Clima-LoCa

Alliance Bioversity & CIAT

CGIAR

Mitigating the effects of food safety regulation on cadmium in cacao

Mirjam Pulleman, Mayesse da Silva, Wietse Wiersma, and the Clima-LoCa project team

EGU Vienna, 2 May 2025

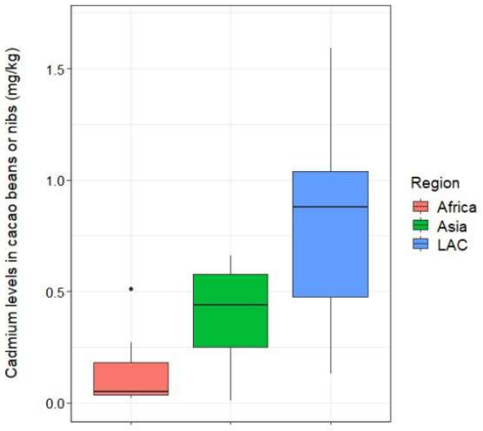
1

Cadmium in cacao: A growing concern for producers and global markets

Different regulations and limits apply for final products (not for beans):

- EU: Since 2019 **Cd**, 2025: Ni
- Proposition 65 warning on package (**Cd,** Pb)
- Codex Alimentarius recommended (**Cd**)
- Latin America has highest bean Cd concentrations in beans, on average (especially the Andean countries).

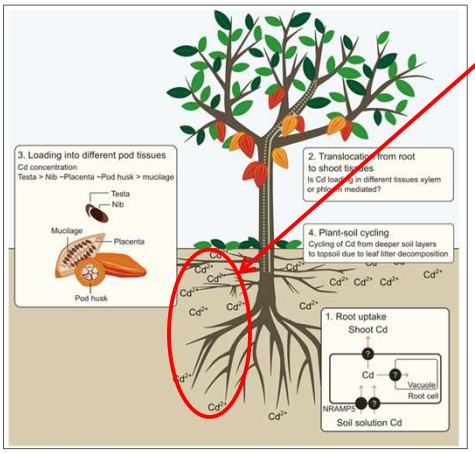
EU Regulation- Product	Max. level (mg/kg)
Milk chocolate with < 30% total dry cocoa solids	0.10
Chocolate with < 50% total dry cocoa solids; milk chocolate with ≥ 30% total dry cocoa solids	0.30
Chocolate with ≥ 50% total dry cocoa solids	0.80
Cocoa powder sold to the final consumer or as an ingredient in sweetened cocoa powder sold to the final consumer (drinking chocolate)	0.60



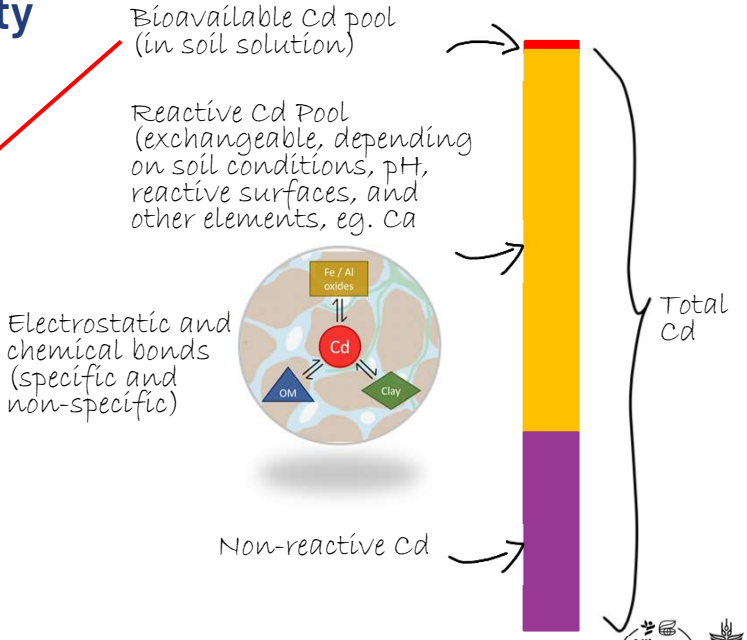
Meter et al. 2019;
https://platform.climaloca.org/chocosafe

