Agronomic countermeasures for reducing cadmium (Cd) uptake in cacao plantations in Ecuador

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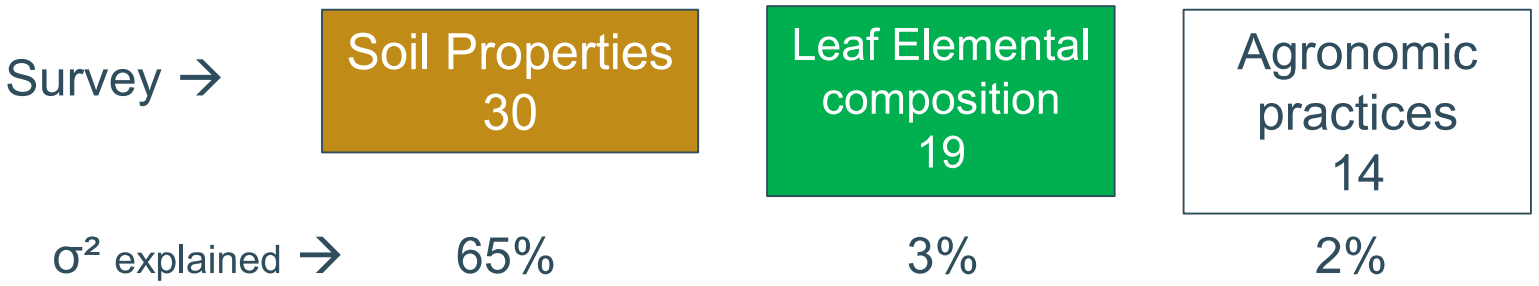
Soil to plant relationship



$$log_{10}(Cd\_Bean) = 1.66 + 0.94 \times log_{10}(soil\ Cd_T) - 0.21 \times pH - 0.63 \times log_{10}(\%OC)$$ ($R^2 = 0.57$)

Parameter	95 % CI
Intercept	1.42 – 1.90
Soil Cd $_T$	0.86 – 1.01
pH	-0.24 – -0.17
%OC	-0.74 – -0.52

Assuming all the average values

Bean Cd = 0.67 mg kg^{-1}

Increasing pH by 1 unit

Bean Cd = 0.42 mg kg^{-1}

RF = 1.6

Double %OC

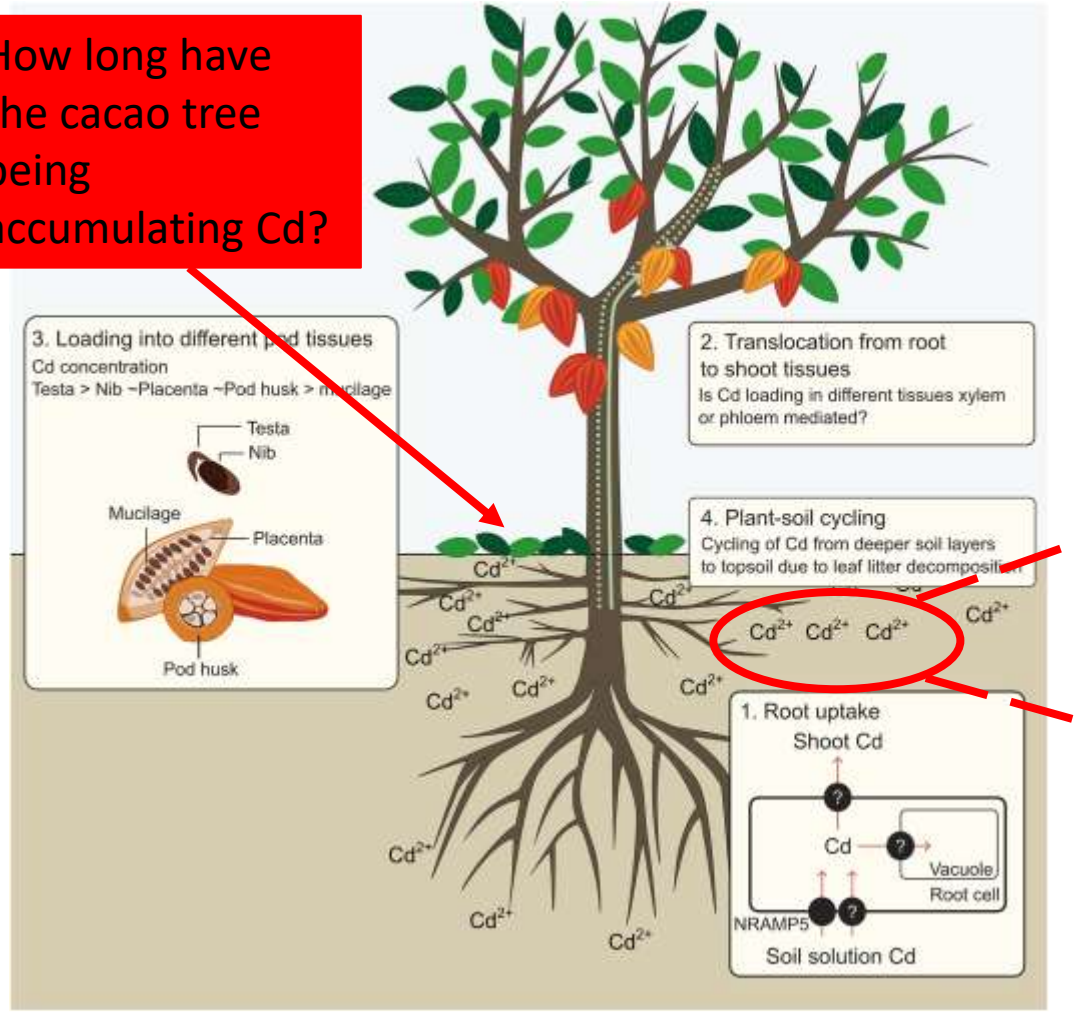
Bean Cd = 0.44 mg kg^{-1}

RF = 1.5

Smolders E., 2022

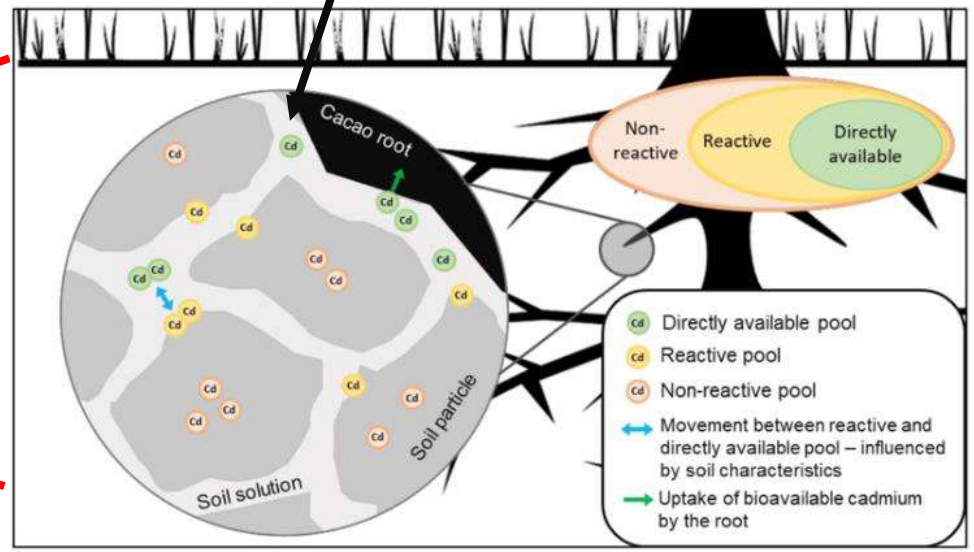
Previous knowledge

How long have the cacao tree being accumulating Cd?



