Linking adsorption – desorption characteristics with grain Zn concentrations and uptakes by teff, wheat and maize in different landscape positions in Ethiopia

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INTRODUCTION

- Zinc (Zn) is an important soil nutrient for optimum crop production and quality.
- Its availability in the soil and uptake by the plant is governed by adsorption-desorption process.
  - Retention
  - Releases
- Again, these process are affected by several soil parameters WP3 Summary of data.xlsx

Locations and experimental details

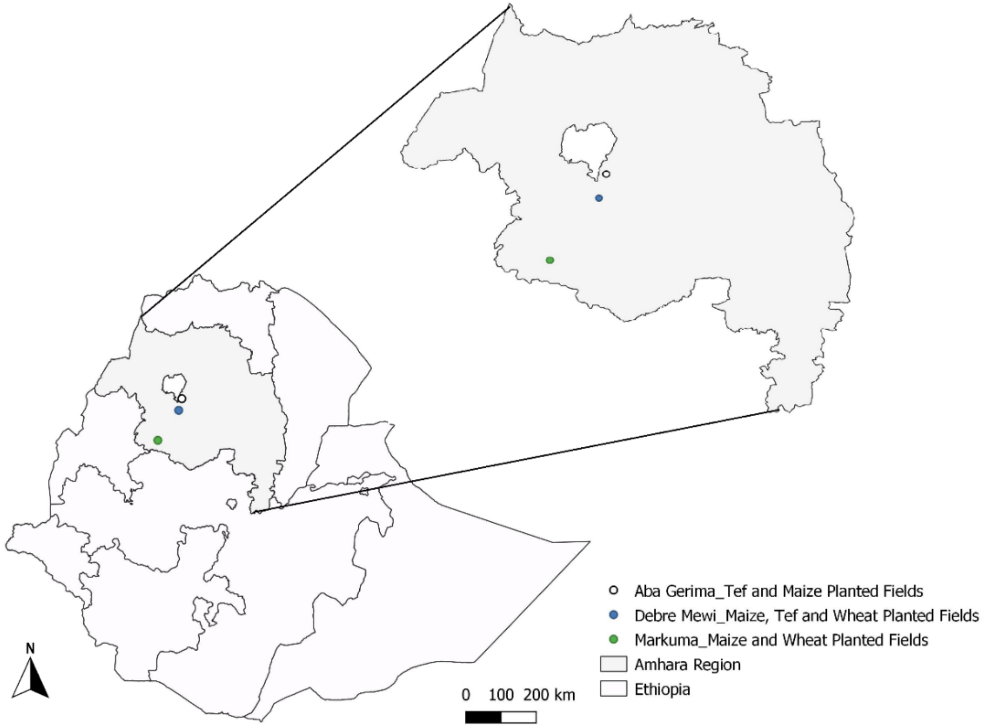

Figure 1: Location of the study sites in the Amhara region, Ethiopia.

- Site: 4 Locations
- Landscape Positions: Three
- Farmers per landscape position per location: Five
- Crop types: Three [Maize (45), Teff (30) and Wheat (30)]
- Total Number of Soil samples: 60

Adsorption-desorption studies on soils

- Adsorbed and desorbed Zinc

$$Qad = (Co - Ce)\frac{V}{W} \qquad \text{Equation 1}$$

$$Qde = (Cde)\frac{V}{W} \qquad \text{Equation 2}$$

- where C_o, C_e and C_{de} (mg L^{-1}) are the initial, equilibrium and desorbed concentrations of Zn in the solution, respectively. Q_{ad} and Q_{de} (mg kg^{-1}) is the amount of adsorbed and desorbed Zn per unit mass of soil, respectively. V is the volume of the solution added (in L), and W is the weight of the soil used (in kg).

