Structure liming of agricultural clay soils

What is the benefit for the farmer and the environment?

Foto: Jens Blomquist

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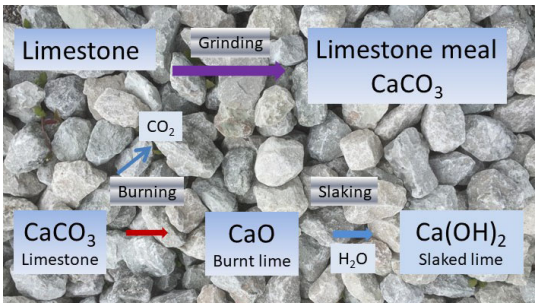
The effect of liming on soil

- **Chemical- pH, base saturation**
- **Biological- affects the microflora and fauna**
- **Physical – soil structure changes**





There is a difference between lime and lime!



There is a difference between lime and lime!

Soil structure lime

	possible pH	possible Ca-ion conc.
Burnt lime, CaO	>12*	1000 mg/l water
Slaked lime, $Ca(OH)_2$	>12*	1000 mg/l water
Limestone meal, $CaCO_3$	8	6 mg/l water

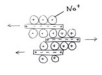
*short term

Reactions in the soil are faster and more efficient at higher pH and higher Ca concentration

Calcium products physical effects

Base exchange (monovalent ions are exchanged by divalent Ca ions)

clay-$2H^+$ + Ca^{2+} → clay- Ca^{2+} + 2 H^+




- Increased aggregation
- less "sticky/soapy"
- Less tendency to shrink and swell
- **the reactions benefit from high Ca-ion concentration**
- Very fast reactions (minutes/hours)

Calcium products physical effects

Pozzolanic reactions (cementation)

$Ca(OH)_2$ + Si och Al → CASH, CSH, CAH

(calcium aluminate silicate hydroxides)

Lime carbonation

$Ca(OH)_2 + CO_2$ → $CaCO_3$

calcium carbonate bridges between grains

- Stabilizes the soil structure
- dependent on the availability of silicates and aluminates (= clay)
- **Need high pH and Ca $(OH)_2$**
- Temperature dependent and slow reactions (years)

More calcium products

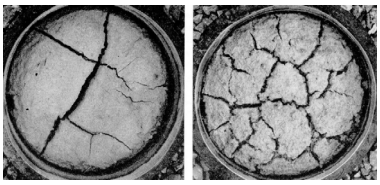
Gypsum	$CaSO_4 \cdot 2H_2O$	Doesn't raise pH in the soil High solubility, flocculating effect
Dolomite lime	$CaMg(CO_3)_2$	Mg-ion has some flocculating effect, similar to limestone meal, low solubility
Lime kiln dust	$CaCO_3$ + $CaO/Ca(OH)_2$	Rest product from the lime industry when you burn the limestone

Similar to the lime products now used in Sweden for structural liming of agricultural clay soils (Mixed lime = ≈15 % slaked lime($Ca(OH)_2$) and the rest is calcium carbonate ($CaCO_3$))

Structure liming – effects

Improved soil structure

Less shrinking/swelling and less big cracks, water infiltrates over a greater area = less surface runoff



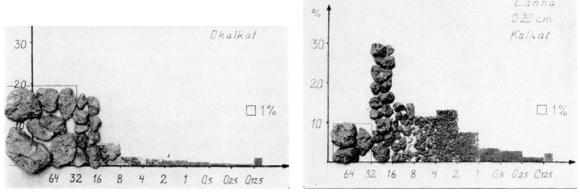
No lime Structural liming

Källa: Wiklander, L. 1963. Kalkens betydelse för markens struktur.
Sidorna 249- 259 i Minnesskrift utgiven av KSLA: Svenskt Jordbruk och skogsbruk 1913-1962.

Structure liming – effects

Aggregation

Better aggregate size distribution



No lime Structural liming (CaO 12 t/ha) Applied 28 years earlier

Källa: Wiklander, L. 1963. Kalkens betydelse för markens struktur.
Sidorna 249- 259 i Minnesskrift utgiven av KSLA: Svenskt Jordbruk och skogsbruk 1913-1962.

Structure liming – effects

Higher yields? Yes, but not always

Four field trials with 1, 2 och 6 t CaO/ha **slaked lime and mixed lime**. Harvested 2011–2014.

