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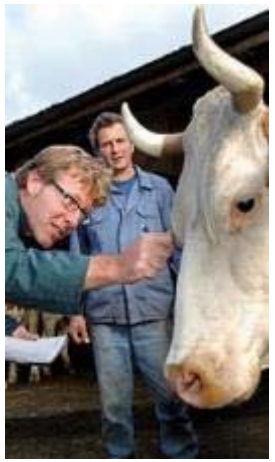


Cadmium availability and uptake in four different cocoa production systems in Bolivia

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Lima Peru

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Background and motivation

- ✧ Cadmium (Cd) is a toxic element, it causes kidney failure and it is carcinogenic.
- ✧ The EU defined max. levels for Cd in cocoa products for 2019.

Relevance

- ✧ Identify sources.
- ✧ Identify factors influencing Cd availability in soils and uptake.

Problem identification

Elevated Cd concentrations were found in cocoa beans from many countries in Latin America

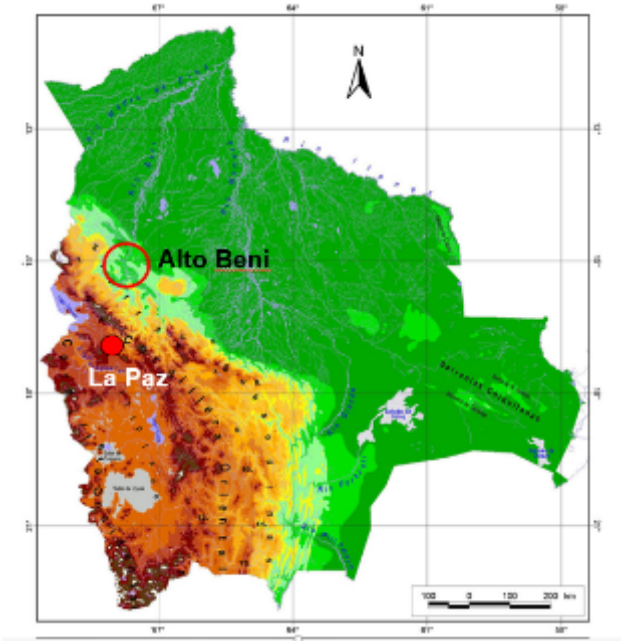
Approach

Investigation of soil, variety and management effects on Cd availability in soil and uptake in cocoa plants in a long-term field trial in Sara Ana (Bolivia), where cocoa performance in monocultures and agroforestry systems under conventional as well as organic management is compared.

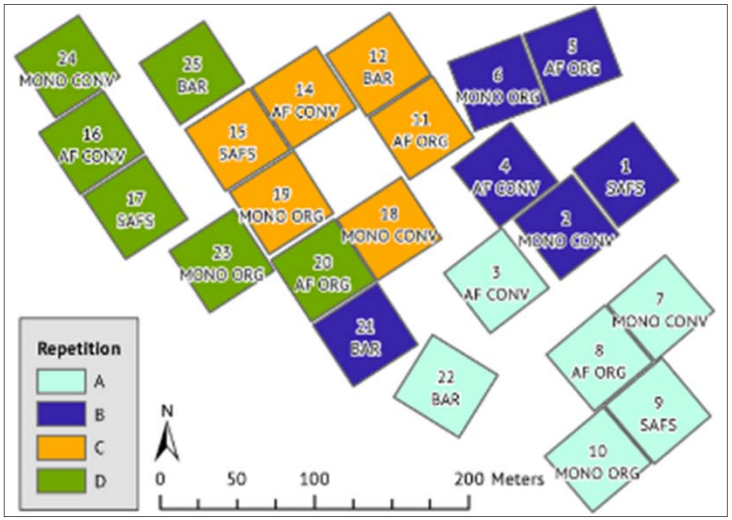
Methods

Site description

- Bolivia, Alto Beni, alluvial terraces of the river Alto Beni, transition zone Andean plateau and Amazon
- 400 m asl, precipitation: 1'550 mm, winter dry
- 20 years of fallow land before set up of trial



