Soil weathering in relation to soil acidification and sustainable forestry in Sweden

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Weathering – the most important natural factor for counteracting acidification, and important for plant nutrition

Chemical weathering leads to release of base cations and counteracts acidity.

Ex: $3\ KAlSi_3O_8 + 2H^+ + 12\ H_2O \rightarrow KAl_3Si_3O_{10}(OH)_2 + 6\ H_4SiO_4 + 2\ K^+$

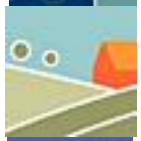
Acidification

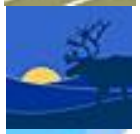
The environmental objectives of Sweden


Reduced climate impact


A protective ozone layer

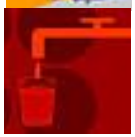

A safe radiation environment


A varied agricultural landscape


A magnificent mountain landscape

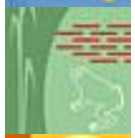

Clean air

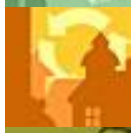

A Balanced Marine Environ-ment, Flourishing Coastal Areas and Archipelagos


Good quality groundwater

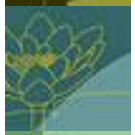

Natural acidification only


Zero eutrophication

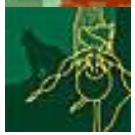

Thriving wetlands


A good built environment


A non-toxic environment


Flourishing lakes and streams


Sustainable forests


A rich diversity of plant and animal life

History

-1967:

- Ulf Lundin, fishery expert in Uddevalla, contacted Svante Odén, SLU: fish death and low pH in lakes!
- Svante Odén had time series of precipitation chemistry. He found out that pH had decreased substantially in 20 years.

-1967: Article named "Nederbördens försurning" in DN. About increased acidification of precipitation due to S emissions, leading to acidified surface waters and fish death

-1979: UN/ECE Convention on Long-Range Transboundary Air Pollution!

-Critical loads (Kritisk belastningsgräns) definied 1988

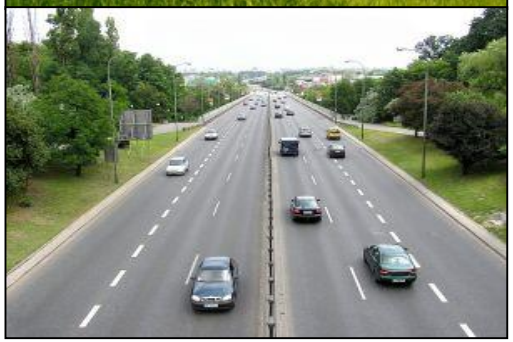
-1999: Gothenburg protocol, target year: 2010

-2012: Revised Gothenburg protocol

Acid rain - Sources and acidification processes
Sources

Sulphur

Nitrogen



Forestry

Acid rain – sources and acidification processes
Sulphur

Main source of S: Combustion of coal and oil.
Also industries, ships, etc.

$S + O_2 \leftrightarrow SO_2$

$SO_2 + O_2 \leftrightarrow 2\ SO_3$

$SO_3 + H_2O \leftrightarrow 2\ H^+ + SO_4^{2-}$

Acid rain – sources and acidification processes
Oxidized nitrogen (NO_x)

Main source of NO_x: Traffic

$N_2 + O_2 \leftrightarrow 2\ NO$

$2\ NO + O_2 \leftrightarrow 2\ NO_2$

$2\ NO_2 + H_2O \leftrightarrow HNO_2 + H^+ + NO_3^-$

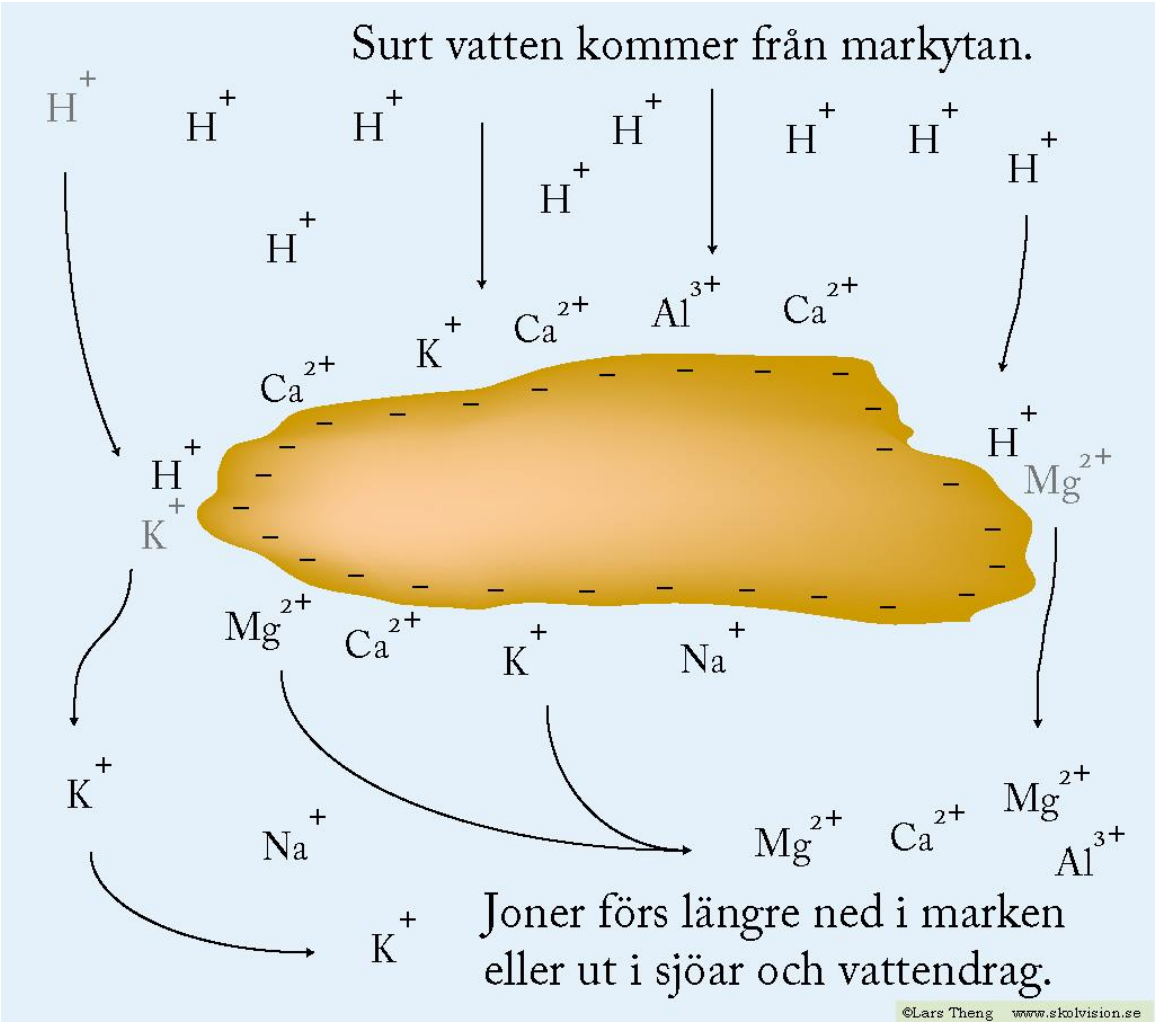
Acid rain – sources and acidification processes - *Reduced nitrogen (NH_3)*

Main source of NH_3: Fertilizers

$$NH_3 + H_2O \leftrightarrow NH^{4+} + OH^-$$

$$NH_4^+ + 2\ O_2 \leftrightarrow 2\ H^+ + NO_3^- + H_2O$$

Acid rain – sources and acidification processes



(Från www.capensis.se)

Acid rain – sources and acidification processes
Effects

-Low pH and high concentrations of toxic aluminium

-Negative effects on fish and other water living organisms

-Risk of negative effects on vegetation

-Increased leaching of nutrients important for trees (e.g. Mg and K) which can lead to nutrient imbalance

-Increased leaching of heavy metals (e.g Cd and Pb)

Present situation and trends

What does the environmental objective say?

"The acidifying effects of deposition and land use must not exceed the limits that can be tolerated by soil and water. In addition, deposition of acidifying substances must not increase the rate of corrosion of technical materials located in the ground, water main systems, archaeological objects and rock carvings." (Riksdagen)

Clarifications (preciseringar):

-Deposition of S and N should´t exceed what soils and water can take (avoiding harmful effects)

-The effect of landuse should be counteracted by adapting forest management to site conditions

-Lakes and strams should reach good status without liming

-Soil acidification should not accelerate corrosion or harm biodiversity

What does the environmental objective say?

"It is not possible to reach the environmental objective to 2020 with the decided or planned measures. The development is positive.