8501A, (C-län) Soil type: mmhML 8502 (C-län) Soil type: mmhSL	**No** statistically significant **treatment effects on yield,** not in an individiual year or as average for several years
8501B (C-län) Soil type: mmhML	Statistically significant **negative** effects in some treatments 2 out of 4 years (11 % at the most)
8503 (C-län) Soil type: nmhML	Statistically significant **yield increase** 2 out of 4 years (3-5 %)

Structure liming – effects on nutrient leaching / Swedish trials

	Bornsjön		Wiad	
	2007/2013		2011/2013	
	Burnt lime	Control	Mixed lime	Control
TP (kg ha−1 year−1)	0.59*	0.97	0.13*	0.30
PP (kg ha−1 year−1)	0.46*	0.82	0.07	0.14
DRP (kg ha−1 year−1)	0.13	0.15	0.08*	0.15
TN (kg ha−1 year−1)	30	29	14	12

In Sweden, P-leaching on clay soils is dominated by particulate-P

Clay content:
Bornsjön topsoil 59 %, subsoil 60 %.
Wiad topsoil 26 %, subsoil 37-53 %

Application rates (CaO):
Bornsjön ca 5 t CaO/ha (as 5 tonnes burnt lime)
Wiad ca 5 t CaO/ha (as 11 tonnes mixed lime)

Reference:
Ulén, B & Etana, A. 2014.
Phosphorus leaching from clay soils can be counteracted by structure liming

Structure liming – effects

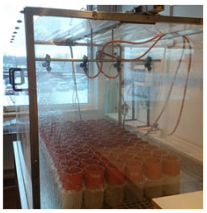
In most field experiments we use aggregate stability as an indicator of the risk of P-losses.

Stabile aggregates = decreased risk of leaching of soil particles and particulate-P

Aggregate stability measured as turbidity in leaching water after rain simulation of aggregates sizes 2-5 mm from seed-bed

Aggregates 2-5 mm

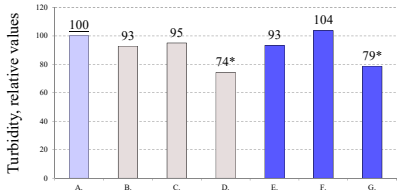
Rain simulation



Measuring turbidity in leaching water

Structure liming – effects

Aggregate stability
Stabile aggregates = less leaching of soil particles and phosphorus



	Treatment
A.	0 ton No lime
B.	1 t CaO/ha as $Ca(OH)_2$
C.	2 t CaO/ha as $Ca(OH)_2$
D.	6 t CaO/ha as $Ca(OH)_2$
E.	1 t CaO/ha as Mixed lime
F.	2 t CaO/ha as Mixed lime
G.	6 t CaO/ha as Mixed lime

Turbidity in leaching water after rain simulation of aggregates 2-5 mm from seed bed
Turbiditet, aggregat 2–5 mm från såbädd i försök 8501A, 8501B och 8502 våren 2013.
Turbiditeten i led D och G var signifikant lägre (*) än i led A.

Berglund, K., Blomquist, J., Etana, A. & Simonsson, M. 2014. Markstrukturförbättring och begränsning av fosforförluster från åkermark med hjälp av inblandning av olika kalciumprodukter i matjorden. Slutrapport avseende SLF-projekt H1070272

Soil structure liming project (LOVA14) with mixed lime
Southern Sweden(Skåne)

LOVA = local water conservation projects, subsidies for e.g soil structural liming

16 field trials on soils with varying clay contents (10-47 %)

Experimental design (3 replicates)
A: No treatment– 0 ton/ha
B: 4 t/ha Mixed lime
C: 8 t/ha Mixed lime = normal rate
D: 16 t/ha Mixed lime

Mixed lime
Nordkalk Aktiv Struktur (NKAS) = ≈15 % slaked lime($Ca(OH)_2$) and the rest is calcium carbonate ($CaCO_3$)

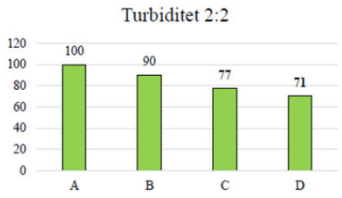
References: GEMENSAM SLUTRAPPORT FÖR PROJEKTEN
- Strukturkalkning för minskat näringsläckage i Skåne (Lst nr 501-4274-2014)
- Fosforreducering till Östersjön (SJV nr 4.1.18–11580/14)

Jens Blomquist, Agraria Ord & Jord

Aggregate stability one year after spreading

16 LOVA14 field trials

(Turbidity in leaching water after rain simulation of aggregates 2-5 mm)



