Clima-LoCa

Fostering low-cadmium and climate-relevant innovations to enhance the resilience and inclusiveness of the growing cocoa sectors in Colombia, Ecuador and Peru.

DeSIRA PARTNERSHIPS FOR INNOVATION

Funded by the European Union

Alliance

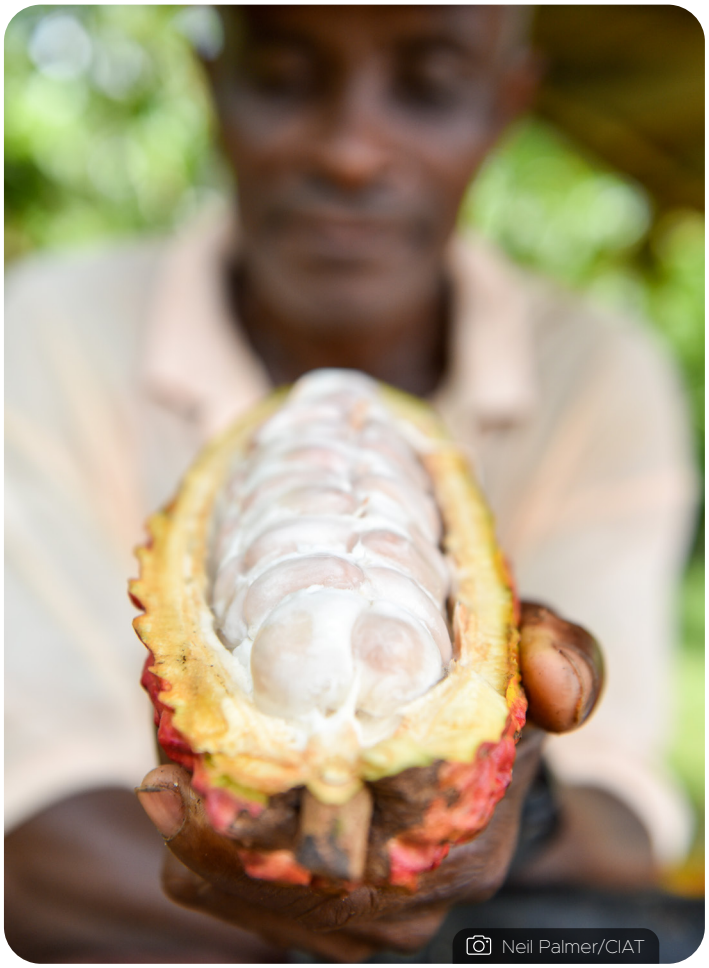
Bioversity International | CIAT International Center for Tropical Agriculture | CGIAR

Policy Brief No. 1

Cadmium in cacao: why it occurs, how it is regulated, and why it is a concern for producers

First Clima-LoCa policy brief on cadmium in cacao

Neil Palmer/CIAT



Neil Palmer/CIAT

Key Messages

- Cadmium, a heavy metal that occurs naturally in soil, is absorbed by cacao plants and can pose health risks to humans when cacao is consumed.
- Food safety regulations, especially since 2019 in the European Union, restrict acceptable concentrations of cadmium in cacao products such as chocolate and cocoa powder.
- This has ramifications for the cacao sector worldwide as many farmers, particularly in Latin America, may lose market access if they cannot meet these regulations.
- Actors across the cacao value chain, including farmers, must be informed and supported to adapt to these regulations.

November 2021

Introduction

Cadmium in food products can be a serious health risk. Accumulation of cadmium in the human body over time can cause kidney problems and bone demineralization and it has been shown that cadmium is carcinogenic. Therefore, food safety regulations in several countries establish maximum concentrations for cadmium in several foodstuffs. The European Union (EU), for example, has set cadmium limits for a variety of food products, including several vegetables and fruits, potatoes, rice, wheat, seafood, and different kinds of meat, among others (Commission Regulation (EC) No. 1881/2006 [1], which was recently amended [2]. In 2014, the European Commission first established the maximum allowed cadmium concentration in chocolate and cocoa powder. This regulation has been in force since January 2019 (Table 1). Similar regulations for cadmium in cacao products have been, or are expected to be, implemented worldwide, for example, in Australia and New Zealand [3], Russia [4], and in the countries within the Southern Common Market, that is, Brazil, Argentina, Uruguay, Paraguay, Bolivia, and Venezuela [5]. In California (United States), chocolates with elevated cadmium concentration must have a Proposition 65 warning on their packaging.