Acidification status today

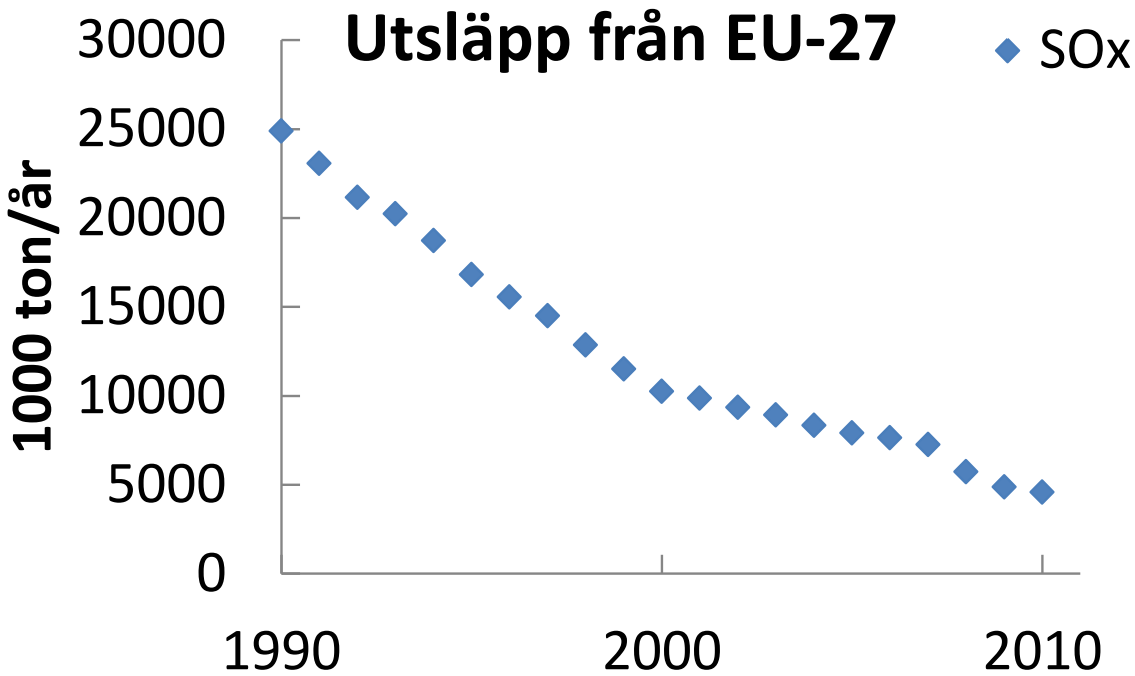
- 10% of Swedish lakes and 20% of the forest soils are assessed as acidified.

- In SW Sweden 50% of the lakes and forest soils are assessed as acidified.

- 200 million SEK are spent on lake liming every year

- Measurements and modelling indicate slow recovery

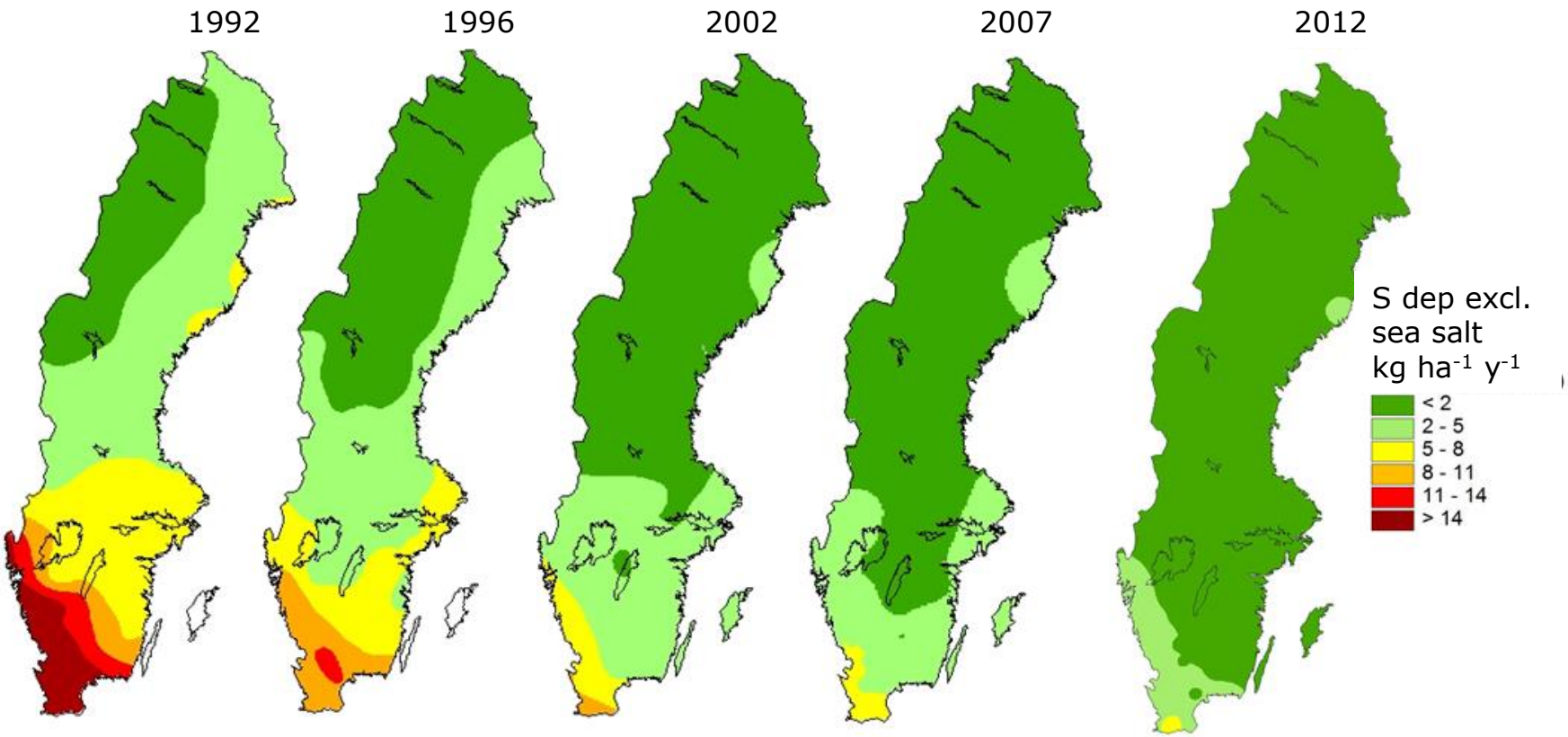
Reductions of emissions in Europe



~80 % reduction

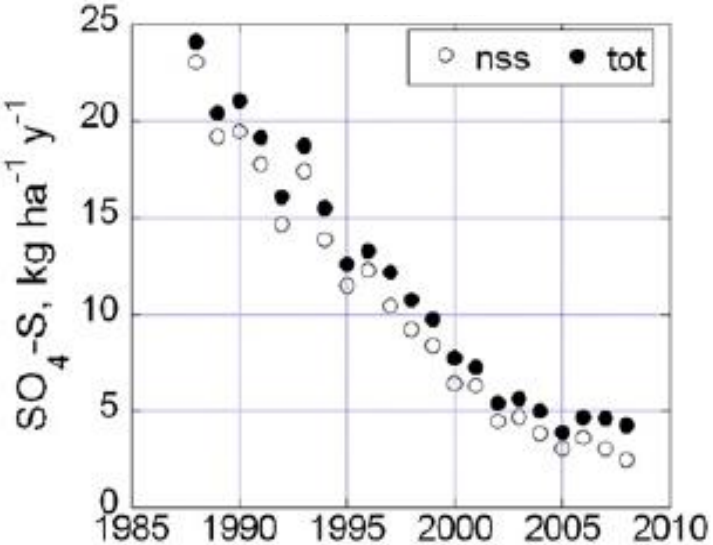
From EMEP, www.emep.int, april 2013

Sulphur deposition trends



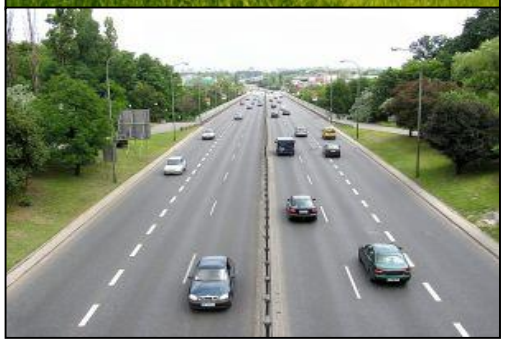
(Based on data from the SWETHRO network. Modified from Pihl Karlsson et al, 2011, Env. Poll.)

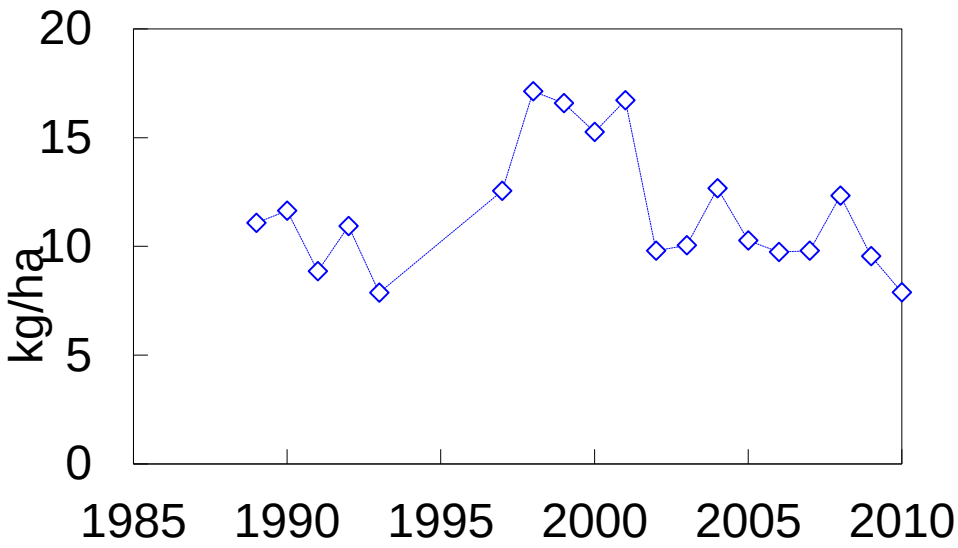
Sulphur deposition trends (Arkelstorp, Skåne)