Trial layout



- Long-term trial, set up in 2008-2009
- Fully replicated 4 times
- Gross plot: 48 m x 48 m (144 cocoa trees), net plot 24 m x 24 m (36 cocoa trees)
- 12 cocoa cultivars: 4 local selected clones, 4 international clones and 4 hybrids of int.clones

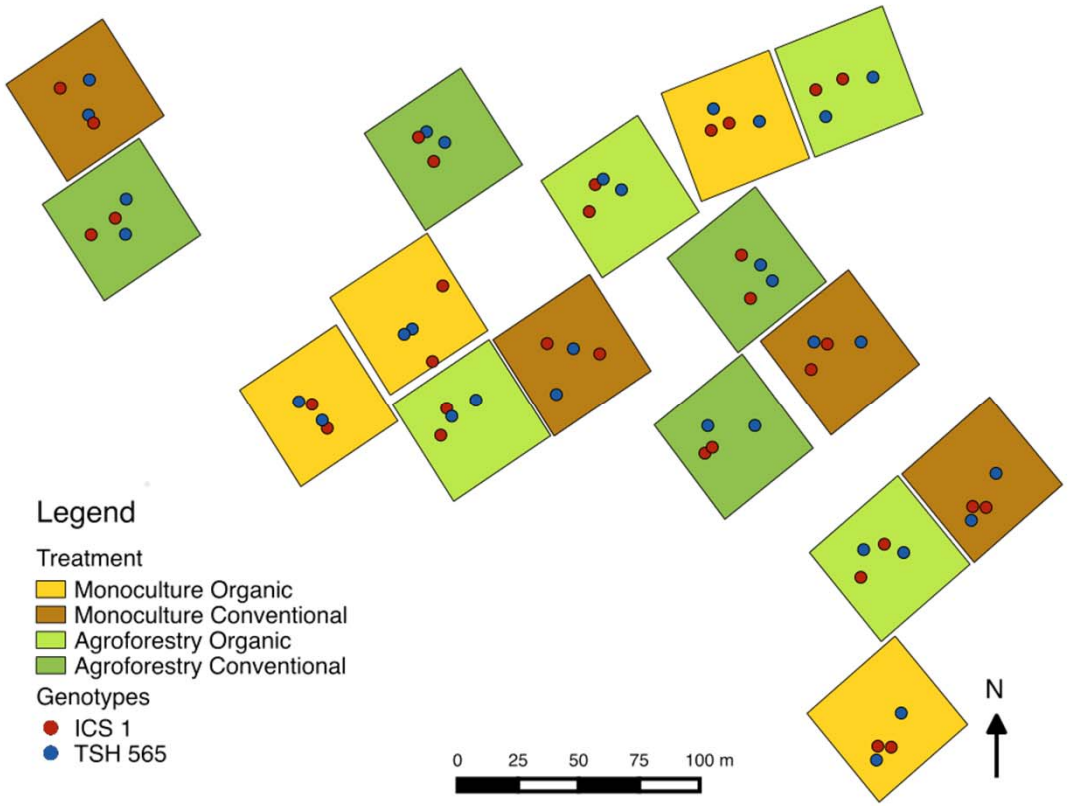
Methods

Production systems

	Monoculture		Agroforestry	
Management	Conventional	Organic	Conventional	Organic
Shade tree canopy	- banana trees in establishment phase	- banana trees in establishment phase	42 trees $plot^{-1}$ (227 trees ha^{-1}): legumes, timber, fruit trees, etc. Banana followed by plantain	42 trees $plot^{-1}$ (227 trees ha^{-1}): legumes, timber, fruit trees, etc. Banana followed by plantain
Fertilization	Mineral fertilizer. Occasional foliar sprays	Compost	Mineral fertilizer. 50% of monoculture dose. Occasional foliar sprays	Compost. 50% of monoculture dose.
Weed control	Herbicides (4-5 $year^{-1}$) Manual weeding, brushcutters	Perennial legume cover (*Neonotonia wightii*) Manual weeding, brushcutters	Herbicides (4-5 $year^{-1}$) Manual weeding, brushcutters	Perennial legume cover (*Neonotonia wightii*) Manual weeding, brushcutters
Pest and disease control	Manual control, occasional insecticides against leave cutting ants	Manual control	Manual control occasional insecticides against leave cutting ants	Manual control

