K-minerals

Huig Bergsma, Joost Vogels, Roland Bobbink, Maaike Weijters
and Chris Rövekamp

the backbone of acid neutralization in Dutch nature reserves

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The Anthropogenic Mass Extinction

- Already or nearly dissapeared from the Netherlands: Hoopoe, Golden Plover, Ortolan, Tawny Pipit, Red backed shrike, Black grouse, Wryneck, Wheatear
- And these are only birds
- Trees are not doing much better (Oak)….. Or insects and reptiles.

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Silicate minerals are the most important source of nutrients in nature reserves

- Soil minerals release nutrients through weathering
- Nutrients are stored in the cation exchange complex
- High acid input speeds up weathering and replaces nutrients by Al^{3+} and H^{+}
- Dramatic changes in soil chemistry cause loss of biodiversity

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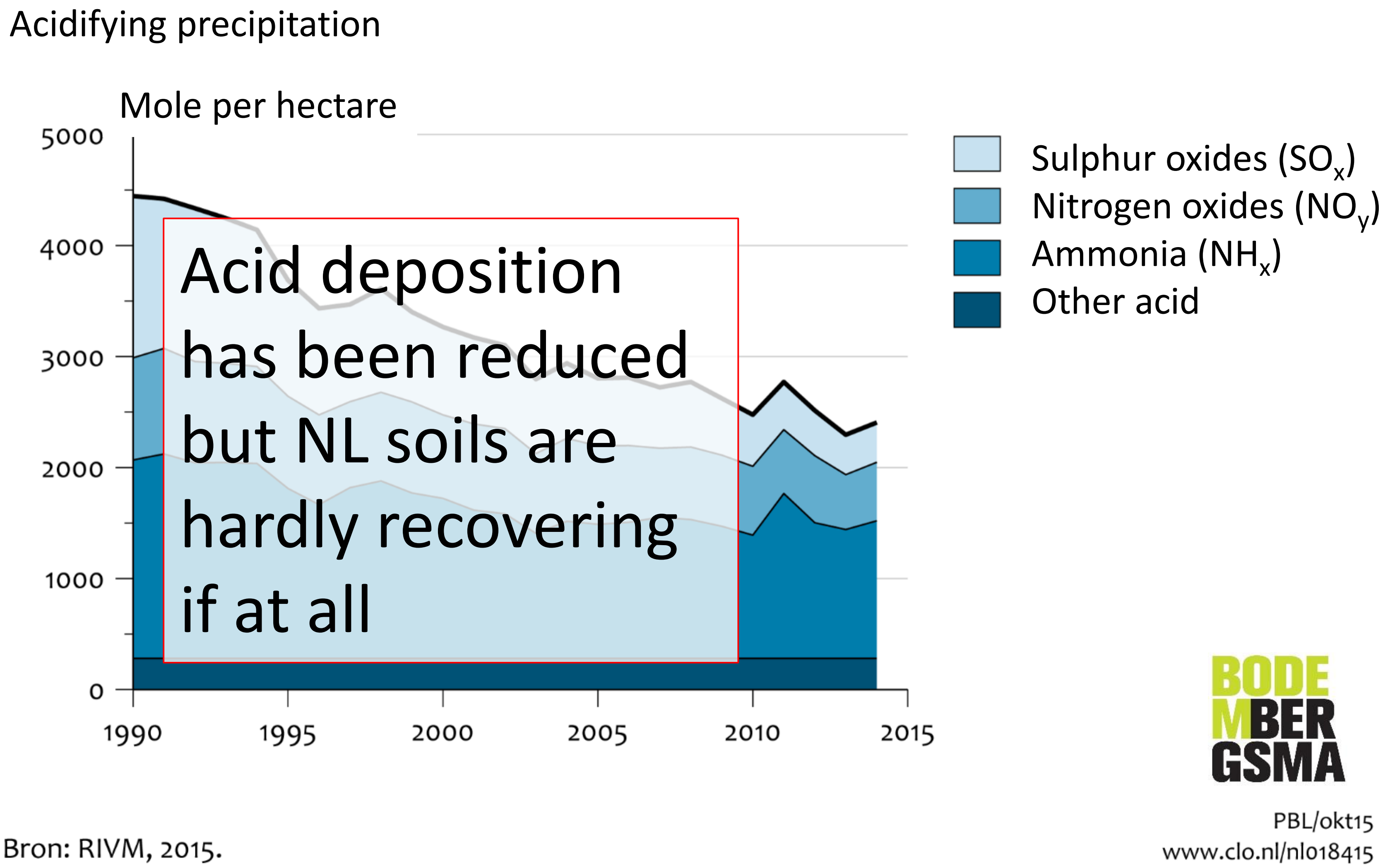
Aad Goudappel

Acid rain: a problem of the past?

- Cumulative acid deposition since last ice age (11.650 yr): **500-750 kmol/ha**
- Acid deposition since 1900: **300-450 kmol/ha**



What did acid rain do to Dutch sandy soil?

- The effect on soil pH and base saturation has been widely studied.
- The effect on soil mineralogy has never been studied. Why?
  - Mineral weathering in a defined period of time can only be studied in chronosequences
  - Chronosequences are usually studied in areas where parent material is rich in fast weathering minerals (calcite, biotite, hornblende)
  - As K-feldspar, muscovite and albite were the last minerals to disappear they were considered to weather very slow.
  - As they are the most important minerals in Dutch sandy soils, the mineral soil was considered not to contribute significantly to neutralization of acid deposition!!