Vanderschueren, Argüello, Blommaert, et al., 2021

Is water-soluble Cd the only plant-available Cd for cacao trees



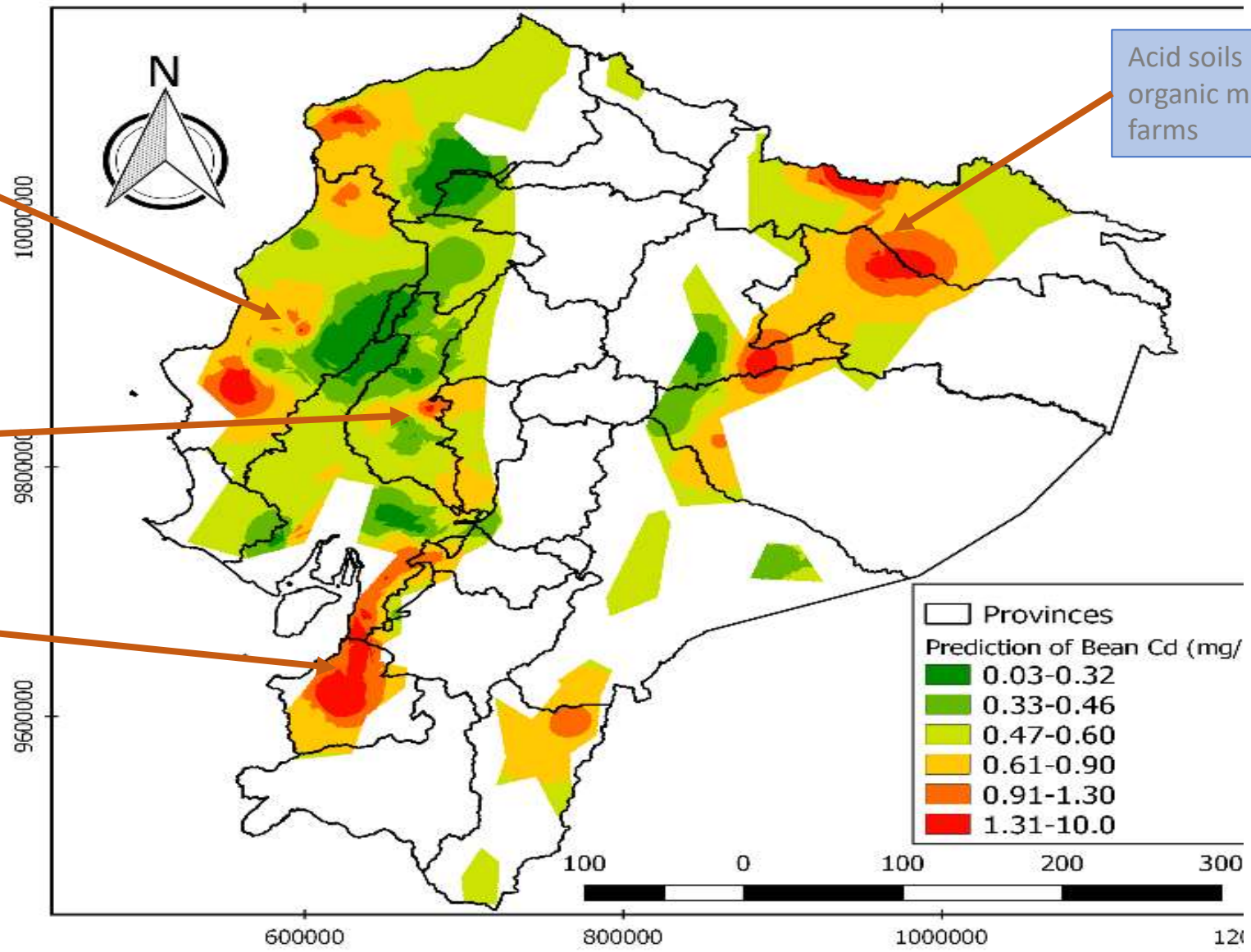
Meter et al., 2019

Alkaline soil =
Organic matter and micro-nutrients, three farms

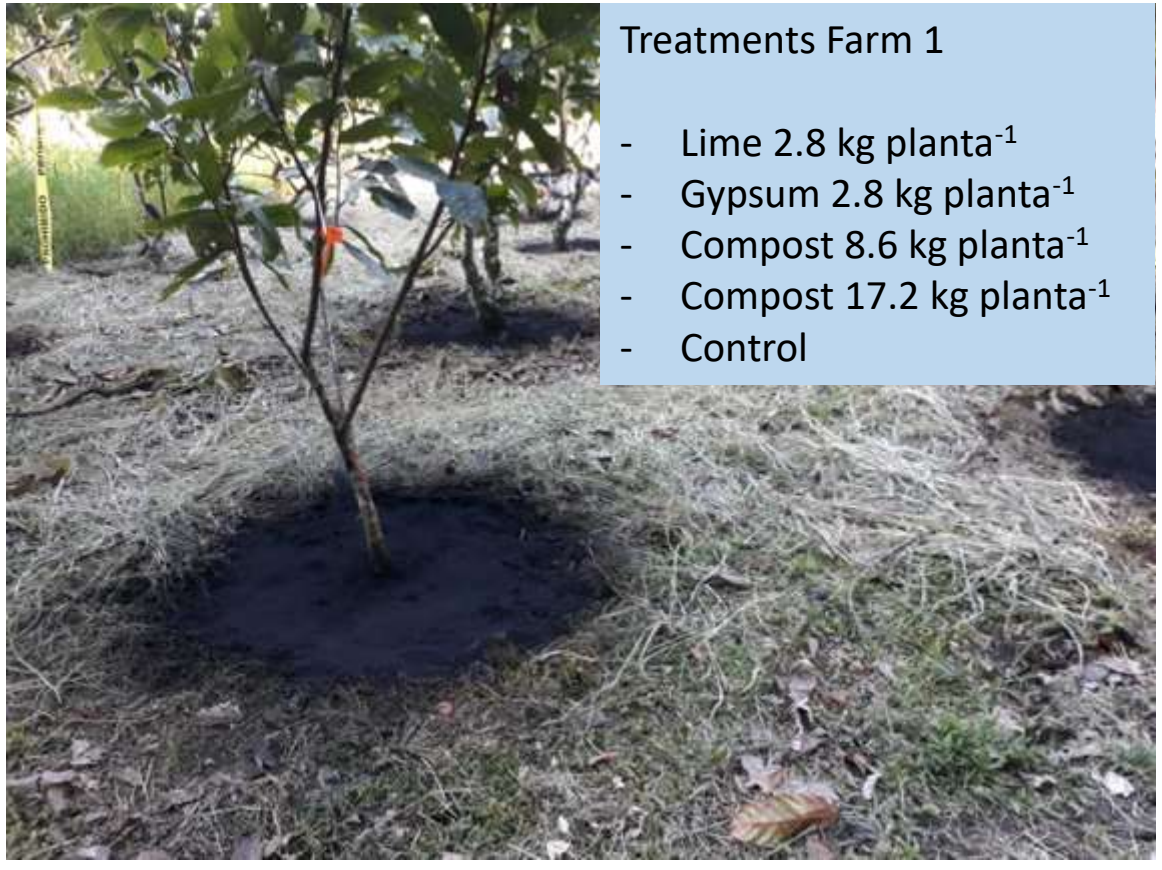
Neutral pH soil = fertilizers, one farm

Acid soils =
Lime, organic matter and fertilizers, six farms

Acid soils (Amazon) = Biochar, organic matter, fertilizers. Three farms

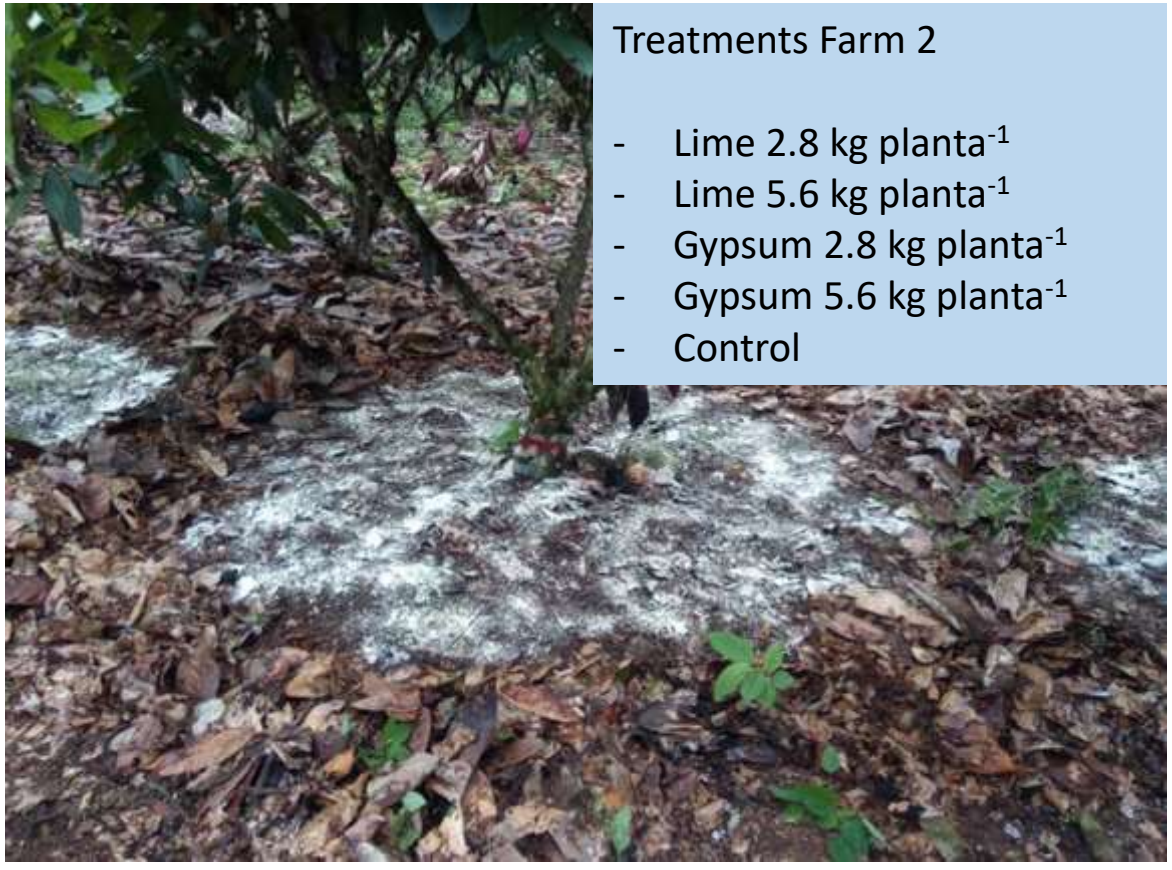