(Based on data from the SWETHRO network, IVL: Akselsson mfl, 2013)

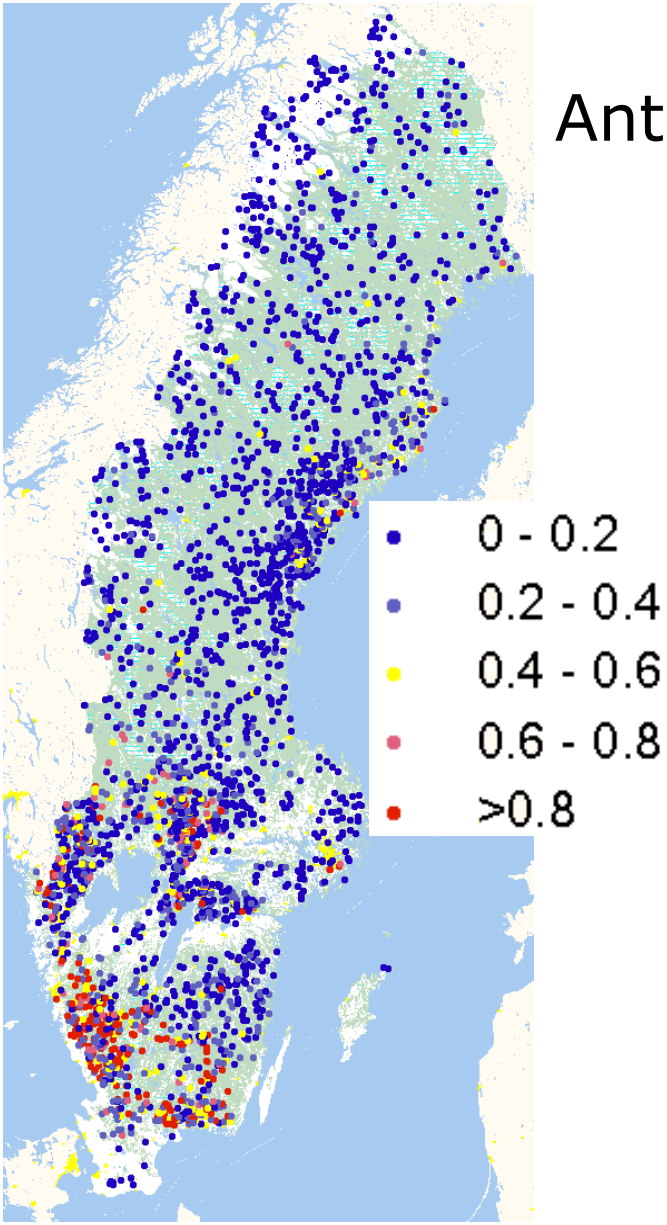
Nitrogen deposition trends (Västra Torup, Skåne)

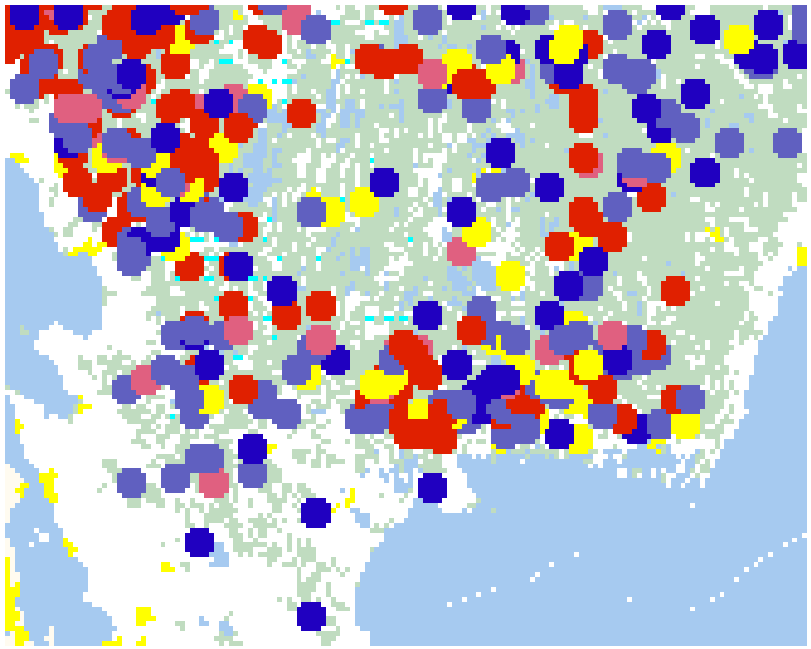




(Based on data from the SWETHRO network, IVL)

Antropogenically acidified lakes



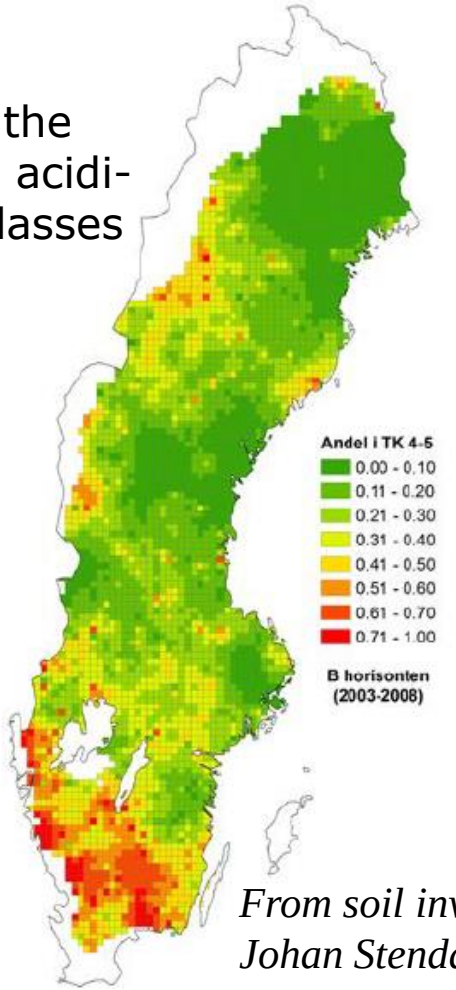


Lakes (> 1 ha) in different effect classes in the year 2010, based on there modelled pH decrease since before insustrialization

(Filip Moldan, IVL, www.ivl.se/magiclibrary)

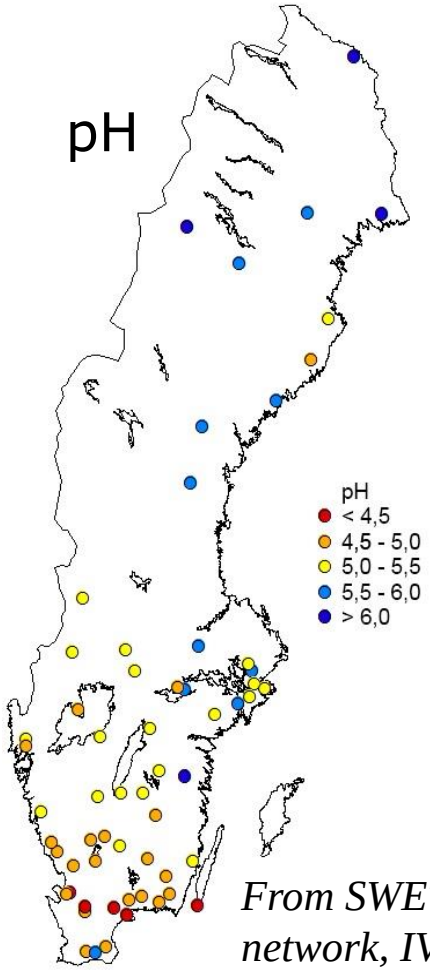
Acidification in solid soil (left) and soil solution (right)

