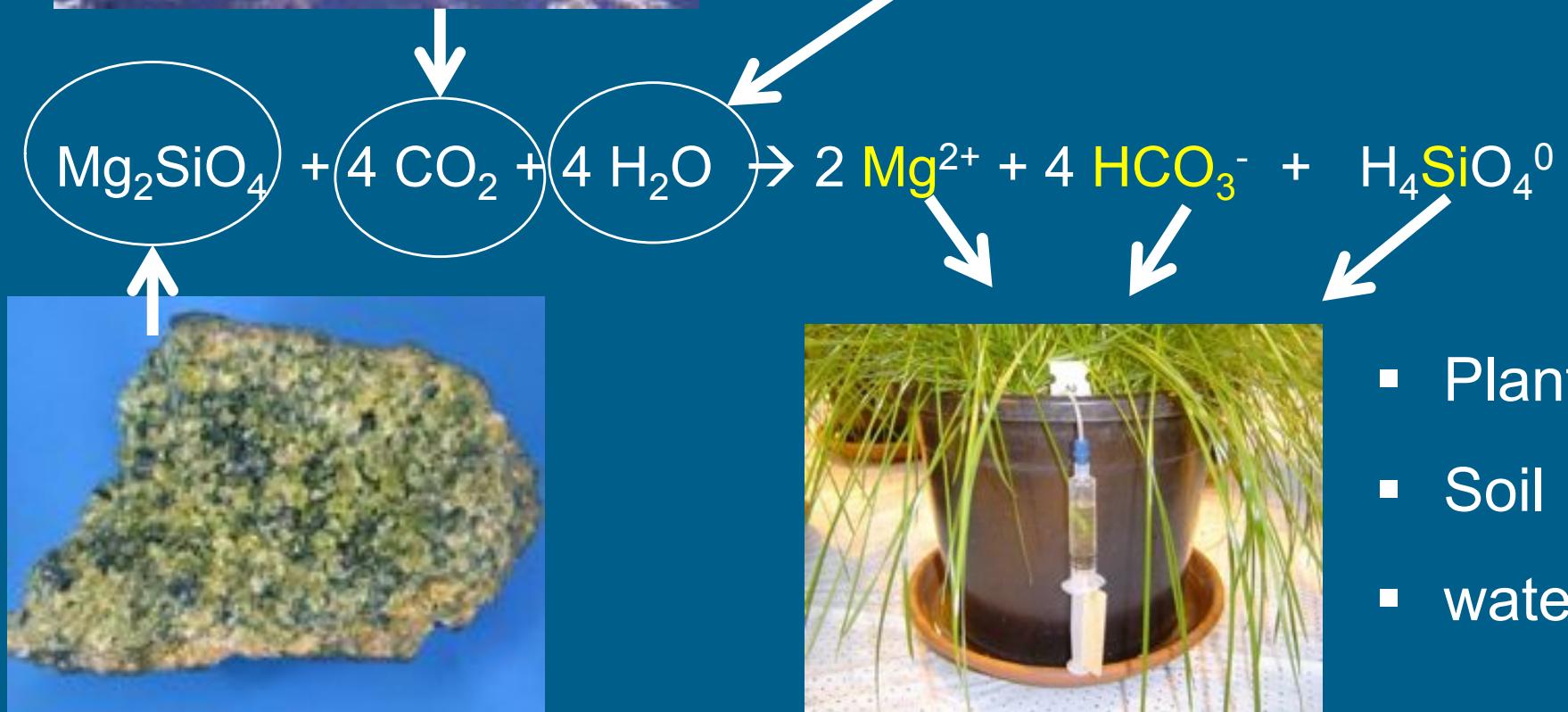


Olivine Weathering in Soil, and its Effects on Growth and Nutrient Uptake in Ryegrass: *a pot experiment*

Hein ten Berge, Hugo van der Meer, Johan Steenhuizen, Paul Goedhart, Pol Knops, Jan Verhagen





- Plant
- Soil
- water





23.5% Mg

0.24 % Ni

	Content (mg per kg olivine)
Ca	488
Fe	40153
K	1659
Mg	234881
Mg (bioavailable)	204
Ni	2445
Ni (bioavailable)	0.020



Objectives

To assess:

- weathering rate of olivine in rooted soil
- Effect on crop biomass production
- Effect on crop element uptake (Mg, Si, Ni)
- Effect on soil pH
- Effect on element availability (Mg, Ni, Si) in soil and water



Grass as a ‘model crop’



- Intensive rooting
interception of solutes
- Large biomass
accumulation of solutes
- Flexible concentrations
Mg, Si, Ni
- Sequential harvests
allowing for time series
- Simple harvesting
- Important ‘crop’
(EU $70 10^6$ ha
world $3400 10^6$ ha)



- 
- 7 different Magnesium rates
 - Sources: olivine and kieserite (soluble MgSO₄)
 - Other nutrients (N, P, K) as in NL farm practice
 - 4 replicates
 - August 2009 - April 2010 (8 months)
 - Outdoors – greenhouse - outdoors