Description	pH¥	SOC	WHC	Fe_{Ox}£	Al_{Ox}£	Mn_{Ox}£	eCEC	Ca-excφ	Total Cd
		%	(ml kg^{-1})	g kg^{-1}			$cmol_c$ kg^{-1}		mg kg^{-1}
Field Trial Farm 1	6.6	1.18	380	4.02	1.01	0.40	14.5	13.3	1.01
Field Trial Farm 2	5.1	3.54	430	10.2	2.07	1.46	17.3	12.2	0.85
Incubation and column experiment	4.9	7.14	560	9.57	28.1	0.45	6.39	3.88	0.56



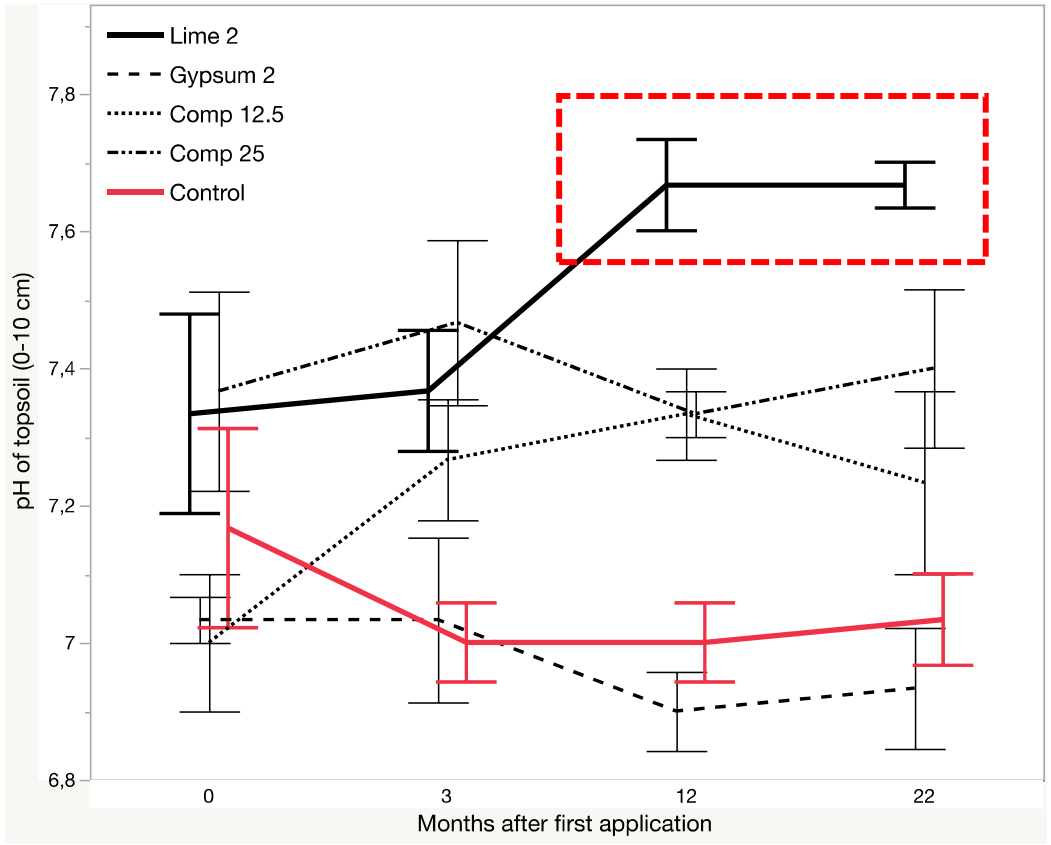
Treatments Farm 1

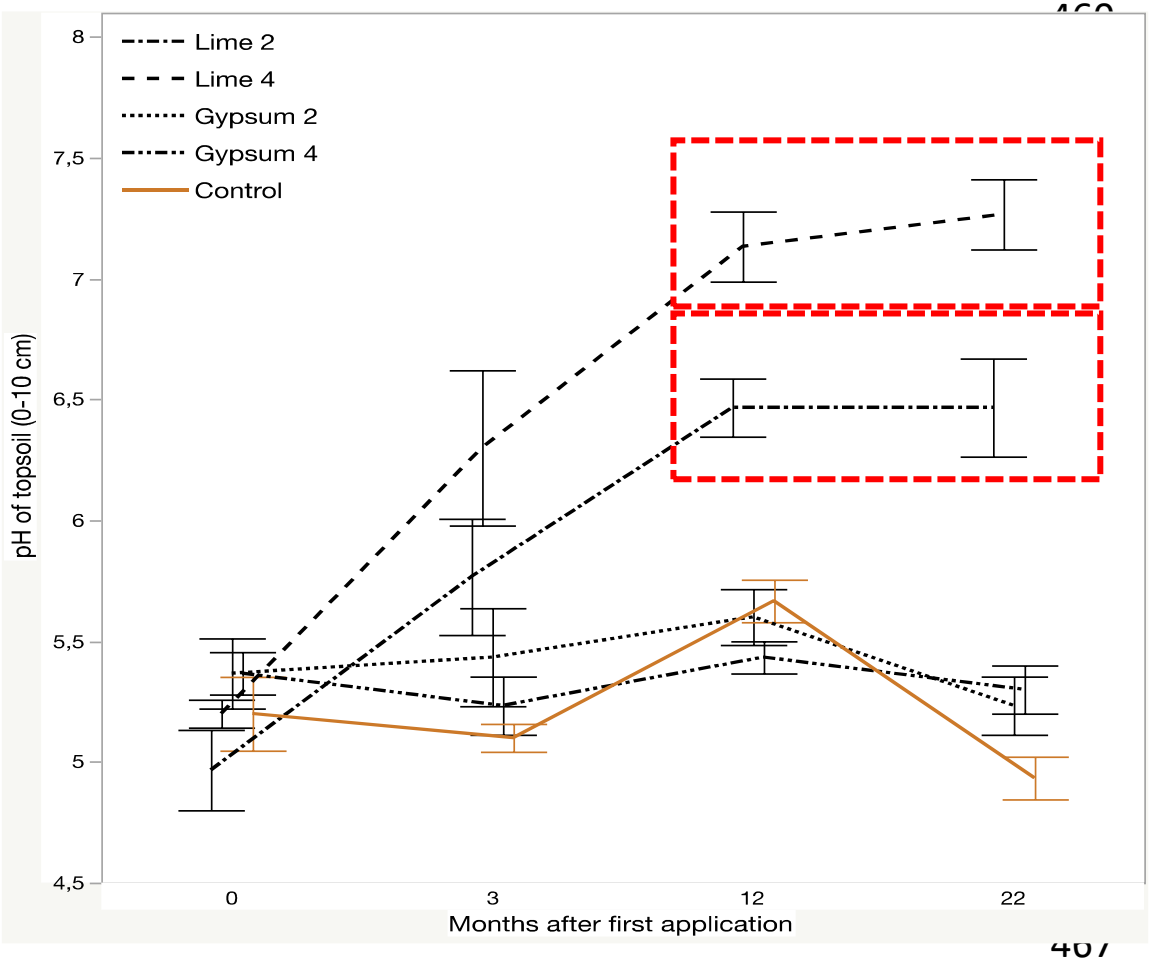
- Lime 2.8 kg $planta^{-1}$
- Gypsum 2.8 kg $planta^{-1}$
- Compost 8.6 kg $planta^{-1}$
- Compost 17.2 kg $planta^{-1}$
- Control



