity to support ongoing monitoring and risk assessment of cadmium levels in cocoa. Cocoa bean, soil, and water samples were collected from each farm. All samples were analysed for Cd; as well as for factors which influence bioavailability of Cd to the cocoa tree such as pH, organic matter, Mn and Zn contents.

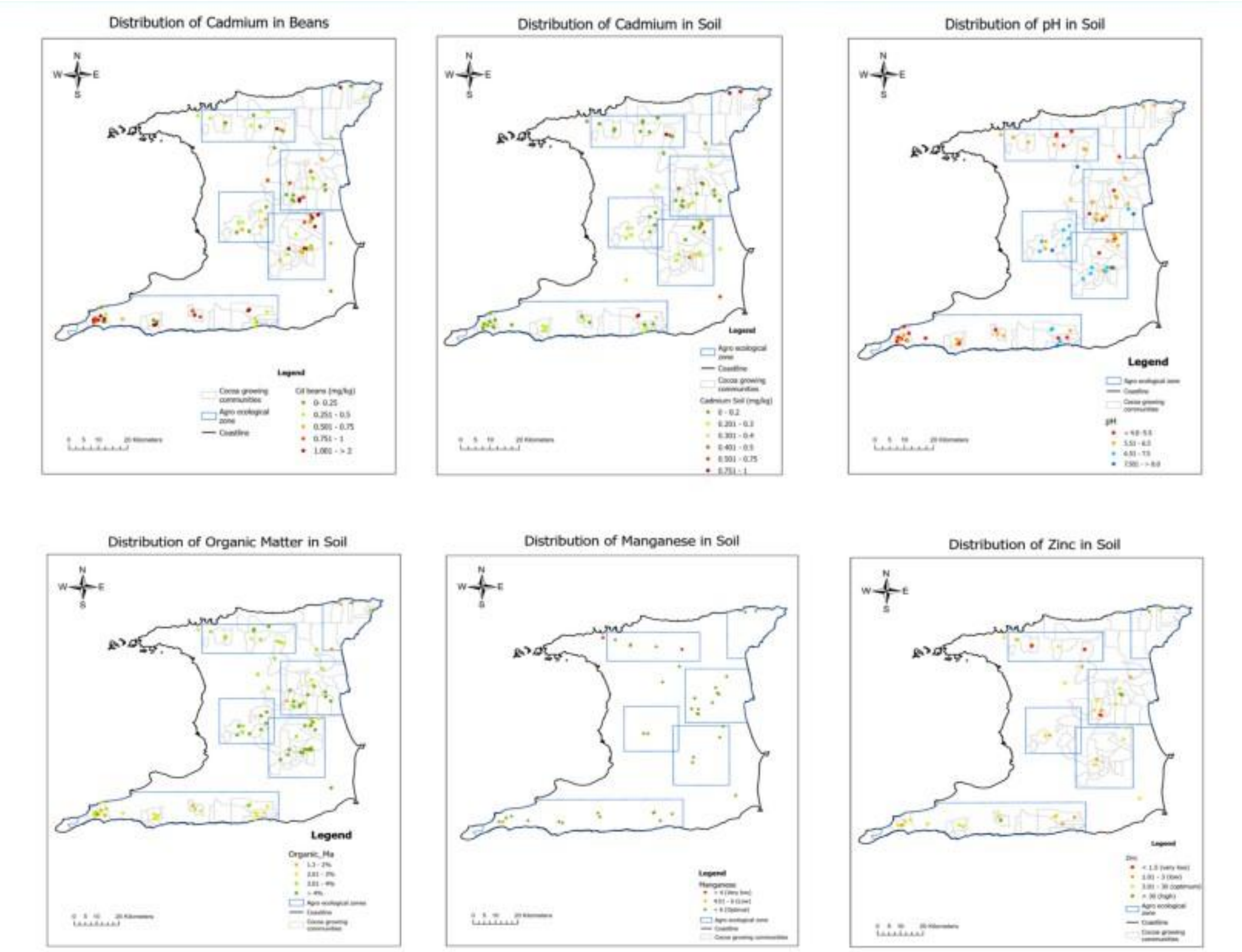


Figure 5: Updated map of Cd distribution in the soils and beans from cocoa farms across Trinidad. The distribution of the other physicochemical soil properties is also shown.

3.2 Activity: *Implement a programme of coordinated testing for cadmium in cocoa, soils, fertilizers and water to complete the mapping.*

Colombia

In October 2023, 29 (28 males and 1 female) technical assistants from the National Federation of Cocoa Growers (Fedecacao) received training on cadmium (Cd) contamination in cocoa. Each assistant was responsible for selecting one farm per Department (Antioquia, Cundinamarca, Huila, Norte de Santander, Santander, and Tolima) within their assigned work area. Farms were required to have an established nutritional plan for the collection of soil, fertilizer, and fermented and dried cocoa bean or fresh pod samples. On each selected farm, the following composite samples were collected for Cd content analyses: 250g of soil, 250g of chemically synthesized fertilizer, 250g of organic fertilizer, 250g of mineral amendment (CALMAG), and 100g of fermented and dried cocoa beans or three cocoa pods.

Results showed that both organic and synthetic fertilizers are a significant source of Cd contamination on farms in Colombia. Analysis has shown that some fertilizers contain up to 40 mg kg^{-1} of Cd (**Figure 6**), with the highest concentrations found in organic and synthetic fertilizer products sampled from Santander **Figures 6A&B.** In all municipalities of Santander Cd concentration in the soil (black bars **Figure 6C**) was lower than that in the fermented and dried cocoa beans or pods (red bars **Figure 6C**). As a result, fertilizers may contribute substantially to Cd accumulation in the region. Implementing regulations on these products could help farmers reduce Cd build-up in their soils. These findings were published in Food Additives & Contaminants Part A: https://doi.org/10.1080/19440049.2025.2537872

In Colombia, most cocoa is consumed domestically, with 92.6% of production staying within the country in 2023. Since Cd regulations primarily affect international trade, there are no restrictions on Cd levels in cocoa products consumed locally. Addressing high Cd concentrations in Colombian cocoa is crucial to protecting public health. Meanwhile, the 7.4% of beans exported mainly to Mexico, Belgium, the United States, Malaysia, and Japan must meet international Cd standards. Farms