Adsorption-desorption studies

- Adsorption and desorption are significantly affected by soil pH and SOC

$$\text{Adsorption} = -0.92 + 0.26\,\mathbf{pH} + 0.03\,\mathbf{SOC},\ \text{adjusted } r^2 = 0.90 \qquad \text{Equation 3}$$

$$\text{Desorption} = 0.89 - 0.11\,\mathbf{pH} - 0.03\,\mathbf{SOC},\ \text{adjusted } r^2 = 0.70 \qquad \text{Equation 4}$$

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Plant Available Zinc Is Influenced by Landscape Position in the Amhara Region, Ethiopia

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Treatments selected from the On-farm trials

- Soil based applied treatments such as
    - Control,
    - Basal Zn, and
    - Basal Zn + side dressing Zn

- The application rates of Zn in the basal, and side dressing treatment were 5.5 and 2.75 kg of Zn ha^{-1}, respectively, and these were the same for the three crops teff, maize and wheat.

Net Zn from the applied fertilizers

$Zn_{ad} = Zn_a * Adsorption$ Equation 5

$Zn_{de} = Zn_{ad} * Desorption$ Equation 6

$Net\ soil\ Zn = \Sigma((Zn_a - Zn_{ad}) + Zn_{de}))$ Equation 7

where Zn_a, Zn_{ad} and Zn_{de} refers to the amount of Zn applied as a fertilizer, adsorbed and desorbed (kg ha^{-1}), respectively.

The aim of this research …

- Finally, net soil Zn (Equation 7) was linked to the grain Zn concentrations and uptakes of teff, maize and wheat on the same plots.
- Furthermore, potential soil parameters affecting Zn uptake by the crop and nutrient interactions (total N, S and K for synergetic and P, Ca, Cu and Fe for antagonistic effects) in the plant influencing translocation of Zn into the grain were identified through correlation and significance tests.

RESULTS....

Table 1: Average soil characteristics (pH, Total N, SOC, Olsen P, total Zn, eCEC and clay) for the different landscape positions and all crop/site combinations.

Crop	Locations	Landscape position	pH	Total N (%)	SOC (%)	Olsen P (mg kg^{-1})	Zn (mg kg^{-1})	eCEC (cMolc kg^{-1})	Clay (%)
Teff	Aba Gerima; Debre Mewi	Upslope	5.56	0.138	1.61	4.63	96	23.5	44
		Midslope	5.67	0.099	1.16	3.21	103	26.9	46
		Footslope	5.52	0.125	1.46	4.41	98	24.2	57
Wheat	Debre Mewi; Markuma	Upslope	4.92	0.175	2.21	4.17	74	14.3	44
		Midslope	5.19	0.150	1.88	2.92	72	17.1	48
		Footslope	5.68	0.132	1.77	2.77	81	26.7	56
Maize	Aba Gerima; Debre Mewi; Markuma	Upslope	4.98	0.164	1.99	4.34	77	13.1	44
		Midslope	5.32	0.142	1.73	3.12	80	20.5	46
		Footslope	5.30	0.131	1.66	3.72	86	21.8	42
	LSD		0.40	0.04	0.47	1.60	14	7.51	8
	DF		46	46	46	46	46	46	46

Results….

Table 2: Grain Zn concentrations and uptake in the grain for teff, wheat and maize, dependent on landscape position and Zn treatment.

Landscape Position	Treatments	Teff	Wheat	Maize
		Grain Zn (mg kg^{-1})	Grain Zn (mg kg^{-1})	Grain Zn (mg kg^{-1})
Upslope	Control	24.35	21.13	15.86
	Basal	27.06	27.50	16.71
	Basal + Side Dressing	27.18	28.51	18.44
Midslope	Control	25.43	26.15	15.06
	Basal	26.27	29.78	17.56
	Basal +Side Dressing	27.31	29.61	16.38
Footslope	Control	26.86	26.27	14.41
	Basal	29.19	32.20	16.24
	Basal + Side Dressing	29.08	31.14	16.10
LSD		1.12^{TL}	2.37^{TL}	NS
DF		79	66	92

^{TL} Significant for treatments and landscape position, not for interactions; ^{L} Significant for landscape position only; LSD = Least significant difference; DF = Degrees of freedom

Which soil factors found to influence grain Zn concentrations?

Parameters	**Teff**	**Maize**	**Wheat**
Net Zn	Yes	Yes	Yes
Clay	Yes	No	Yes
Soil Total Zn	No	Yes	No

Results….