Treatments Farm 2

- Lime 2.8 kg $planta^{-1}$
- Lime 5.6 kg $planta^{-1}$
- Gypsum 2.8 kg $planta^{-1}$
- Gypsum 5.6 kg $planta^{-1}$
- Control

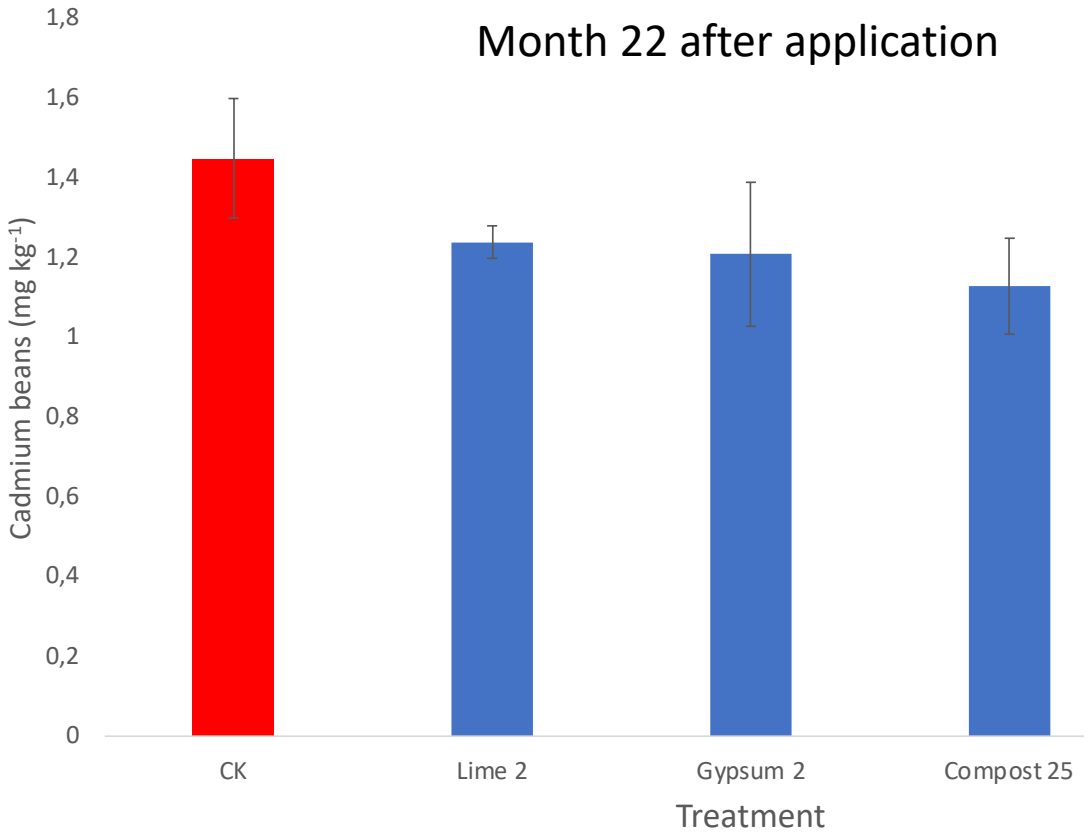




After 12 month of (last) application, soil pH is higher in limed soils by factors 1.07 to 1.4. These results were observed in these and other (n = 4) farms in the Amazon

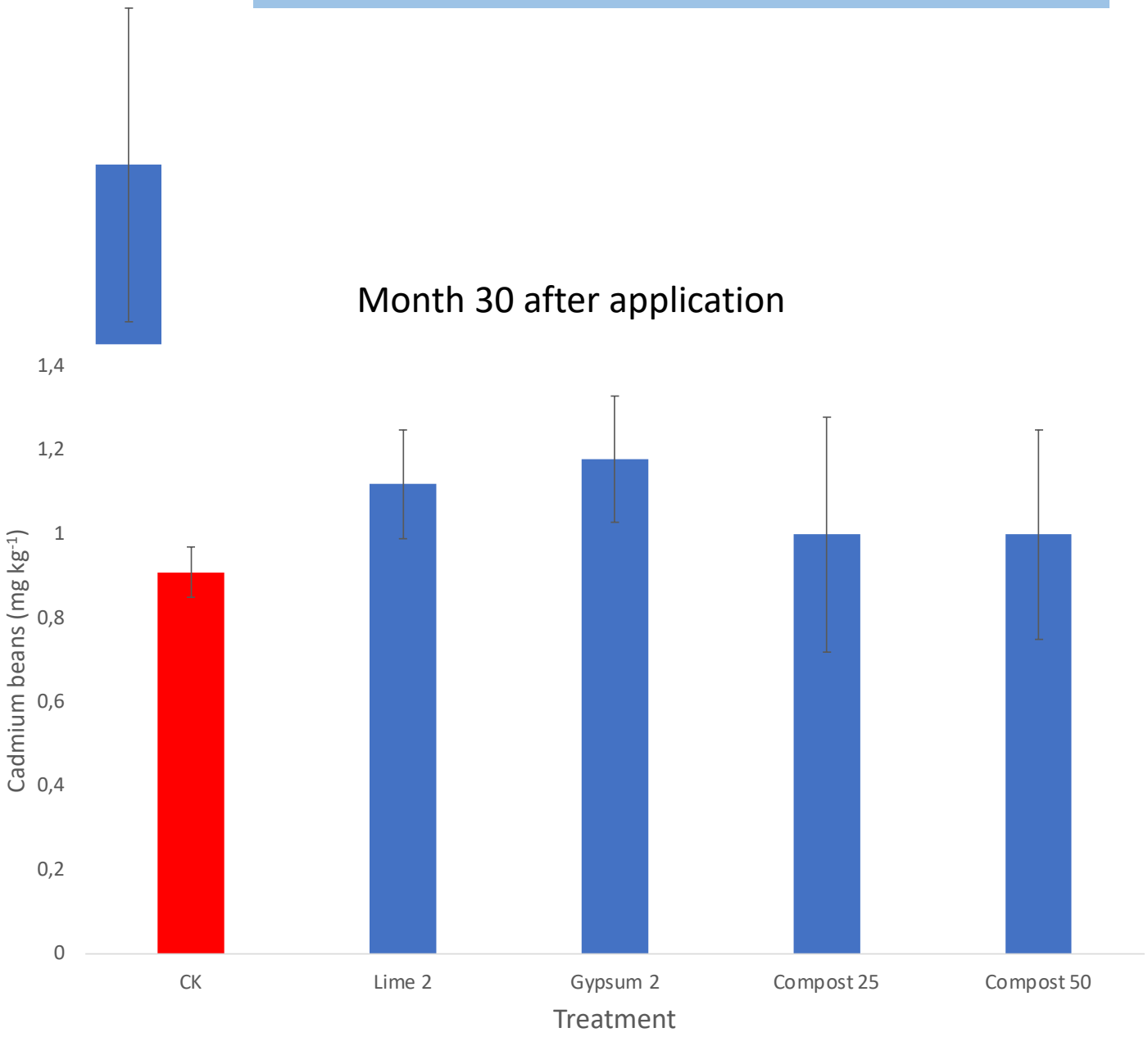
Argüello et. al., 2022 submitted for publication