Cadmium in cacao products such as chocolate originates from the cacao beans rather than from contamination during processing or other ingredients. However, most regulations, including the EU and U.S. regulations, apply to the final product sold to consumers and not to the cacao beans. Cadmium limits for final products cannot be translated one to one to cadmium concentration in the beans nor to cocoa powder used as an intermediary product in processing.

Considering that the cadmium in chocolate originates from the beans, the cacao processing industry has translated the official EU regulations into unofficial industry thresholds that apply to the beans. These unofficial thresholds vary from company to company and are raising concern with cacao growers that are affected by the new food safety regulations, especially in Latin America.

In addition, affected cacao growers are in urgent need of solutions that can help to diminish cadmium concentrations in cacao beans. However, these solutions are not straightforward. On the one hand, our scientific knowledge of the various factors and processes that affect cadmium accumulation in cacao beans is incomplete. On the other hand, any solution that is technically feasible also needs to be applicable and affordable considering the socioeconomic context in which smallholder cacao producers operate.

Farmers, practitioners, policymakers, industry officials, and other relevant actors in the cocoa value chain have many questions regarding cadmium in cacao. The objective of this set of Clima-LoCa Policy Briefs is therefore to address common questions regarding cadmium in cacao in a science-backed manner and to iron out some persisting misconceptions.

This first Policy Brief deals with commonly asked questions about the origin of cadmium in cacao and about the interpretations and consequences of the EU food safety regulations. A second Policy Brief in this series deals with the mitigation measures or, in other words: What options exist for affected cacao producers to adapt to food safety regulations on cadmium in cacao?

Q1 What are the new EU limits and how do they translate to cacao beans?

Europe is the largest importer of cocoa globally. Specialty cocoa, including fine flavor cocoa, is mainly sourced from Latin America. Overall, imports from Latin American countries have increased at an average annual rate of 4.5% in the past five years [6] in line with higher consumer demand for sustainable and higher-quality chocolate. As indicated above, in 2014 [1], the EU limits on cadmium in chocolate and cocoa powder were added to the existing food safety regulation that sets maximum concentrations of cadmium in a range of foodstuffs sold for final consumption on the European market. The limits for cacao products depend on the cacao solids content of the final product. Table 1 gives an overview of the EU limits for chocolate and cocoa products, which have been in effect since 2019. According to the recent amendment [2] of the EC food safety regulation, the limits on cadmium in cacao have not changed.

Table 1. Maximum limits for cadmium in chocolate and cocoa powder sold on the European market.

EU regulation in force from 1 January 2019	Maximum concentration (mg Cd/kg wet weight)
Milk chocolate with <30% total dry cocoa solids	0.10
Chocolate with <50% total dry cocoa solids; milk chocolate with ≥30% total dry cocoa solids	0.30
Chocolate with ≥50% total dry cocoa solids	0.80
Cocoa powder sold to the final consumer or as an ingredient in sweetened cocoa powder sold to the final consumer (drinking chocolate)	0.60

Research has shown that cadmium in chocolate and cocoa powder originates mostly from the cacao beans [7, 8, 9, 10, 11] rather than from contamination during processing or from other ingredients (e.g., sugar or milk powder). Therefore, cocoa processing companies in Europe are setting unofficial limits on the cacao beans they purchase from their suppliers. Within the cacao bean, cadmium is mostly present in the non-fat cacao solids. This means that cadmium concentrations in cacao butter is negligible.

Because the cadmium concentration in chocolate depends on the percentage of cocoa solids in the product and because EU regulations also vary based on the cacao solids content, the acceptable concentration in cacao beans depends on the type of product that will be made with those beans. An online tool was therefore developed by the Alliance of Bioversity International and CIAT to help different actors in the industry with these calculations, which can be accessed at www.chocosafe.org. It shows that cacao beans with up to 0.30 mg Cd/kg can be safely used in the production of all chocolate types (not cocoa powder) included in Table 1. However, acceptable concentrations in cacao beans intended for the production of dark chocolates are much higher. For example, cacao beans (or liquor) with up to 1.2 mg Cd/kg can be used to produce a chocolate with 65% cocoa solids without exceeding the maximum limits established by the EU regulation.

For cocoa powder, the type of cocoa powder in terms of fat content of the product should be considered. Acceptable bean cadmium thresholds are lower for fat-reduced cocoa powder (<20% cocoa butter) vis-à-vis regular cocoa powder (≥20% cocoa butter) [12, 13]. For example, cacao beans (or liquor) with up to 0.43 mg Cd/kg can be used to produce a cocoa powder with 30% cocoa butter without exceeding the EU limit for cocoa powder (0.60 mg Cd/kg). The production of fat-reduced cocoa powder with only 20% cocoa butter requires cacao beans or liquor with up to 0.38 mg Cd/kg.