% soil in the 2 highest acidification classes



From soil inventory, Johan Stendahl, SLU

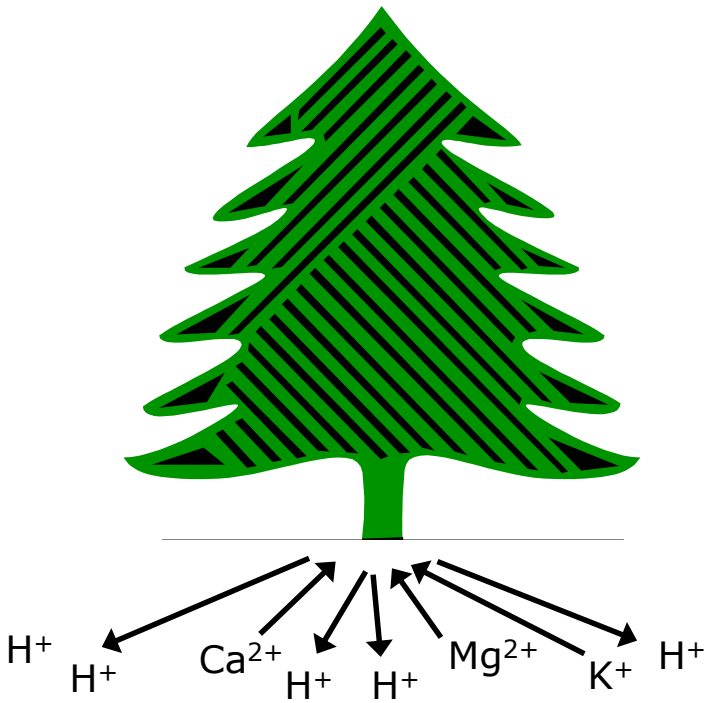
pH



From SWETHRO network, IVL

Acidification from forestry

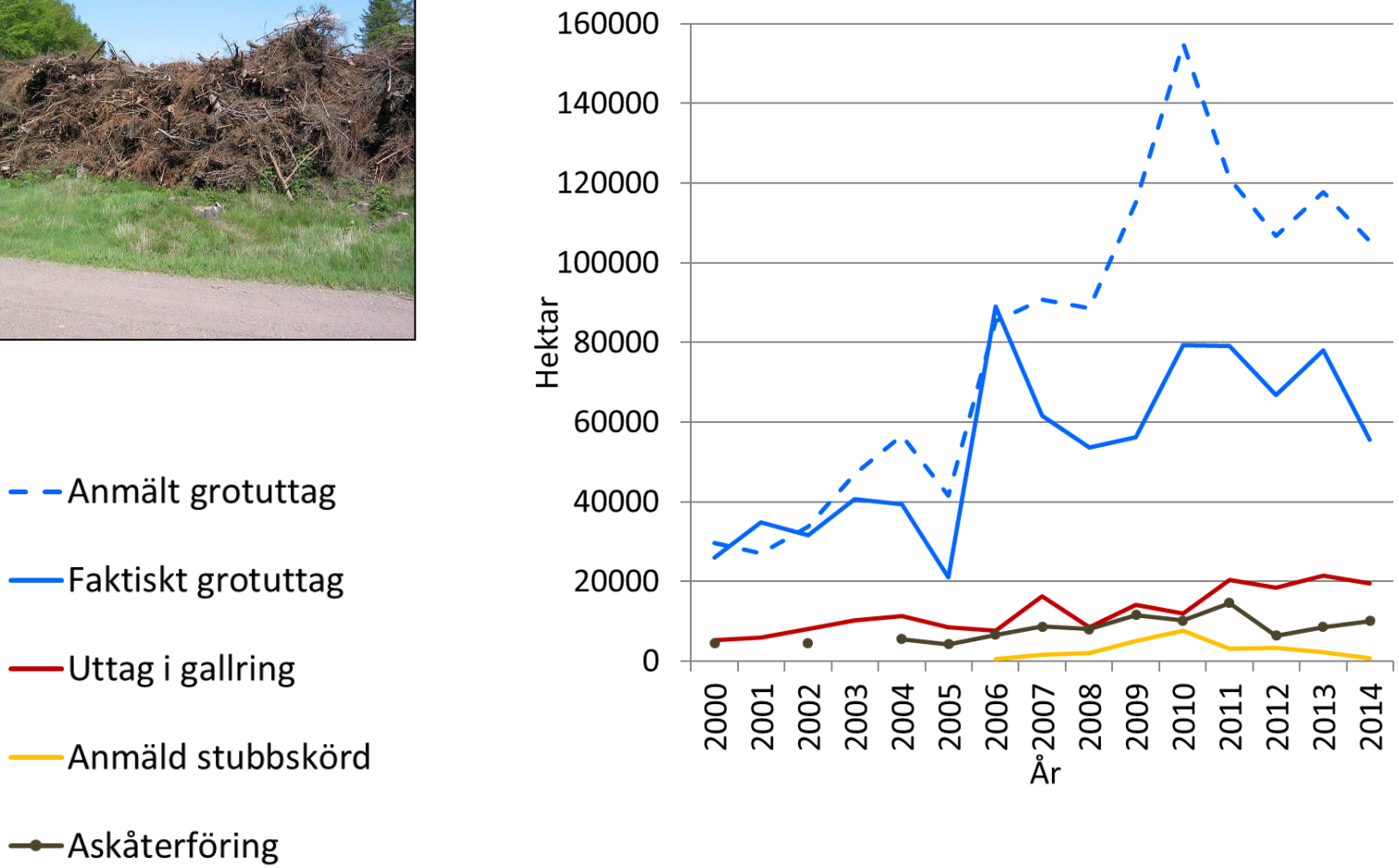
Acidification from forestry



Tree growth: Uptake of base cations –BC: Ca, Mg, K. Release of H^+.

Biomass harvesting: The BC losses and acidification becomes permanent

Acificaton from forestry – increased biomass harvesting



(Swedish forest agency)

Acidification from forestry

Acid rain removes base cations and acidifies…

…and biomass harvesting too.

Chemical weathering leads to release of base cations and counteracts acidity.

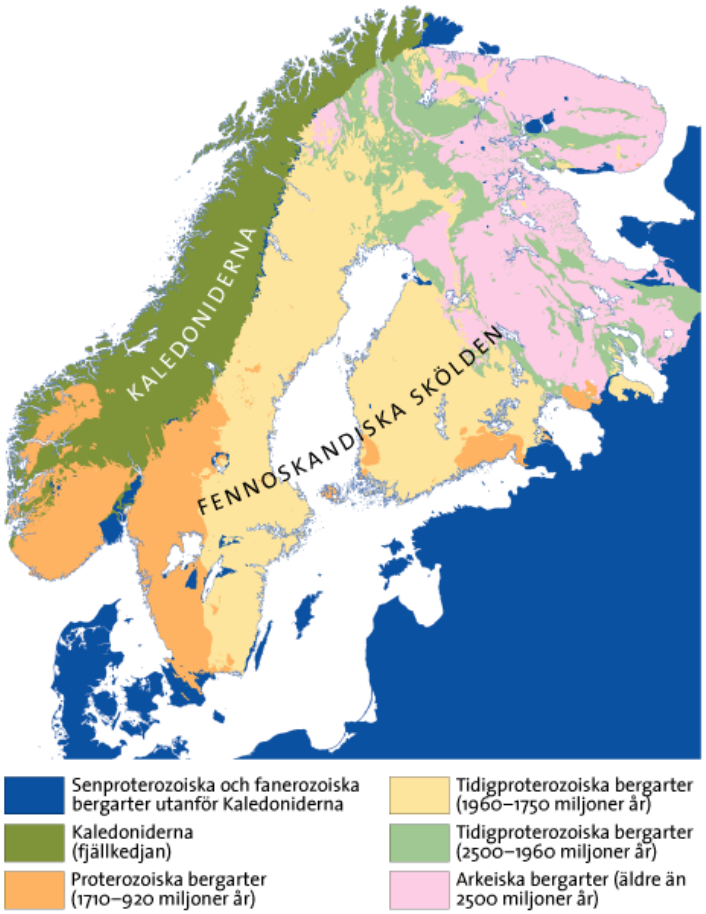
Ex: $3\ KAlSi_3O_8 + 2H^+ + 12\ H_2O \rightarrow$
$KAl_3Si_3O_{10}(OH)_2 + 6\ H_4SiO_4 + 2\ K^+$

Acid deposition and forestry lead to losses of nutrients…

…and nutrients are necessary for all living organisms

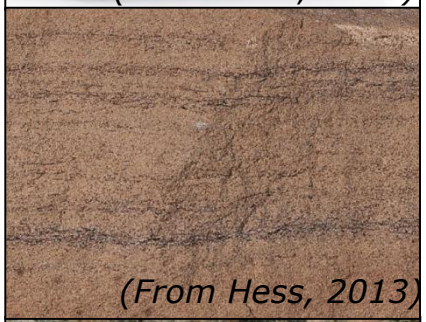
Acidification in the perspective of Swedish rocks, soils and landforms

Acidification in the perspective of Swedish rocks, soils and landforms



www.sgu.se

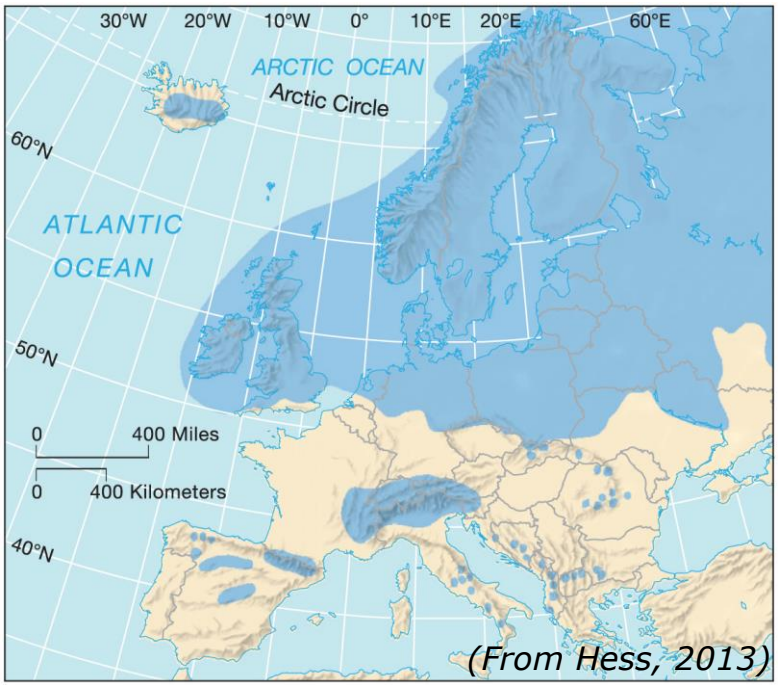
(From Hess, 2013)



(From Hess, 2013)

(Photo: Jonas Åkerman)