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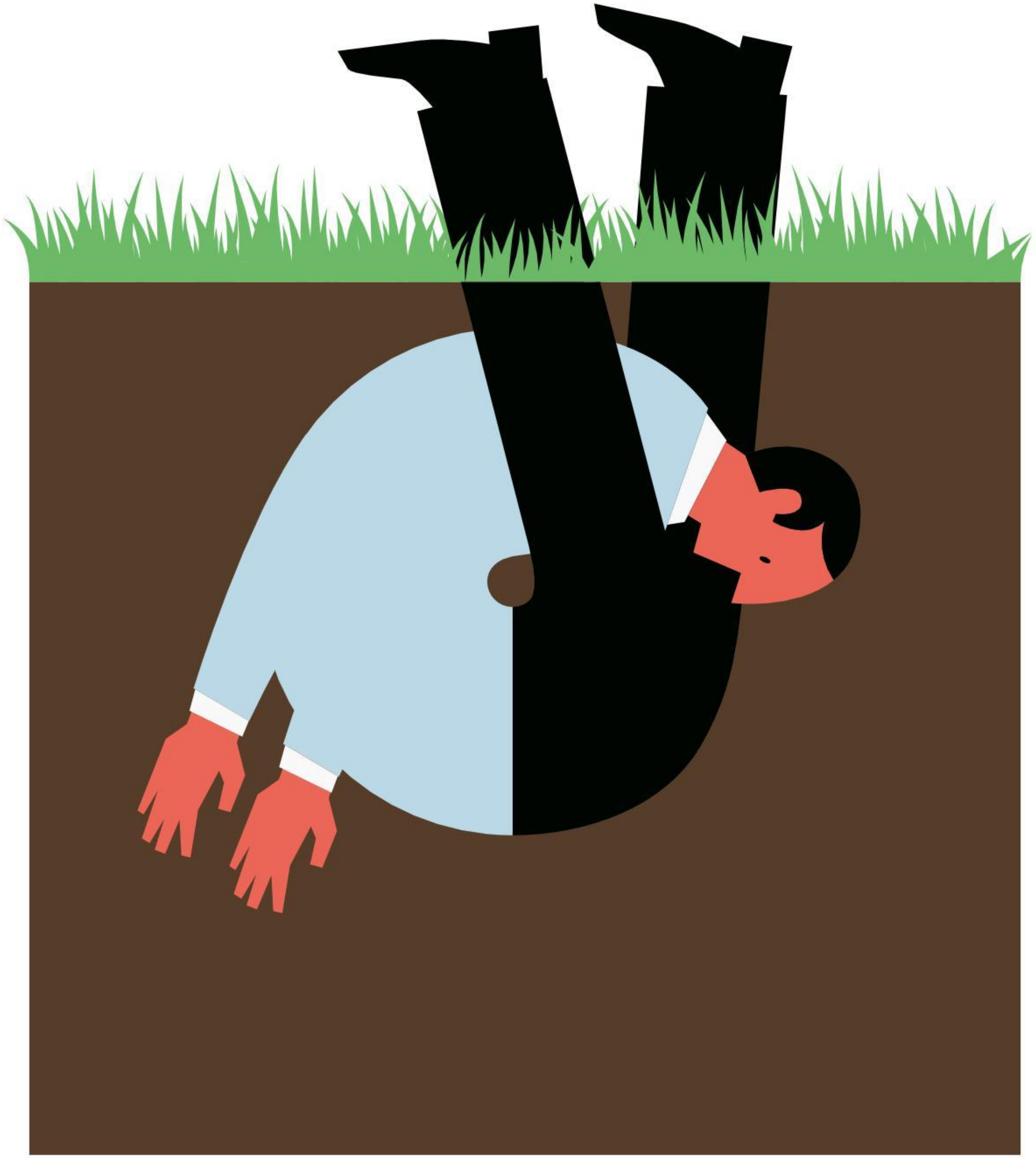
Three questions:

- How fast?
- Which minerals?
- Did we know?



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How fast?

- Three locations (micro chronosequences)
- Two methods

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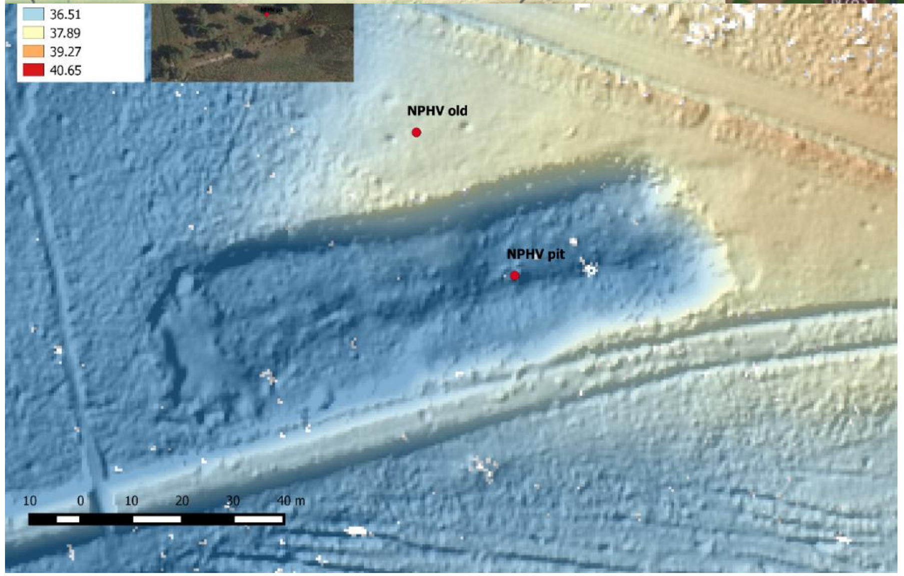
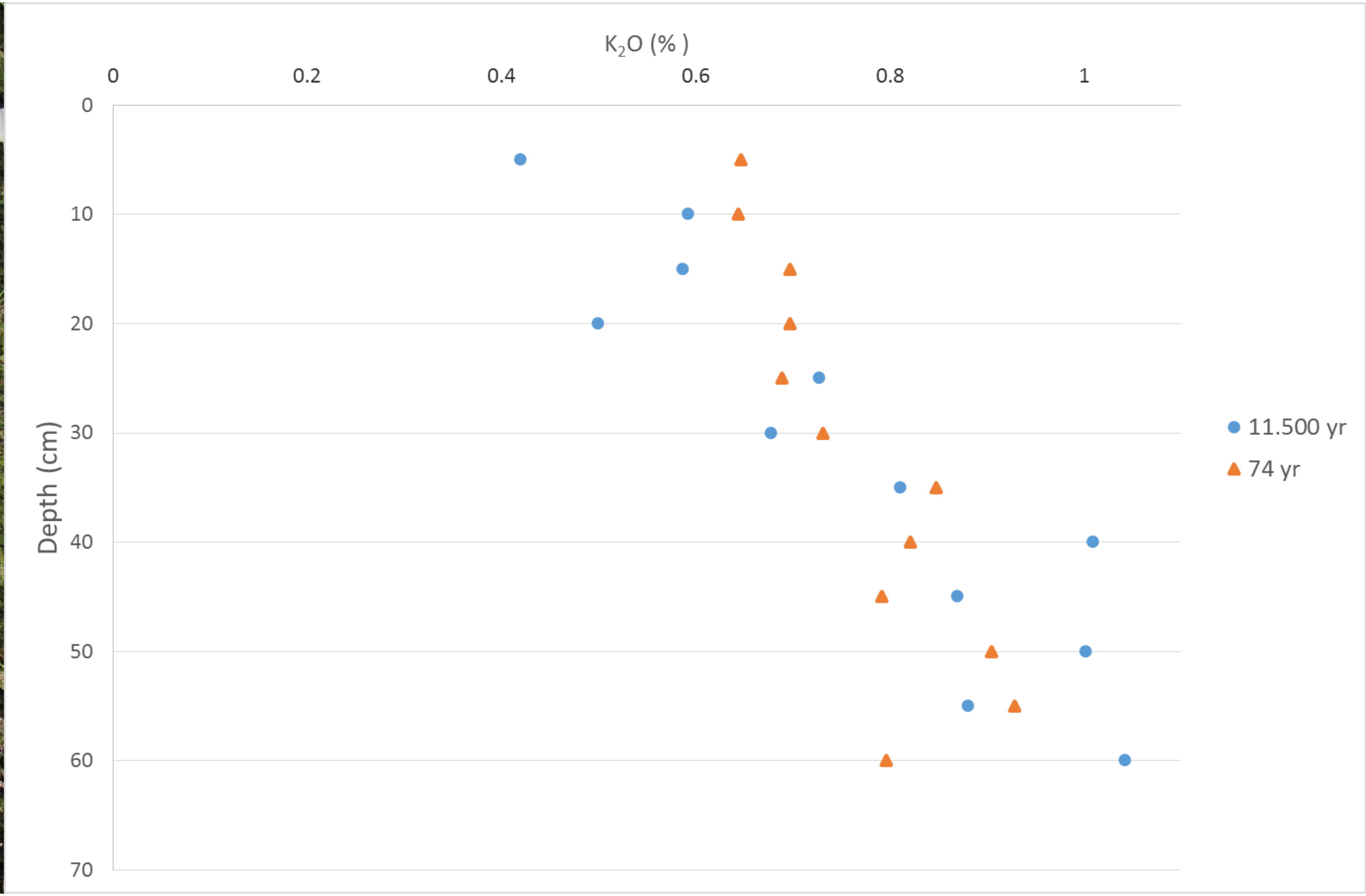
Two point chronosequence: No 1 Hoge Veluwe