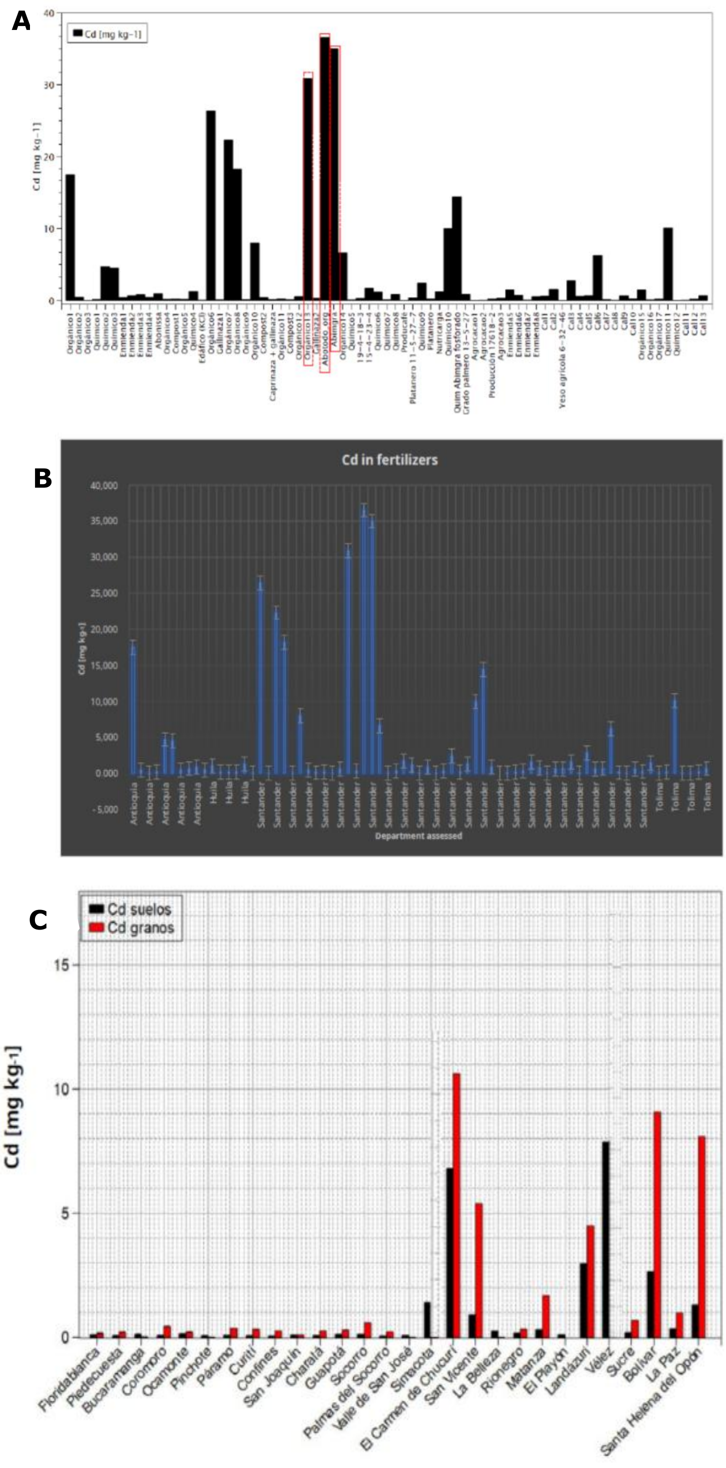


Figure 6: Cadmium (Cd) analysis results for soil, fertilizers, and fermented and dried cocoa beans or pods from cocoa farms with an established fertilizer nutrition plan in Antioquia, Cundinamarca, Huila, Norte de Santander, Santander, and Tolima Departments of Colombia.
(A) Cd contamination levels in mineral amendments (CALMAG), organic and synthetic fertilizers from all 7 Departments.
(B) Cd contamination levels in fertilizers by Departments. Highest levels are in the Santander Department
(C) Cd contamination levels from Soil (Black bars) and Cocoa bean and pod samples (Red bars) from all municipalities sampled in

supplying export markets should undergo assessments, and mitigation measures should be applied where necessary to ensure compliance.

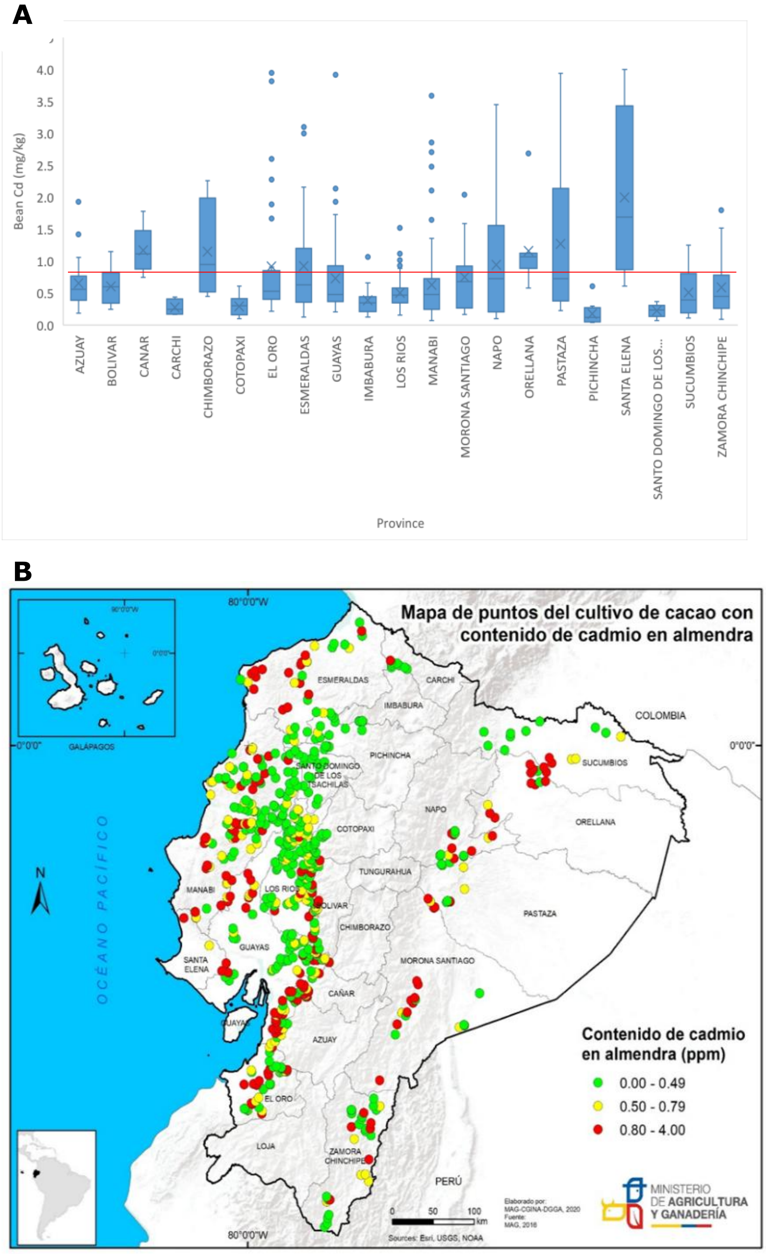


Figure 7: Cadmium (Cd) analysis results for soil, fertilizers, water and cocoa beans samples from 21 of Ecuador's 24 provinces.

(A) Box and Whisker plot of the bean Cd concentrations from 21 provinces in Ecuador. Mean values are represented by the 'X' within the box. The red line highlights a bean Cd concentration of 0.8 mg kg-1.

(B) Map of Ecuador displaying bean cadmium (Cd) concentrations from farms across 21 provinces. Farms where bean Cd concentrations exceed 0.8 mg kg^{-1} are depicted in red.

Ecuador

Fertilizer, soil, water, and cocoa bean samples were collected and analyzed for cadmium (Cd) from 21 of Ecuador's 24 provinces. Bean Cd concentrations across these provinces ranged from 0.04 to 4 mg kg^{-1}. The mean and median Cd levels in beans from Azuay, Bolívar, Carchi, Cotopaxi, Guayas, Imbabura, Los Ríos, Manabí, Morona Santiago, Pichincha, Santo Domingo de los Tsáchilas, Sucumbíos, and Zamora Chinchipe were below 0.8 mg kg^{-1}, while those from Cañar, Chimborazo, Orellana, and Santa Elena exceeded 0.8 mg kg^{-1} (**Figure 7A**). The data was used to update the cadmium (Cd) distribution map for Ecuador (**Figure 7B**). The map, along with a box-and-whisker plot, indicates that most Ecuadorian farmers produce cocoa beans with Cd concentrations below 0.8 mg kg^{-1}. However, 26% of analyzed samples exceeded this threshold, with high-Cd farms dispersed throughout the country.