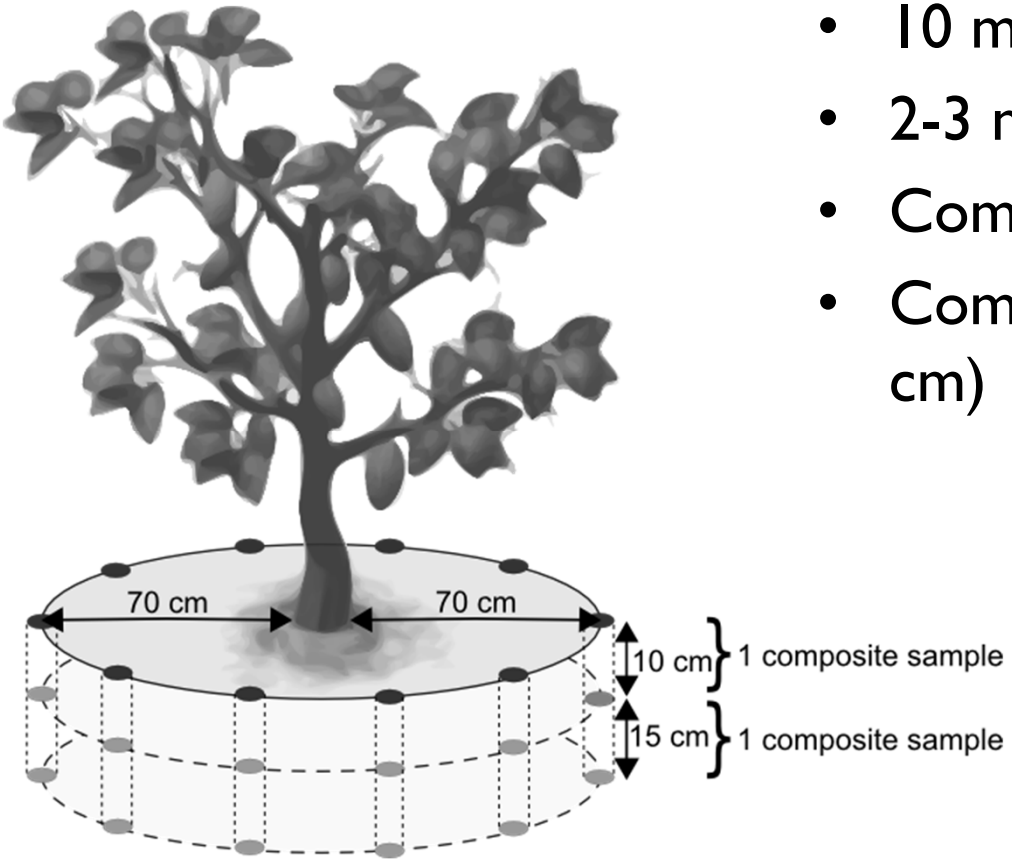
Data collection for this study in year 2014

