



Image: Johan Six

Coop Research Program

# Cadmium availability in soils and its uptake by cocoa in Latin America

**Cocoa products must meet new European Union thresholds for cadmium content in order to limit consumers' exposure to the toxic trace metal. These regulations could affect many smallholder farmers in the tropics, as they could lose access to the European market. This project measured cocoa bean cadmium concentrations in Bolivia and Honduras, finding levels varied widely. Cocoa products made from beans from certain locations would even exceed EU limits. Soil parent material and soil acidity were found to affect soil and bean cadmium levels.**

## Motivation

Cadmium is a trace metal toxic to plants, animals, and humans even at low concentrations. In comparison to other plant products, cocoa beans readily accumulate cadmium. Therefore, the European Union (EU) has set maximum permitted levels in cocoa products that will enter into force in 2019. The new regulation is particularly relevant to smallholder farmers in Latin America, where cocoa beans tend to have higher levels of cadmium than in other regions. Cadmium concentrations vary strongly among locations but the causes, such as soil parent material or cultivation practices, and possible countermeasures remain unclear.

## Objective

The project used a long-term cocoa cultivation trial site in Bolivia and a selection of 55 farms in Honduras to investigate the sources of cadmium in the soils and potential factors influencing cadmium uptake by cocoa plants. The sites covered different soil and climate conditions, cropping systems (agroforestry or monocultures), management types (organic or conventional), and cocoa cultivars (see figure).

## Research Highlights

This project found that bean and soil cadmium concentrations varied greatly among the sampled sites in Latin America but were not correlated. At the test site in Bolivia, the bean cadmium concentrations were lower than in Honduras, although trees were growing in soils with higher cadmium concentrations. In contrast, the bean cadmium concentrations in some sites in Honduras were so high that cocoa products would exceed EU limits, despite low soil cadmium levels. The high levels of soil cadmium in some sampled sites were not attributed to human-caused pollution but to natural conditions.

At the test site in Bolivia, cadmium concentrations in cocoa beans were low ( $0.21 \text{ mg kg}^{-1}$ ), although the trees were growing



Project members, Prof. Rainer Schulin and Dr. Anja Gramlich, and partners sampling soil on a cocoa farm in Honduras.

on soil with comparatively high cadmium concentration ( $1.2 \text{ mg kg}^{-1}$ ). Here, bean cadmium concentration were also not found to be affected by cropping system, management, or cultivar type. Thus, chocolate made from these beans would comply with EU cadmium limits.

In Honduras, bean cadmium concentrations were on average five times higher than in Bolivia ( $1.1 \text{ mg kg}^{-1}$  vs.  $0.21 \text{ mg kg}^{-1}$ ). Chocolate products made from these beans could exceed EU limits. Interestingly, soil cadmium concentration were lower in Honduras than in Bolivia ( $0.25 \text{ mg kg}^{-1}$  vs.  $1.2 \text{ mg kg}^{-1}$ ). Most sampling sites were located away from intensive farming or factories, common sources of cadmium pollution. Here, cadmium seemed to originate mainly from the parent material in the soils, and cadmium levels were particularly high (up to  $0.6 \text{ mg kg}^{-1}$ ) in floodplains and volcanic soils. The higher cadmium uptake on the soils in Honduras, as compared to the test site in Bolivia, appeared to be primarily due to a higher availability of the cadmium in the Honduran soils for plant uptake, which is affected by soil acidity (pH). In acidic soils, liming could be a promising practice to control bean cadmium contents, as beans from trees growing on acidic soils, in general, contained more cadmium than beans from alkaline soils. In a complementary pilot study on a cocoa plantation in Peru, increasing the pH of the topsoil by liming indeed led to a decrease of 70% in the concentration of soil cadmium available for plant uptake. Unfortunately, the effect on cocoa beans could not be verified because the study had to be interrupted due to security reasons.

### Relevance to Stakeholders

This project identified the sources of cadmium in the soil and the factors affecting its uptake. Elevated cadmium levels

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**Project Duration** 2014-2017

**Funding** WFSC Coop Research Program

**Food System Challenges Addressed** Sustainable production systems, soil health, food safety

[www.worldfoodsystem.ethz.ch/research/research-programs/CRP/cdocoa.html](http://www.worldfoodsystem.ethz.ch/research/research-programs/CRP/cdocoa.html)

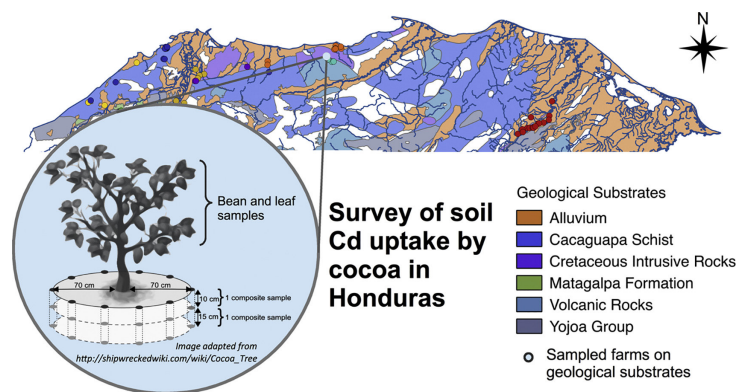


Figure: Sampling area in northern and eastern Honduras with geological substrates. Points indicate farms where samples were taken (Source: Gramlich, A.; Tandy, S.; et al. 2018).

in cocoa beans from Honduras could mean loss of access to the European chocolate market, affecting both farmers and chocolate producers. Therefore, special attention is needed to keep smallholder farmers as viable suppliers under the new EU rules. The results also established that checking soil conditions and liming are possible means to control cadmium concentrations in this important cash crop. As soil parent material and soil acidity are major factors influencing soil and bean cadmium levels, farmers should check soil conditions including the cadmium content before establishing new plantations. In acidic soils, adding lime can increase the pH and, thereby, decrease the availability of soil cadmium for uptake by plants.

### Selected Publications

Gramlich, A.; Tandy, S.; et al. **Cadmium uptake by cocoa trees in agroforestry and monoculture systems under conventional and organic management.** *Sci. Total Env.* **2017**, 580, 677-686.

Gramlich, A.; Tandy, S.; et al. **Soil cadmium uptake by cocoa in Honduras.** *Sci. Total Env.* **2018**, 612, 370-378.

### Master thesis

Bertoni, A. The effect of different cocoa varieties on Cadmium uptake in cocoa beans. MSc Thesis, ETH Zurich, **2017**.

Engbersen, N. Distribution patterns of Cadmium in different tissues of cocoa trees. MSc Thesis ETH Zurich, **2017**.

Schneider, L. Effects on liming on Cadmium availability in soil and uptake by cocoa. MSc Thesis, ETH Zurich, **2016**.

### Media

Rüegg, P. **Cadmium, cocoa beans and chocolate.** *ETH News* [Online], **October 2016**.

The WFSC would like to thank the Coop Sustainability Fund and the ETH Zurich Foundation for supporting this project.