Q2 Are these limits of concern to cocoa producers?

Currently available research shows that cadmium concentrations are generally higher in cacao beans and chocolate produced with cacao beans from the Americas compared with other cacao-producing continents such as Africa [9, 11, 14]. The first report of elevated concentrations in Latin American cacao compared with cacao from other origins dates back to 1979 [15]. Average cadmium concentrations reported in the literature vary from 0.02 to 0.51 mg/kg for African beans, while average concentrations in Central and South American cacao are reported to range from 0.10 to 12.0 mg/kg [16]. However, elevated concentrations do not occur everywhere; a lot of variation exists across the Latin American region and within countries. There are so-called hotspots, areas with higher cacao bean cadmium concentrations than others, and these hotspots exist on national, regional, and even farm scale [16, 17]. In other words, not all cacao in Latin America contains concentrations that are problematic in the light of the EU requirements. However, the data available in the literature thus far suggest that at least a relevant part of the production in Latin America exceeds the EU requirements, at times even by several orders of magnitude. The limits are thus definitely of concern to producers, although not all cacao producers will be negatively affected.

The socioeconomic impacts in the affected areas can be substantial. Farmers of fine flavor cacao may no longer be able to sell to exclusive markets via their cooperative and might have to sell to local markets via intermediaries instead, which can result in lower prices. On the other hand, mixing cocoa beans from different areas may be needed to decrease the cadmium content in the cocoa, which, in areas that are known for their high sensorial value, can affect the flavor profile and thus the price. Finally, countries such as Colombia that promote cacao to replace illegal crops in areas that suffer from drug-related violent conflict can see their substitution programs threatened by the cadmium concern.

Q3 Where does the cadmium in cacao beans come from?

In general, cadmium in cacao comes from the soil. All soils in the world naturally contain cadmium, but some contain more than others. Soils in large parts of Central and South America, including the Caribbean, are considered as young soils on the geological time scale. In comparison, the soils in West Africa are older and more weathered. As a result, their cadmium concentrations are lower.

Even though soil cadmium concentrations are generally higher in Latin America than in Africa, reported soil cadmium concentrations for the Latin American region are still below 1 mg Cd/kg in most cacao-growing areas. This means that they are within the range generally considered for non-contaminated soils. Research to date indicates that cadmium in cacao in Latin America is mostly of natural origin rather than anthropogenic, that is, it is generally not due to soil contamination although anthropogenic inputs causing soil cadmium contamination can be of importance in localized cases. The use of fertilizer, such as mineral phosphorus fertilizer, is often mentioned as a potential source of cadmium in cacao; however, its contribution is likely negligible. To increase the soil cadmium concentration by only 0.1 mg/kg, farmers would have to continuously apply significant amounts of fertilizer with high cadmium content (i.e., >100 mg Cd/kg P_2O_5) for 100 years [16]. Considering that most smallholder cacao producers rarely use (larger quantities of) fertilizer because of economic constraints, this is highly unlikely. Hence, fertilizer is not the main source of cadmium on cacao farms, certainly not on a large scale. Irrigation water or flooding of riparian areas can be a relevant source of cadmium locally in areas affected by industrial activity or mining.

In addition to the soil cadmium concentration, two other soil properties are important for explaining the extent of cadmium accumulation in cacao beans: soil pH and soil organic matter (see Figure 1). Based on a large data set [16], we showed that >40% of the variability in bean cadmium concentration found in the field can be explained by the combination of total soil cadmium concentration, soil acidity (pH), and soil organic matter (or carbon) content. This is because the amount of cadmium that is available for plant uptake or, in other words, present in a form that can be taken up by the roots of the cacao trees, increases with decreasing soil pH and with decreasing soil organic carbon. The combination of soil cadmium, soil pH, and soil organic carbon can vary a lot among and within farms, which explains why cacao bean cadmium concentrations also show a very high spatial variation, even within farms.

