# SOIL CADMIUM UPTAKE BY COCOA IN HONDURAS

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## Introduction

Cadmium (Cd) is a trace metal without essential biological functions, and it is toxic to plants, animals and humans already at low concentrations. It occurs naturally in soils, but inputs from anthropogenic sources have significantly increased Cd contents in many soils worldwide. Cd uptake by cocoa (*Theobroma cacao* L.) has recently attracted attention, as the European Union (EU) is going to establish values for maximum Cd concentrations in cocoa products, which would be exceeded with the Cd concentrations currently found in some cocoa bean provenances from Latin America. While regional variation in cocoa bean Cd concentrations has been attributed to different soil parent materials, also other soil factors or management factors such as Cd inputs with fertilizers may play a role for Cd uptake by cocoa (Zarcinas et al., 2004). In order to identify the sources of Cd in cocoa and the factors governing its uptake, we carried out a survey of Cd concentrations in cocoa leaves, pod husks and beans and their relationship to a variety of soil and site factors on 55 cocoa farms in northern and eastern Honduras.

## Methods

The farms were selected to represent a wide range of site conditions. On each farm, leaves, pod husks and beans of two randomly chosen trees were sampled. Composite topsoil samples were taken at a distance of 70 cm around each trunk. In addition to Cd, we also measured the iron (Fe) and zinc (Zn) contents of the dried plant samples. Total soil Cd was analysed using aqua-regia and bioavailable Cd by ammonium-acetate-EDTA extraction and the Diffusive-Gradients-in-Thin-Films (DGT) method. The influence of soil and other site factors on soil and plant Cd was assessed using robust multivariate regression analysis.

## Results

In contrast to a recent survey in Ecuador, in which beans showed higher Cd concentrations than leaves (Chavez et al., 2015), we found with 2.6±0.4 mg $kg^{-1}$ on average much more Cd in the cocoa leaves than in pod husks and beans. Still, the bean Cd concentrations averaged 1.1±0.2 mg $kg^{-1}$ in our study, thus exceeding the limit value proposed by the EU for cocoa powder nearly by a factor of two. The Cd concentrations of leaves, pod husks and beans were highly correlated with $R^2$ values of 0.75 (beans/pod husks) and 0.49 (beans/leaves). Bean Cd concentrations showed large differences between regions and geological soil substrates. Particularly high bean Cd concentrations were found on alluvial soils (Figure 1a).

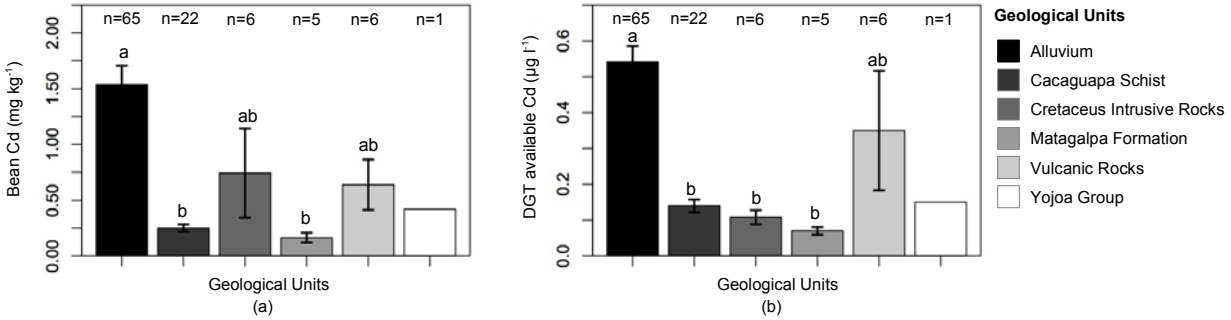


**Figure 1.** Bean Cd concentrations (a) and DGT-available soil Cd (b) vs. geological substrate. Error bars represent standard errors of the means. Different letters indicate significant differences with $p < 0.05$.

**Table 1.** Best-fit weighted least square multiple linear regression models (forward/backward variable selection), optimizing the AIC (Akaike Information Criterion) with 104 observations. The full model included the variables «DGT-available Cd», «geological unit», «aqua-regia extractable Cd», «soil clay content», «soil organic matter content», «soil pH», «DTPA-extractable Fe» and «DTPA-extractable Zn».

| Model (predicted ~ explanatory variables) | Adjusted $R^2$ |
|---|---|
| (1.1) Bean Cd ~ DGT-available Cd | 0.53 |
| (1.2) Bean Cd ~ aqua-regia extractable Cd + DTPA-extractable Fe + geological unit | 0.59 |

Among all analysed factors, DGT-available soil Cd was by far the best predictor for bean Cd (Figure 1, Table 1.1). If DGT was not considered, bean Cd was best predicted by aqua-regia extractable soil Cd, DTPA-extractable Fe and geological substrate (Table 1.2). The DTPA-Fe effect may include the effect of soil pH, as the two variables were strongly correlated. We found no influence of direct fertilizer inputs.

## Conclusions

DGT-available soil Cd was the best predictor of Cd uptake by cocoa beans, pod husks and leaves. It explained in particular a large part of the influence of the geological substrate, notably the high uptake on alluvial soils. No pH effect was found, probably due to masking by correlation of soil pH with DTPA-extractable Fe.

## References

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