The increased granularity revealed that Cd mitigation strategies should be designed and implemented in a targeted manner, reflecting the distinct environmental and agronomic conditions of each hotspot.

In 2022, Ecuador's cocoa bean exports were valued at approximately $937 million USD, meaning international Cd regulations could negatively impact around $235 million in export earnings. Recommendations were provided for high-Cd areas to address this issue.

Implementing a region-based blending strategy, which ensures all exported beans comply with international Cd limits, could serve as an effective solution for Ecuadorian cocoa.

Soil and cocoa bean samples were also collected from a demonstration plot in Río Negro, a province of El Oro. Soil Cd concentrations ranged from 0.34 to 0.95 mg kg^{-1}, while bean Cd concentrations varied between 0.72 and 2.91 mg kg^{-1}, with a mean of 1.67 ± 0.08 mg kg^{-1}. Notably, only one sample had a bean Cd concentration below 0.8 mg kg^{-1}. Ongoing mitigation efforts using soil amendments aim to reduce bean Cd concentrations on this plot. Continuous monitoring will help identify effective mitigation strategies for Ecuadorian farms.

Additionally, Cd analysis was conducted on 58 fertilizers (both solid and liquid), revealing that 13.7% exceeded Ecuador's maximum allowable Cd level of 1.5 mg kg^{-1}. The Cd concentrations of these fertilizers are detailed in **Table 3**.

Table 3: Fertilizers exhibiting higher Cd concentrations than that of the established maximum allowable level of 1.5 mg kg^{-1} for Ecuador.

Sample number	Cd (mg kg^{-1})
FERT-22	5.52
FERT-30	21.56
FERT-32	13.34
FERT-35	34.60
FERT-50	11.00
FERT-58	9.88
FERT-61	21.46
FERT-67	12.96

The circulation and use of fertilizers containing cadmium (Cd) concentrations above Ecuador's established regulations highlights the need for improved national fertilizer monitoring. Integrating the E-max instrument into monitoring strategies will reduce costs and enhance the efficiency and effectiveness of these systems. This is crucial to ensure that fertilizer use does not contribute to nor increase Cd availability in the soil, potentially affecting cocoa plants.

Table 4: The Cd concentrations of sampled fertilizers from the San Martín, Huánuco, and Piura regions in Peru.

Region	District	Fertilizer	Cd concentration (mg kg^{-1})
SAN MARTÍN	Tabalosos	Organic fertilizer (poultry manure, phosphate rock, K, Zn, Mg and Cu sulphates and Ulexite)	38.4
	Fundo Tierra Nueva	Compost (Harvest residues such as cocoa husks, beans, cassava, lime, ash, and whey)	0.574
	Shanao	Compost (Harvest residues such as cocoa husks, beans, cassava, lime, ash, and whey)	0.508
	Parcela	Compost (Harvest residues such as cocoa husks, beans, cassava, lime, ash, and whey)	0.965
HUÁNUCO	Huamalies	Dolomite	0.01
	Huamalies	Phosphoric rock	75.9
	Huamalies	Agricultural cal	0.978
PIURA	Chulucanas	Organic fertilizer (Worm humus)	1.66
	Las Lomas	Biol (phosphate rock, serum, mountain microorganisms and cane molasses)	0.105
	Las Lomas	Organic fertilizer (goat guano, cow guano, plant material and ash)	2.27

Peru

Given that most Peruvian cocoa farms rely on nearby water sources for irrigation, water samples were collected upstream from streams and reservoirs in Piura (20 samples) and San Martín (10 samples). Acidified to pH 1–2 and analyzed via ICP-MS, no Cd was detected above the instrument's 0.005 mg L^{-1} detection limit. Additionally, ten fertilizer samples from the three regions were tested for Cd concentrations, ranging from 0.01 to 75.9 mg kg^{-1}. Two exceeded the 2.5 mg kg^{-1} threshold: an organic fertilizer from Tabalosos, San Martín (38.4 mg kg^{-1}), and a phosphate rock fertilizer from Huamalíes, Huánuco (75.9 mg kg^{-1}).

Trinidad and Tobago

In addition to the soil, water and bean samples analysed for Cd concentration from 100 farms, the Cd concentration of fertilizers used across cocoa farms in the country was also quantified. Concentrations ranged from 0.105–8.75 mg kg-1 (**Table 5**).

Table 5: Cd concentrations of fertilizers used for cocoa production in Trinidad and Tobago

Fertilizer	Cd concentration (mg kg^{-1})
NPK Ferquido 13-12-24	5.95
Fersan 8-16-32	1.69
Castalloy Enro 15-12-24	8.75
Nitrofosua Eurochem 12-12-17	1.98
Yara 12-11-18 Mg+TE+S	0.43
Enro 15-5-20	0.22
NPK 13.13.21	0.105
NPK 12.24.12	3.138
NPK 12.11.18	0.634
NPK 12.12.17+2+TE	2.401
Calcium nitrate (Cal-nitro)	0.125
NPK 15.5.20	0.142

3.3 Activity: *Devise appropriate mitigation recommendations for high cadmium areas (hotspots)*

Analyses of Cd contamination sources and hotspots highlight the need for continued research on effective mitigation strategies in cocoa production. Multiple factors influence Cd deposition, making targeted interventions essential. Key insights were gained on factors affecting Cd levels in cocoa beans, pods, and cocoa-growing regions across the four project countries.

In Trinidad and Tobago, the improved hotspot map granularity generated under PG/577 enabled the development of a systematic Farm Categorization Model to better target mitigation actions. The Cocoa Research Centre (CRC) approach involved compiling a detailed compendium of environmental characteristics and constraints for each Cocoa Growing Community (CGC) within the Agro-Ecological Zones (AEZs). This included information on soil pH, organic matter, cation levels, Cd-to-soil ratios, and flooding risk. Using this framework, targeted mitigation strategies were developed, and Cocoa Growing Communities (CGCs) were classified into four categories based on these factors combined with average cadmium levels in cocoa beans: Category 1 (>0.8 mg/kg), Category 2 (0.6–0.8 mg/kg), Category 3 (0.5–0.6 mg/kg), and Category 4 (<0.5 mg/kg) (**Figure 8**).

This Farm Categorization Model enabled the development of an intervention matrix linking mitigation strategies such as low-Cd rootstock selection, soil liming, organic matter addition, balanced fertilization, flood control, and bean blending to contamination severity (**Tables 6 and 7**). This approach may also be applicable to Andean countries, where smallholder farmers dominate cocoa production despite differences in sector scale (**Table 8**) ultimately leading to a Regional Manual with appropriate best Cd mitigation strategies.