Acidification in the perspective of Swedish rocks, soils and landforms



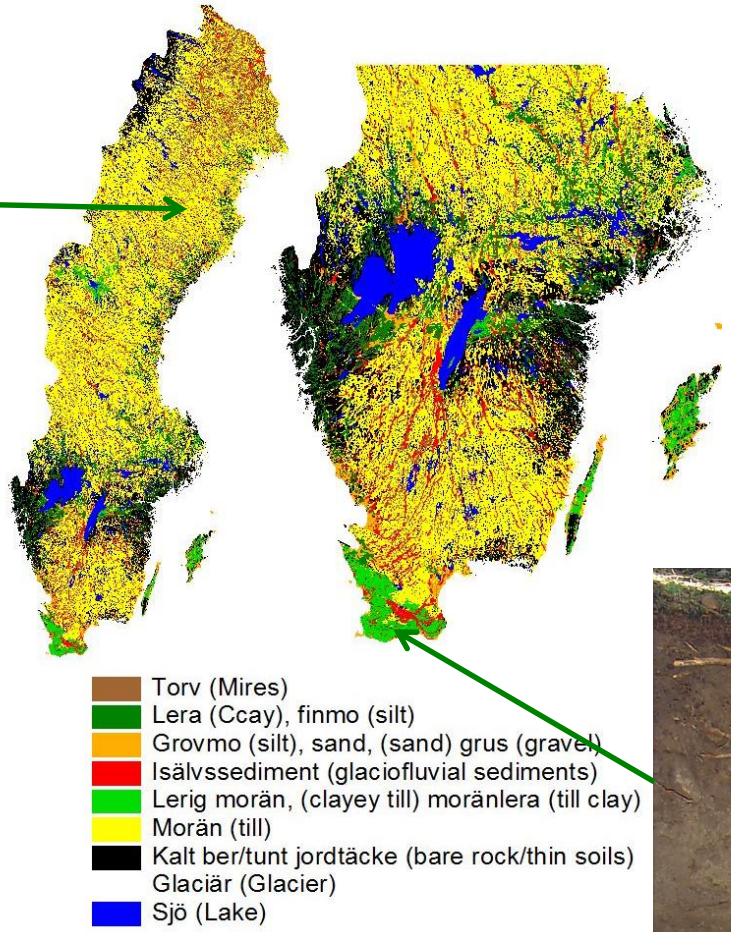
(From Hess, 2013)


(Photo: Cecilia Akselsson)

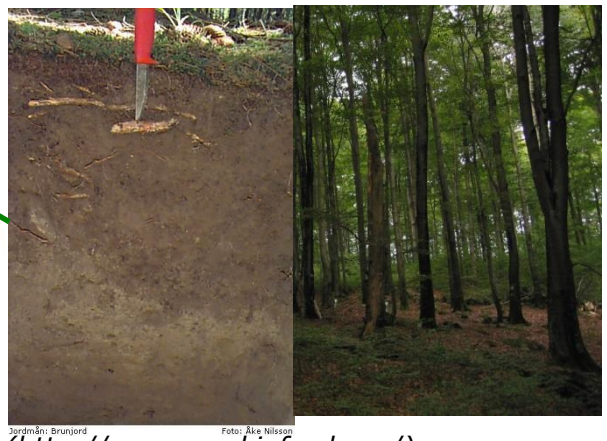

(Photo: Jonas Åkerman)

Acidification in the perspective of Swedish rocks, soils and landforms

(http://www-markinfo.slu.se/)



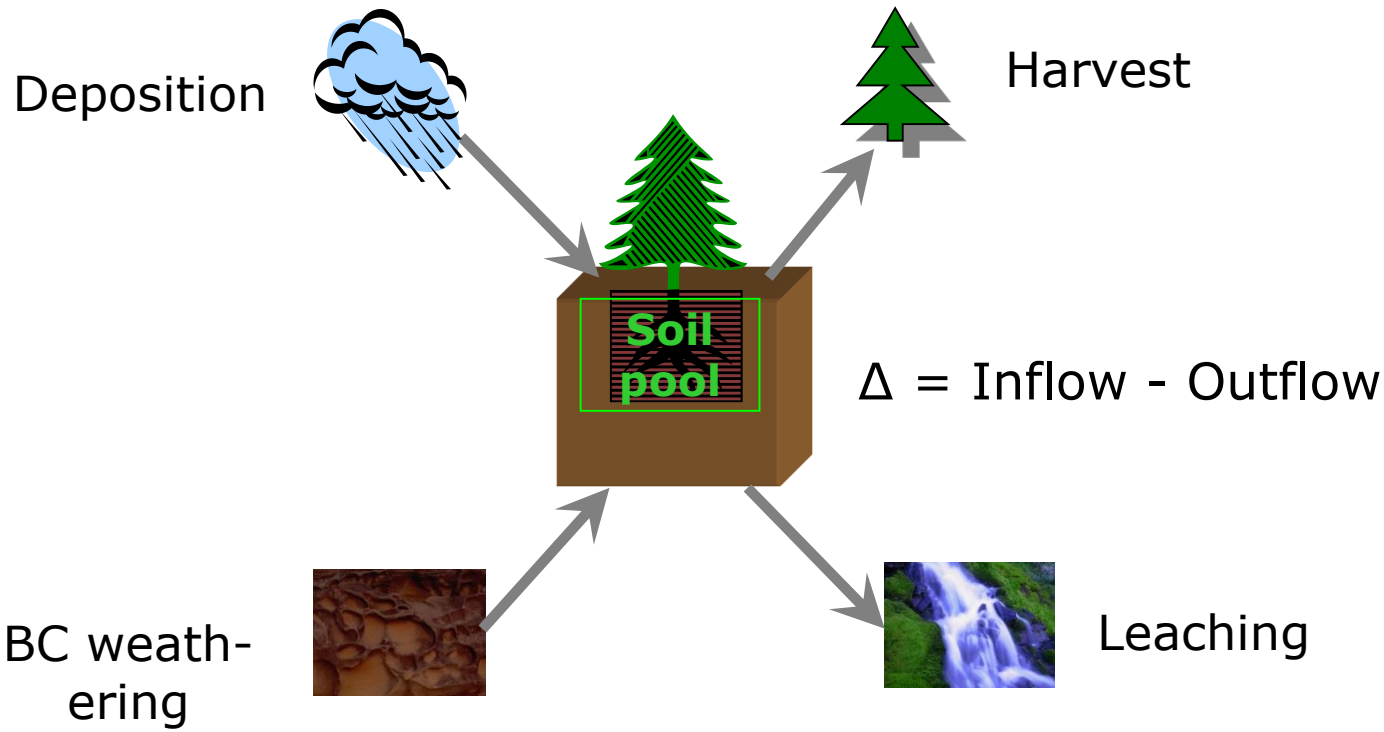
(soil map from SGU)



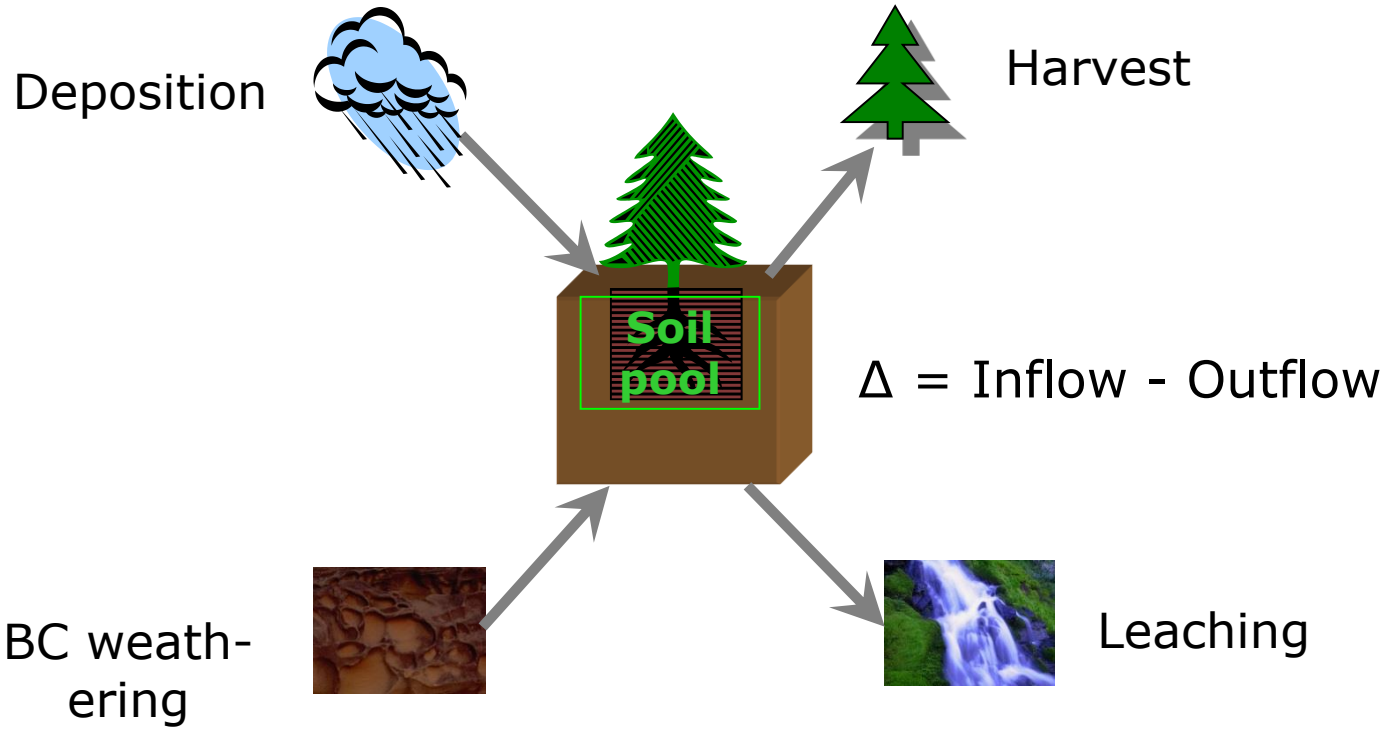
(http://www-markinfo.slu.se/)

Chemical weathering of base cations (BC; baskatjoner) (Ca, Mg, K, Na) in forest soils for sustainable forestry: Introduction to exercise

Nutrient balance calculations



What will happens with the base cation balance if harvesting increases?