Sampling strategy



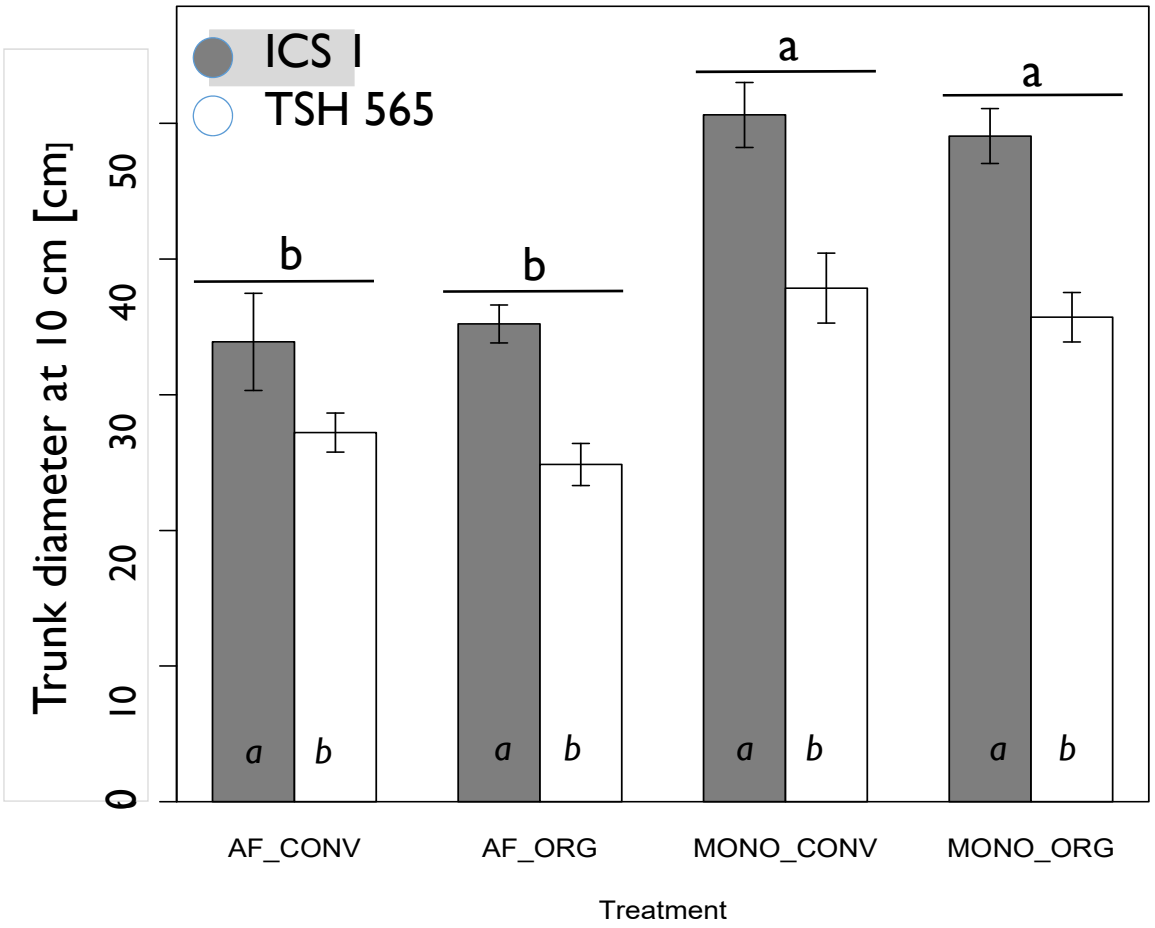
✧ **In each plot two trees of two different clones were sampled (fruits, leaves and roots) and soil samples were taken at 70 cm distance from the trunk.**

Sampling strategy



- 10 medium aged leaves per tree
- 2-3 mature fruits per tree
- Composite soil sample (0-10 cm)
- Composite soil sample (10-25 cm)