Magnesium
in kieserite 16.2%
in olivine 23.5%

Treatments

**Five-fold
increments**

	Dose gram/pot	Dose kg/ha	Magnesium g/pot	Magnesium kg/ha
Control	0	0	0	0
Kiserite-1	1.5	300	0.24	48
Kiserite-2	3.0	600	0.49	97
Olivine-1	8	1,630	1.9	381
Olivine-2	40	8,150 *	9.4	1,904
Olivine-3	200	40,700	47.0	9,524
Olivine-4	1000	204,000**	235	47,622

* Equivalent to 0.7 mm layer powdered olivine

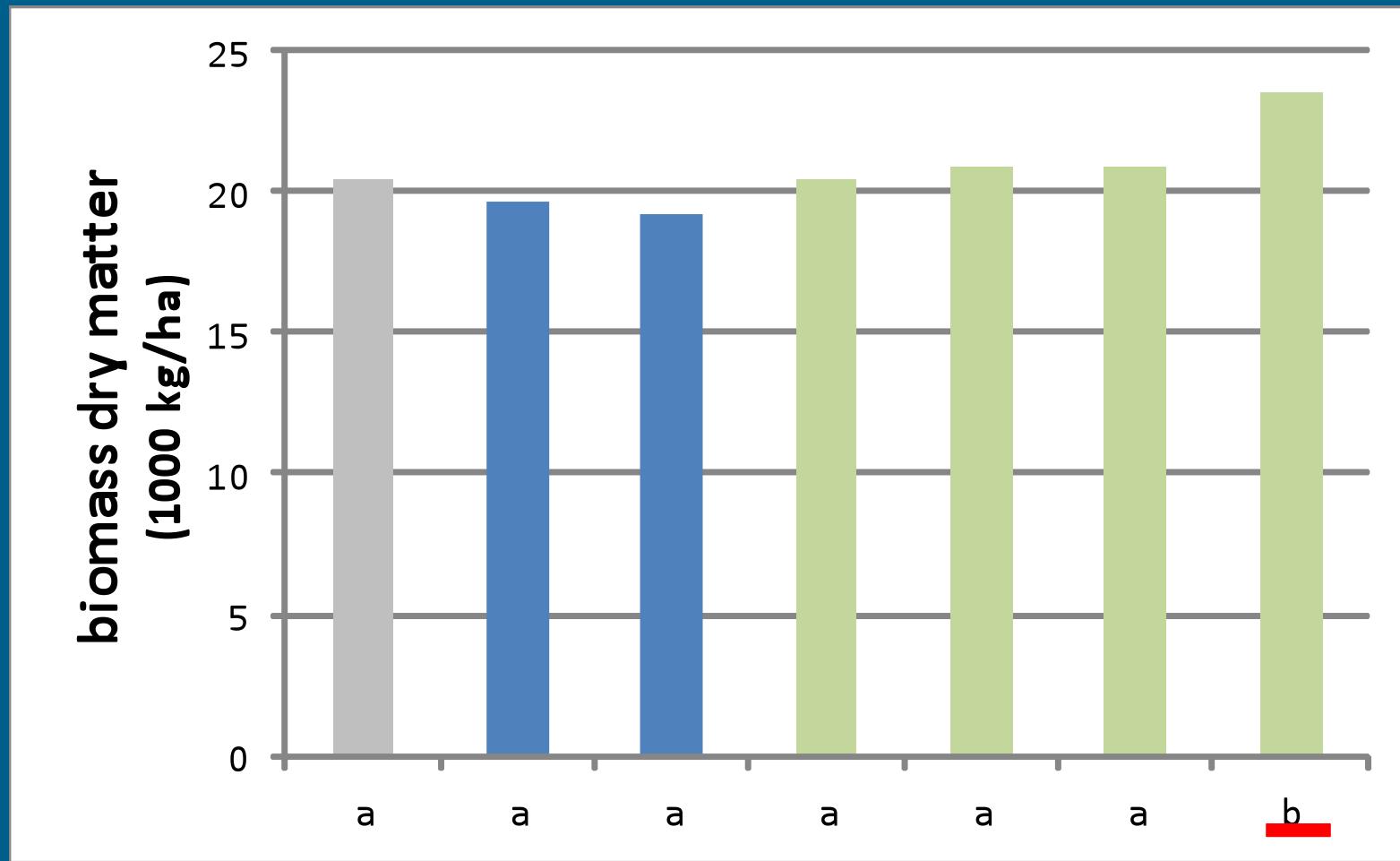
** Equivalent to 17 mm layer powdered olivine