FARM 1 = NEUTRAL SOIL

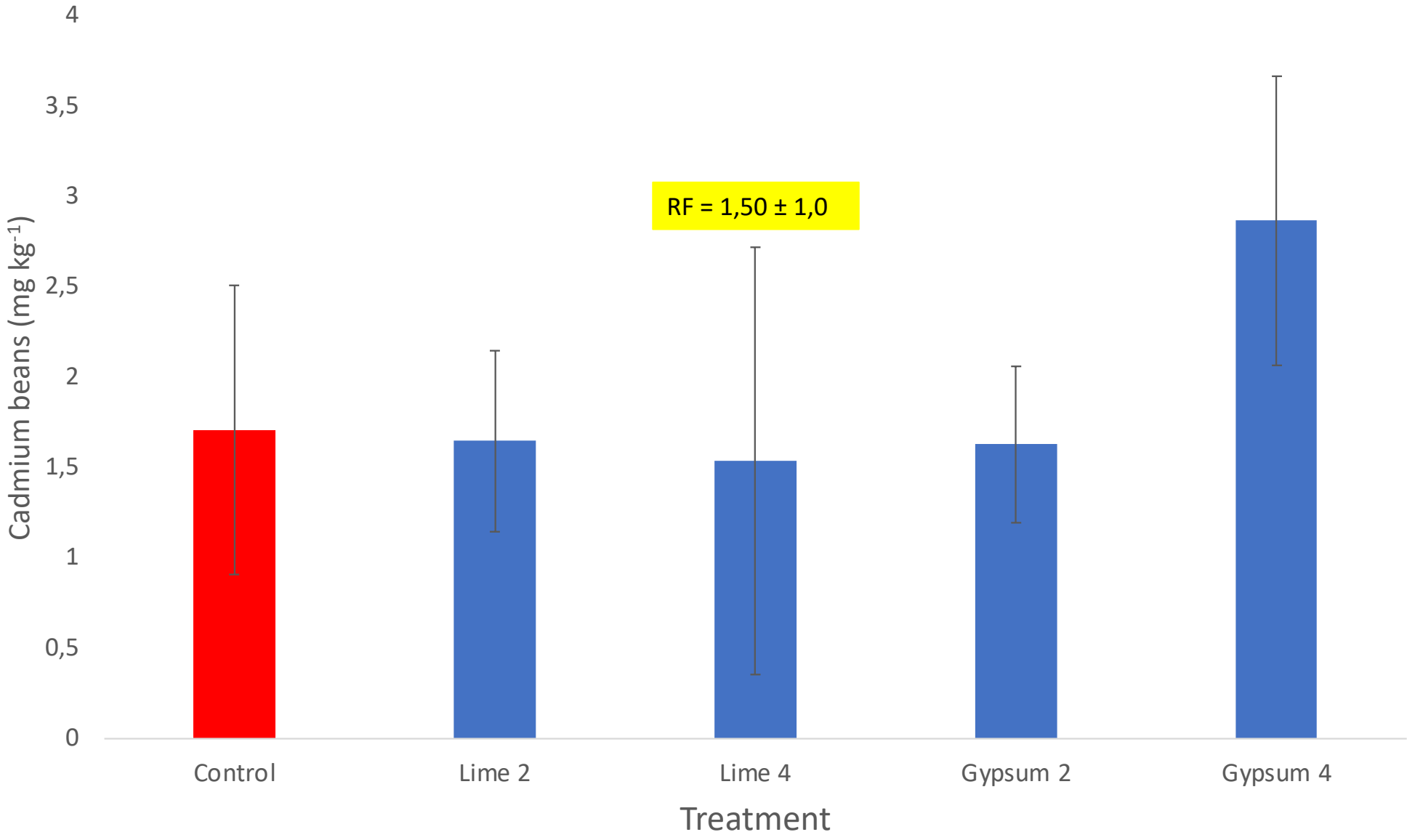


Argüello et. al., 2022 submitted for publication

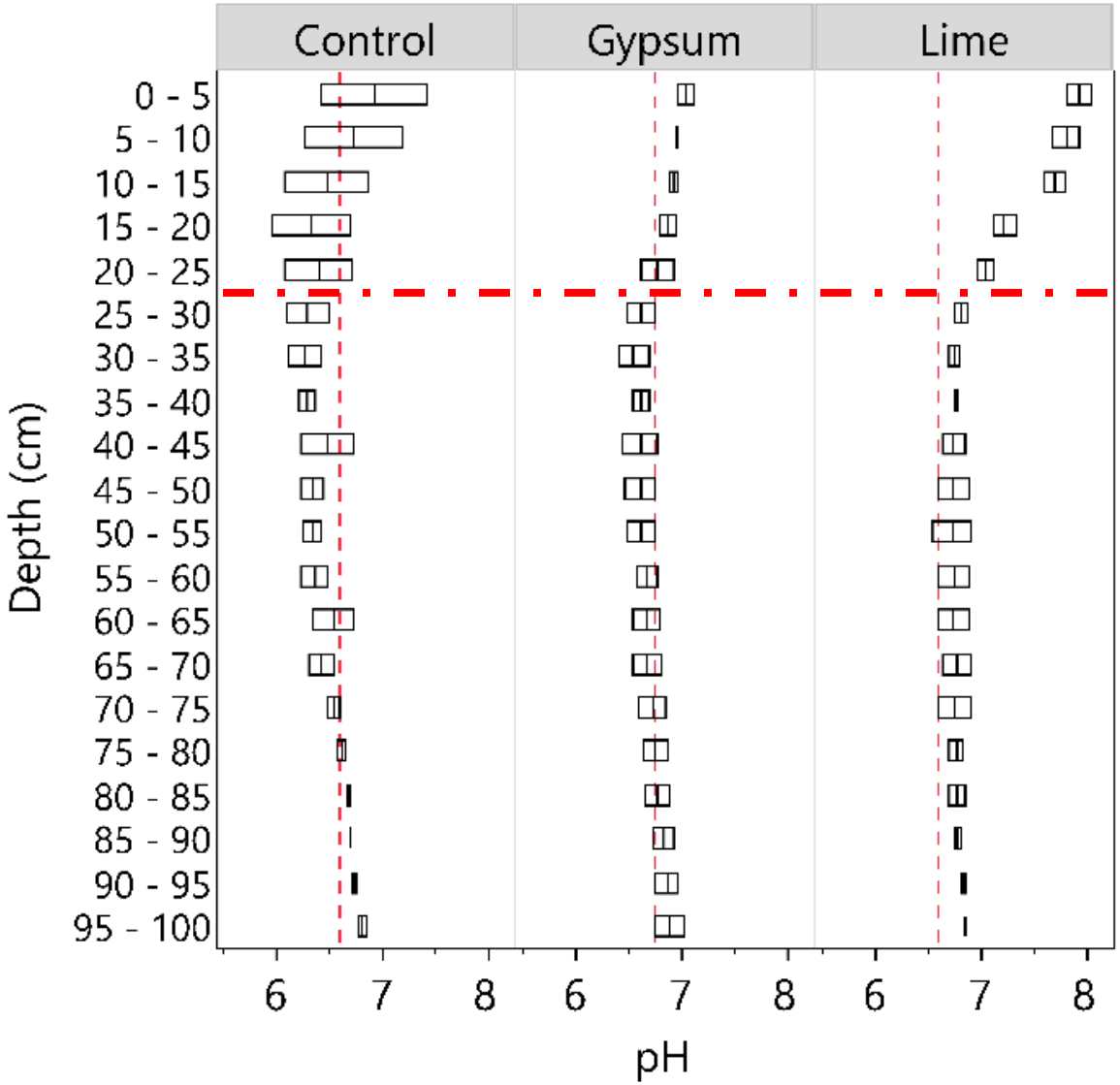
RF = 1,5 ± 0,7