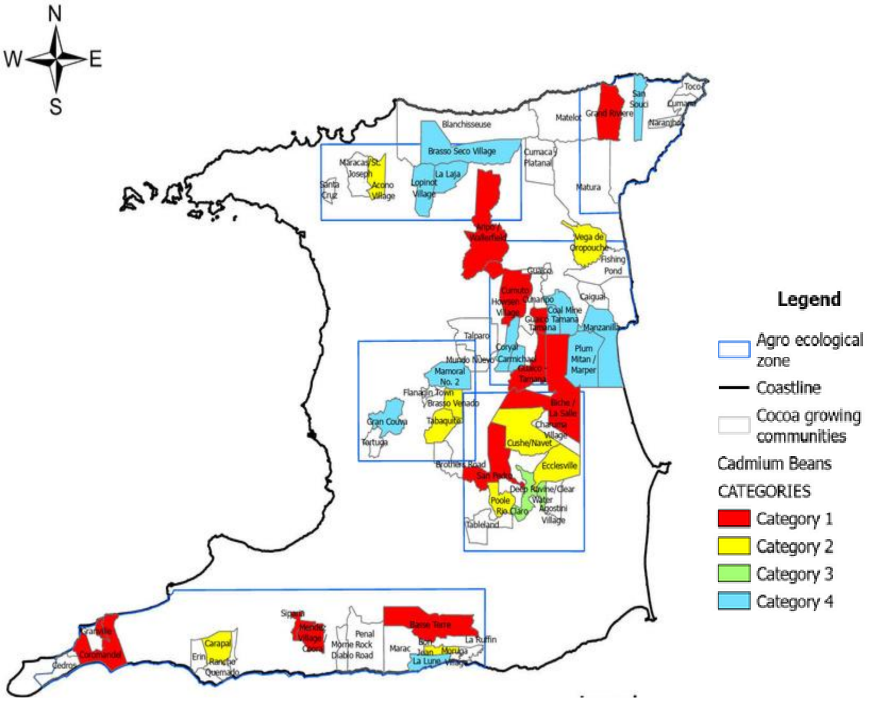


Figure 8: Map of Trinidad depicting categorized cocoa farming regions based on bean cadmium (Cd) concentrations.

Table 6. Bean cadmium (Cd) concentrations and farm conditions for **Category 1 farms**, where the mean bean Cd concentration exceeds 0.8 mg kg⁻¹. **Recommended mitigation measures for each cocoa-growing community** (CGC) are also included.

CGC	Bean Cd (mg kg^{-1})	Conditions	Mitigation measures
Eastern Lowlands AEZ			
CGC-Biche 1 Biche 2 Biche 3	2.34 2.29 1.83	Low-Mod pH of 5.6, 5.8, 6.0, respectively; Good Ca/Mg, Fe, Mn, and Zn	Low Cd bioaccumulating rootstock; Lime application; Flood control measures.
CGC-Rio Claro	1.44	Low pH of 5.1; Good Ca/Mg, Fe, Mn, and Zn.	Low Cd bioaccumulating rootstock; Lime application.
CGC-Ecclesville 1 Ecclesville 2	1.06 0.9	Mod-Good pH of 6.1, 7.0, respectively; Good Ca/Mg, OM; Low-Mode Mn, Fe, Zn.	Low Cd bioaccumulating rootstock; Mn, Fe, Zn application.
CGC-Cushe	0.94	Mod pH of 6; Good Ca/Mg, OM, Fe, Mn, but Mod Zn.	Low Cd bioaccumulating rootstock; Lime application, Zn application.
Western Flank AEZ			
CGC-Preysal	2.17	Good pH 7.1; Low-Mod Mg and Mn; Low Fe and Zn.	Low Cd bioaccumulating rootstock; Mg, Mn, Fe, Zn application.
CGC-Tortuga	1.81	Good pH 7.0; Low Zn, Mod Fe.	Low Cd bioaccumulating rootstock; Fe, Zn application.
CGC-Gran Couva	1.81	Good pH 6.9; Low Fe and Mn, Mod Zn.	Low Cd bioaccumulating rootstock; Fe, Mn, Zn application.
CGC-Talparo	0.96	Low pH of 5.9; Good Ca/Mg, Fe, Mn, and Zn.	Low Cd bioaccumulating rootstock; Lime application.

Table 7. Bean cadmium (Cd) concentrations and farm conditions for **Category 2 farms**, where the mean bean Cd concentration ranges from 0.6 to 0.8 mg kg⁻¹. **Recommended mitigation measures for each cocoa-growing community** (CGC) are also included.

CGC	Bean Cd (mg kg^{-1})	Conditions	Mitigation measures
Eastern Lowlands Agro Ecological Zone (AEZ)			
CGC-Rio Claro 1	0.69	Good pH 6.4; Good Ca/Mg, Low Fe, Mod Zn.	Fe and Zn application.
Rio Claro 2	0.57	Good pH 7.7; Good Ca/Mg, Low Fe, Mod Mn, and Zn.	Fe, Mn, and Zn application.
CGC-Clear Water, Rio Claro	0.55	Good pH 7.4; Good Ca/Mg, Low Fe, Mod Mn.	Fe and Mn application.
CGC-Poole, Rio Claro	0.6	Mod-Good pH of 6.3; Good Ca/Mg, OM, Low Fe, Mod Zn.	Fe and Zn application.
CGC-Ecclesville	0.6	Mod-Good pH of 6.3; Good Ca/Mg, OM, Low Fe, Mod Zn.	Fe and Zn application.
Western Flank AEZ			
CGC-Tabaquite	0.65	Good pH of 6.9; Good Ca/Mg, Fe, Low Mn.	Mn application.
CGC-Brasso Venado	0.65	Good pH of 6.9; Good Ca/Mg, OM, Low Mn, and Zn.	Mn and Zn application.

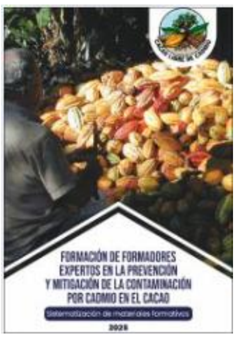
Significant progress was made regionally, with nine mitigation actions endorsed for inclusion in the National Cocoa Sector Plans of Colombia, Ecuador, and Peru (Annexes 1 & 2). In Trinidad and Tobago, the Ministry of Agriculture, Lands, and Fisheries (MALF) has begun implementing these strategies, including procuring an E-max analyzer in alignment with PTA-1-112023 Recommendation #4. The updated National Cocoa Sector Plan is currently advancing through parliamentary approval. The project provided MALF with two sets of KUL bean and soil Cd reference samples ++to strengthen quality assurance in Cd analysis. Under Dr. Gideon Ramtahal's guidance, these materials will enhance analytical accuracy and monitoring.

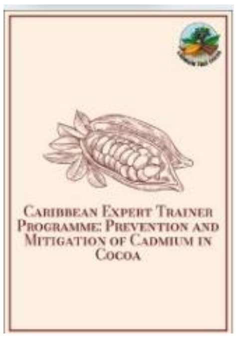
Table 8. Overview of the cocoa sectors in Colombia, Ecuador, Peru, and Trinidad and Tobago. This table presents key metrics, including cocoa production (in metric tons), total acreage (in hectares), number of farmers, and average farm size for each country. The data offers a comparative analysis of the cocoa industries in these four nations, highlighting their scale and contribution to the global cocoa market.

Country	Production (MT)	Acreage (ha)	Number of Farmers
Colombia	65,174 (2021)	194,428 (2021)	Predominantly smallholders, averaging 3 ha per farm ~65,000
Ecuador	400,000–430,000 (2022–2023)	601,954 hectares (2019)	Over 100,000 families involved in cocoa farming, averaging 90% of production on 1 to 5 ha farms
Peru	70,000 (2014)	Approximately 40,000	45,000–100,000 farmers, with average farm sizes of 2 ha
Trinidad & Tobago	1,000 (2018)	15,000 acres (~6,070 ha)	Approximately 800–3,500 farmers, average farm size is 2 to 6 ha low productivity at 150 to 200 Kg/ha. Rated 100% Fine and Flavour cocoa

4.1 Activity: *Curriculum developed and Trained Master trainers from cocoa extension providers*

The Ecuadorian team developed and published INIAP Guide 17 (ISBN 978-9942-22-605-1) under this project, a comprehensive training manual titled "**Learning Tools for the Prevention and Mitigation of Cadmium in Cocoa**". All project countries adapted the guide to their specific contexts with infographics and visual aids in this process. The **Master Trainer curricula** include the guide along with the visual aids as annexes and are freely available in both **Spanish**[1] and **English**[1]. English-language annexes were translated into **French** for Haiti, broadening their impact in the Caribbean and enabling extensionists to create tailored training materials for Andean and Caribbean regions.