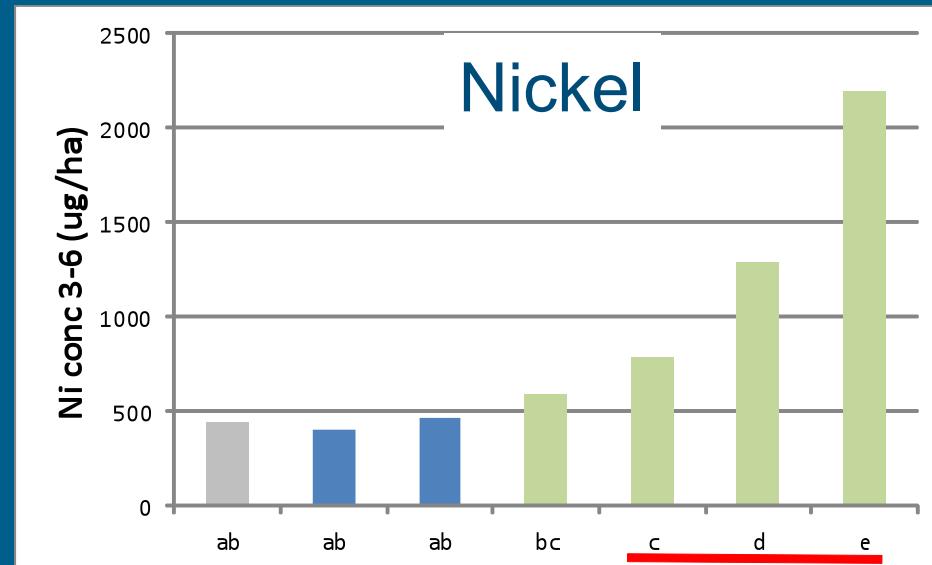
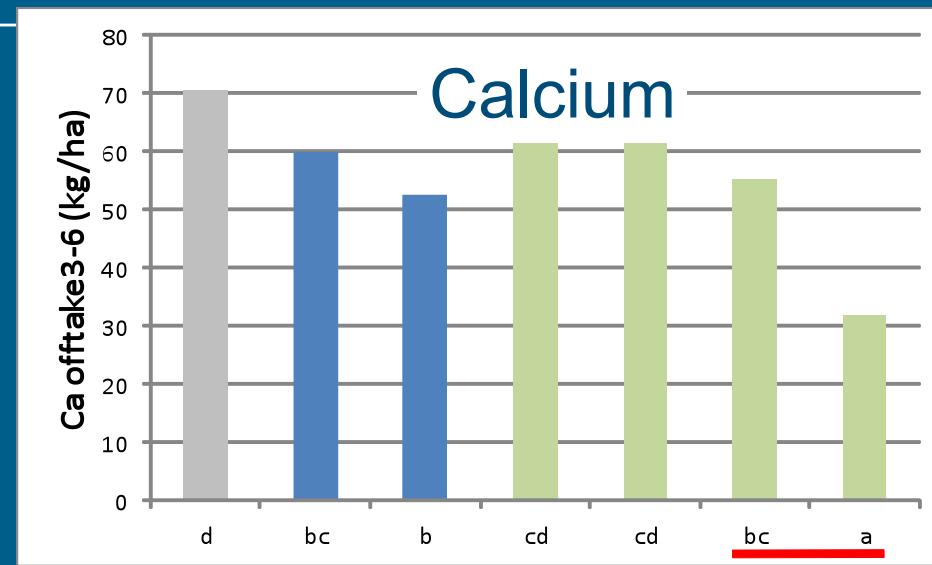