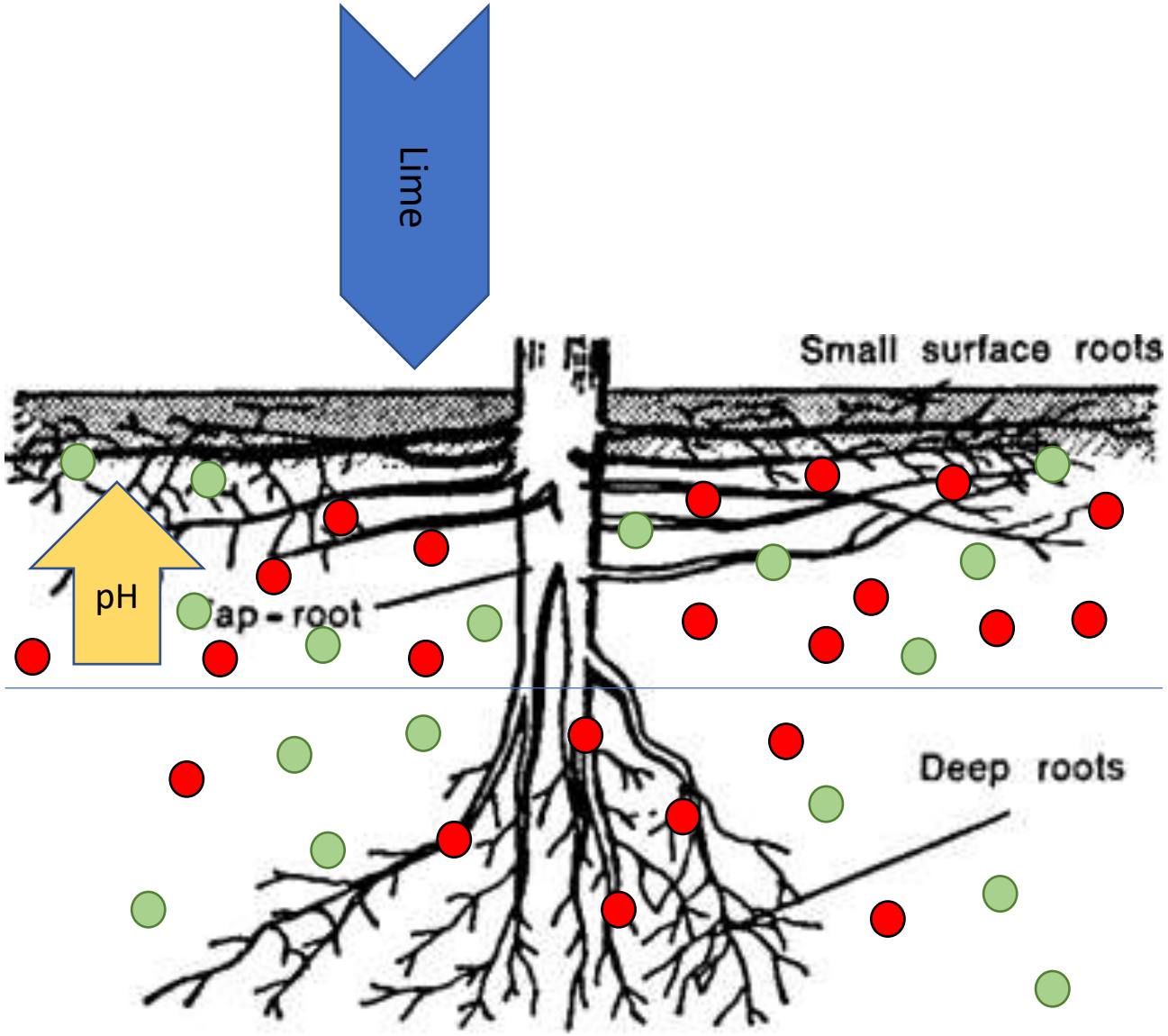


FARM 2 = ACID SOIL



Argüello et. al., 2022 submitted for publication





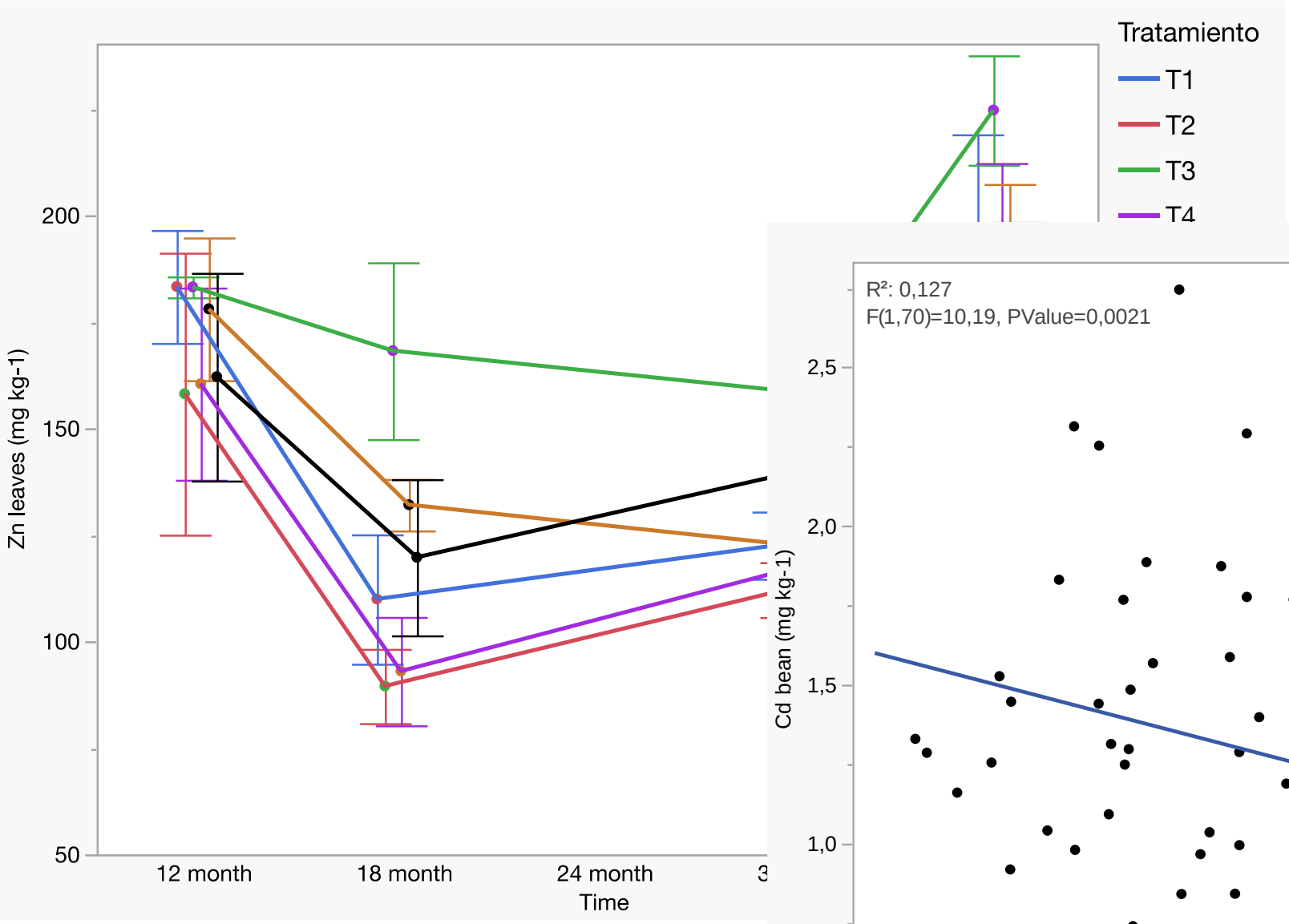
Argüello et. al., 2022 submitted for publication