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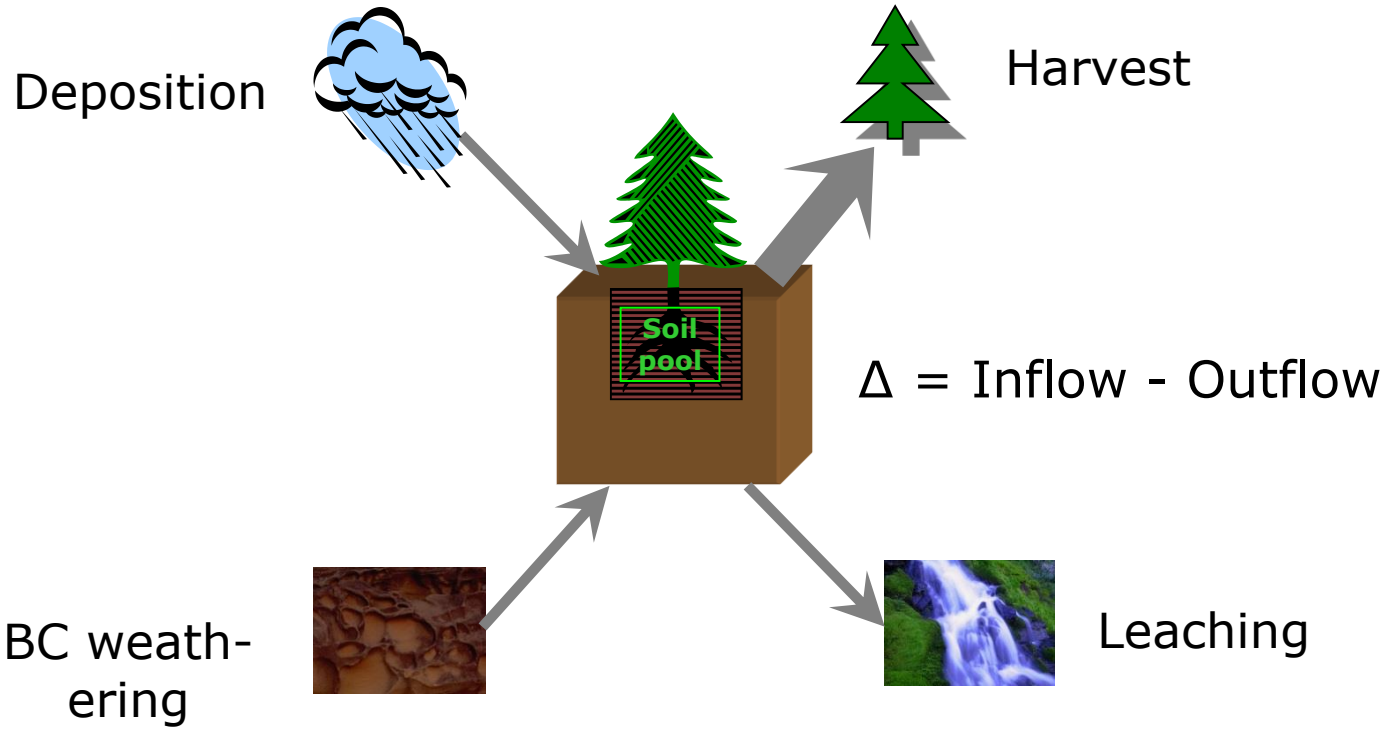
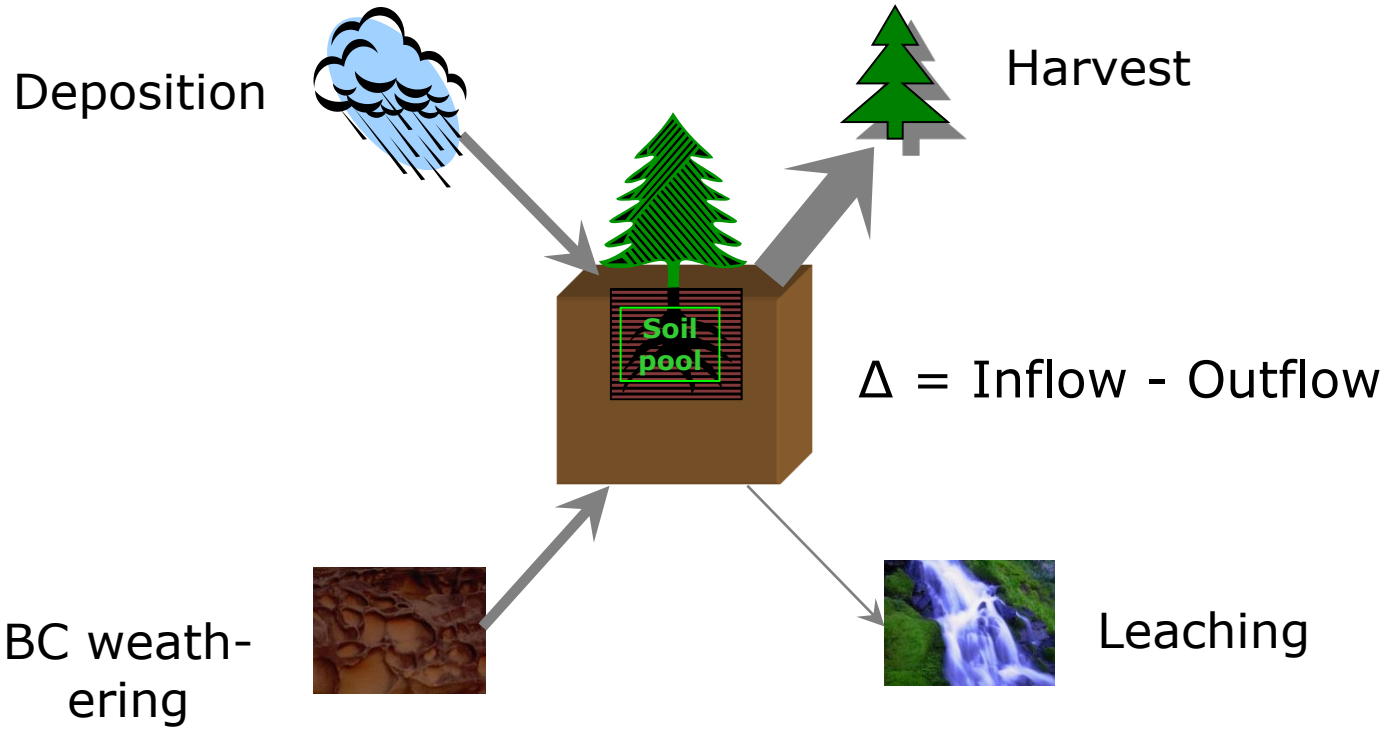


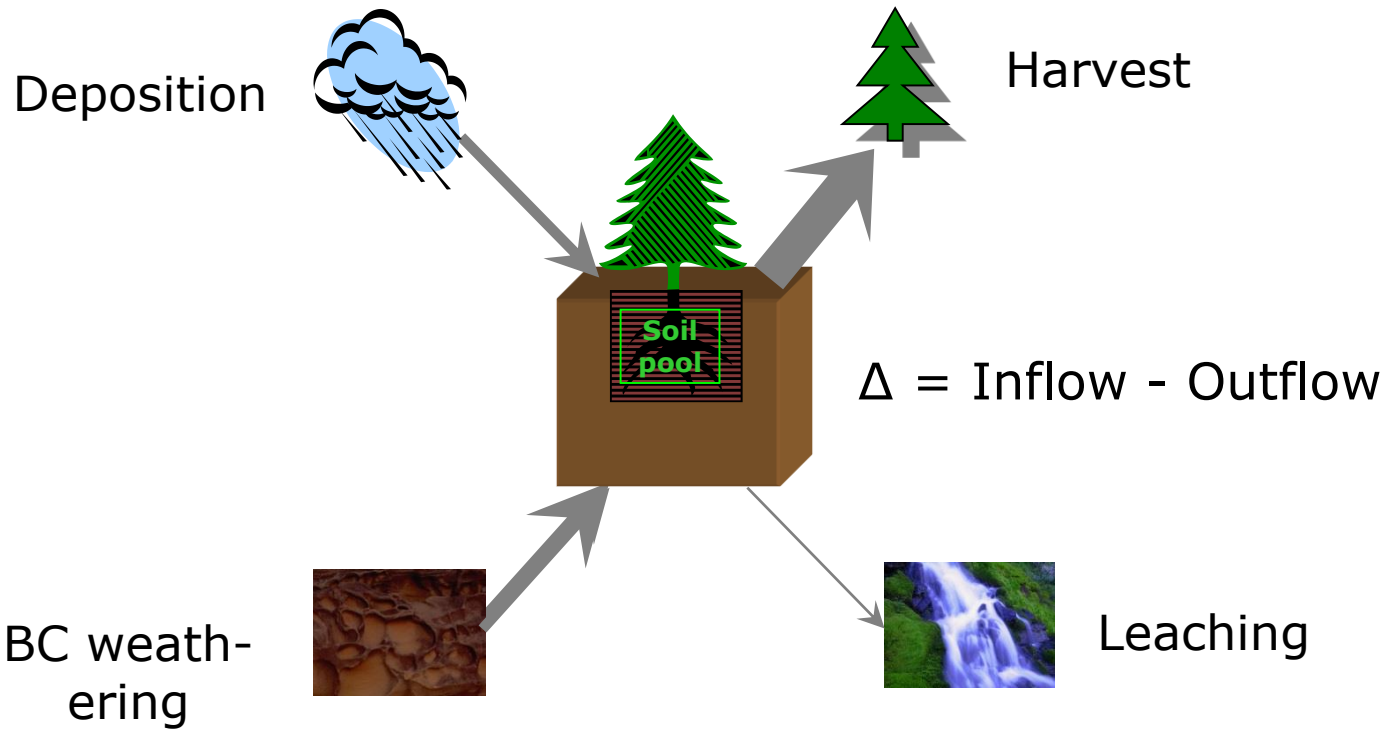
Reduced soil pool…

What will happens with the base cation balance if harvesting increases?