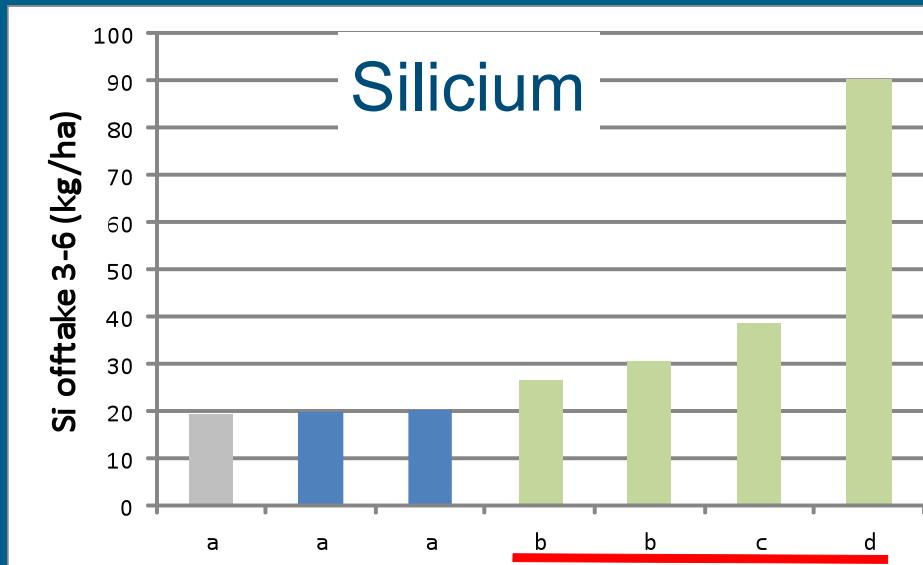
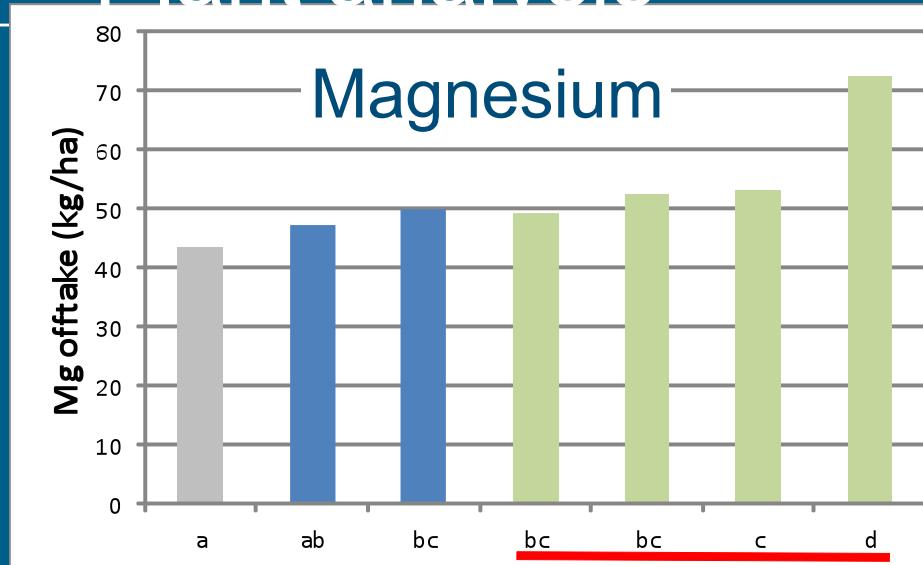
Results



