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Potential impact of forest biomass harvest on the acidity of Swedish surface waters

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- Can biomass harvest acidify surface waters?
- Is there a need for ash return or liming?
- Spatial variations in effects/needs?

Foto: P-E Larsson respective T. Zetterberg

Soil solution sampling at Lövliden by Hans-Göran Nilsson, SLU.

Photo: Therese Zetterberg

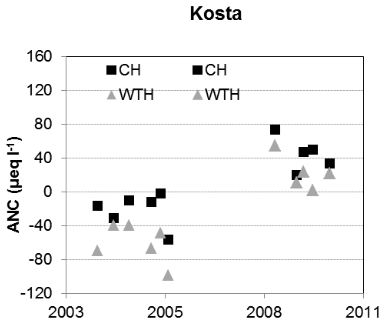
Temporarily, more acidic soil solution after WTH at the HELTRAD sites

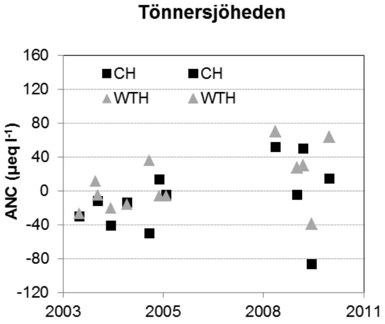
27-30 years after harvest

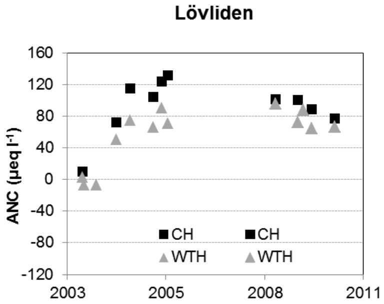
	Treatment	
	CH	WTH
pH	4.92	4.87
ANC ($\mu eq\ l^{-1}$)	9	-7
DOC ($mg\ l^{-1}$)	5	4
Ca^{2+} ($\mu eq\ l^{-1}$)	43	26
Mg^{2+} ($\mu eq\ l^{-1}$)	24	19
Na^{+} ($\mu eq\ l^{-1}$)	152	138
K^{+} ($\mu eq\ l^{-1}$)	8	9
SO_4^{2-} ($\mu eq\ l^{-1}$)	91	76
Cl^{-} ($\mu eq\ l^{-1}$)	124	118
$RCOO^{-}$ ($\mu eq\ l^{-1}$)	37	30
Alt ($\mu g\ l^{-1}$)	403	396
Alo ($\mu g\ l^{-1}$)	141	109
Ali ($\mu g\ l^{-1}$)	311	336

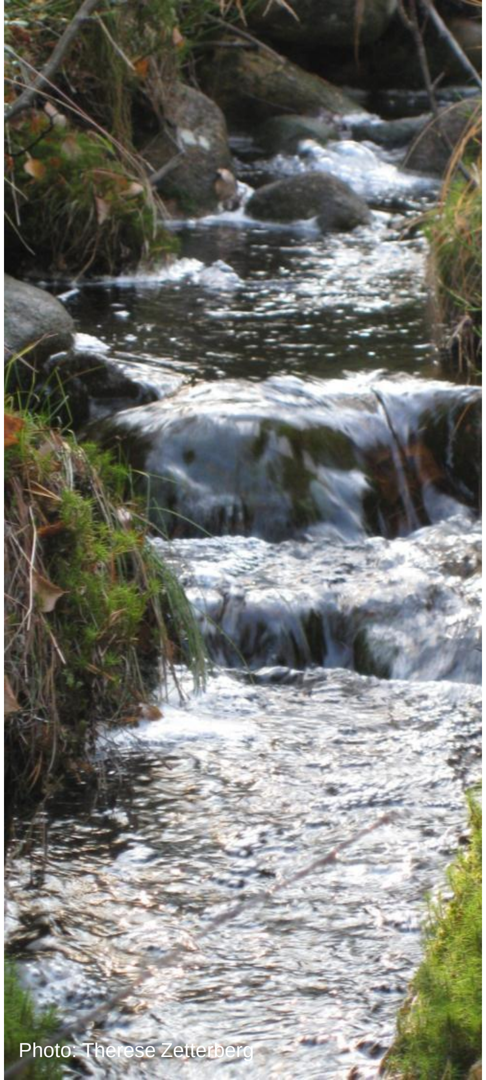
Zetterberg et al., 2013. The effect of harvest intensity on long-term calcium dynamics in soil and soil solution….Forest Ecology and Management, 302: 280-294