- Pit dug for extraction of sand for construction railroad in 1942
- Bottom of the pit is fresh surface
- Undisturbed weathering profile (Glacial Outwash Plain)
- Homogenous mineralogy and grainsize
- Standard weathering loss calculation using Qtz possible (Starr & Lindroos 2005)

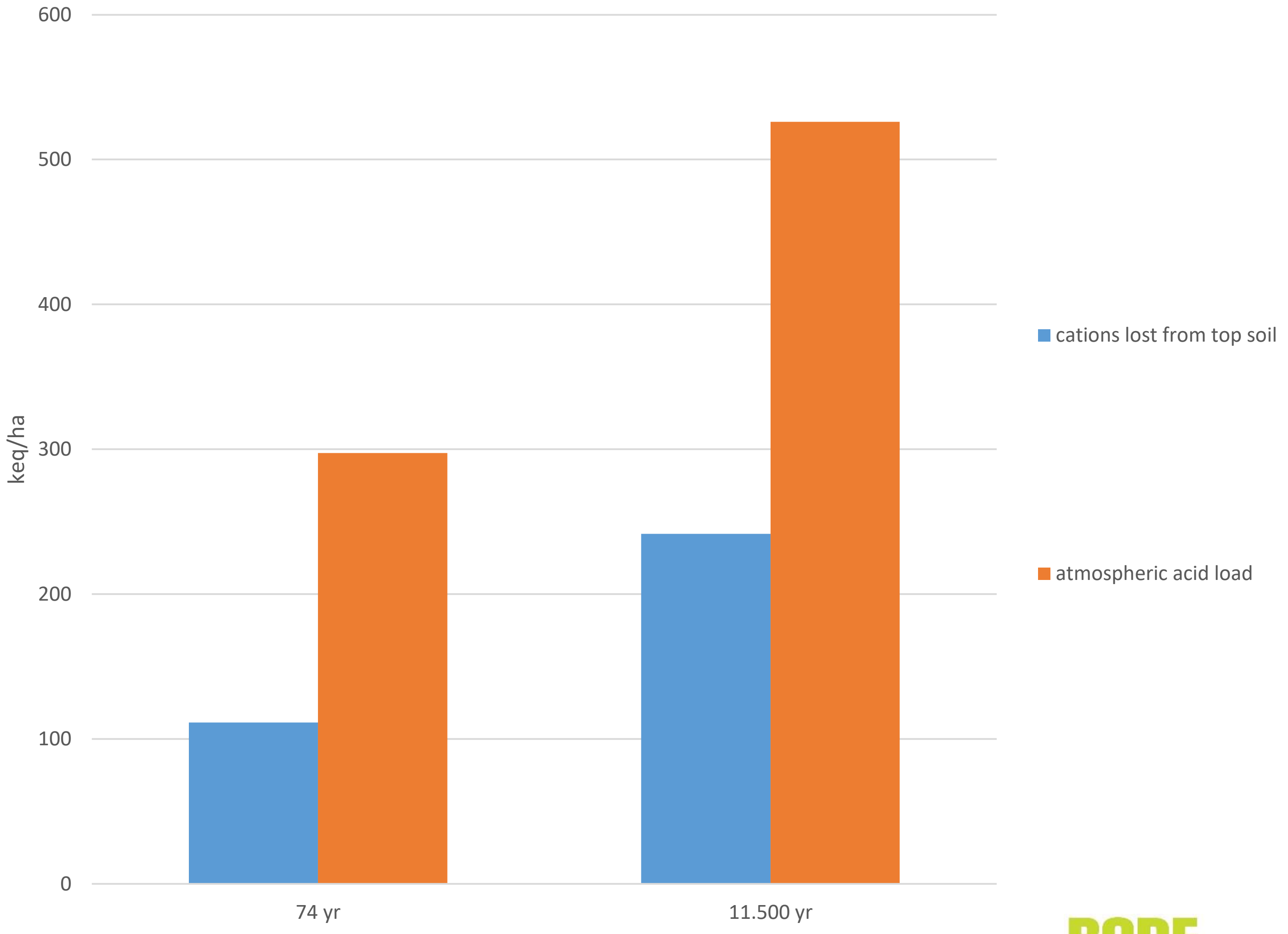


Potassium weathering profile



Depletion Method (Starr and Lindroos 2006)