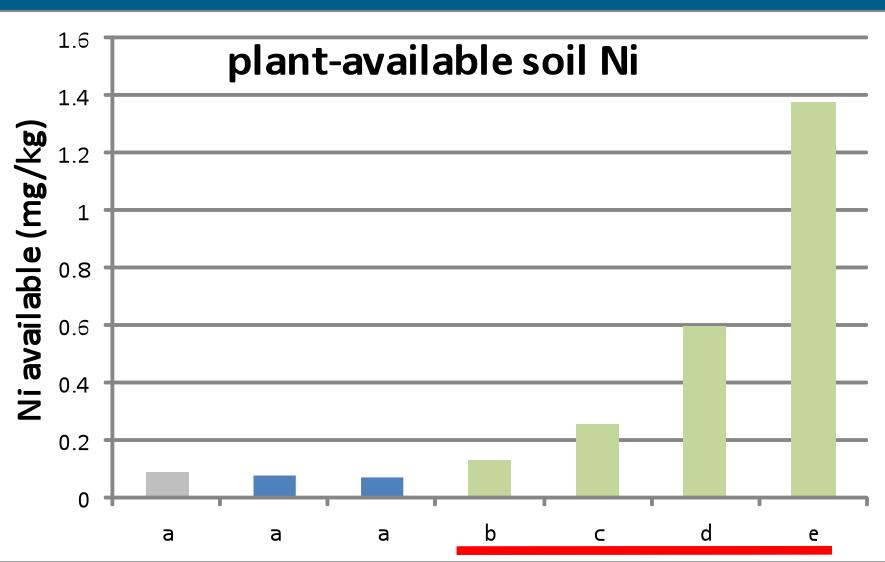
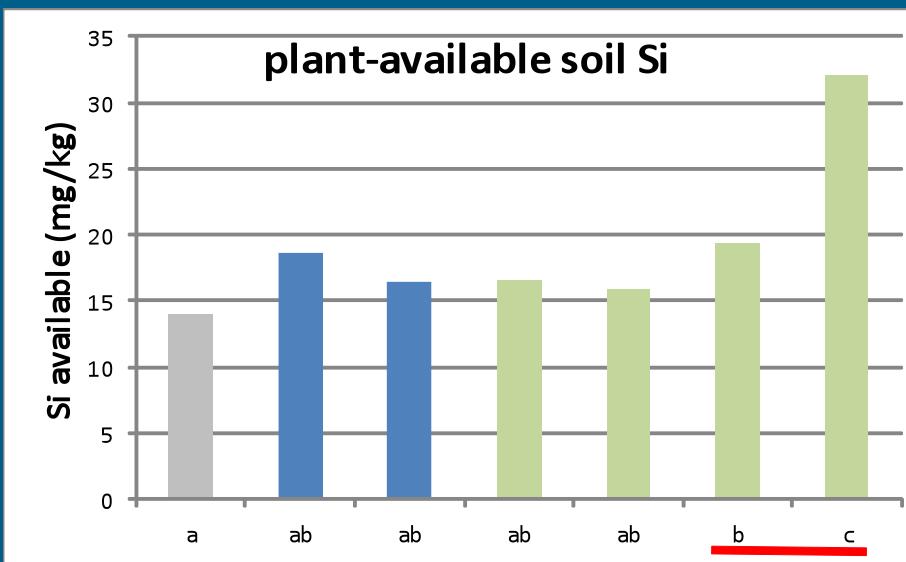
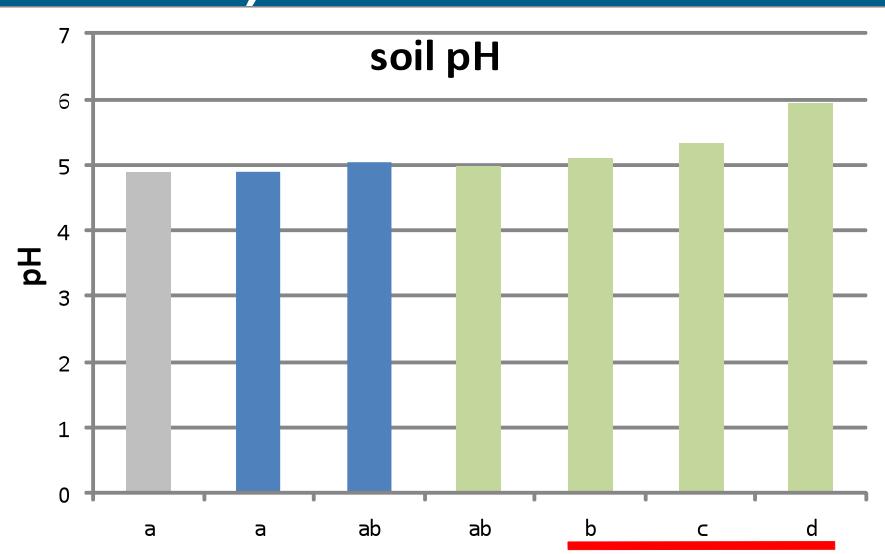
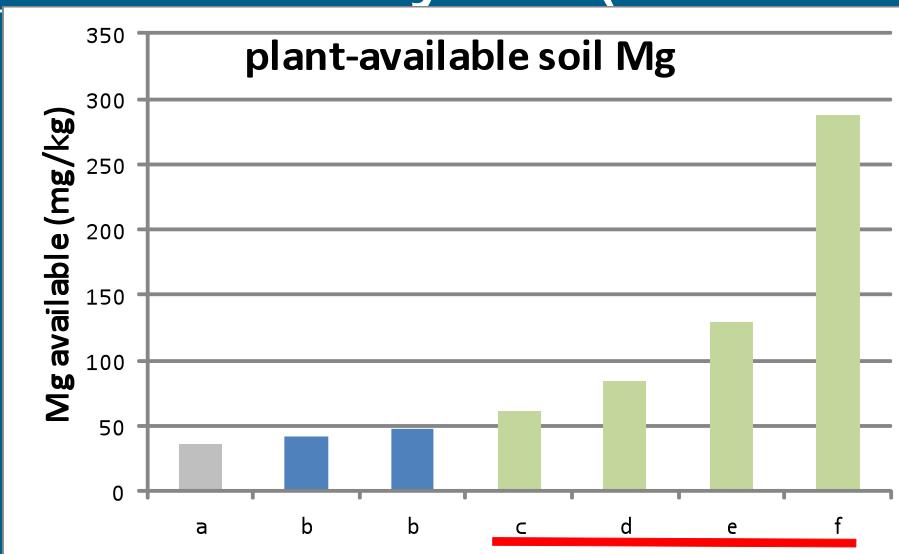
Crop biomass harvested (dry matter)