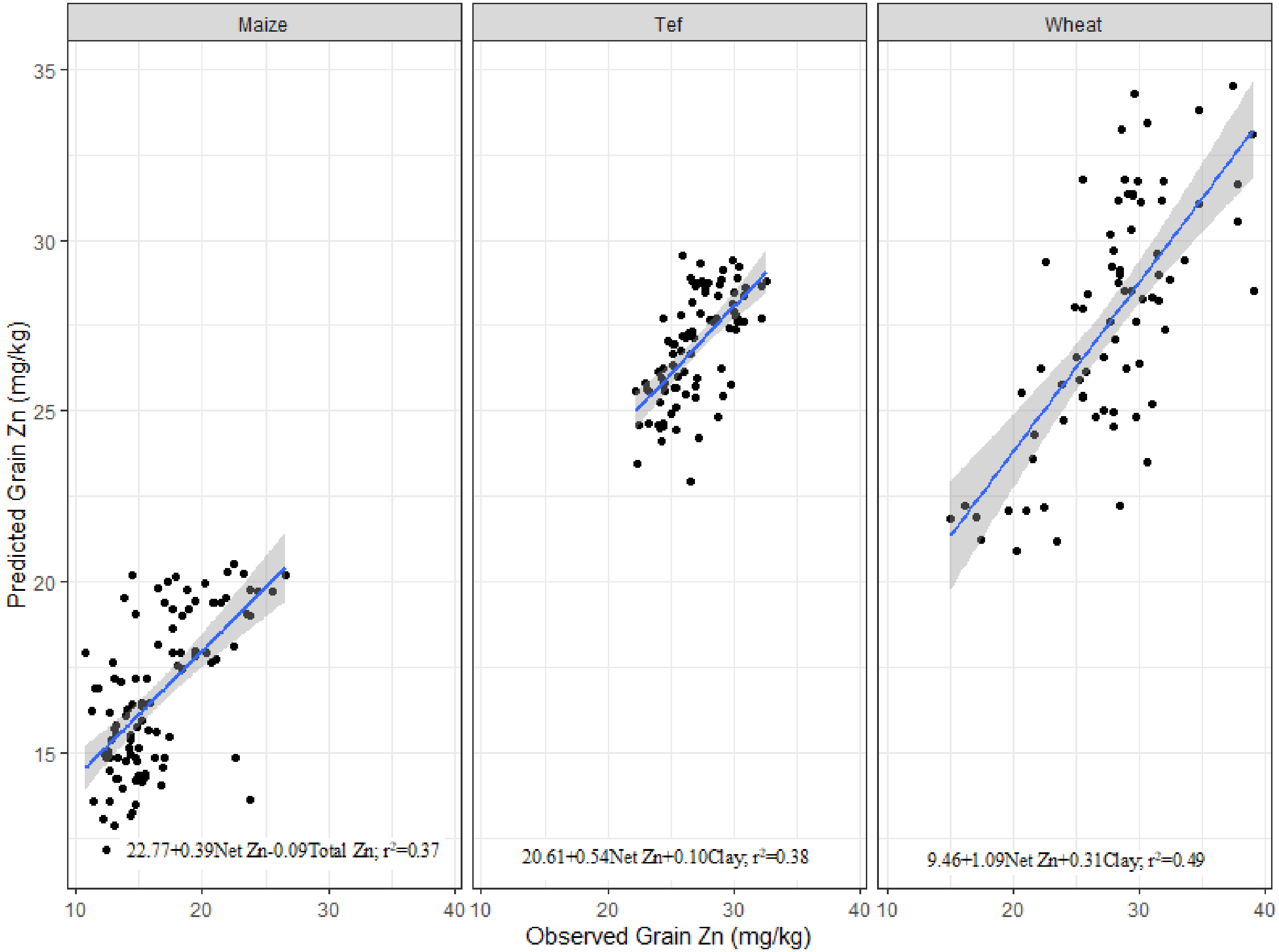

Figure 2: Observed versus predicted Grain Zn concentrations for maize, teff and wheat across all sites and landscape positions. The equation describes the best fitting predictive model and the related regression coefficient is given where N, Zn and C refers to Net Zn, total soil Zn and Clay respectively.

Which soil factors found to influence grain Zn uptakes?