> **4.1.1 Activity:** *At least 30 Master Trainers trained from cocoa extension service providers in project countries for massive dissemination of best practices to cocoa farmers*

Extension service providers received training as Master Trainers in cadmium (Cd) mitigation strategies for cocoa through the curricula, enabling them to transfer knowledge to producers and stakeholders across the cocoa value chain. A total of 173 extensionists, 30 in Colombia, 54 in Ecuador, 73 in Peru, and 16 in Trinidad and Tobago, comprising 132 men and 41 women, completed the training, surpassing the target of 30 by 577%. These Master Trainers subsequently facilitated the training of 2,309 cocoa farmers (600 in Colombia, 997 in Ecuador, 599 in Peru, and 113 in Trinidad and Tobago) comprised of 632 women and 1,677 men. This cascading training approach is expected to accelerate the adoption of best practices for reducing Cd levels in cocoa beans across Latin America and the Caribbean.

Colombia
A structured training program equipped 30 FEDECACAO technical assistants and 300 producers with knowledge in Cd mitigation. Training reached the Santander, Antioquia, Huila, and Tolima regions responsible for 58% of Colombia's cocoa production. Educational materials included 3,000 printed booklets and five project-related videos. Two national symposiums covered key topics, including Cd origins, its impact on cocoa cultivation, international regulations, and best agricultural practices.

Ecuador
Fifty-four technical personnel became Master Trainers through a three-module program on Cd management. These trainers educated 997 producers across Los Ríos and El Oro, covering soil sampling, mitigation strategies, and post-harvest management. An additional 130 cocoa value chain stakeholders received training on organic and chemical amendments. A tailored training guide facilitated learning for 117 participants in Los Ríos, Santo Domingo, Napo, and Peru, improving understanding of Cd in cocoa by 46%.

Peru
Seventy-three Master Trainers received intensive training in San Martín, Piura, and Huánuco, covering soil dynamics, Cd bioavailability, and integrated soil fertility management. Learning tools/infographics and visual aids transformed complex topics into accessible resources. These trainers then educated 815 cocoa producers (25% women). Field exercises proved especially effective, enhancing participants' understanding of Cd challenges and solutions.

Trinidad and Tobago
The Ecuadorian training guide was adapted to develop a national curriculum, resulting in the certification of 16 Master Trainers. These trainers cascaded knowledge to 80 extension workers and producers. Impact assessments were conducted through reports and pre/post-training evaluations. Educational bulletins, manuals, and a Cd management video were also distributed.

Across all participating countries, these initiatives significantly strengthened local knowledge to mitigate Cd in cocoa, enabling sustainable and compliant production practices.

> **4.2 Activity:** Awareness-raising and distribution of best practices. *At least 10 bulletins/messages developed and one paper submitted to journal for publication*

The project was very prolific in dissemination of knowledge and user appropriate information utilizing a wide range of media channels.

Webinar Series on Cadmium in Cocoa ("Cd Talks")

As part of the project's awareness raising efforts, a webinar series titled **"Cd Talks"** was developed with simultaneous English/Spanish and Spanish/English interpretation to engage regional and international stakeholders on cadmium (Cd) in cocoa. The series featured five webinars, each including two expert presentations on key aspects of cadmium contamination in cocoa, regulations, and mitigation strategies. Regional and international specialists in cadmium in cocoa and related fields contributed their expertise:

- **Webinar 1: 26 Sep 2023 (ENG and SPN)**[1]
  - *Talk 1: Cadmium in Food and Regulations to Protect Human Health* – Dr. Leslie Hoo Fung – International Center for Environmental and Nuclear Sciences (ICENS) Jamaica
  - *Talk 2: Cadmium and Soils – Mr. Daniel Guarin, PhD Candidate Penn State University USA*
- **Webinar 2: 31 Oct 2023 (ENG and SPN)**[1]
  - *Talk 1: Factors Affecting Cd in Cocoa Plants and Beans – Mr. Kevin Carrillo & Mr. Luis Solano - National Institute for Innovation and Transfer in Agricultural Technology (INTA) Costa Rica*
  - *Talk 2: Cd, Cocoa Beans, and the Market – Mr. Marc Joncheere- Cargill USA & Dr. Christina Rohsius- Rausch GmbH Germany*
- **Webinar 3: 28 Nov 2023 (ENG and SPN)**[1]
  - *Talk 1: Quality Assurance in Laboratory Testing for Cd in Cacao Soil and Tissue Samples – Mr. Jesse Dekeyrel, PhD Candidate, Ku Leuven University Belgium*
  - *Talk 2: Cadmium in Cacao: From Field Sampling to Lab Quantification – Ms. Ruth Quiroga & Ms. Deisy Toloza Moreno – AGROSAVIA Colombia*
- **Webinar 4: 30 Jan 2024 (ENG and SPN)**[1]
  - *Talk 1: Managing Cadmium Levels in Cocoa at the Pre-Harvest Phase – Dr. Gideon Ramtahal – Cocoa Research Center (CRC) UWI Trinidad and Tobago*
  - *Talk 2: Cadmium Mitigation Strategies During Cocoa Fermentation Processes – Dr. Frank Intriago - Universidad Técnica de Manabí (UTM) Ecuador*
- **Webinar 5: 09 Apr 2024 (ENG and SPN)**[1]
  - *Presenters: Ms. Rachel Wallace, Mr. Nicholas Hoskyns, & Mr. Albert Tucker*
  - *Talk 1: Empowering Small Farmers to Overcome Challenges and Meet Market Requirements – Ètico – The Ethical Trading Company London*
  - *Talk 2: Opportunities Emerging from Market Requirements – Ètico – The Ethical Trading Company London*

The webinar series engaged **217 (105 females and 112 males) participants from 32 countries (the Americas, Europe, Africa, Asia** and **Oceana/Australia**) representing diverse stakeholders across the global cocoa value chain, including farmers, NGOs, academics, sourcing agents, private and public sectors. The sessions aimed to deepen participants' understanding of Cd in cocoa and foster discussions on effective mitigation strategies through both technical and industrial approaches. Feedback surveys indicated a high level (95%) of satisfaction with the information presented. To ensure ongoing access to these valuable discussions, summary videos with Q&A readouts in English and Spanish of each webinar have been made available on IICA's **Agriperfiles platform**[1] or videos only can be accessed with the links provided above for each webinar.

5.1-5.3 Activities: *Workshops and Results Dissemination*

Reports from the Inception (24 Oct 2022) Midterm (20-24 Nov 2023) and End of Project (18-22 Nov 2024) Workshops were also produced and disseminated. Summaries are presented in Section 8 on Communications and Outreach.