A= no lime, B = 4 t/ha mixed lime, C = 8 t/ha mixed lime, D =16 t/ha mixed lime

Källa: GEMENSAM SLUTRAPPORT FÖR PROJEKTEN
- Strukturkalkning för minskat näringsläckage i Skåne (Lst nr 501-4274-2014)
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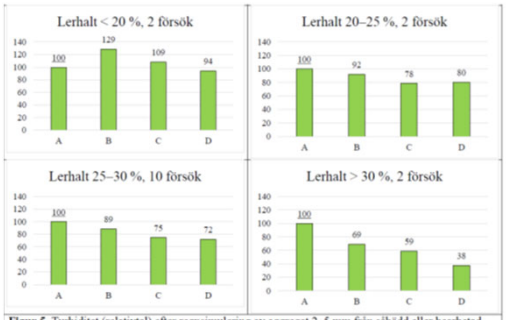
Aggregate stability - effect of clay content
No significant differences in turbidity 2:2 between treatments A–D



Figur 5. Turbiditet (relativtal) efter regnsimulering av aggregat 2–5 mm från såbädd eller bearbetad jord efter indelning i olika lerhaltsgrupper. Led A=100

Källa: GEMENSAM SLUTRAPPORT FÖR PROJEKTEN
- Strukturkalkning för minskat näringsläckage i Skåne (Lst nr 501-4274-2014)
- Fosforreducering till Östersjön (SJV nr 4.1.18–11580/14) ,Jens Blomquist, Agraria Ord & Jord

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Soil structure liming, where? On clay soils

2010–2020, approximately 60,000 hectares of clay soil in Sweden were structure-limed with 5-8 t/ha of mixed lime

- The whole field
- Along water courses
- Compacted part of a field
- Backfill of drainage trenches
- Around surface water wells
- Prevention along roads

Foto: Jens Blomquist

Foto: Jens Blomquist

Soil structure liming in practice

Soil tilth

Tåå gård
Soil type: 25-40 % clay
mjälig mellanlera

No lime

Foto: Fredrik Jerlström

5 t/ha mixed lime
Perfect conditions when applying and mixing lime and soil

Foto: Fredrik Jerlström

Soil structure liming in practice

Improved soil structure

Less shrinking/swelling and less big cracks, water infiltrates over a greater area = less surface runoff

No lime, clay soil (25-40 % clay)

Foto: Fredrik Jerlström, Tåå gård, Nyköping

Structural liming (Mixed lime 5 ton/ha)

Foto: Fredrik Jerlström, Tåå gård, Nyköping

Soil structure liming in practice

Turbidity of drainage water

Turbidity(FTU)

Foto: Dennis Wiström

From field with
4-5 t/ha mixed lime
+
lime filter drainage
(6 kg mixed lime/m)

No lime

The nearby stream

Water samples 2011-01-21

Sampled by Dennis Wiström i Östergötland
40 % clay

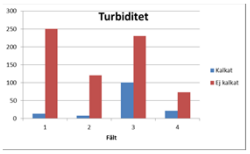
Soil structure liming in practice!!

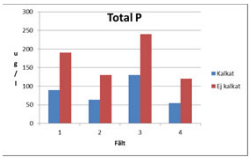
Leaching

St Berga, Östergötland
Heavy clay soil (60 % clay)
2013
7 t/ha mixed lime
Perfect conditions when applying and mixing lime and soil in late summer after a green manure crop

Water samples taken from drainage pipes from limed fields and neighbouring fields with no liming autumn 2013-11-04 after a dry period.

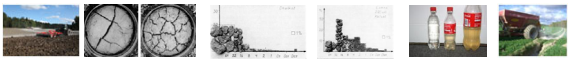
Blue = with lime, **Red** = no lime





Remember this!

- **You can test the effect youself with a bag of slaked lime** before investing a lot of money.
- **It only works on clay soils**!
- **Conditions must be good** (dry soil and warm) when you apply the lime and mix it with the clay soil. Preferably in august after early harvest.
- Better to wait one year than liming late in the autumn or under bad condiditions.



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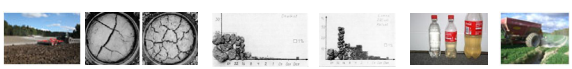
Remember this!

- To get less variable field conditions. Apply more lime where the soil structure is bad. Make your own map of the field and mark bad areas where you want more lime.
- **Mix soil and lime as fast as possible**. Preferably directly after spreading or at least within 24 hours.
- **Important with a good mixing**. Use equipment that does the job well, plowing won't do the job. Mix to the depth you normally cultivate.
- Leave an area untreated (no lime). Use gps to secure the location so you (or the researchers) can use it for comparising in the future (20x20m).



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Soil structure liming - research questions

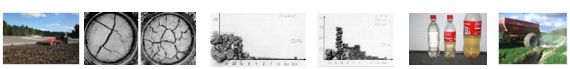
Liming rates on different type of soils

What significance does the clay content have for the effect?
- clay mineral type
- organic matter content
- pH/base saturation level

Mixed lime, is it enough with 15 % slaked lime?

How long will the soil structure effect last?

Alternatives for organic farming?



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