Parameters	Teff	Maize	Wheat
Net Zn	No	No	No
Clay	No	Yes	No
Soil Total Zn	No	Yes	No
Soil Total K	Yes	No	Yes

Results....

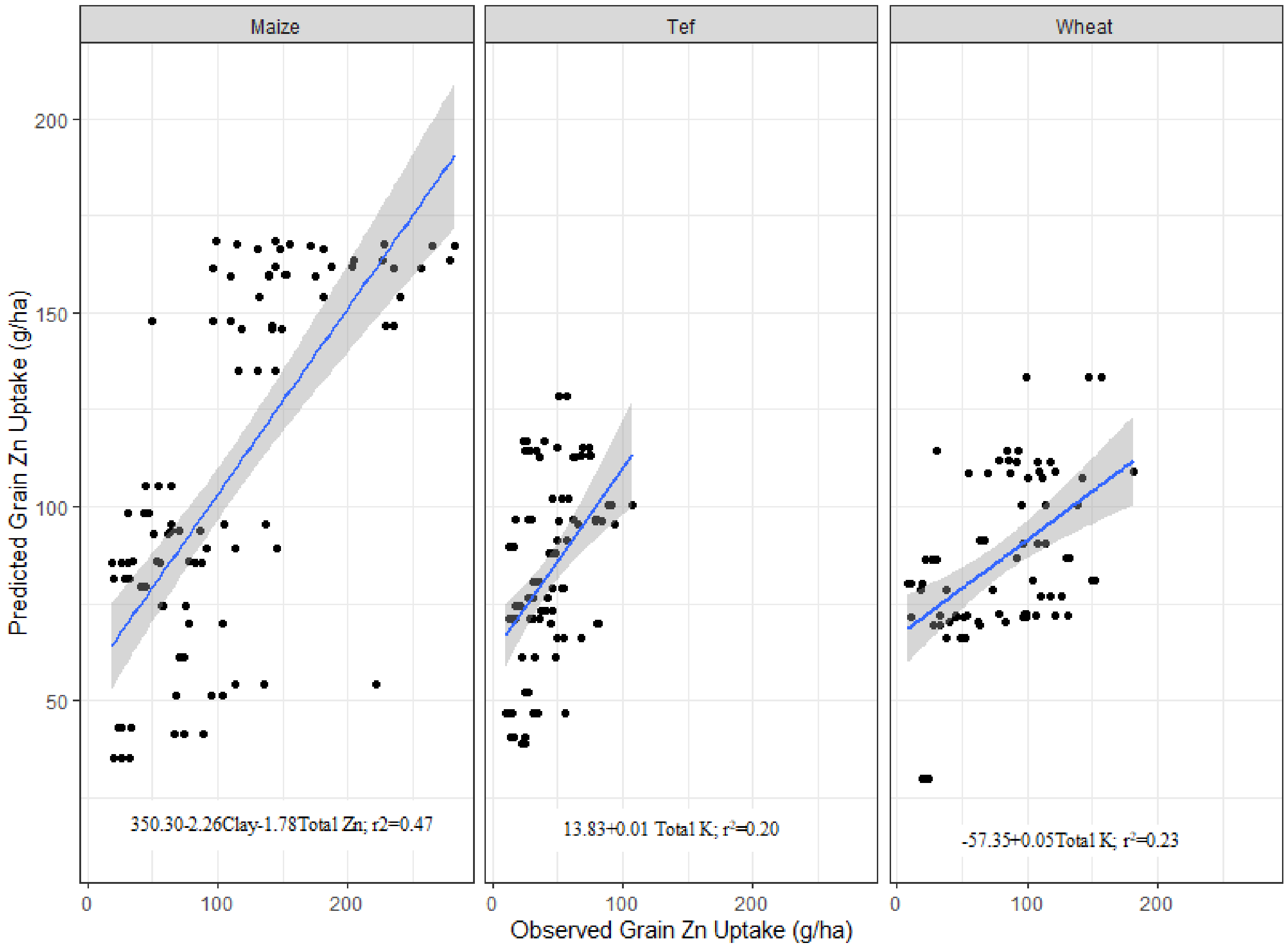

Figure 3: Observed versus predicted Grain Zn uptakes for maize, teff and wheat across all sites and landscape positions. The equation describes the best fitting predictive model and the related regression coefficient is givenwhere C, Zn and K refers to Clay, total soil Zn and K respectively.