Bulletins, publications and videos on (Agriperfiles platform)[1]

Colombia
Journal Publication **-** First national mapping of cadmium in cacao beans in Colombia – Sci. Tot. Env. – 954:
Journal Publication - Cadmium in fertilisers used for cacao production: a case study in Colombia – Food Additives & Contaminants: Part A- 42(9):1213-28
Journal Publication - Assessment of monochromatic X-ray fluorescence spectrometry as a reliable analytical technique for cadmium quantification in cacao systems - Spectrochimica Acta Part B: Atomic Spectroscopy: 235

- Video General - Proyecto STDF Cadmio en Cacao_VF (subtítulado).mp4
- Video Temático 1 (Conceptos básicos) - Proyecto STDF Cadmio en Cacao_VF (subtítulado)....
- Video Temático 2 (Protocolo muestras análisis cadmio) - Proyecto STDF Cadmio en Cacao_...
- Video Temático 3 (Análisis, calidad, innovación y reporte de cadmio en cacao) – Proyecto S...
- Video Temático 4 (Geoanálisis del cadmio en cacao) – Proyecto STDF (720p50).mp4

Ecuador

Video - Master Trainers for the Prevention and Mitigation of Cd in Cocoa

Guia 17 – Herramientas de Apprendizaje para la Prevención y Mitigación de la Presencia de Cadmio en Cacao. **ISBN 978-9942-22-605-1 pp77**

Trinidad and Tobago

- CADMIUM managemnt best practices Manual for T&T.pdf
- STDF Bulletin 1 (General).pdf
- STDF Bulletin 2 (Technical).pdf
- STDF Bulletin 3 (Technical).pdf
- STDF Bulletin 4 (Technical).pdf
- STDF BULLETIN 5 (General) Improving Cocoa Yield.pdf
- STDF BULLETIN 6 (General) Pruning Cocoa Trees.pdf
- STDF BULLETIN 7 (General) Managing Cocoa Disease.pdf
- STDF BULLETIN 8 (General) Crop Propagation.pdf

In total eight Bulletins, two Manuals in ENG, FRE (for Extensionist Master Trainer Curriculum only) and SPN, three peer review publications, six videos and five webinars with video summaries and Q&A were produced by this project which surpassed the target by 220%.

4.1 Project goal and outcome level results

Project Goal: Countries (Colombia, Ecuador, Peru, and Trinidad & Tobago) comply with international trade measures established for cadmium limits in cocoa and cocoa derived products.
Project Purpose: Countries (Colombia, Ecuador, Peru, and Trinidad & Tobago) put in place a coordinated pathway to meet the international regulations regarding cadmium concentrations in cocoa and cocoa-derived products.

The project has advanced a coordinated pathway across Colombia, Ecuador, Peru, and Trinidad and Tobago to meet international cadmium regulations for cocoa and cocoa-derived products. By strengthening scientific, technical, and institutional capacities, the project lays the foundation for full integration into National Cocoa Sector Plans, ensuring sustained compliance with international trade standards and reducing the risk of export rejections.

4.2 Output Summary

Across the four project countries, significant progress was achieved under all outputs, directly strengthening national capacities to comply with international cadmium (Cd) limits and maintain market access for cocoa and cocoa-derived products.

Output 1: Framework for Coordination and Information Sharing on Best Practices for Cadmium Mitigation and Remediation

The project established a regional coordination platform that brought together lead research agencies from Colombia, Ecuador, Peru, and Trinidad and Tobago with invited public and private sector interventions to harmonize approaches on cadmium monitoring and mitigation. Through this platform, project countries reached agreement on standardized Cd testing methodologies and jointly systematized 140 technical resources in a KOHA database. All four Ministries of Agriculture reviewed their national cocoa sector plans for incorporation the project’s nine recommended mitigation strategies; Colombia, Ecuador, and Peru formally endorsed its inclusion, while Trinidad and Tobago has already begun implementing the recommendations as it finalizes revisions and approval processes of its National Cocoa Sector Plan.
Outcome: These actions strengthened regional coordination and provided countries with a unified, science-based framework essential for meeting international cadmium standards and protecting long-term market access.

Output 2: Enhanced and Standardized Capacity to Analyze Cadmium Levels

The project significantly surpassed its target by training 80 technicians (26 women and 54 men) across the four countries, which is ten times the original goal. All countries adopted the regional Glossary of standardized terminology and the Latin America and the Caribbean Standard Operating Procedure (SOP) for Cadmium Analysis, both published in English and Spanish. The project scientifically validated the efficiency of the X-ray fluorescence (XRF) E-max analyser, leading to its adoption by project countries, including procurement by the Ministry of Agriculture in Trinidad and Tobago, which strengthened analytical capacity and improved testing efficiency.
Outcome: These achievements created a more efficient, cost effective and standardized analytical system across project countries, improving their ability to monitor cadmium levels accurately and meet international market requirements. They also established the foundation for more reliable and harmonized cadmium surveillance across the LAC region, supporting long-term compliance with global export standards.

Output 3: Improved Knowledge of Cadmium Presence in Cocoa Growing Areas Through Analysis and Mapping

PG/577 enhanced the granularity of cadmium hotspot maps for Ecuador and Trinidad and Tobago, produced Colombia’s first national map of cadmium in cocoa beans, and deepened understanding of hotspots in Piura, Huánuco, and San Martín in Peru. In Trinidad and Tobago, the higher-resolution maps enabled the development of a Farm Categorization model to guide farm-specific cadmium mitigation strategies. Comprehensive analyses of soil, beans, water, and fertilizers provided key

insights into risk pathways, identifying fertilizers as a potential source of bioavailable cadmium for cocoa. These outputs support targeted interventions in areas where cadmium levels exceed regulatory thresholds.
Outcome: Improved understanding of the factors driving cadmium hotspots in cocoa production areas will facilitate practical, targeted, and cost-effective mitigation measures, helping countries comply with international cadmium standards.

Output 4: Awareness Raising Among Stakeholders in the Cocoa Supply Chain

The project demonstrated that 173 Master Trainers, using the same curriculum supplemented with context-specific visual aids, could effectively raise awareness of cadmium in cocoa and mitigation strategies among more than 2,300 producers across the four project countries in less than a year. This community-level, cascading approach can be reinforced by broader awareness-raising initiatives. The project also reached diverse audiences through the Cd Talks webinar series (217 participants from 32 countries) and a range of media products, including bulletins, YouTube videos, and radio segments.
Outcome: Enhanced awareness among farmers, buyers, regulators, and extension providers will support the adoption of cadmium mitigation measures and help ensure compliance with international cadmium import standards

4.3 Other unexpected results

The data generated from the project is being utilized by two graduated students, Rosario Alarcorn in Peru for a Master of Science degree and supported the completion of a PhD thesis entitled, "Mitigación del cadmio en cacao (Theobroma cacao L.) mediante el uso de enmiendas orgánicas y químicas en suelos tropicales", by Mr. Edgar Patricio Cedeño Coll in Ecuador.

4.3.1 Other institutional spillovers

Public–private collaboration and stakeholder engagement were strong throughout the project. A notable example was the positive feedback received by project lead Dr. Daniel Bravo in Colombia, highlighting the project's tangible benefits for international exporters. Alfredo Faubel, a major cocoa exporter to Europe, publicly expressed his appreciation on social media for the project's work. Such recognition underscores the project's contributions to building industry confidence and supporting export growth.

> Original message:
> *'Estimado Daniel,*
> *Acabo de encontrar "The First National Survey of Cadmium in Cacao Farm Soil in Colombia".*
> *Con mi hermano Alberto exportamos grano a Europa. Somos conscientes del obstáculo que representa el cadmio. Así que GRACIAS por tu valiosa aportación!*
> *Saludos cordiales, Alfredo'*
>
> English Translation:
> *'Dear Daniel,*
> *I just found "The First National Survey of Cadmium in Cacao Farm Soil in Colombia".*
> *With my brother Alberto we export beans to Europe. We are aware of the obstacle that cadmium represents. So THANK YOU for your valuable contribution!*
> *Best regards,'*
> *From: Alfredo Faubel. Direkter Kontakt. Founder at Miura Board® leading in sustainable materials innovation*

4.3.2 Infrastructure spillovers

Colombia and Trinidad and Tobago both strengthened their national cadmium testing and surveillance systems through new investments in E-max monochromatic X-ray fluorescence technology. In Colombia, testing capacity was expanded using E-max equipment previously validated under STDF/PG/577 and acquired through the Arauca cocoa cadmium mitigation project

(ID 1001450), with funding from the BPIN and the Ministry of Agriculture and Rural Development. Working with FEDECACAO, this upgrade now allows high-resolution cadmium testing in cocoa beans and significantly improves national hazard surveillance.