Impact not great enough to reverse the positive trend in ANC









...or fully prevent the general recovery from historic acidification

SOIL SOLUTION

42-401 μEq l^{-1} [2.0-21 μEq l^{-1} yr^{-1}] (Löfgren & Zetterberg, 2011)

10-430 μEq l^{-1} [0.6-22 μEq l^{-1} yr^{-1}] (Akselsson et al., 2014)

	Lövliden	Kosta	Tönnersjö
		ANC (μEq l^{-1})	
ΔWTH-CH (2003-2005)	44	8	34

STREAMS

9.6-176 μEq l^{-1} [1.6-11 μEq l^{-1} yr^{-1}] (Löfgren et al., 2009)

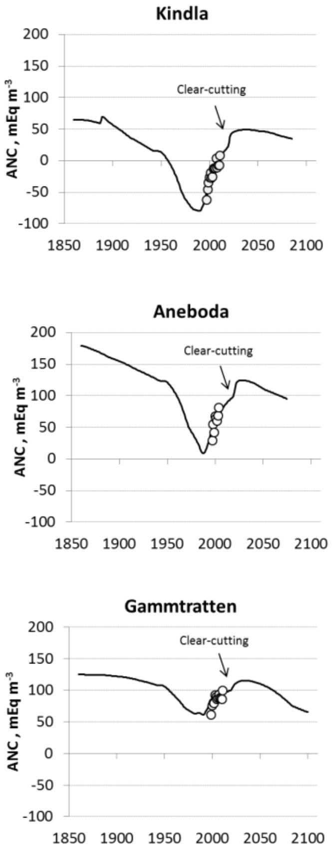
LAKES

ca. 50 μEq l^{-1} [ca 2.2 μEq l^{-1} yr^{-1}] (Futter et al., 2014)

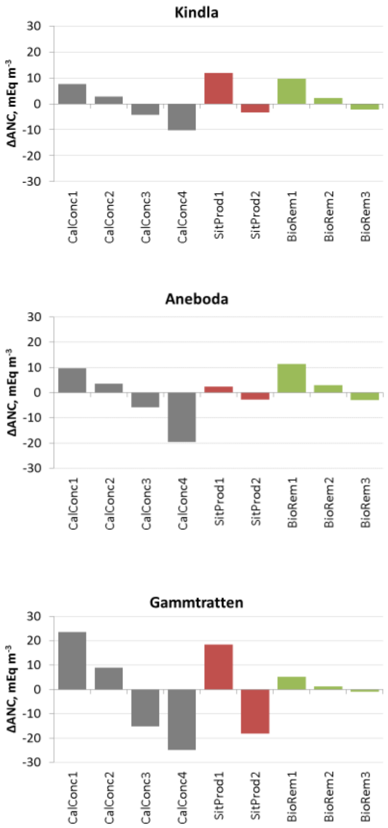
Assumptions on BC uptake and harvest important: MAGIC

Swedish IM sites

Base Scenario



Alternate Scenarios

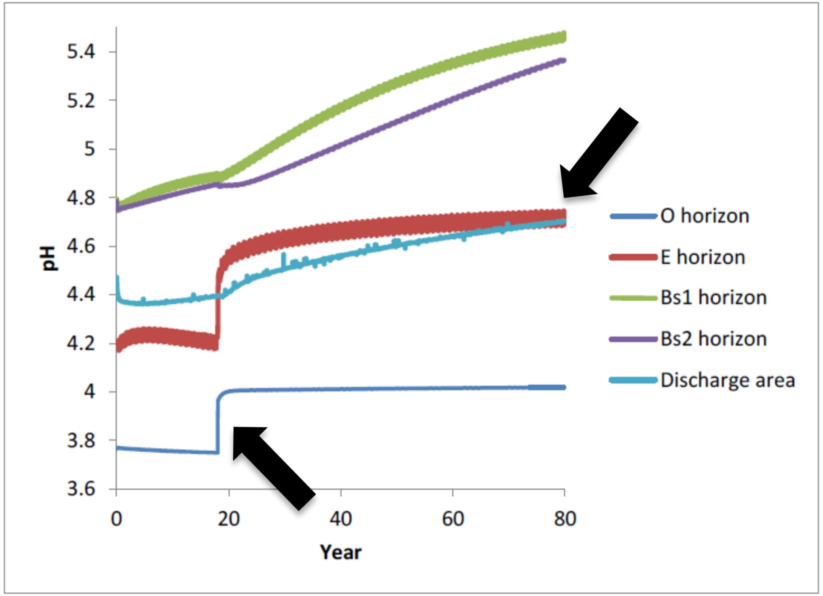


Zetterberg et al., 2014.