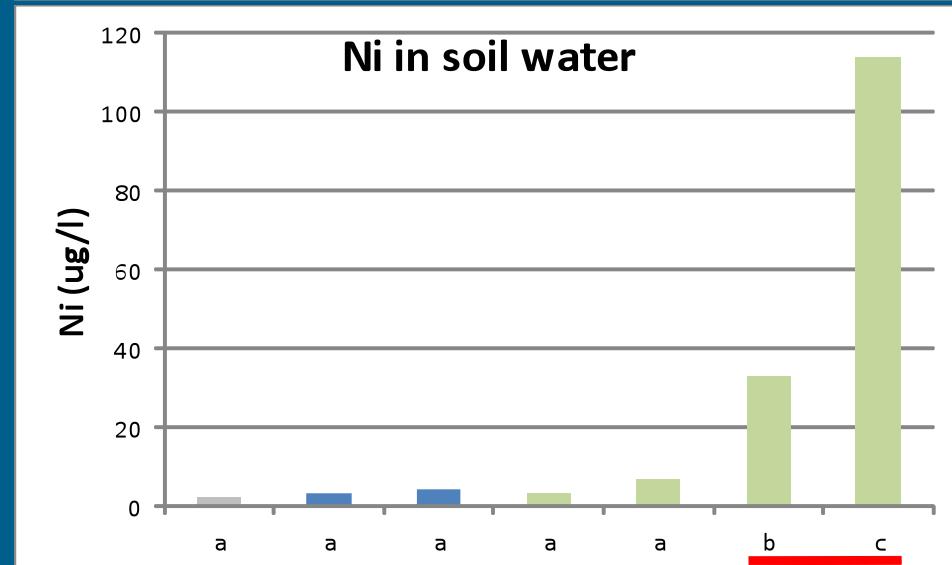
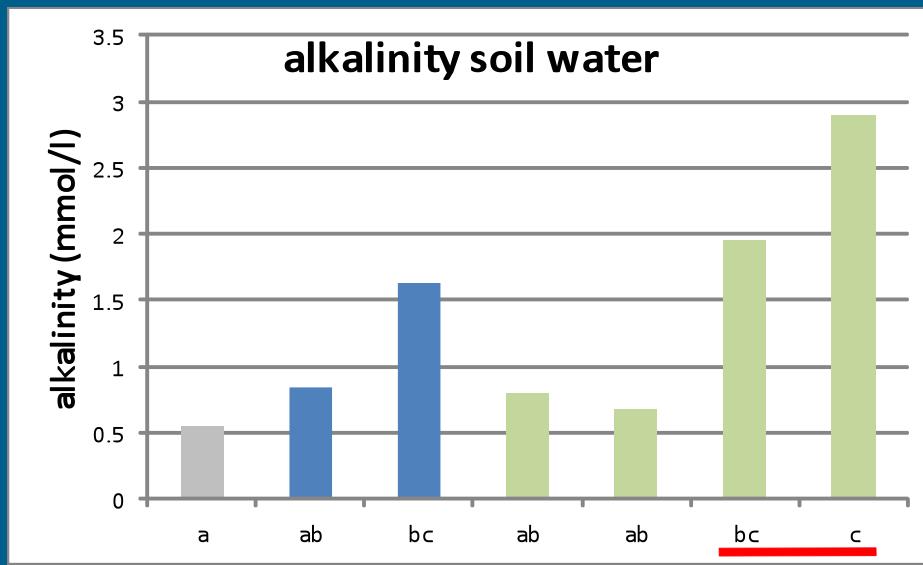
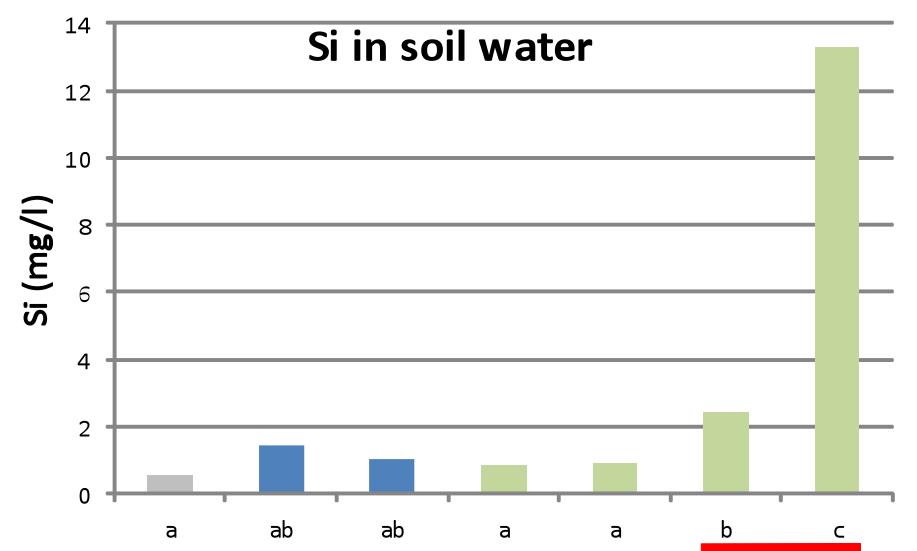
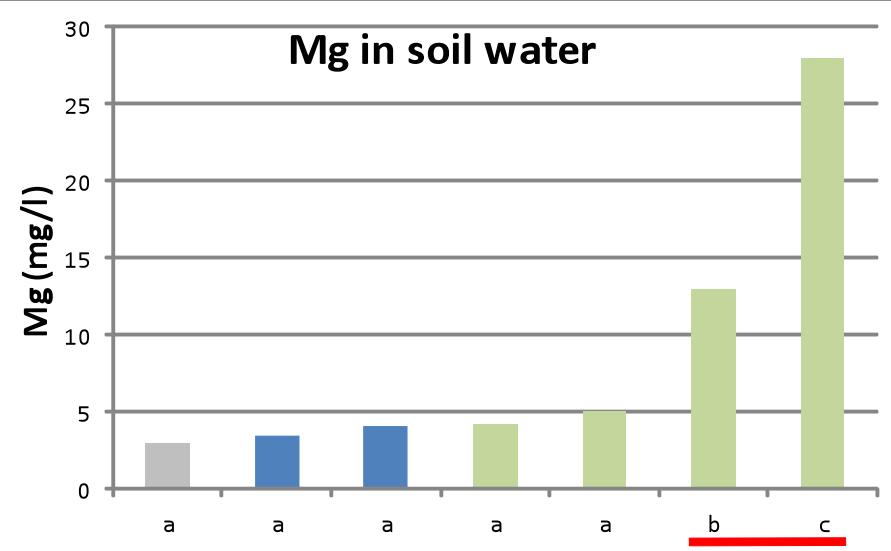
Plant analysis