- ±20 tons of minerals lost in 74 years.
- ±50 ton tons of minerals lost in 11.500 years
- 40% lost due to sulphate and nitrogen deposition



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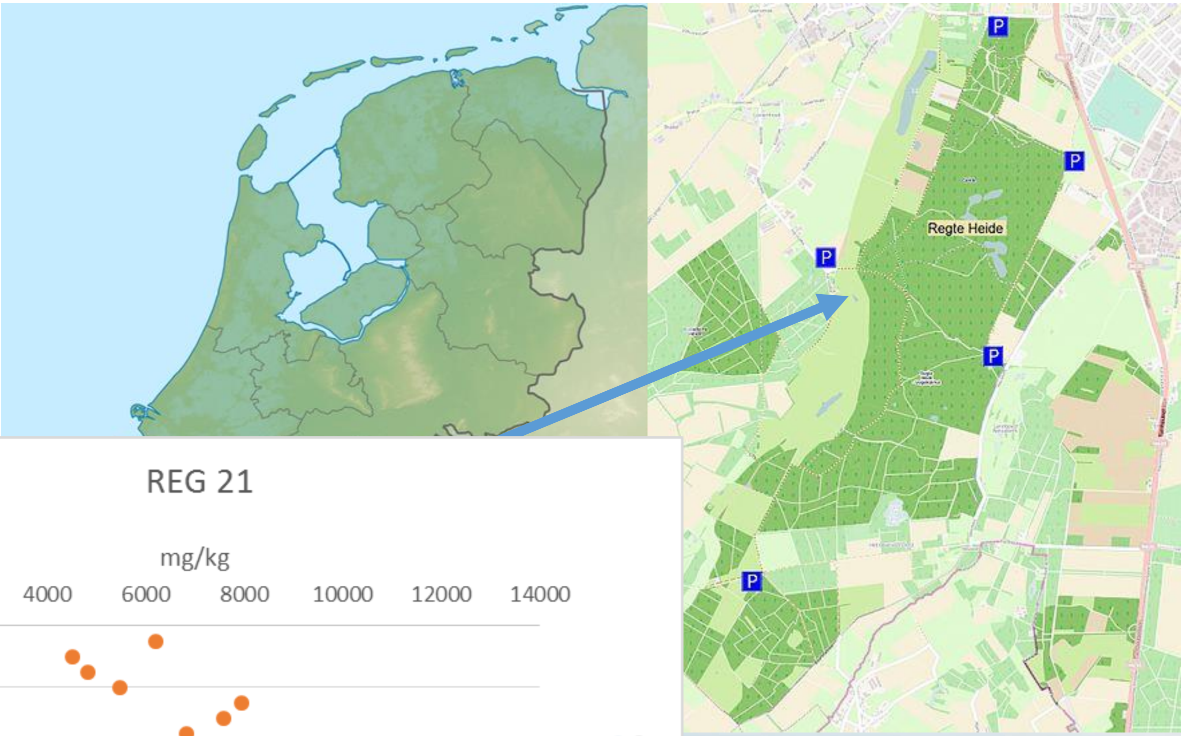
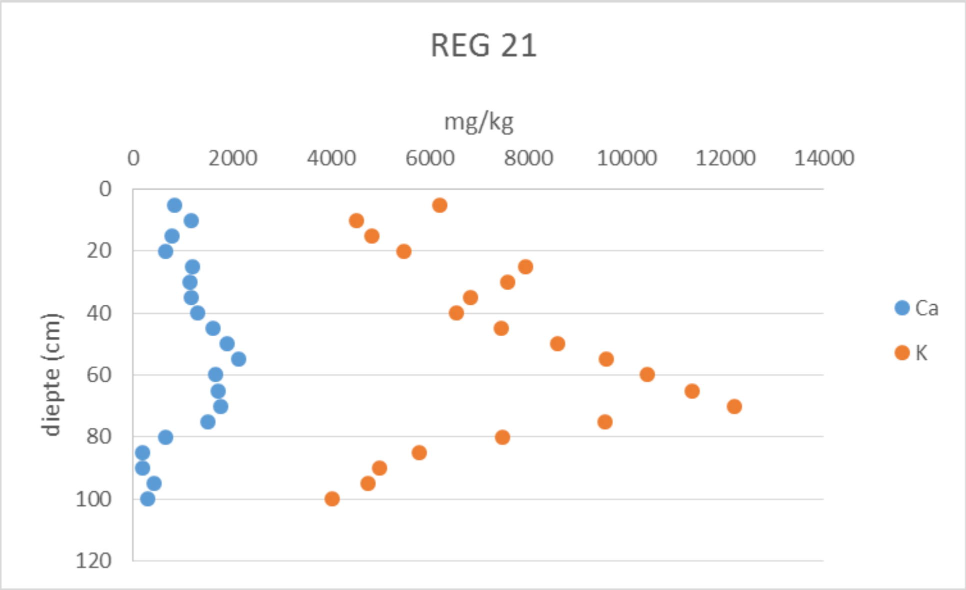
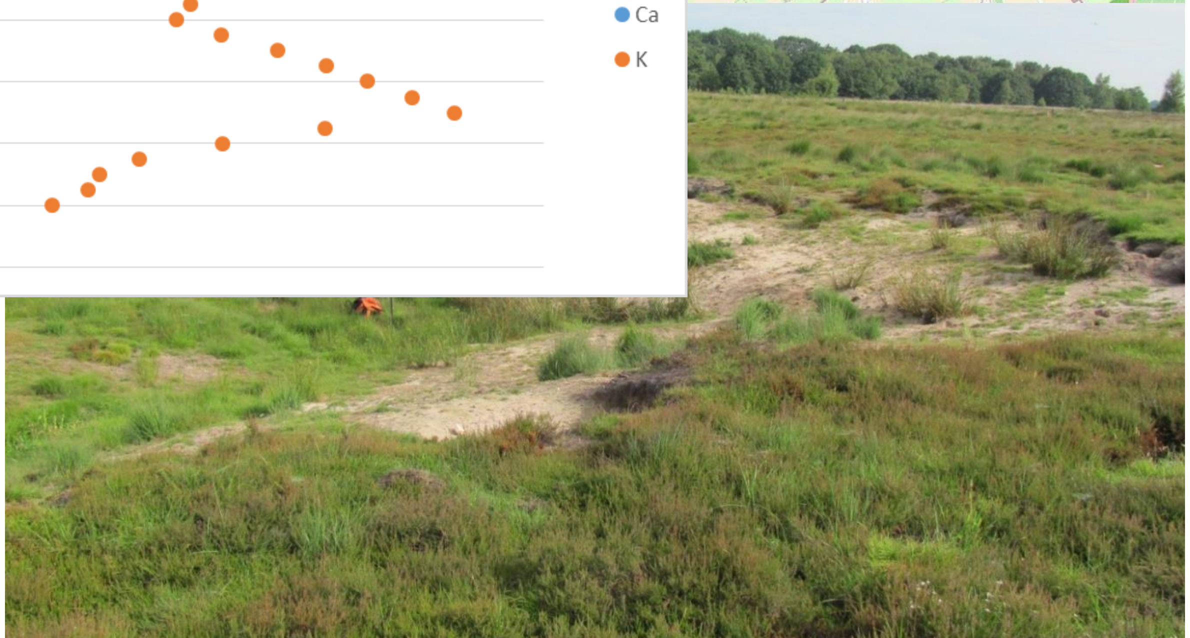
Two point Chronosequence: No 2 Regte Heide