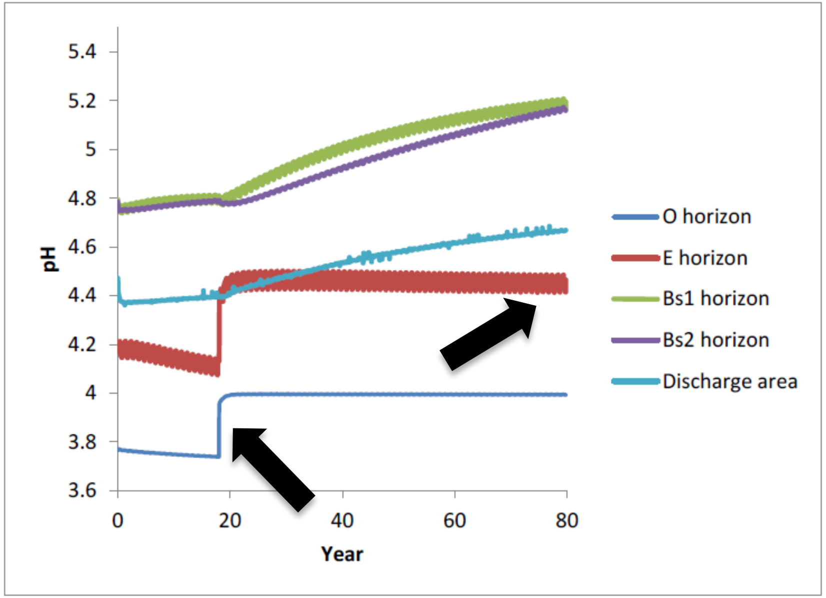
HD-MINTEQ simulations

(Aneboda IM)