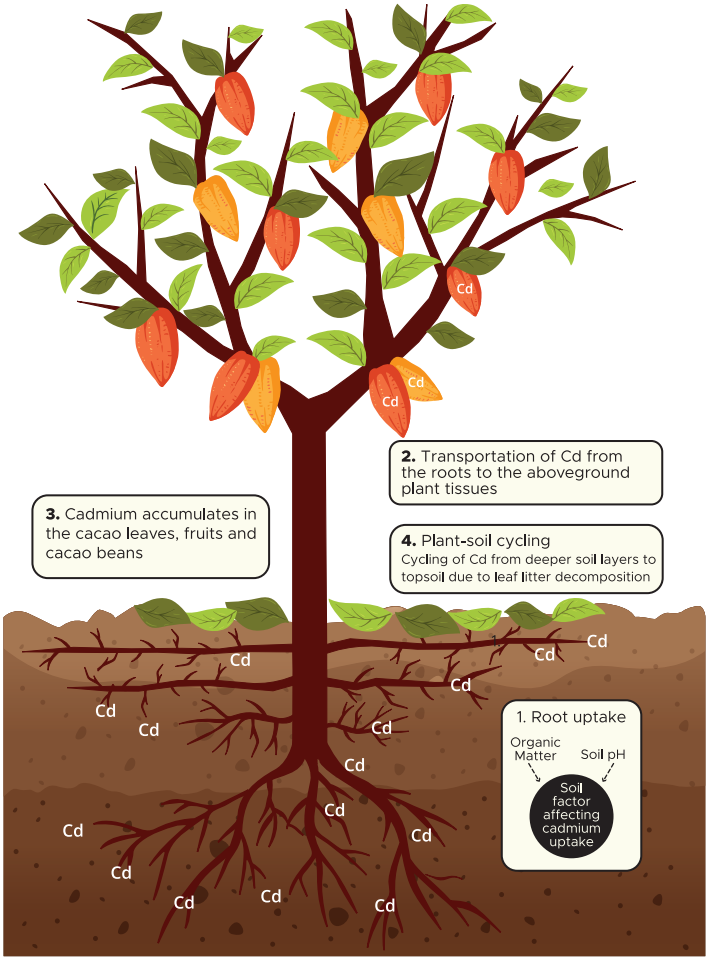


Figure 1. Journey of cadmium from soil to the cacao bean. The figure shows cadmium (Cd) uptake by cacao roots, Cd transportation in the plant and accumulation in cacao tissues including the cacao beans. Soil pH and organic matter in soil are key factors that affect the bioavailability of Cd in the soil and the uptake of Cd by the roots of the cacao trees (adapted from Vanderschueren et al 2021 [16]).

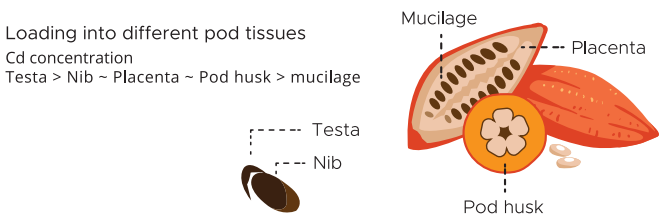


Figure 2. Cadmium concentrations in the cacao pod differ for the different pod tissues. Cadmium concentrations are highest in the testa, followed by the nib, placenta and pod husk and finally the lowest concentrations are found in the mucilage (adapted from Vanderschueren et al 2021 [16]).

Q4 How can farmers know whether their cacao exceeds EU cadmium requirements?

Knowledge is power. Accurate knowledge regarding the cadmium concentration in their cacao beans allows farmers and cacao exporters to negotiate with European cacao buyers and/or enables farmers to take appropriate actions to safeguard their income. Bean or liquor cadmium concentrations can be measured by accredited laboratories. These analyses signify additional costs for cacao producers and exporters. For the information to be reliable, the laboratory should use adequate analytical equipment and protocols and must include certified cocoa reference materials in their analysis. If no cacao beans or liquor are available yet, for example, when assessing the suitability of a field for a new plantation or when the trees are still young, soil analysis can also offer some insights into whether the location presents cadmium-related risks for cocoa production. As stated previously, the cadmium concentration in cacao beans is related not only to the total soil cadmium concentration but also to soil acidity (low pH) and soil organic matter (or carbon), so soil analyses should include those three parameters as a minimum. More information on selecting an adequate laboratory for cadmium analyses can be found in other sources, for example, in the *"Caja de herramientas para la prevención y mitigación de la contaminación de cadmio en la cadena de cacao – Ecuador"* (Toolkit to prevent and mitigate contamination by cadmium in the cacao supply chain – Ecuador), published by the Ministry of Agriculture and Livestock of Ecuador [18].