- Sand extraction site 1910-1970
- Fluviatile sediments alternating from silt to fine gravel
- Standard depletion calculation using Qtz or Ti not possible
- New method needed

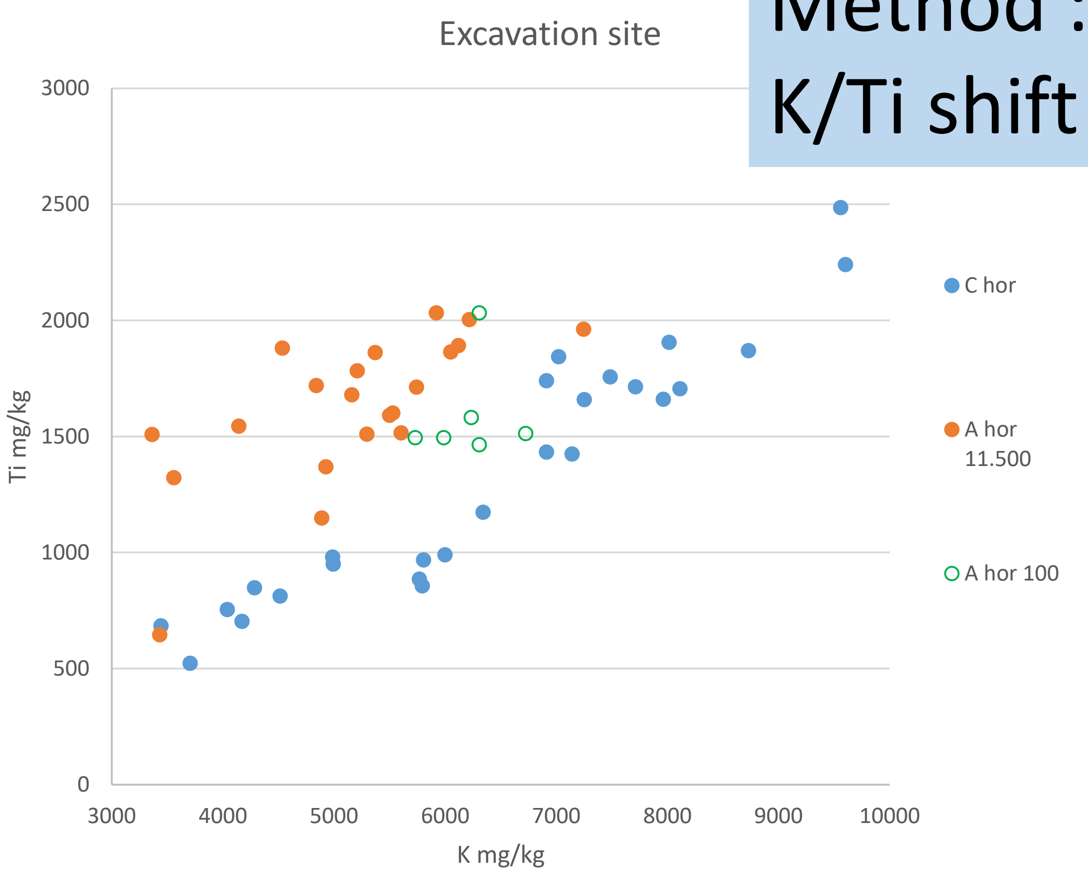


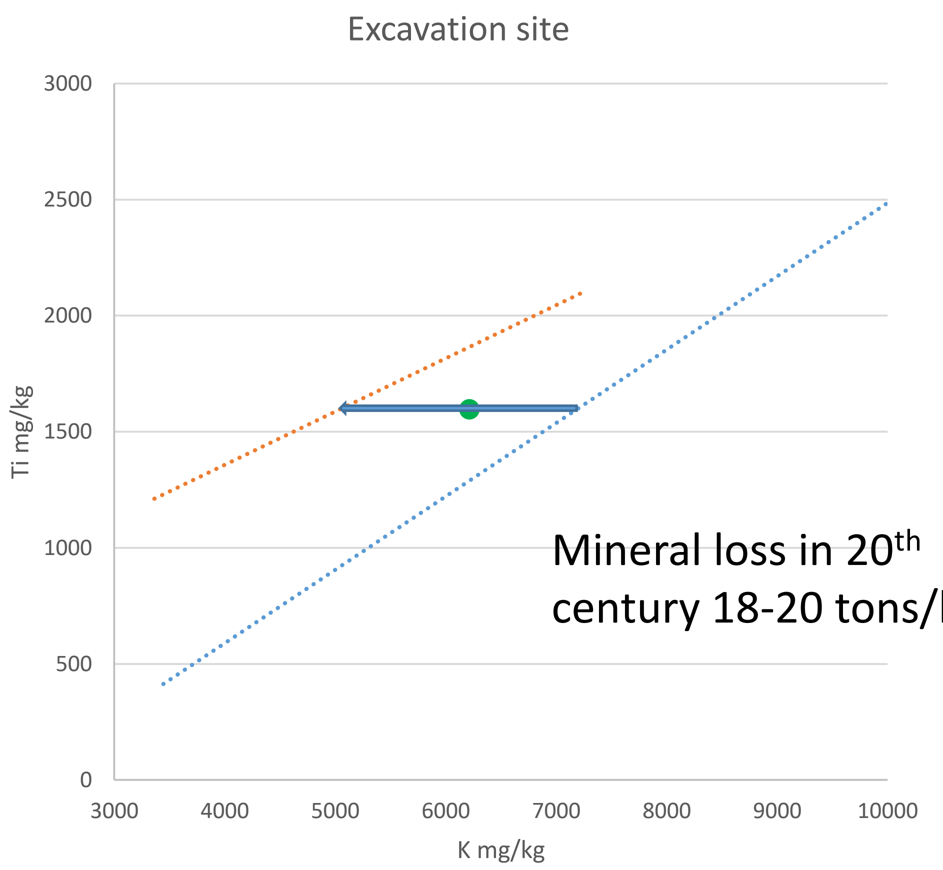