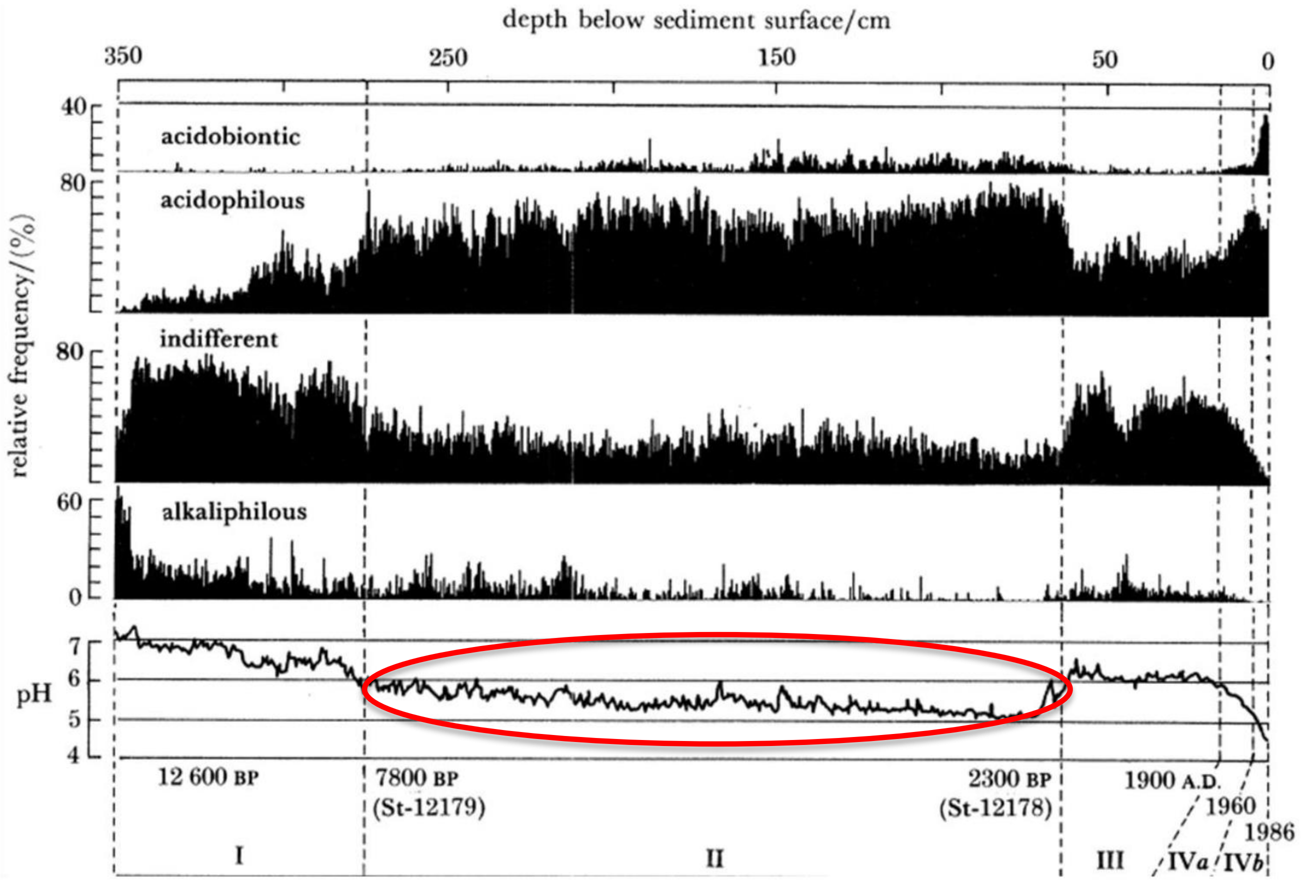
No harvest



Whole-tree harvest



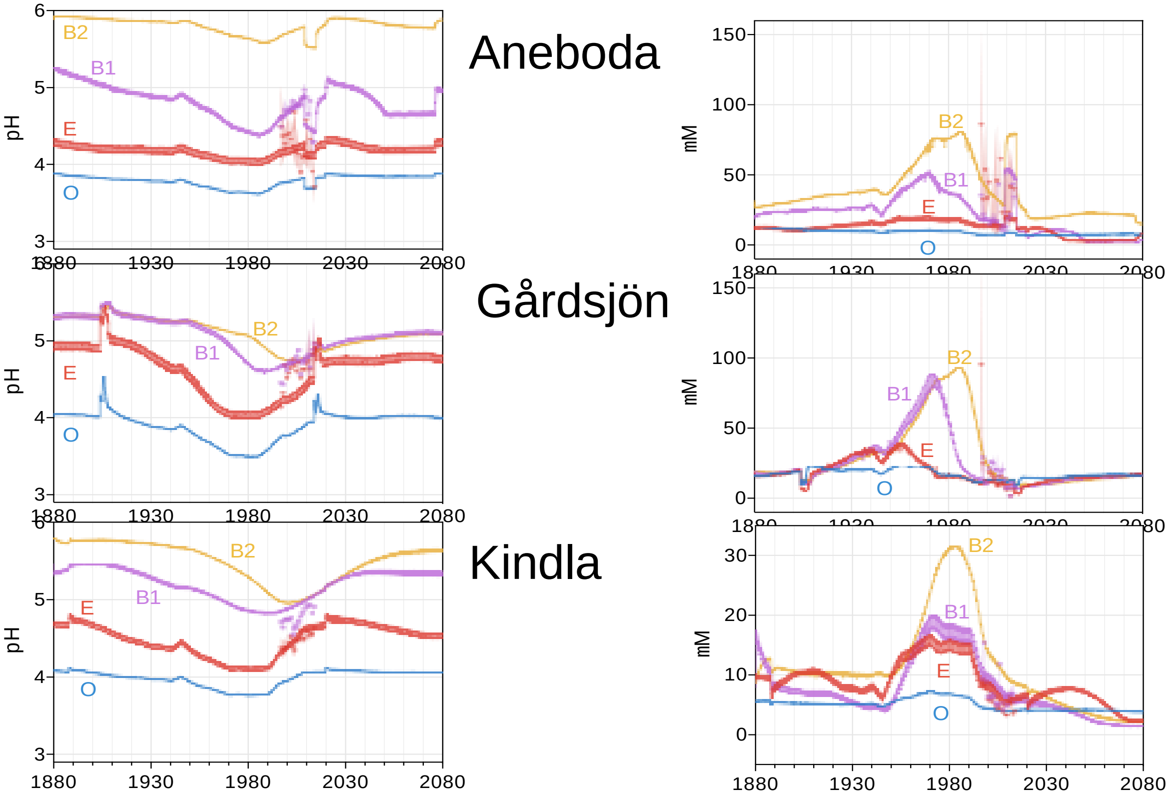
Löfgren et al., 2017.