2

Cadmium bioavailability and uptake



Vanderschueren et al. 2021
Vanderschueren & Pulleman, 2021

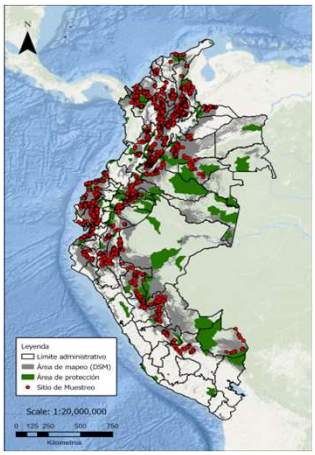


3

Research on Cd in cacao production systems

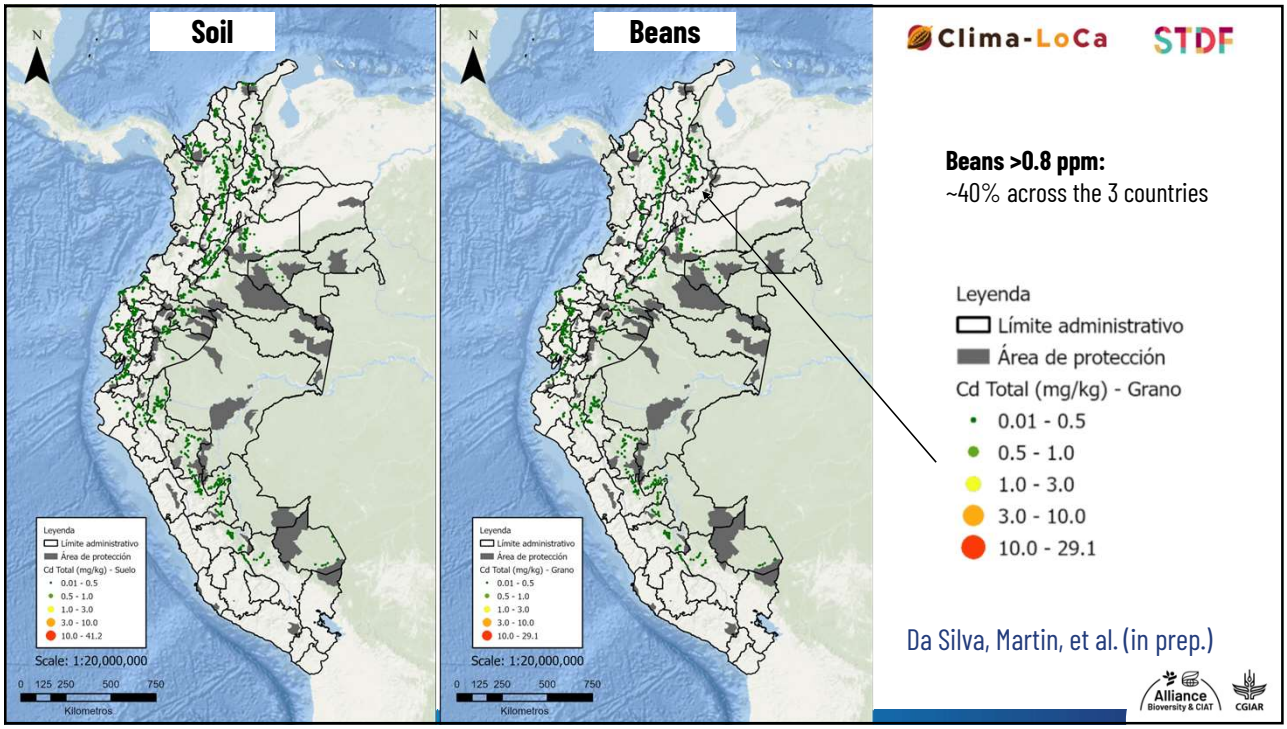
Clima-LoCa
STDF

1) understanding the spatial variation in Cd in cocoa and soils



2) identifying mitigation practices that can effectively lower Cd uptake by cacao trees