Maps are also available in the literature that provide predicted cadmium concentrations in soils and cacao beans within a country or a region [17]. However, these maps are only indicative and cannot be used to accurately predict soil or bean cadmium concentration in a specific location or farm. Because of the uncertainties in the predictions, actual cacao bean cadmium concentrations in specific farm plots can be up to twofold higher or lower than the value given on the maps. Actual measurements are thus needed to have more precise information as required for commercial purposes or to know whether a specific location may present cadmium risks when cacao is produced.

Q5 What options do cacao producers have to adapt to the cadmium regulations?

The easiest immediately implementable option is to mix high-cadmium cacao beans with low-cadmium cacao beans to meet the standards in the final product. Mixing can be done on a farm level or at cooperatives provided that accurate and reliable cacao bean Cd analyses are available. Mixing is also already performed on a large scale in the processing industry, where cacao beans from different continents are combined during the chocolate production process to obtain the desired characteristics for the final product. However, high-cadmium areas with known sensorial value may struggle with mixing as it can affect the unique flavor quality of the product. With Latin America being the main producer of specialty and fine flavor cocoas, and the region most affected by the cadmium regulations, this problem disproportionally affects producers and exporters of specialty cacaos in Latin America.

At the level of the cacao farms, it is important for producers to use good agricultural practices in order to prevent soil acidification and to maintain or improve soil organic matter content as those soil conditions allow cadmium to be taken up more easily by the cacao trees. However, for those farmers located in cadmium hotspots, additional targeted measures will be needed. Specific mitigation interventions on affected cacao farms may provide solutions in the medium to long term but require extensive field research to evaluate their effectiveness and implications for farmer income in different soil types and agroecological conditions. Promising strategies may include the use of soil amendments that can decrease the transport of cadmium from the soil to the cacao tree, selection and use of genetic materials that take up less cadmium, or interventions in postharvest processing of the beans. Research is being conducted by Clima-LoCa partners and other research organizations in the affected regions. Our second Policy Brief deals specifically with this topic.

Useful resources

Clima-LoCa project: https://climaloca.org/

Chocosafe: www.chocosafe.org

Vanderschueren et al. 2021. Mitigating the level of cadmium in cacao products: Reviewing the transfer of cadmium from soil to chocolate bar. *Science of the Total Environment* Vol. 781, 146779. Available at: https://doi.org/10.1016/j.scitotenv.2021.146779

References

1. European Union. 2006. Commission Regulation (EC) No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R1881

2. European Union. 2021. Commission Regulation (EU) 2021/1323 of 10 August 2021 amending Regulation (EC) No. 1881/2006 as regards maximum levels of cadmium in certain foodstuffs. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32021R1323&from=EN

3. Australia New Zealand Food Standards Code. 2017. Schedule 19: Maximum levels of contaminants and natural toxicants. https://www.legislation.gov.au/Details/F2017C00333

4. Ministry of Health of the Russian Federation. 2011. Chief State Sanitary Inspector of the Russian Federation Resolution No. 36 – On Enactment of Sanitary Rules.

5. Mercosur (Southern Common Market). 2011. Reglamento técnico Mercosur sobre límites máximos de contaminantes inorgánicos en alimentos (Derogación de las Res. GMC N° 102/94 y N° 36/96). Asunción, Paraguay. 18 p. http://www.puntofocal.gov.ar/doc/r_gmc_12-11.pdf

6. Centre for the Promotion of Imports from developing countries (CBI). 2020. What is the demand for cocoa on the European market? https://www.cbi.eu/market-information/cocoa/trade-statistics

7. Villa JEL; Peixoto RRA; Cadore S. 2014. Cadmium and lead in chocolates commercialized in Brazil. Journal of Agricultural Food Chemistry 62(34):8759–8763. https://doi.org/10.1021/jf5026604

8. Yanus RL; Sela H; Borojovich EJC; Zakon Y; Saphier M; Nikolski A; Gutflais E; Lorber A; Karpas Z. 2014. Trace elements in cocoa solids and chocolate: An ICPMS study. Talanta 119:1–4. https://doi.org/10.1016/j.talanta.2013.10.048

9. Abt E; Fong J; Gray P; Robin LP. 2018. Cadmium and lead in cocoa powder and chocolate products in the U.S. market. Food Additives & Contaminants: Part B 11(2):92–102. https://doi.org/10.1080/19393210.2017.1420700