No harvest but BC leakage 5500 yrs → increased protonation of NOM

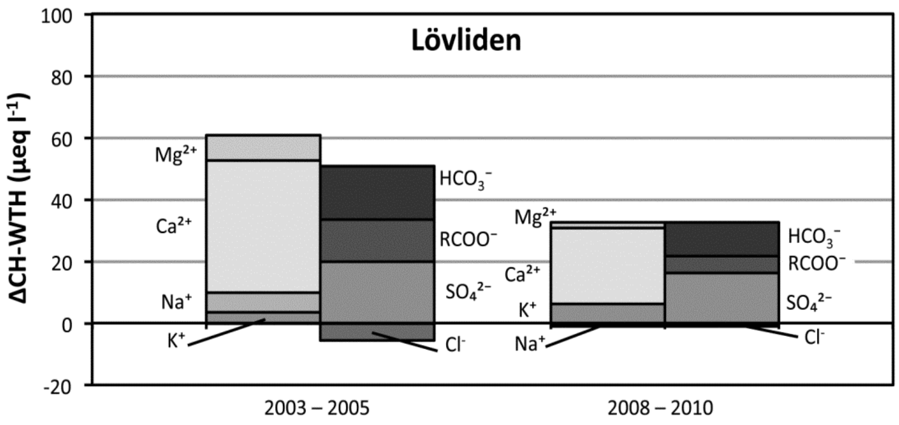
Renberg 1990

HDMINTEQ simulated effects of whole-tree harvest on pH and Ca^{2+} in soil solution



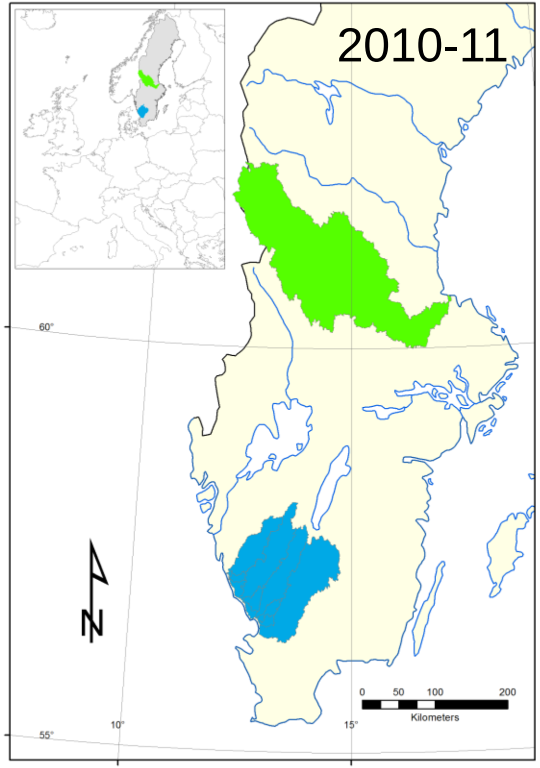
BC (H^+ and Al^{n+}) leaching differences between CH and WTH explained by mobile anions

(Reuss & Johnsson, 1986)



Zetterberg et al., 2013.

pH sensitivity in ≈200 randomly selected forest streams



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Impact of whole-tree harvest on soil and stream water acidity in southern Sweden based on HD-MINTEQ simulations and pH-sensitivity ☆