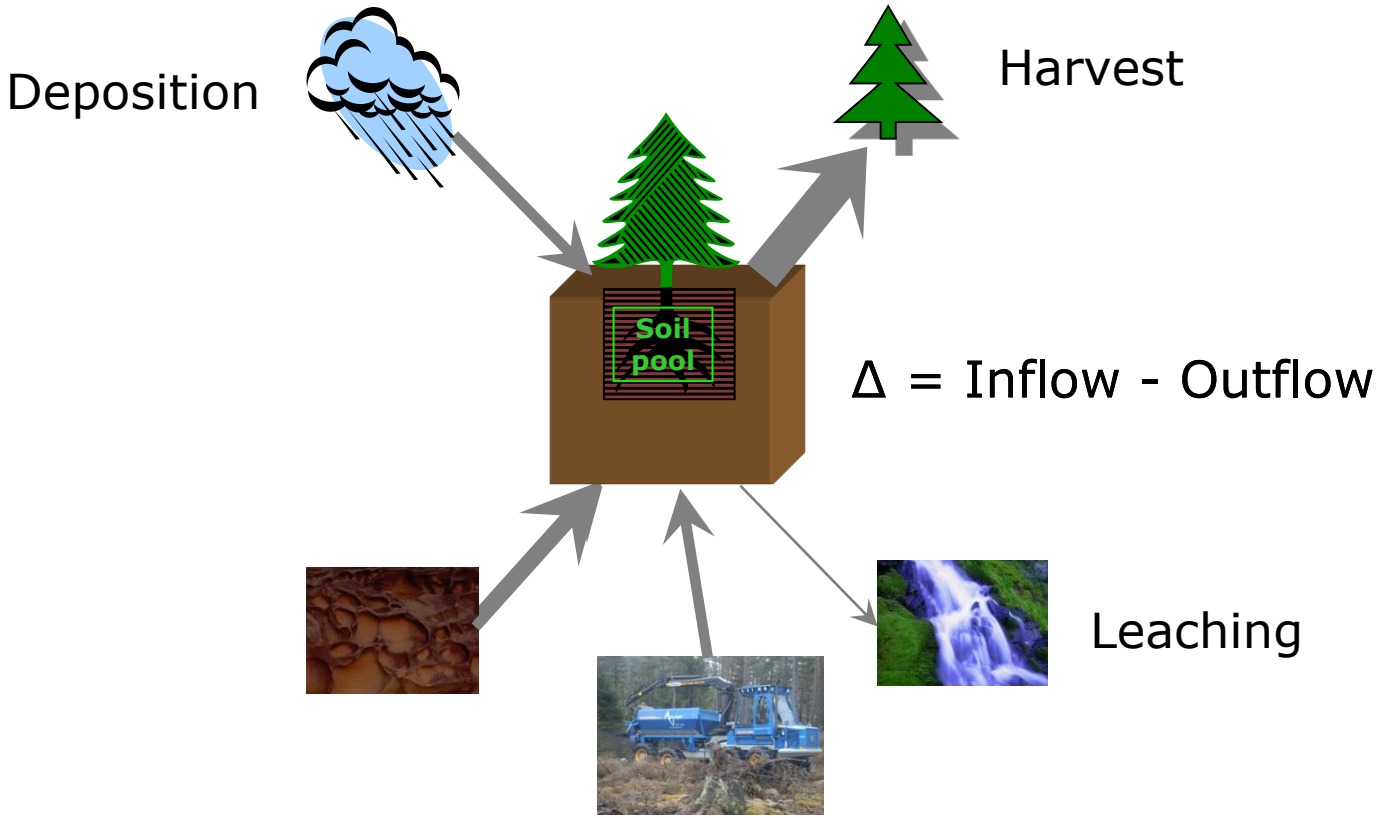
…and eventually reduced leaching.

What will happen if harvesting increases?



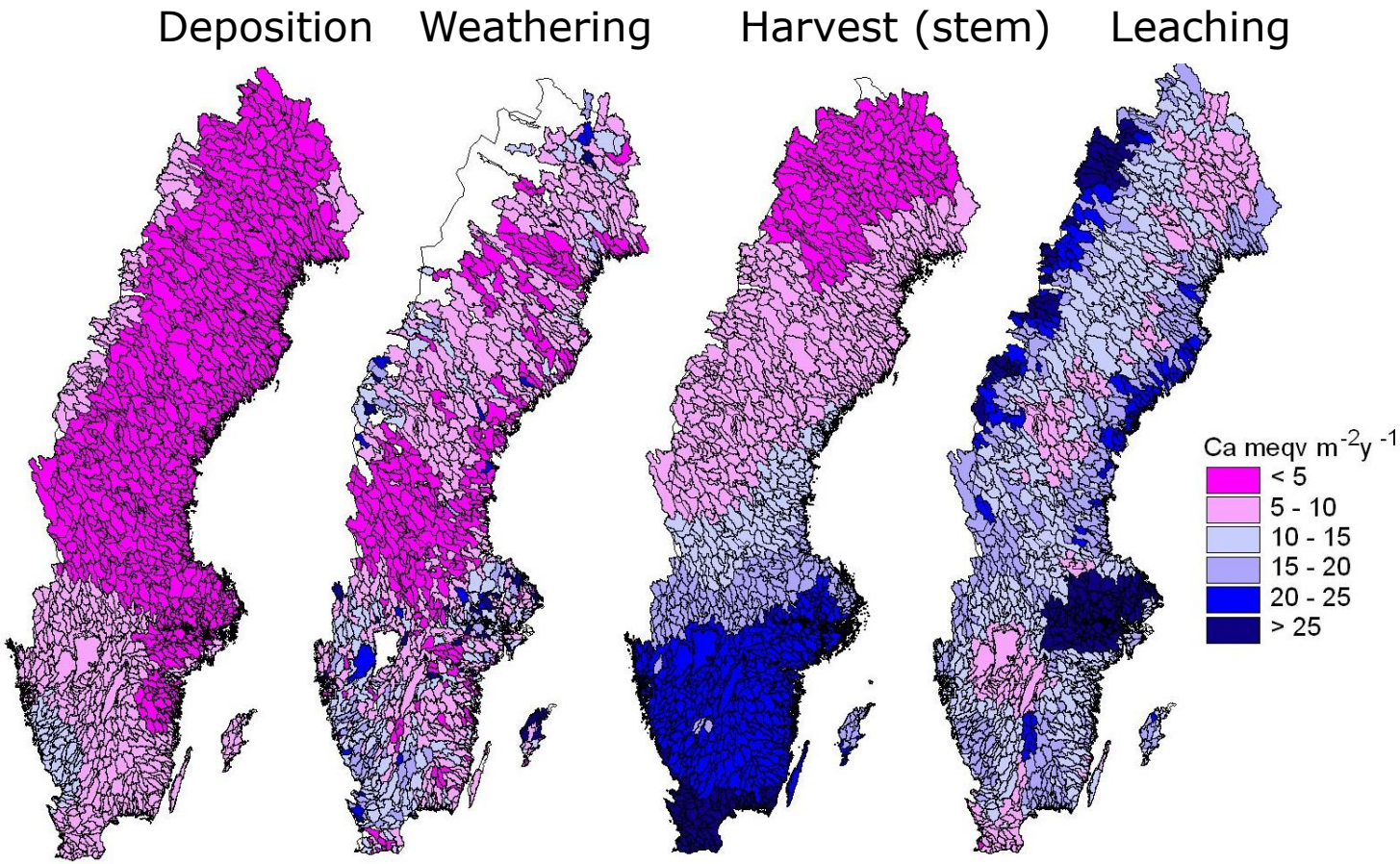
Weathering may increase as well! But to compensate it has to increase as much as the harvest losses.

What will happen if harvesting increases?