In Trinidad and Tobago, the Ministry of Agriculture, Lands and Fisheries procured an E-max analyser following the project's science-based validation and recommendation, commissioning it on 9 April 2025. Training for eight technicians (five women, three men) at the Centeno lab was delivered by the analyser's inventor, Dr. Seuw Chen, who made the session interactive and user-friendly. Ongoing remote support, replicate analyses, and KUL reference samples (donated by PG/681 with logistics supported by PG/577) addressed concerns about test variability, while the project's SOP provides a standardized methodology. Testing services for farmers began in June 2025 and, together with strengthened market-surveillance systems, provide a robust foundation for food-safety monitoring in the cocoa sector.

5. CROSS-CUTTING

5.1 Gender

5.1.1 Summary and analysis of how gender was mainstreamed in the project and how it promoted gender equality

Across all four countries, the project demonstrated a strong commitment to gender inclusion. In Ecuador, women accounted for 30.8% of cadmium-mitigation training participants, bringing diverse perspectives and helping close gender gaps in knowledge-sharing and decision-making. In Peru, women made up an average of 31% in the Master Trainer course and 25% in producer replication workshops, ensuring equitable access to capacity-building along the cocoa value chain. In Trinidad and Tobago, 48% of the 138 trained participants were women, reflecting the cocoa sector profile where women constitute roughly 30% of farmers and 47% of the technical workforce. This deliberate gender balance strengthened women's technical skills, leadership potential, and roles across the sector, contributing to a more equitable and resilient cocoa industry regionally.

5.2 Environment, Biodiversity and Climate Change

The project promoted environmental sustainability across all participating countries by encouraging targeted, eco-friendly practices. Project events incorporated environmentally conscious measures, such as replacing single-use plastics with refillable water dispensers, paper cups, and personal tumblers, reducing the project's ecological footprint. These efforts also raised awareness of sustainable practices that support soil health and broader environmental protection.

6. FINANCIAL OVERVIEW

The initial project budget for Colombia, Ecuador, Peru, and Project Execution totaled USD 381,946 from the STDF, with USD 347,224 allocated for project implementation and USD 34,722 (10%) for overhead fees. As a non-ODA (Official Development Assistance) recipient, ICCO secured an additional USD 65,254 from the 11th EDF of the European Union to support project activities in Trinidad and Tobago. Together with USD 103,748 in in-kind contributions from the four project countries, the total project value reached USD 550,948.

A unified tracking and reporting system was implemented across all project partners to record both in-cash and in-kind contributions toward technical project activities. Actual in-kind contributions totalled USD 368,743, 3.6 times the original commitment and nearly equal to the STDF in-cash allocation. As a result, the final total project value reached USD 814,119, a 48% increase over the original contracted budget of USD 550,948, reflecting the substantial time and effort invested by partners and commitment to meeting SPS and food safety requirements for cocoa and cocoa products.

Throughout the project's implementation, requests were submitted to and approved by the STDF for no-cost reallocations of funds to enhance the project's agility and ensure responsiveness to evolving circumstances on the ground.

7. CHALLENGES, RISKS & MITIGATION

The project faced several operational challenges that affected the pace of implementation. Some were manageable, such as coordinating activities in both English and Spanish. More significant challenges arose from external factors beyond the project's control. Political instability in Ecuador and Peru during the project start-up in early 2022, combined with ongoing global COVID-19 travel restrictions, delayed initial activities and required a one-year extension of the implementation period.

Delays in the formal engagement of National Project Implementing Agencies (NPIAs) also affected early progress. Trinidad and Tobago's Cocoa Research Centre (CRC) formalized its participation first, followed by Colombia and Peru. Ecuador experienced the most substantial delays due to complex political and security conditions, fully joining in April 2023.

Despite these challenges, all countries demonstrated strong commitment, and full project implementation commenced in May 2023. The Project Management Unit (PMU) maintained momentum by launching the regional platform in October 2022 to foster collaboration and ensure alignment with the 11th EDF timelines.

8. COMMUNICATIONS AND OUTREACH

The project "Improving Capacity Building and Knowledge Sharing to Support the Management of Cadmium Levels in Cocoa in Latin America and the Caribbean" actively engaged stakeholders through multiple communications and outreach efforts.

- **Activities and Links**

Activity	**Link**
Interview on TVAgro about the project	Watch here
Training Video: Formation of Master Trainers (INIAP, Ecuador)	Watch here
FEDECACAO International Symposium Video	Watch on Facebook
Agrosavia News: VII International Cocoa Seminar	Read here
Theobroma for Peace Congress (Dr. Bravo's Presentation)	Watch here (from Minute 27:16)
Agrosavia News: Cadmium Research at Theobroma	Read here
Video General Proyecto STDF Cadmio en Cacao VF subtítulado	Watch here
Managing Cd levels in cocoa beans in Trinidad and Tobago	Watch here

- **Summaries of Key Events**

Cd Talks Series: Organized by the PMU (IICA Jamaica), the Cd Talks webinars targeted stakeholders across the cocoa value chain. The series focused on raising awareness about cadmium contamination in cocoa, mitigation strategies, and compliance with EU regulations. Five webinars were held, featuring technical presentations, discussions, and Q&A sessions with experts. The series ran from Sep 2023 to Apr 2024 and attracted participants from 32 countries in 5 continents in the Cocoa value chain.

Inception Workshop (October 2022): The virtual Inception Workshop officially launched the project, introduced the objectives and work plan, and established coordination mechanisms among Colombia, Ecuador, Peru, and Trinidad & Tobago. The "Cadmium Free Cocoa" logo was unveiled, and country status updates were shared. 137 participants joined from Latin America, the Caribbean, Europe, North America, and Africa.

Midterm Workshop (November 2023, Bogotá): Agrosavia and IICA Colombia hosted a project evaluation meeting involving Steering Committee Members, IICA technical leads, and NPIA representatives. Key decisions included the extension of the project to November 2024 and strategic planning for remaining activities. A project booth at Chocoshow 2023 showcased outputs to over 18,000 visitors, strengthening public engagement.

End of Project Workshop (November 2024, Guayaquil): INIAP and IICA Ecuador hosted representatives from the STDF, ICCO, project Steering Committee members, and project teams from

Colombia, Ecuador, Peru, and Trinidad & Tobago. The event featured presentations on project achievements, including cadmium mapping, training programs, and mitigation strategies. ICCO and STDF discussed food safety challenges and potential financing opportunities, while a technical forum explored scientific advances and stakeholder strategies for cadmium reduction.