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ABSTRACT

The shift in major drivers of acidification from sulfur deposition to biological acidification has put the focus on the impact of biomass harvest for bioenergy on the acid base status of forests soils and surface waters. This paper presents a model-based assessment in which the impact of whole-tree harvest (WTH) is compared with that of no harvest at two different sulfur deposition levels by use of the HD-MINTEQ model. Additionally, the pH-sensitivity of 179 randomly selected boreal headwater streams was assessed. The results indicate that the exchangeable Ca^{2+} pool in humus and mineral soils (⩽B-horizon) is most affected by harvest. Concerning the pH, the WTH impact is restricted to shallow soils and for a much shorter period of time. The impact of WTH on the soil solution was primarily restricted to the recharge area and much less pronounced in the discharge area. Due to high buffering capacity of riparian soils and low pH-sensitivity of many headwater streams, the pH effects of WTH on surface waters will most probably be small, at least over a rotation period of several decades. Over time perspectives of multiple rotations, the pH effects are more uncertain due to a possible slow successive protonation of organic matter in the riparian zone. Another important aspect is the currently restricted availability of mobile anion charge balancing the acidity produced by tree growth. Therefore, the acidity is to a large extent arrested in the soil. At the current low S deposition levels, southwestern Sweden seems to be the least vulnerable region to further acid input due to high buffer capacity at low pH. The streams in central and northern Sweden are much more pH-sensitive, but restricted availability of mobile strong acid anions and large buffer capacity in the soils make them less vulnerable to WTH. The partly diverging results between experimental and model studies indicate that one or more processes (hydrological, chemical or biological) are not fully understood or that available data are lacking for a proper parameterization. Thus, the results from long-term WTH experiments are very important for understanding the processes involved as well as for improving and validating model predictions. We therefore encourage societal support of maintaining monitoring and research coupled to such experiments. For the future and for improving our current understanding of biogeochemical dynamics in forest ecosystems subjected to active forestry as well as for policy and management purposes, a mixture of experiments and models ought to be used.

1. Introduction

The sulfur (S) deposition in Sweden has decreased by more than 90% since it peaked in the 1980s, and current levels are comparable to those in the 1930s (Bertills et al., 2007). Along with this decline, the contribution of other acidity sources has become more important in both quantitative and relative terms. This has put focus on the biological acidification related to an increased production and more intense forest harvest (e.g. whole tree harvest, WTH) in boreal regions such as Fennoscandia. An increased demand of bioenergy and other forest products in Sweden (Swedish Forest Agency, 2014) and EU (COM, 2006) has created concern that the recovery from acidification following reduced anthropogenic emissions should be counteracted by increased acidification from forest growth. In the worst-case scenario a new era of acidification of Swedish soils and surface waters due to high demands of forest