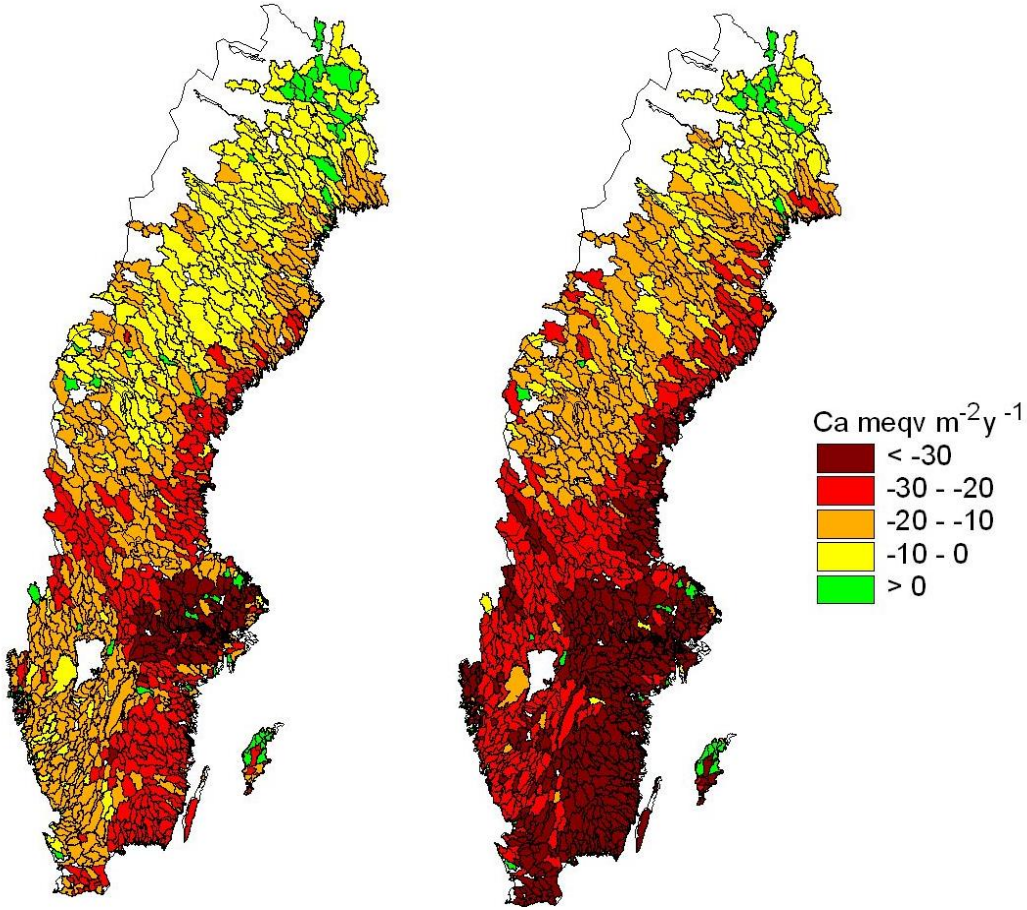
Another way to compensate: wood ash recycling

Calcium (Ca)

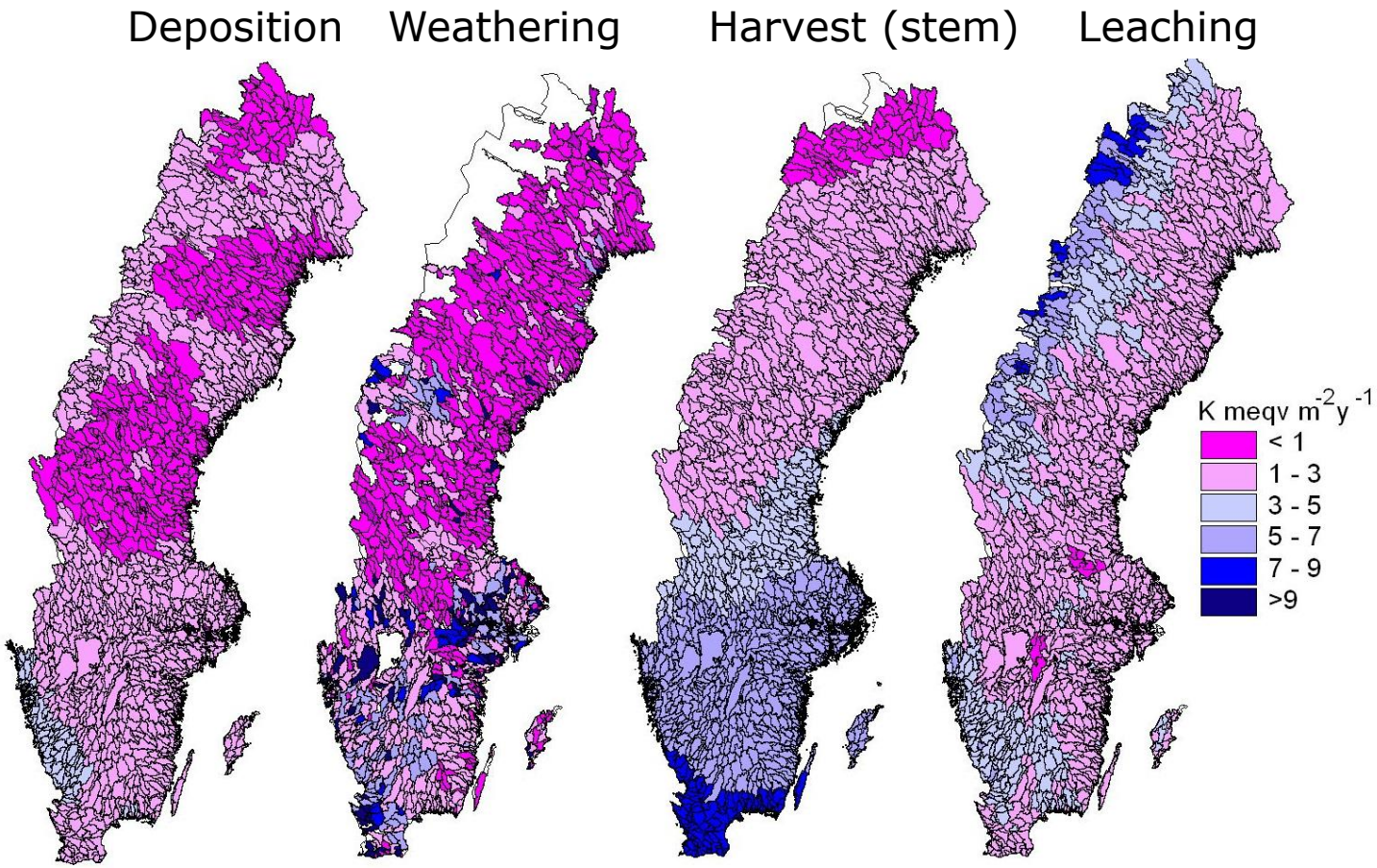

Deposition
Weathering
Harvest (stem)
Leaching
Ca meqv m-2y -1
< 5
5 - 10
10 - 15
15 - 20
20 - 25
> 25

Net accumulation Ca

Stem harvesting Whole-tree harevsting

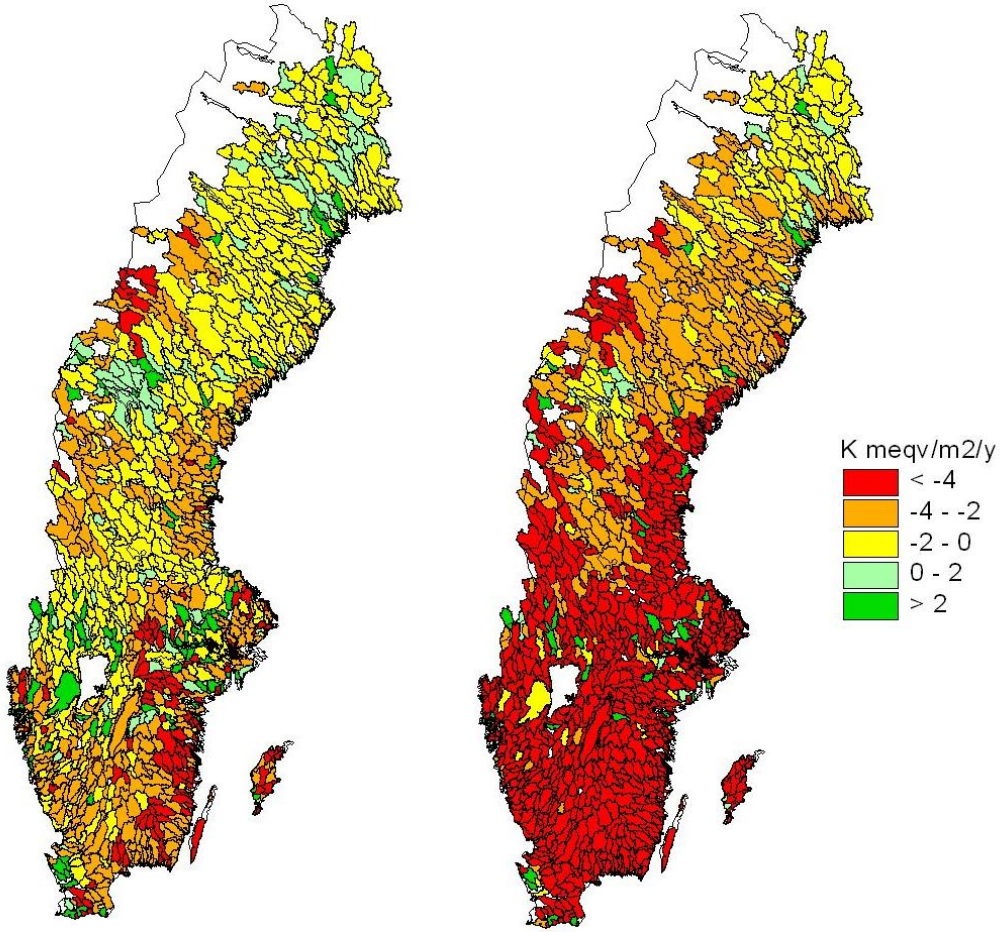


Potassium (K)


Deposition
Weathering
Harvest (stem)
Leaching
K meqv m-2 y-1
< 1
1 - 3
3 - 5
5 - 7
7 - 9
>9

Net accumulation K

Stem harvesting Whole-tree harevsting



Exercise tomorrow:

-Modelling weathering rates for Ca, Mg, Na and K

-Test how temperature, moisture, mineralogy and texture affects weathering rates (e.g what happens if temperature increases according to climate change scenarios)

-Calculate nutrient balances for Ca, Mg and K

Exercise tomorrow – The PROFILE model