Soil analysis (at final harvest)



Water analysis (at final harvest)



Estimates of fraction weathered – Method 1

Magnesium balance

- increment Mg offtake in crop biomass
- increment in available (ionic) soil Mg
- relative to control
- express as fraction of applied Mg

Roughly doubling Mg and CO₂ per fivefold dose increment

	Mg applied	Mg offtake	Mg available	Mg increment	Fraction weathered
	g/pot	g/pot	g/pot	g/pot	
Control	0.000	0.21	0.36	0.000	
Olivine 1	1.88	0.24	0.61	0.28	0.148
Olivine 2	9.40	0.26	0.85	0.53	0.056
Olivine 3	47.0	0.26	1.30	0.98	0.021
Olivine 4	235.0	0.36	2.87	2.65	0.011



Estimates of fraction weathered – Method 2

'Similarity of fate' Indicator values for olivine relative to kieserite

- kieserite highly soluble: presume 100% dissolved
- find closest matching pair: olivine-x with kieserite-y
- the corresponding amount as in kieserite was dissolved from olivine

indicator	control	Olivine-1	Kieserite-1	Kieserite-2	Mg-kieserite / Mg-olivijn	Fraction weathered
Mg dose (g/pot)	0	1.88	0.24	0.49		
[Mg] in grass (g/kg)	2.13	2.41	2.41	2.60	0.24/1.88	0.13
Mg offtake (kg/ha)	43.49	49.19	47.20	50.00	0.49/1.88	0.26
[Ca] in grass (g/kg)	4.38	3.93	3.90	3.49	0.24/1.88	0.13
Ca offtake (kg/ha)	70.62	62.43	59.88	52.42	0.24/1.88	0.13
Mg avail soil (mg/kg)	36.3	61.3	42.0	47.4	> 0.49/1.88	>0.26



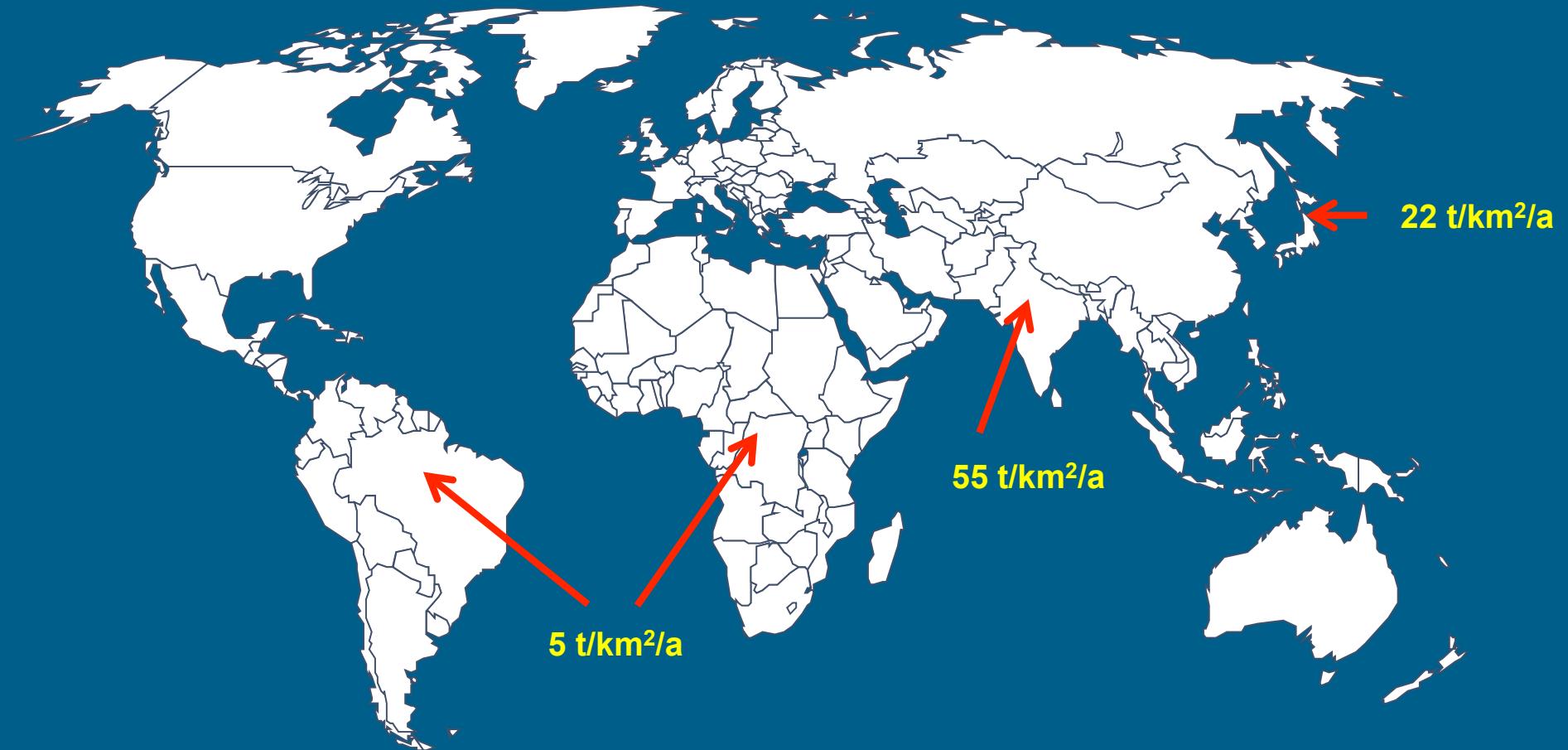
Conclusions

- Olivine caused significant increments:
 - in grass: of Mg, Ca, Ni, Si
 - in soil : of available Mg, Ni, Si; and pH
 - in water: of Mg, Ni, Si, pH
- 13 % to 26% of olivine applied dissolved in 8 months
- Fraction dissolved reduced substantially with higher dosage
- Nickel issue to be addressed