10. Lo Dico GM; Galvano F; Dugo G; D'ascenzi C; Macaluso A; Vella A; Giangrosso G; Cammilleri G; Ferrantelli V. 2018. Toxic metal levels in cocoa powder and chocolate by ICP-MS method after microwave-assisted digestion. Food Chemistry 245:1163–1168. https://doi.org/10.1016/j.foodchem.2017.11.052

11. Vanderschueren R; Montalvo D; De Ketelaere B; Delcour JA; Smolders E. 2019. The elemental composition of chocolates is related to cacao content and origin: A multi-element fingerprinting analysis of single origin chocolates. Journal of Food Composition and Analysis 83:103277. https://doi.org/10.1016/j.jfca.2019.103277

12. European Parliament Directive. 2000. Directive 2000/36/EC of the European Parliament and of the council of 23 June 2000 relating to cocoa and chocolate products intended for human consumption. https://bit.ly/3jPHI4c

13. CODEX Alimentarius. 1981. Norma para el cacao en polvo (cacaos) y las mezclas secas de cacao y azúcares. https://bit.ly/3nKhnFM

14. Bertoldi D; Barbero A; Camin F; Caligiani A; Larcher R. 2016. Multielemental fingerprinting and geographic traceability of Theobroma cacao beans and cocoa products. Food Control 65:46–53. https://doi.org/10.1016/j.foodcont.2016.01.013

15. Knezevic G. 1979. Mitteilung: Über den Gehalt an Cadmium in Rohkakao und in Kakao-Halb-un Fertigprodukten. Deutsche Lebensmittel-Rundschau 75(10):305–309.

16. Vanderschueren R; Argüello D; Blommaert H; Montalvo D; Barraza F; Maurice L; Schreck E; Schulin R; Lewis C; Vazquez JL; Umaharan P; Chavez E; Sarret G; Smolders E. 2021. Mitigating the level of cadmium in cacao products: Reviewing the transfer of cadmium from soil to chocolate bar. Science of the Total Environment. 781:146779. https://doi.org/10.1016/j.scitotenv.2021.146779

17. Argüello D; Chavez E; Lauryssen F; Vanderschueren R; Smolders E; Montalvo D. 2019. Soil properties and agronomic factors affecting cadmium concentrations in cacao beans: A nationwide survey in Ecuador. Science of the Total Environment 649:120–127. https://doi.org/10.1016/j.scitotenv.2018.08.292

18. Ministry of Agriculture and Livestock. 2021. Caja de Herramientas para la Prevención y Mitigación de la Contaminación de Cadmio en la Cadena de Cacao-Ecuador. Quito, Ecuador. https://bit.ly/3CHVWfb

Clima-LoCa is a regional project led by the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), implemented with research partners from Latin America and Europe and funded by the European Commission. This project contributes to the objectives of the 2018 call for "Climate-Relevant Innovation through Research in Agriculture" of the EC-led platform DeSIRA (Development-Smart Innovation through Research in Agriculture), based on the ambition to improve research mobilization and innovation capacity contributing to the sustainable development of the cacao sector.

This project addresses important challenges related to the resilience, competitiveness, and inclusiveness of the growing cacao sector. Here, resilience refers to the capacity of smallholder producers, and other value chain actors, to mitigate the negative impacts of new EU food safety regulations on cadmium in cacao, and of climate change. The project builds on the premise that agricultural innovations require engagement of diverse end users to co-develop context-relevant production systems and practices based on strong interdisciplinary science, while creating an enabling environment for their adoption and scaling.

www.climaloca.org

Contributors to this brief

Content by researchers:

Ruth Vanderschueren, PhD, **KU Leuven**, and recipient of a predoctoral fellowship from the Research Foundation Flanders (FWO-Vlaanderen). Ruth.Vanderschueren@kuleuven.be

Mirjam Pulleman, PhD, senior soil ecologist, **Alliance of Bioversity International and CIAT**. m.pulleman@cgiar.org

Specific inputs: Eliot Gee, Rachel Atkinson, and Andrés Charry (Alliance of Bioversity International and CIAT); Jesse Dekeyrel (KU Leuven); David Argüello (KU Leuven and Escuela Superior Politécnica del Litoral-ESPOL); and Hester Blommaert (KU Leuven and Université Grenoble Alpes).

Correct citation

Vanderschueren R; Pulleman M. 2021. Cadmium in cacao: why it occurs, how it is regulated, and why it is a concern for producers. Clima-LoCa Policy Brief No. 1. International Center for Tropical Agriculture (CIAT). Cali, Colombia. 10 p.

Implemented with

In collaboration with

Disclaimer
This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of the authors and do not necessarily reflect the views of the European Union.