Two point Chronosequence: Regte Heide

Method : K/Ti shift

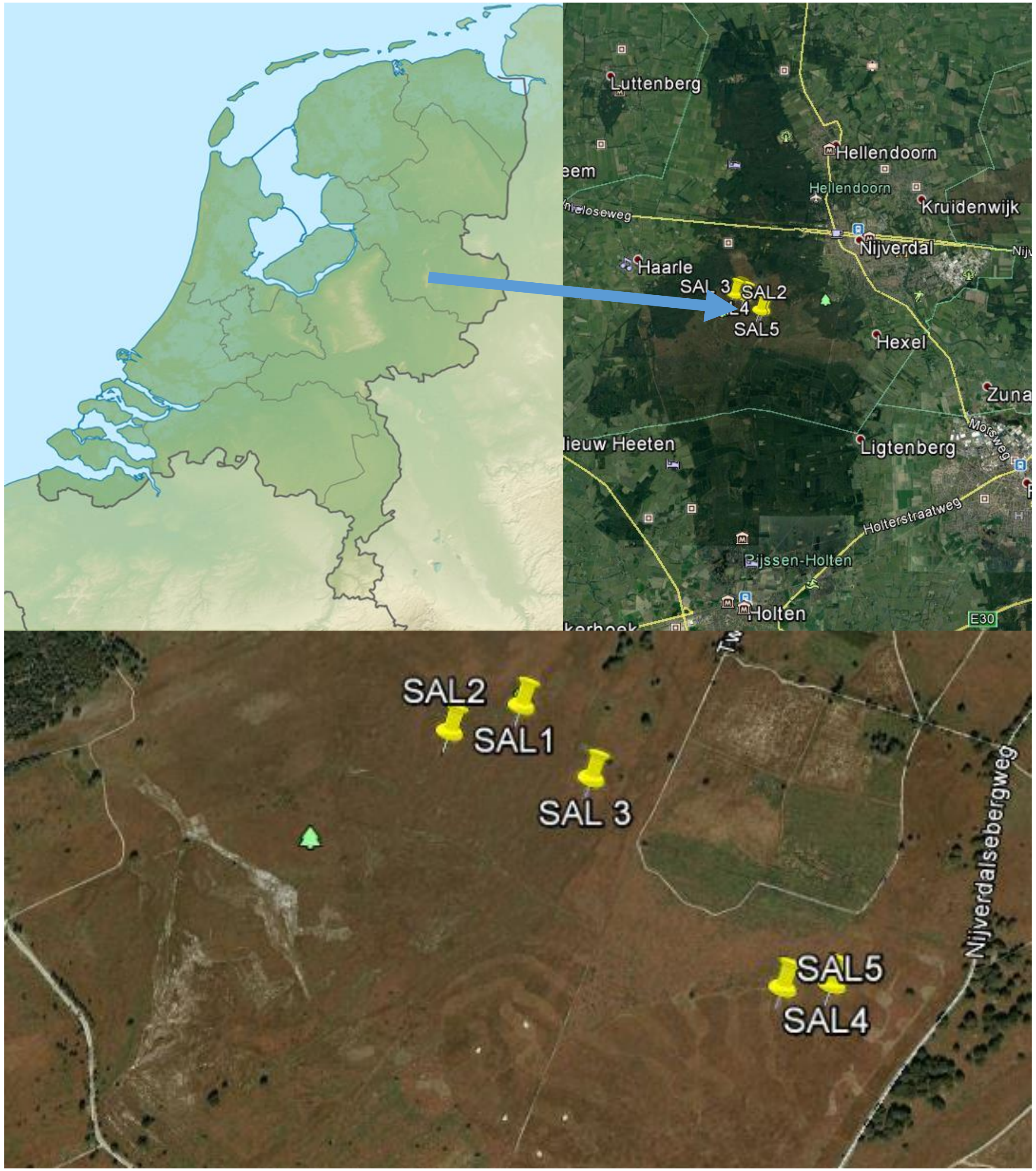




Mineral loss in 20th century 18-20 tons/ha

Two point Chronosequence: No 3 Holterberg

- Push moraine sediment (>115.000 yr)
- Wind blown sediment (800-1.200 yr)