Natural CO₂ fixation by silicate weathering

World average 7 t/km²/a



Our lowest dose 29 t/km²/a



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Upscaling to world agricultural land area

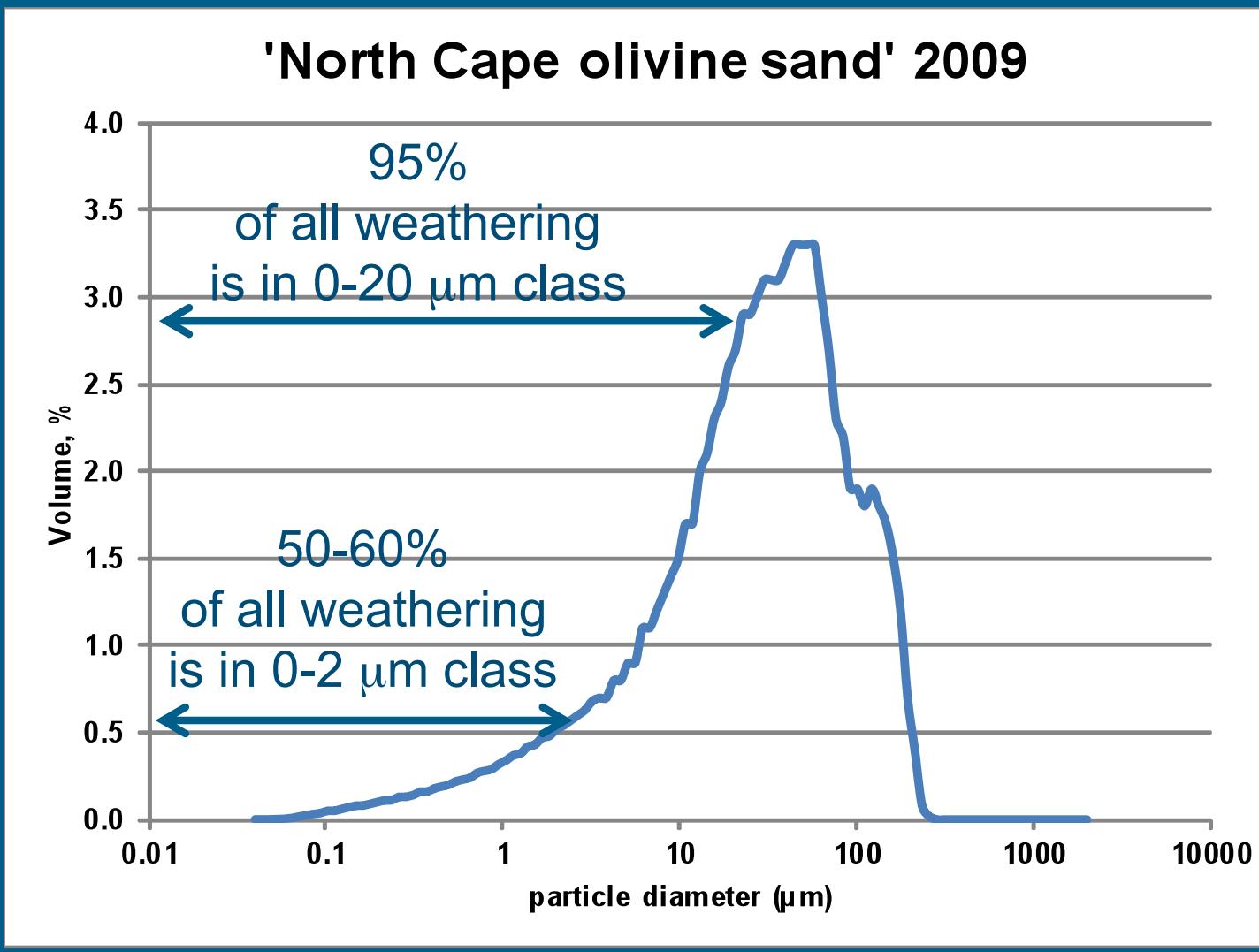
(all types, including degraded, unproductive ...)

- All world agricultural land approx. $5 * 10^9$ ha
- Gross fixation 1.2 kg CO₂ per kg olivine
- 1.5 to 13.9 Gt (=Pg) annually (resp. OLIV1 to OLIV4)
- Is **4.7 %** to **43.6 %** of global annual fossil fuel CO₂

first-year gross capture one-time application



Some issues for discussion



Some issues for discussion

- *Methodology / extrapolation*
 - Skin thickness - porosity (BET surface 10* sphere model)
 - Gross versus net CO₂ fixation

- *Possible impacts ...*
 - Heavy metals
 - Agronomic impacts (nutrients, pH, soil biodiv., org. matter)
 - Catchments: pH shift / biodiversity / ecosystem stability



Thank you for your attention

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	Mg increment	Gross CO ₂ Fixed		
	g/pot	tons km ⁻²	Pg / year	% of annual global fuel CO ₂
Olivine 1	0.28	29	1.5	4.7 %
Olivine 2	0.53	55	2.8	8.9 %
Olivine 3	0.98	100	5.2	16.2 %
Olivine 4	2.65	269	13.9	43.6 %