- **Project Outputs**
    - 8 Bulletins
    - 2 Manuals
    - 1 Glossary of Cocoa terms in Latin America and the Caribbean
    - 6 Training Videos
    - 5 Webinars (with Q&A and video summaries)
    - 3 Peer-reviewed Publications
    - Midterm and End-of-Project Workshop Reports

- **Overall Impact**

Communications activities exceeded targets by 220%, greatly enhancing project visibility, stakeholder knowledge sharing, and regional collaboration for safer cocoa production. Two quotations from Trinidad and Tobago highlight the project's significant impact:

Quote 1:
"The Cadmium training was very beneficial to my profession in the agriculture sector. Although I am not directly involved in cadmium sampling and analysis in my current role, I actively alert farmers and stakeholders to the potential risks and encourage them to have their samples tested. I look forward to participating in future training opportunities."
— Ms. Julia C. Parris, Plant Pathologist (Ag.), MALF

Quote 2:
"The collaborative project on Cadmium in Cocoa, implemented through IICA, has greatly benefited the sector. It reinforced the critical importance of heavy metal testing in cocoa beans. Following project recommendations, the Research Division of the Ministry of Agriculture, Land and Fisheries acquired an Emax machine, enabling the realization of free testing of cocoa beans for farmers seeking access to export markets. Testing services will also be available to other CARICOM nations. This initiative will: (1) Ensure compliance with international standards; (2) Support premium and fine flavor branding; (3) Improve traceability and farm management; (4) Boost farmers' income; and (5) Strengthen industry resilience."
— Mr. Ian Mohammed, Director of Research, MALF and National Steering Committee Member, Cocoa Cadmium Project (T&T).

9. SUSTAINABILITY & FOLLOW-UP

This section highlights the project's engagement with stakeholders to sustain results, support follow-up, and explore scaling and replication. The initiative has inspired similar efforts in Grenada, Dominica, St. Lucia, and Jamaica, while discussions with the European Union aim to secure additional technical and financial support. Proposals to develop cadmium-resilient cocoa genotypes, informed by scientific findings and stakeholder feedback, form part of a coordinated strategy to extend impact nationally and regionally.

Country-level follow-up shows strong momentum. In Colombia, companies such as Casa Luker acknowledged the spatial variability of cadmium in cocoa beans, reflecting growing food safety awareness. In Ecuador, the Master Trainers model continues through local facilitation teams that disseminate technologies and support producers. In Peru, trained personnel integrated into INIA and SENASA strengthen long-term replication and incorporation of cadmium mitigation into national extension systems. In Trinidad and Tobago, collaboration with MALF, CDCTTL, and UWI Cocoa Research Centre aligned project activities with national goals, while awareness campaigns and stakeholder dialogues promoted safer production, consumption, and participation in safer value chains.

10. LESSONS LEARNED

Several regional-level lessons emerged that are broadly applicable to countries addressing cadmium contamination in cocoa. These lessons span innovation, collaboration, sustainability, and institutional strengthening.

1. **Innovative Approaches and Technical Insights**
   Strengthening Analytical Capacity is Foundational
   - Capitalizing on opportunities to test and validate new analytical technologies such as the E-max analyser, significantly improved Cd testing efficiency, reduced processing times, and strengthened decision-making. Adoption of the E-max system in Colombia and Trinidad and Tobago demonstrates how targeted technological upgrades can rapidly enhance national monitoring capacity.
   - All countries demonstrated the value of building national data assets (e.g., Colombia's national Cd map), which offer long-term benefits for research, policy formulation, and targeted field interventions.

   Tailored, Context-Specific Mitigation Approaches Are Necessary
   - Countries validated that Cd uptake is influenced by complex soil–plant interactions and cannot be inferred solely from soil concentrations.
   - Integrated soil fertility management and context-specific mitigation practices are necessary in Cd hotspots, adapted to local soil–plant interactions, geographic conditions, and farm-level realities.

2. **Synergies and Inter-Institutional Collaboration Accelerate Implementation**
   - Collaboration between national research institutes, producer organizations, ministries, and IICA supported by country-specific partnerships with FEDECACAO (Colombia), technical working groups (Ecuador), multisector coordination units (Peru), and national laboratories and universities (Trinidad and Tobago) was a central factor of success, enabling broad outreach and strengthening policy influence across the region.

3. **Capacity Building and Knowledge Transfer**
   Cascade Training Models Are Highly Effective
   - The project's decentralized Master Trainers approach can be adapted to build on country-specific contexts, demonstrated by Colombia's technical assistants embedded in production zones or Peru's training-of-trainers network, to effectively extend outreach and translation of laboratory results into practical cadmium mitigation actions.

   Use of Simplified Teaching Tools Enhances Uptake
   - Infographics were developed and incorporated into the Master Trainers Curriculum to enhance understanding and practical application of cadmium mitigation strategies, highlighting the value of clear and accessible teaching tools for effective knowledge transfer across the region.

   Right Personnel Drive Results
   - Progress across countries depended heavily on committed technical leads and field personnel who were empowered to champion the work and maintain strong relationships with producers.

4. **Sustainability, Policy Uptake and Spillover Effects**
   Sustained Laboratory and Human Capacity is Essential
   - The need for continued investment in laboratory strengthening, equipment maintenance, and skilled personnel is indispensable for long-term Cd monitoring and SPS compliance.

   Policy Integration Ensures Long-Term Impact
   - Embedding the nine project recommendations into national cocoa programmes through measures such as aligning fertilizer regulations (Ecuador), establishing coordinated national Cd surveillance systems (Trinidad and Tobago), and using national Cd maps (Colombia) is a key pathway that requires funding to ensure the long-term sustainability and impact of cadmium mitigation efforts.

11. RECOMMENDATIONS

Building on lessons from Colombia, Ecuador, Peru, and Trinidad and Tobago, the following recommendations aim to sustain impact, strengthen cadmium mitigation, and support replication across cocoa-growing countries in LAC:

1. **Strengthen Partnerships and Collaboration**
    - Forge alliances with public and private institutions, including research institutes, producer organizations, and laboratories, to expand outreach and support for producers.
    - Promote collaboration between EU and LAC laboratories involved in cadmium analyses for trade to harmonize procedures, validate results, and strengthen credibility in the cocoa sector.
    - Incorporate knowledge exchange activities beyond routine meetings to enhance capacity building and facilitate effective knowledge sharing.
2. **Enhance Training and Capacity Building**
    - Expand training for producers and technicians on sampling, analysis, and mitigation practices for cadmium in cocoa.
    - Extend train-the-trainer programs to new regions.
    - Develop flexible learning options, including asynchronous online courses.
    - Use practical tools such as manuals and infographics to simplify cadmium management strategies.
3. **Standardize Monitoring and Analysis**
    - Expand standardized sampling and laboratory procedures for consistent, reliable results across cocoa producing countries.
    - Maintain ongoing cadmium monitoring to evaluate and refine mitigation strategies.
4. **Promote Sustainable Practices**
    - Promote sustainable agricultural practices that minimize cadmium accumulation while safeguarding environmental and public health.
5. **Support Research and Economic Decision-Making**
    - Investigate cadmium bioaccumulation mechanisms to inform targeted strategies.
    - Conduct cost-benefit analyses of mitigation practices to guide informed decisions by producers.

These recommendations provide a practical roadmap to consolidate project results and scale cadmium management across Latin America and the Caribbean.

12. ANNEXES

Attach additional relevant information/documents to be uploaded as a .zip file, including:

1. *Updated logical framework matrix with actual results achieved for each project indicators*
2. *Final signed financial report*
3. *List of key documents produced under the project (e.g. training manuals, codes of good practice, etc.).*
4. *List of key training workshops, outreach events, study tours, etc. organized under the project including dates, location, number of persons (M/F)*
5. *List of key persons (including names and contact details) involved in the project from the implementing organization, other partners, beneficiary organizations, etc.*
6. *Any other relevant documents*