Trunk diameters

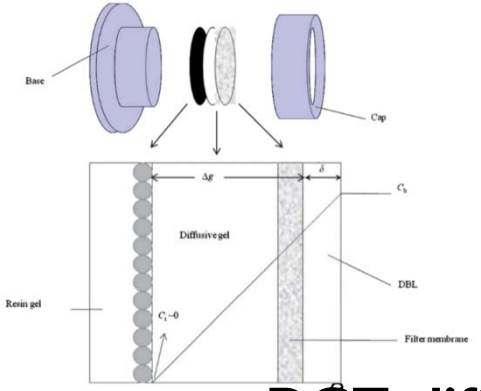


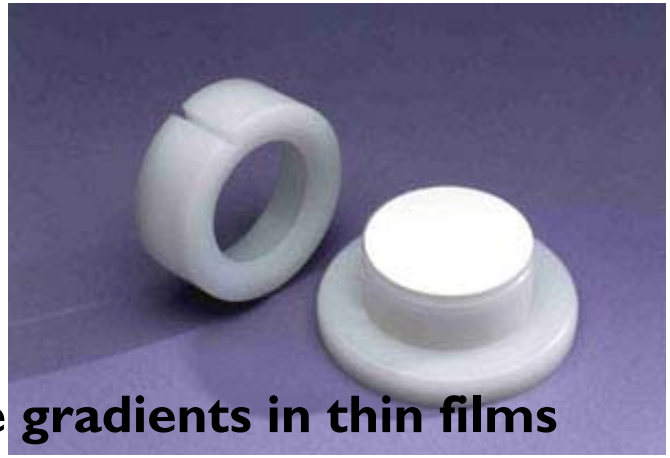
- ICS 1 clones were bigger than TSH 565.
- Trees in monocultures were bigger than the ones in AF.

Parameters analysed in soils and plants

Soil
Soil pH ($CaCl_2$)
Texture
Organic Matter (Walkley Black)
Available P (Olsen P)
K disponible
Cd, Fe, Zn disponible (AAAC-EDTA)
Cd, Zn total (Aqua Regia)
DGT disponible Cd, Zn

Leaves, pod husks and beans
Total Cd, Fe, Zn
Roots
Mycorrhizal abundance
Fertilizers / Pesticides / River water
Total Cd





DGT: diffusive gradients in thin films

Cd levels in plants and soil

	Cd (mg kg^{-1}) total	Cd (mg kg^{-1}) available
Leaves	0.9 ± 0.05	
Pod husks	0.5 ± 0.05	
Beans	0.2 ± 0.02	
Top Soil	1.2 ± 0.05	0.3 ± 0.01
Sub Soil	1.0 ± 0.06	0.2 ± 0.01

Maximum tolerated Cd levels in the EU in
wheat/rice: 0.2 mg kg^{-1}
Chocolate (exp): 0.3 – 0.8 mg kg^{-1}

Worldwide average total soil Cd concentration: 0.2 mg kg^{-1}

- ✧ Cd levels in cocoa beans are in an acceptable range.
- ✧ Cd levels in soils are rather high. Above total Cd levels of 1.1 mg kg^{-1} soils are generally considered as contaminated soils.
- ✧ Higher concentrations were found in the top soil than in the sub soil.

Factors influencing Cd in leaves for Cd in beans we couldn't find

Multiple linear effects model with forward variable selection:

Leaf Cd ~ System + Clon + Cd_{DGT} + Organic matter

R^2: 0.59

P-Values:
System : 0.01
Clon : 0.01
Cd_{DGT} : < 0.001
Organic matter: 0.005

System: Monocultures higher concentrations than agroforestry systems
Clon: ICS 1 has higher Cd contents than TSH 565
Cd_{DGT}: Positive relationship
Organic matter: Negative relationship

Conclusions and outlook Cd

- ✧ The total Cd levels in soils were high, close to the threshold of soils considered as contaminated.
- ✧ The bean Cd concentrations were intermediate.
- ✧ Only a very small part of variance in bean and husk Cd was explained by studied factors.
- ✧ Factors explaining differences in leaf content: system, clone, Cd_{DGT} and organic mater

Outlook:

- Analyse more clones (root and graft)
- Cd allocation in older cacao trees
- Competition for Cd uptake by AF-trees
- In soils with lower pH: test liming and soil organic matter increase

Study published in Science of the Total Environment 2016

Cadmium uptake by cocoa trees in agroforestry and monoculture systems under conventional and organic management

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