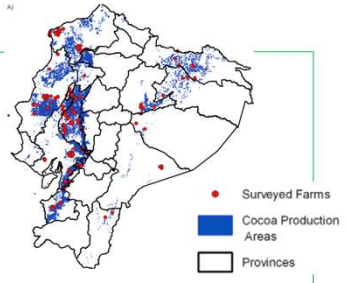
4



5

Predicting Cd in cacao based on empirical models

Ecuador, nationwide survey (n = 560)



$$\log_{10}[\text{Cd-Bean}] = 1.66 + 0.94 \times \log_{10}[\text{CdT}] - 0.21 \times \text{pH} - 0.63 \times \log_{10}[\text{OC}]$$

$$\log_{10}[\text{Cd-Bean}] = 3.11 + 1.07 \times \log_{10}[\text{CdT}] - 0.25 \times \text{pH} - 0.60 \times \log_{10}[\text{OC}] - 0.41 \times \log_{10}[\text{Mn}_{\text{Ox}}]$$

- R^2: 0.57, 0.65, respectively
- Total soil Cd, pH and % organic carbon are the main factors affecting Cd concentration in beans

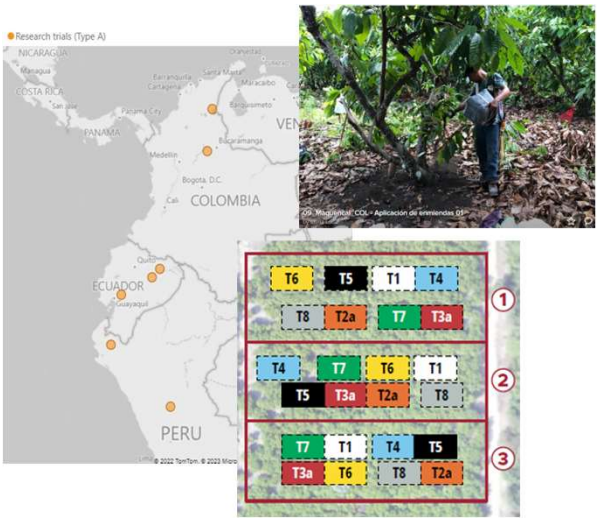
Argüello et al. 2019

Alliance Bioversity & CIAT CGIAR

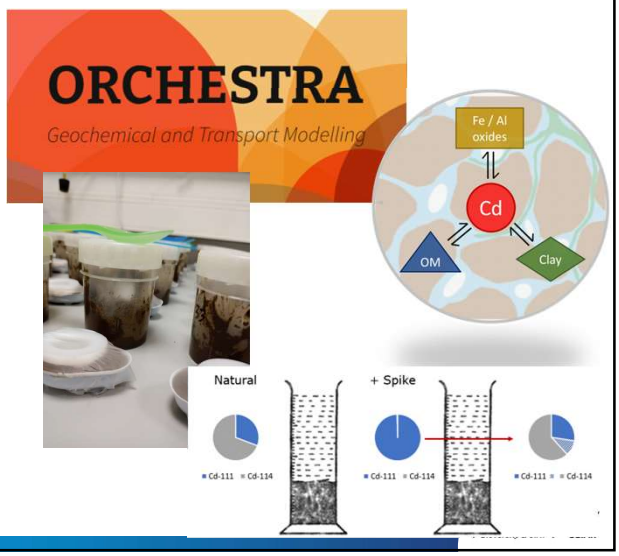
6

Mixed methods approach

Multilocational field trials



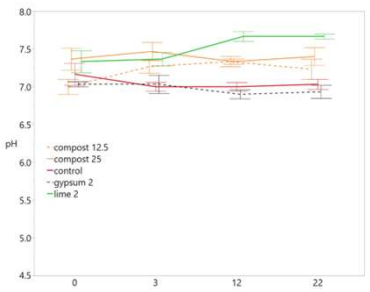
Geochemical modeling (MSMs)