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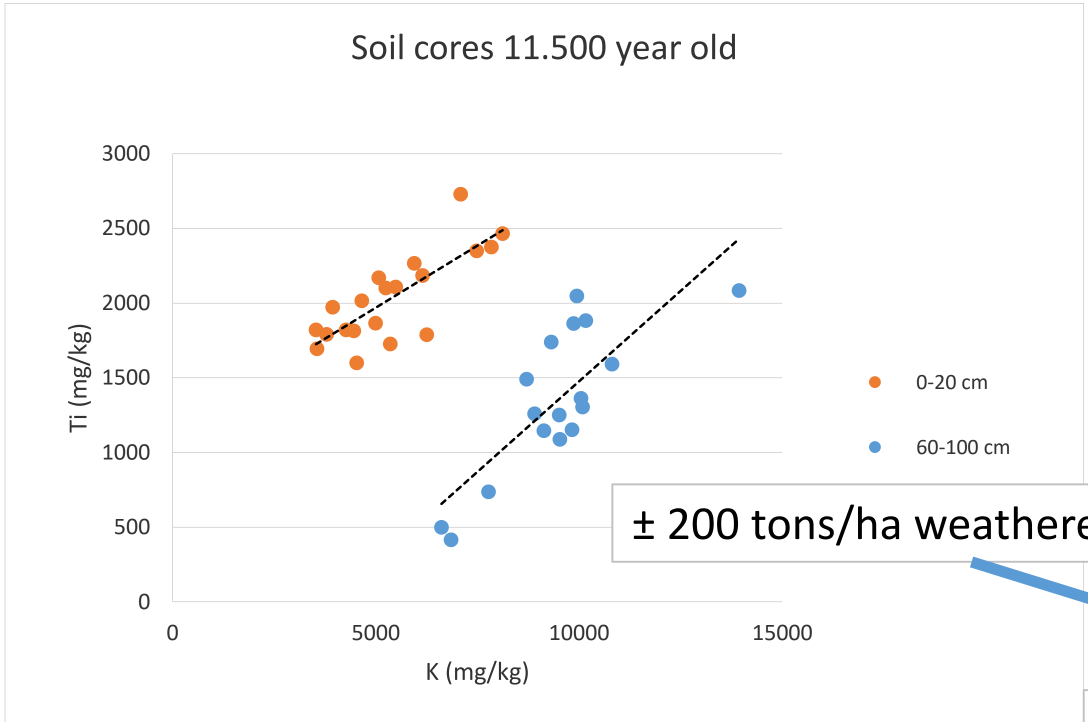
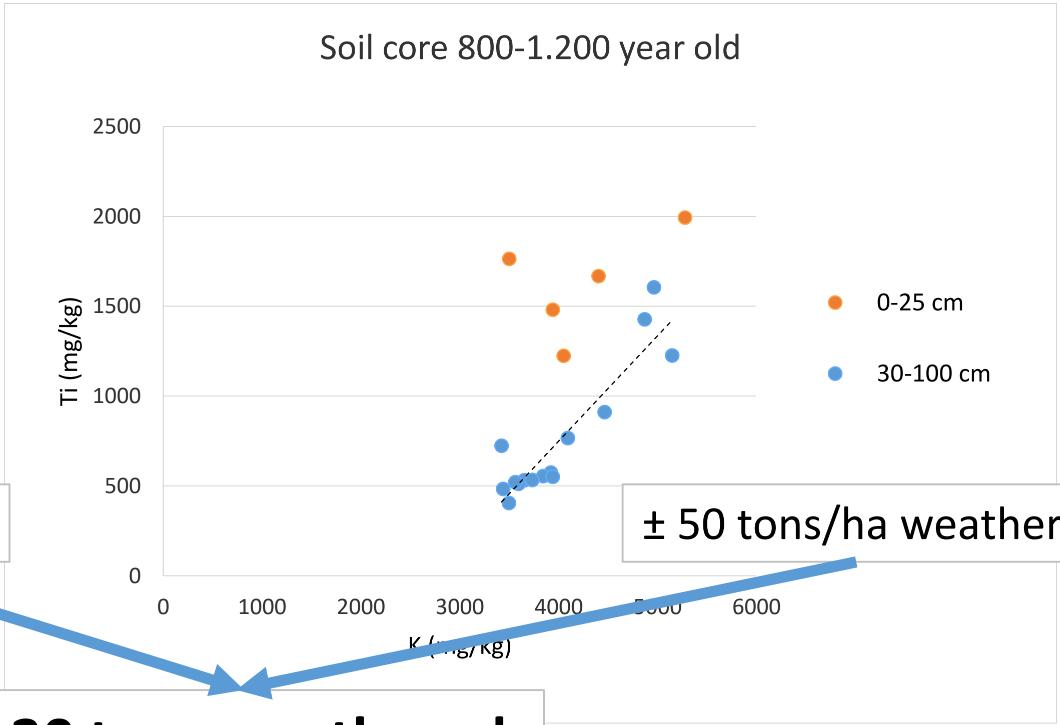
Two point Chronosequence: Holterberg



± 200 tons/ha weathered



± 50 tons/ha weathered

± 30 tons weathered due to atmospheric acidic precipitation

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Which Minerals?

- Which minerals do contribute most to acid neutralisation?
- Are long term weathering rates generally valid?

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Hoge Veluwe: Young Soil- Old Soil

		Topsoil 74 year			Topsoil 11.500 year		
	Cations	A/E	C	decrease	A/E	C	decrease
Depth (cm)		0-25	50-75		0-25	50-75	
Quartz (%)		89.2	85.1		94.1	85.1	
K-feldspar (%)		4.8	6.6	31%	2.6	6.6	64%
Plagioclase (%)		1.78	2.78	39%	0.83	2.78	73%
Muscovite (%)		0.38	0.74	51%	0.24	0.74	71%
Biotite (%)		0.12	0.28	57%	0.05	0.28	82%
Garnet (%)		0.44	0.65	36%	0.08	0.65	89%
Epidote (%)		0.37	0.49	28%	0.09	0.49	84%
Chlorite (%)		0.15	0.31	55%	0.01	0.31	98%
Minerals lost (kg/ha/yr)		289			4.3		

High input of acid and cations seems to relatively increase K-mineral weathering rate.