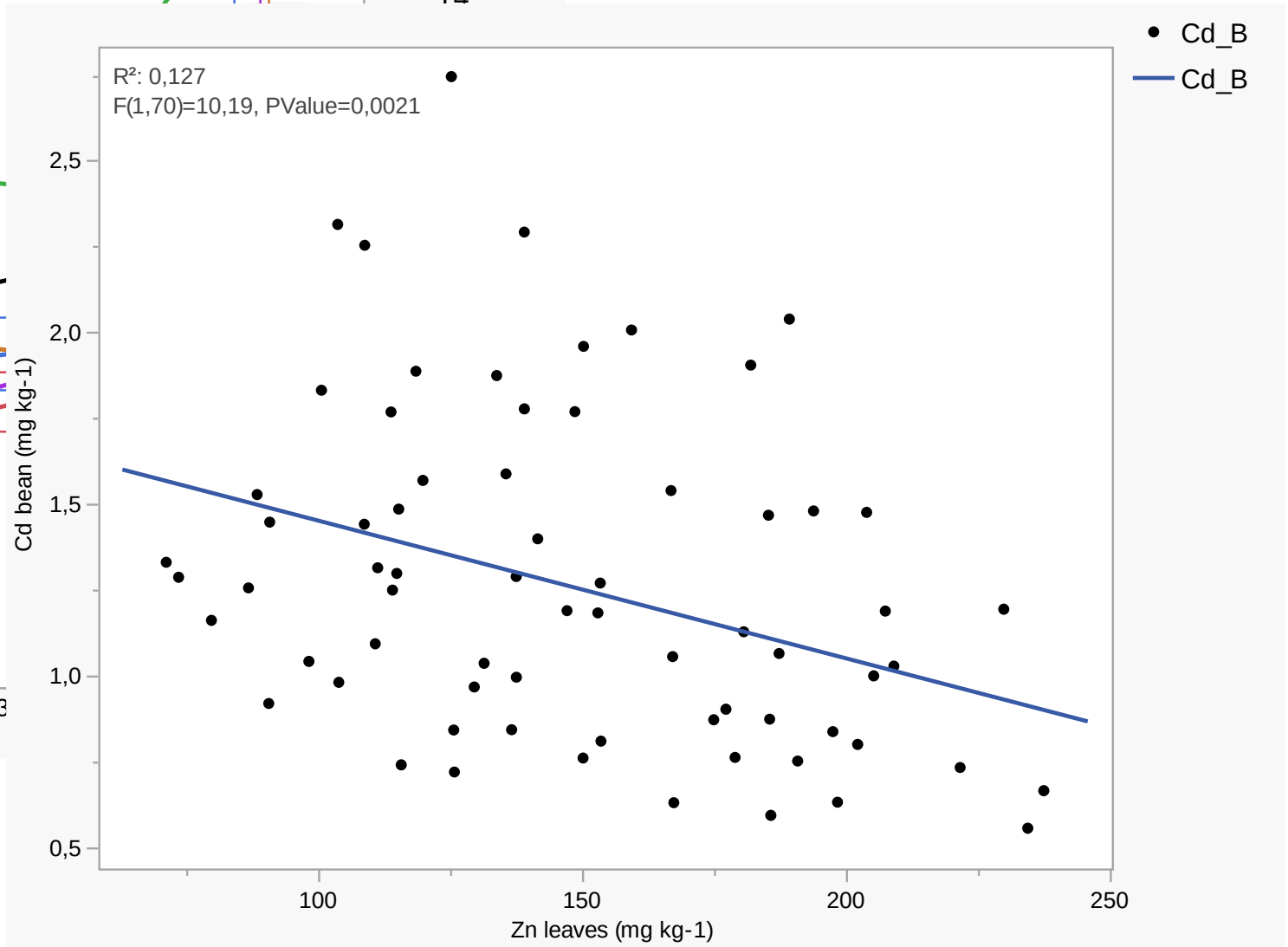
Foliar micronutrients were applied at doses (equivalent) to 6 kg ha^{-1}.

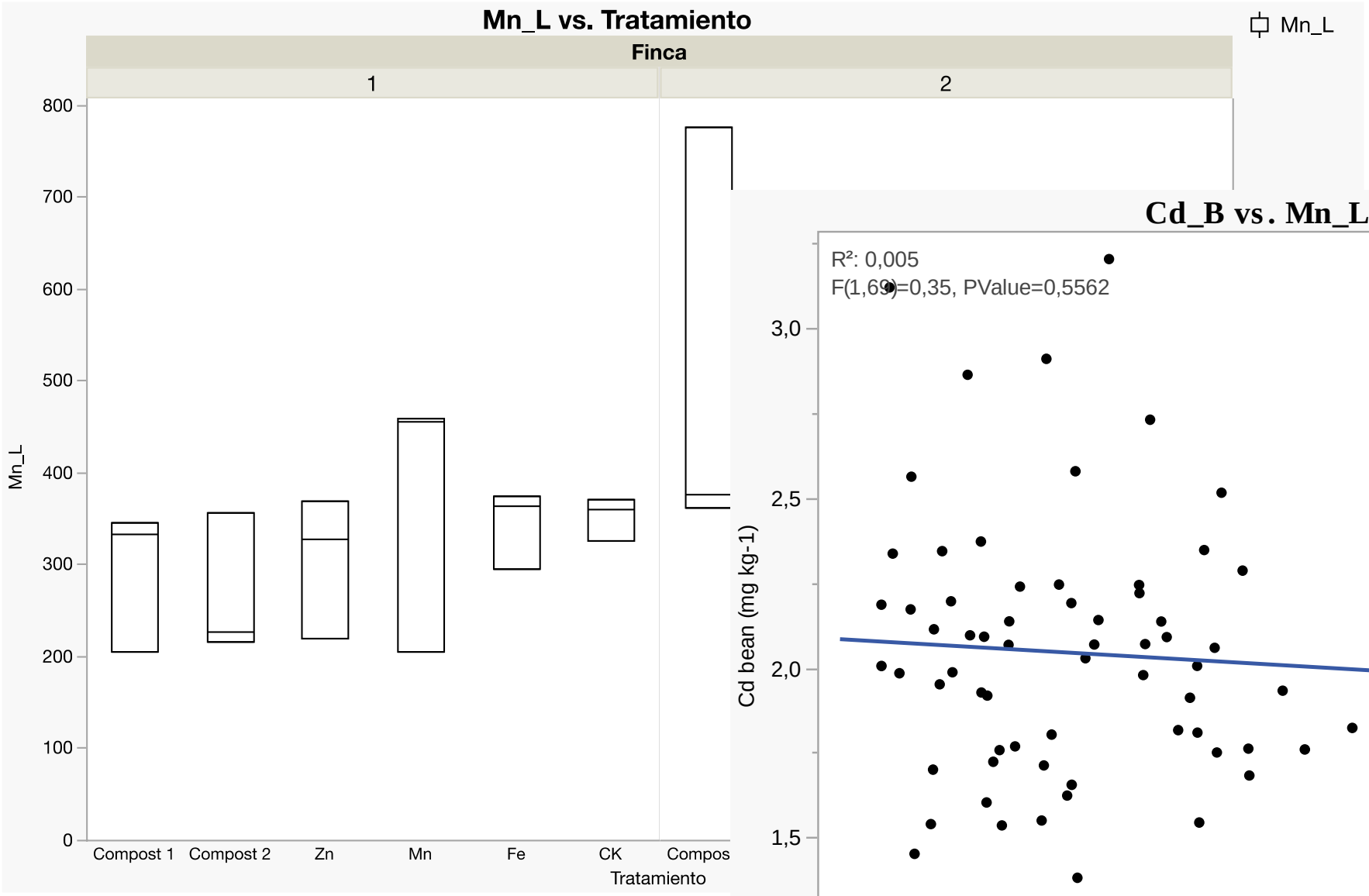
Zn, Mn and Fe in alkaline (pH > 7) soils