Results….

Table 3 Correlations and significance values for grain Zn and uptakes with other soil nutrients affecting Zn

Soil parameter	Teff (n=88)		Wheat (n=75)		Maize (n=101)	
	Grain Zn (mg/kg)	Zn Uptake (g/ha)	Grain Zn (mg/kg)	Zn Uptake (g/ha)	Grain Zn (mg/kg)	Zn Uptake (g/ha)
Soil pH	-0.04	-0.04	0.41**	0.26*	-0.43***	-0.50***
Total N	0.15	0.34**	-0.23*	-0.09	0.41***	0.43***
SOC	0.16	0.39**	-0.36*	-0.05	0.51***	0.58***
Olsen P	0.19	0.16	-0.02	-0.11	-0.21*	-0.22*
eCEC	0.02	-0.04	0.39**	0.27*	-0.38**	-0.44***
Clay	0.45***	0.28**	0.51***	0.24*	-0.18*	-0.38***
Total soil concentrations (mg/kg)						
Ca	0.06	0.03	0.43**	0.31**	-0.47***	-0.54***
Cu	-0.16	-0.08	**-0.09**	0.02	-0.07	-0.01
Fe	-0.31*	-0.14	-0.07	-0.27*	-0.47***	-0.35**
K	0.41***	0.45***	0.25*	0.49***	0.41***	0.31**
Mg	-0.32**	-0.18	**0.39****	0.19	-0.46***	-0.44***
Mn	-0.06	0.15	0.18	0.07	0.18	-0.03
P	0.11	0.18	-0.21	-0.18	0.20*	0.20*
S	0.12	0.28**	-0.29*	-0.11	0.41***	0.46***
Exchangeable Cations (cmolc/kg)						
Ca	0.08	0.04	0.39**	0.29*	-0.33**	0.41***
K	0.15	0.24*	0.51***	0.33*	0.17	-0.19
Mg	-0.26*	-0.16	0.34*	0.12	-0.38**	-0.42***
Na	-0.13	-0.32**	[illegible]	0.08	-0.50***	-0.60***

Results….

Table 4: Interaction of other grain nutrients with grain Zn concentration and uptake in plant concentrations. Shown are correlation and significance values for all three crops across treatments and landscape positions.

Total grain nutrients other than Zn	**Teff (n=88)**		**Wheat (n=75)**		**Maize (n=101)**	
	Grain Zn	Zn Uptake	Grain Zn	Zn Uptake	Grain Zn	Zn Uptake
P	0.32**	0.14	0.40**	0.32**	0.80***	0.69***
K	0.33**	0.11*	0.52***	0.39**	0.85***	0.75***
S	0.55***	0.41***	0.18	0.06	0.56***	0.45***
Ca	0.46**	0.38**	**-0.31****	-0.21	0.51***	0.31**
Mn	0.21*	0.08	-0.09	0.19	0.82***	0.72***
Fe	0.29**	-0.37**	0.33**	0.06	0.70***	0.61***
Cu	0.52***	0.07	**0.01**	-0.05	0.39***	0.34**
Se	0.18*	0.08	-0.24*	-0.11	0.19*	0.06
Mo	0.11	0.12	0.12	-0.02	0.04	-0.03

SUMMARY AND CONCLUSION

- Generally, landscape positions possessing relatively high soil pH, SOC and clay content tend to decreases the net Zn in the soil which is potentially available for the crop uptake while low values of these helps to increase the net Zn from the soil applied fertilizers.
  - For maize and teff, high net Zn is directly associated with increased grain Zn concentrations while low net Zn for low grain Zn.
  - Wheat differs to obey this rule and this could be either due to the genetic makeup of this crop to efficiently use Zn from the soil or the contribution of increasing clay content which would retain some Zn and later able to take up by the roots.
- Predictive models help to make 37-50% of the actual grain Zn
- Besides, we have seen also the presence and significant correlations with Cu and Mg in soils and Cu and Ca in the grain affect the uptakes from the soil and its translocation to the grain.