- 35-50% of acid is neutralized by K-feldspar and muscovite.
- 25-40% of acid is neutralized by albite

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Regte Heide: Cropland-Heathland

- Cropland since 1940
- Wind blown deposits
- Distance between sampling points 400 m

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Regte Heide: Cropland-Heathland

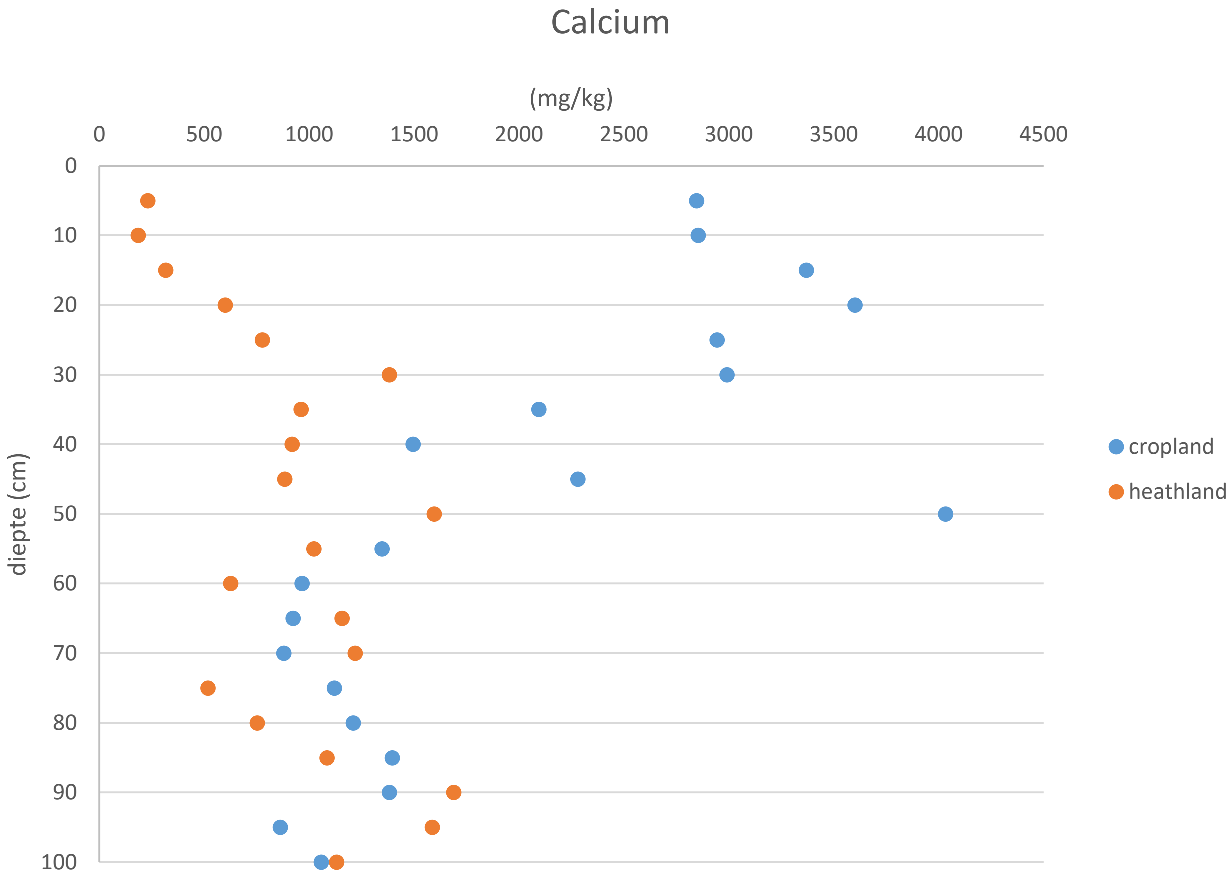
	Cropland			Heathland		
	A-horizon	C-horizon	Decrease	A-horizon	C-horizon	Decrease
Quartz %	93.17	90.73		93.58	90.73	
K-feldspar %	3.51	4.88	30%	3.85	4.88	23%
Plagioclase %	1.58	1.90	19%	1.16	1.90	41%
Biotite %	0.02	0.02	31%	0.01	0.02	67%
Muscovite %	0.04	0.05	29%	0.02	0.05	60%
Illite %	0.09	0.12	28%	0.05	0.12	60%
Chlorite %	0.01	0.06	88%	0.01	0.06	77%
Clay %	0.40	1.13	65%	0.23	1.13	80%
Tourmaline %	0.01	0.07	87%	0.01	0.07	80%
Amphibole %	0.06	0.08	24%	0.05	0.08	33%
Epidote %	0.07	0.08	8%	0.04	0.08	45%
Garnet %	0.11	0.12	4%	0.03	0.12	72%
Total percentage lost %			2.73 %			2.76 %

Weathering of K-feldspar seems increased in cropland

Weathering of Ca-minerals reduced in cropland

Liming does not reduce total weathering

Regte Heide: Cropland-Heathland



- Apparently liming does not protect soil silicates from weathering
- It does enhance weathering of potassium silicates

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Did we know?

- Comparison to data used for Critical Deposition Load modelling
- What do weathering scientists say?

Critical Deposition Load Modelling
(Hoge Veluwe)

Mineral	Classification according to Sverdrup (1990)	Weathering rate used in models (eq/ha/yr)	Weathering rate observed (eq/ha/yr)
K-feldspar, Muscovite	Very slow	2.5	620
Albite	Slow	5	540
Epidote		7.5	0
Biotite		7.5	2
Chlorite		4	210
Hornblende	Intermediate	4	0
Garnet	Fast	75	200
Total		105	1500

Long term and laboratory weathering rates cannot be applied on the current situation

Manual on methodologies and criteria for Modelling and Mapping Critical Loads & Levels and Air Pollution Effects, Risks and Trends (http://www.umweltbundesamt.de)

What do weathering scientists say?

Roughly two tribes:

- Tribe 1: those who say rates are predominantly mineralogy related (Taylor & Blum, Lichter, White, Starr & Lindroos, Houle etc…)
- Tribe 2: those who say rates are predominantly acid driven (Hyman, Pierson-Wickmann, Yang)

NL results are in line with the second tribe

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Concluding remarks:

- Acid deposition enhanced weathering severely underestimated
- K-minerals carry bigger part of the burden
- High input of NH_4^+ , Ca^{2+} and H^+ changes weathering rates of various minerals
- Soil mineral weathering rates must be revaluated and consequences understood
- Poses liming with carbonates a risk?
- Further research on K/Ti shift weathering index.
- High K rock fertilizers needed

Thank you!

info@bodembergsma.nl