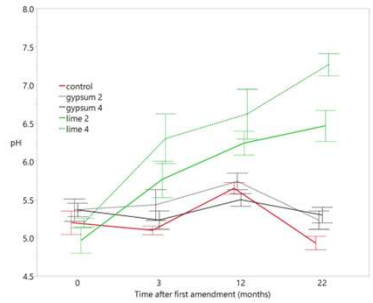


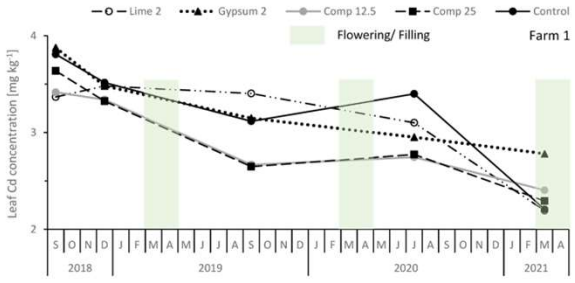
7

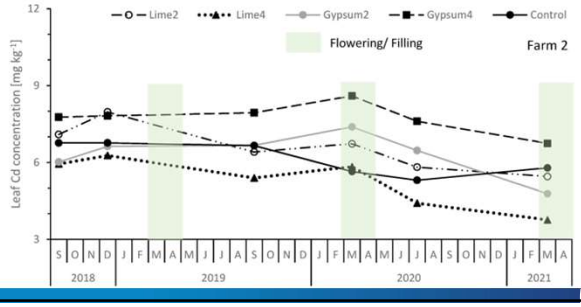
Results from field trials (example, Ecuador)

Argüello et al. 2023









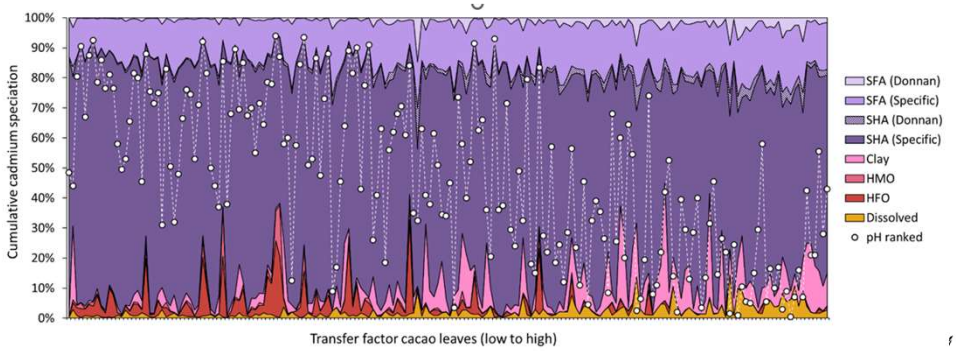
Alliance Bioversity & CIAT
CGIAR

8

Results mechanistic geochemical modeling

- Up to 73% (bean Cd) and 82% (leaf Cd) of variation was explained by soil solution Cd intensity indicators predicted by MSMs.
- Cacao Cd content was more strongly linked to electrostatically bound Cd in clay and organic matter than to Cd bound to organic functional groups or metal oxides, highlighting the soil's buffering capacity.
- Soil pH was the main factor controlling Cd partitioning, speciation, and soil-plant transfer.

Wiersma et al. 2025 (PhD thesis)



9

Take home / practical implications

- Soil amendments can reduce Cd uptake by cacao, but effects vary greatly over time and space, making universal recommendations difficult.
- Multisurface models, like empirical ones, can effectively predict Cd uptake
- These models offer insight into underlying mechanisms - They can help explain inconsistent amendment outcomes and support site-specific recommendations.
- While soil properties explain most Cd variation in cacao, limited knowledge of plant physiology hinders full understanding of Cd dynamics.
- There are no silver bullets: Solutions are context-specific and diverse (including soil management, cacao genetics and/or postharvest mixing)
- Digital soil maps are an essential resource to guide policies and target mitigation practices

10

Thank you!!

The team: Mayesse da Silva, Wietse Wiersma, Rachel Atkinson, Martin Cepeda, Eduardo Chavez, Bert-Jan Groenenberg, Jesse de Keyrel, Javier Martin, William Melo, Leidi Sierra Erik Smolders.

The funders

https://climaloca.org

11