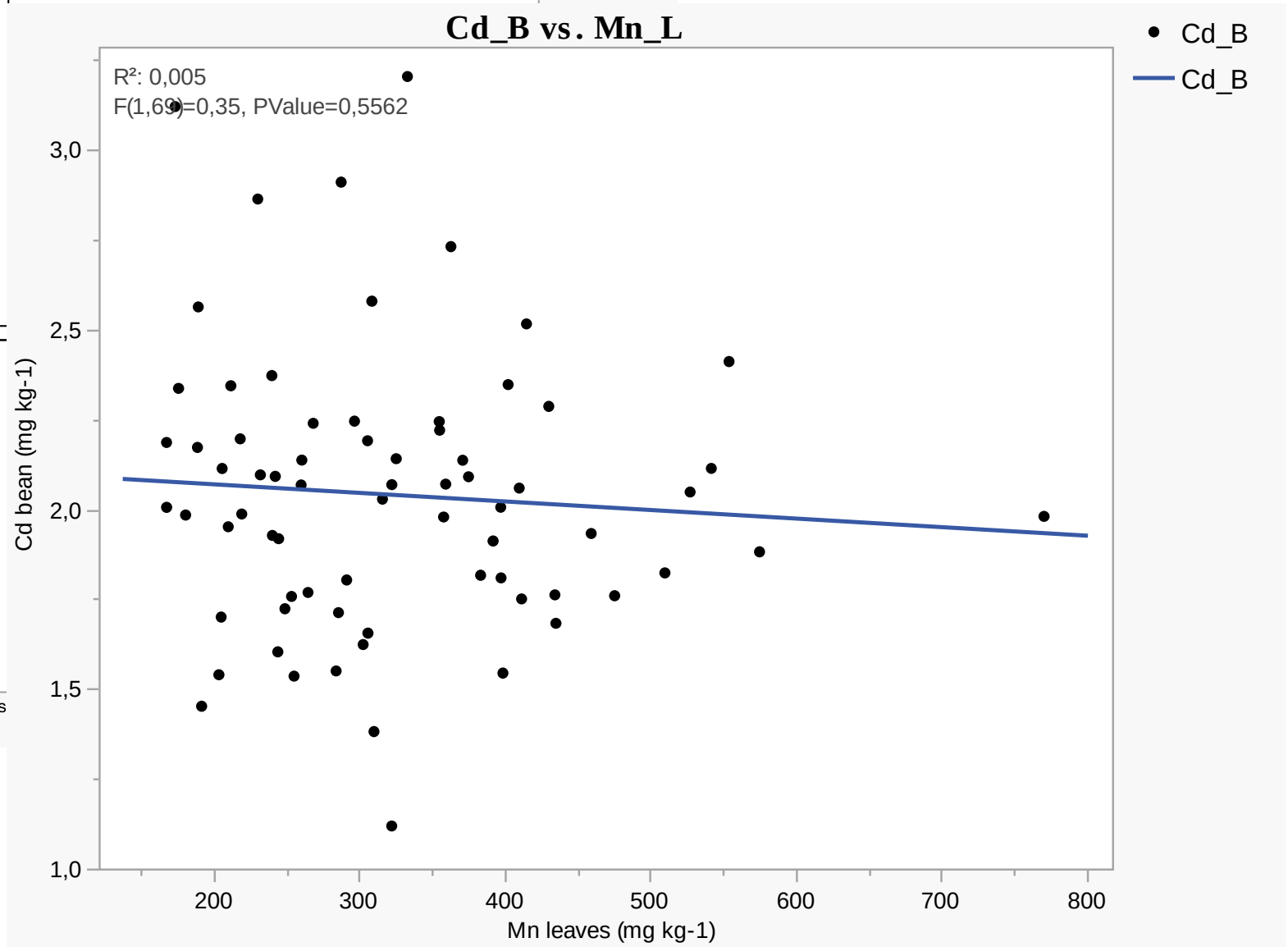
All micronutrients are applied as chelates (EDTA)

Finca	Tratamiento	pH (H_2O)	Mat. Org (%)	Zn * mg kg^{-1}	Mn * mg kg^{-1}	Fe * mg kg^{-1}
Farm 1	T1	6.1 ± 0.2	3.90 ± 1.27	183.4 ± .23	410 ± 110	53.7 ± 6.70
	T2	6.1 ± 0.2	4.00 ± 0.64	158.2 ± 57.4	367 ± 61.5	58.7 ± 20.3
	T3	6.2 ± 0.1	3.84 ± 0.47	183.3 ± 4.30	362 ± 59.8	60.1 ± 14.6
	T4	6.1 ± 0.1	3.15 ± 0.85	160.5 ± 39.1	400 ± 88.2	49.4 ± 13.3
	T5	6.1 ± 0.1	4.52 ± 0.83	178.2 ± 29.0	406 ± 157.5	51.3 ± 4.2
	TC	6.1 ± 0.4	4.82 ± 0.21	162 ± 42.2	386 ± 147.5	53.2 ± 7.45
Farm 2	T1	6.9 ± 0.2	2.13 ± 0.46	21.5 ± 1.20	427 ± 58.5	84.3 ± 8.11
	T2	7.2 ± 0.2	2.24 ± 0.48	23.7 ± 4.60	351 ± 75.2	113 ± 40.3
	T3	6.9 ± 0.5	2.05 ± 0.45	23.7 ± 7.60	375 ± 154	101 ± 28.8
	T4	7.2 ± 0.6	1.64 ± 0.17	22.2 ± 5.60	403 ± 156	103 ± 8.71
	T5	7.1 ± 0.6	1.89 ± 0.06	22.0 ± 6.80	376 ± 169	97.4 ± 30.5
	TC	7.2 ± 0.5	1.78 ± 0.41	19.2 ± 6.50	378 ± 176	72.2 ± 11.6
Farm 3	T1	6.1 ± 0.2	3.83 ± 0.27	95.1 ± 41.4	215 ± 8.80	93.1 ± 29.7
	T2	6.3 ± 0.3	3.89 ± 0.60	81.6 ± 48.4	273 ± 107	77.4 ± 12.7
	T3	6.2 ± 0.1	3.15 ± 0.71	124 ± 22.3	291 ± 102	66.2 ± 10.2
	T4	6.2 ± 0.1	3.20 ± 0.39	62.4 ± 4.30	168 ± 26.0	76.8 ± 15.2
	T5	6.3 ± 0.4	2.98 ± 0.41	101 ± 32.5	199 ± 45.5	57.8 ± 17.7
	TC	6.1 ± 0.1	3.60 ± 0.19	81.4 ± 16.7	180 ± 18.8	101 ± 26.5


Tratamiento
T1
T2
T3
T4
200
150
100
50
Zn leaves (mg kg-1)
12 month
18 month
24 month
Time


Cd_B
Cd_B
R²: 0,127
F(1,70)=10,19, PValue=0,0021
2,5
2,0
1,5
1,0
0,5
Cd bean (mg kg-1)
100
150
200
250
Zn leaves (mg kg-1)


Mn_L vs. Tratamiento
Mn_L
Finca
1
2
800
700
600
500
400
300
200
100
0
Mn_L
Compost 1
Compost 2
Zn
Mn
Fe
CK
Compos
Tratamiento


Cd_B vs. Mn_L
Cd_B
Cd_B
R²: 0,005
F(1,69)=0,35, PValue=0,5562
3,0
2,5
2,0
1,5
1,0
Cd bean (mg kg-1)
200
300
400
500
600
700
800
Mn leaves (mg kg-1)

Final remarks

- Soil properties can be modified which can lower soil/plant Cd.
- For acid pH soils (i.e., pH < 5.5), lime at a rate of 4 Mg ha^{-1} is the most suitable alternative.
- Side effects of liming should be also address, decreased Zn availability and shallow penetration depth, for instance.
- For alkaline soils, the application of compost at a high rate (50 Mg ha^{-1}) or Zn, potentially lower bean-Cd. However, the effect is not as clear as liming. How to make the plants take more micronutrients?
- Monitoring farms will be maintained for 2-3 years. Best alternatives are now being extended to farmers.

Research partner

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Graduate Students

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Funding agencies/companies

vliruos

cooperación alemana
DEUTSCHE ZUSAMMENARBEIT

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Il seme della solidarietà

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