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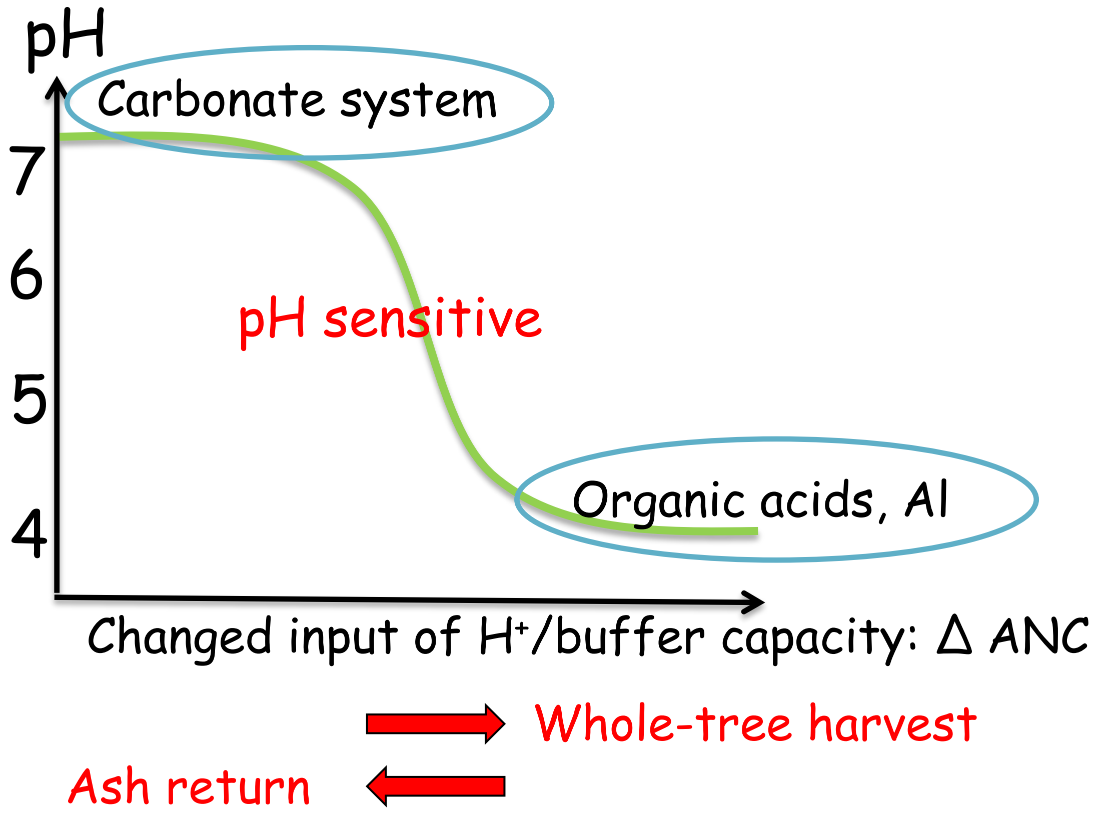
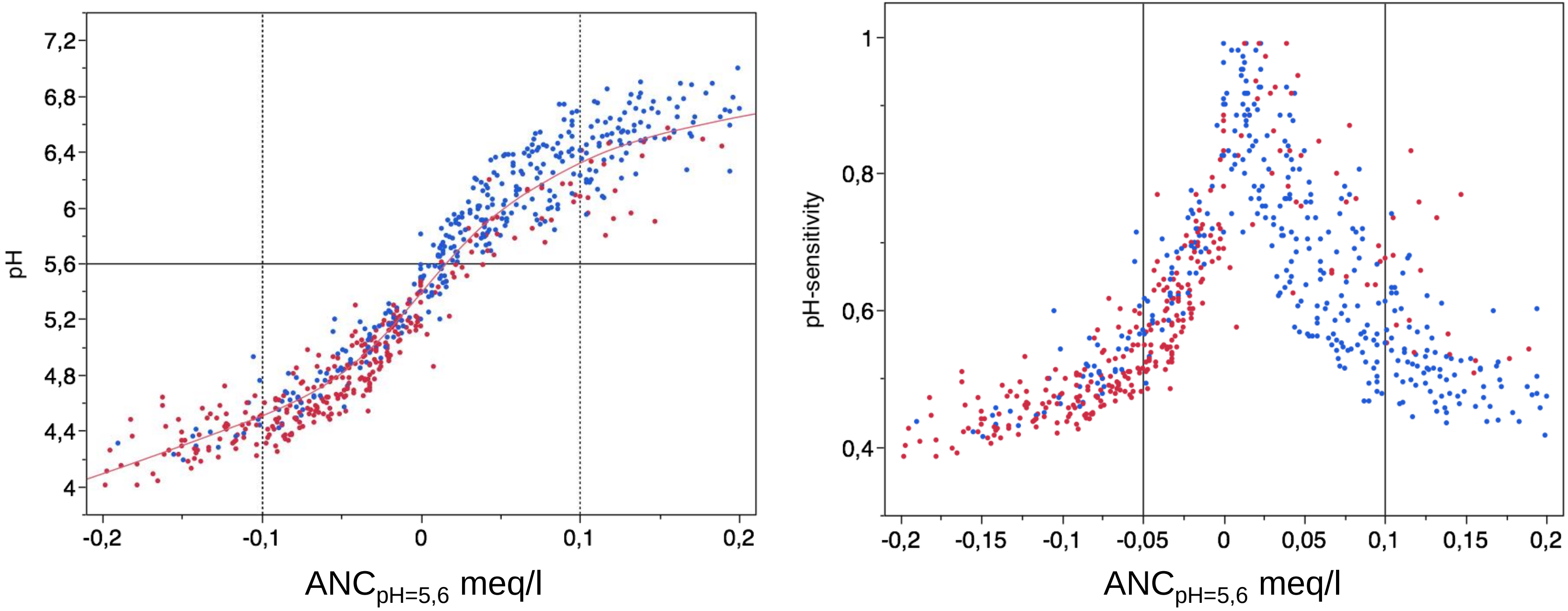
pH sensitivity

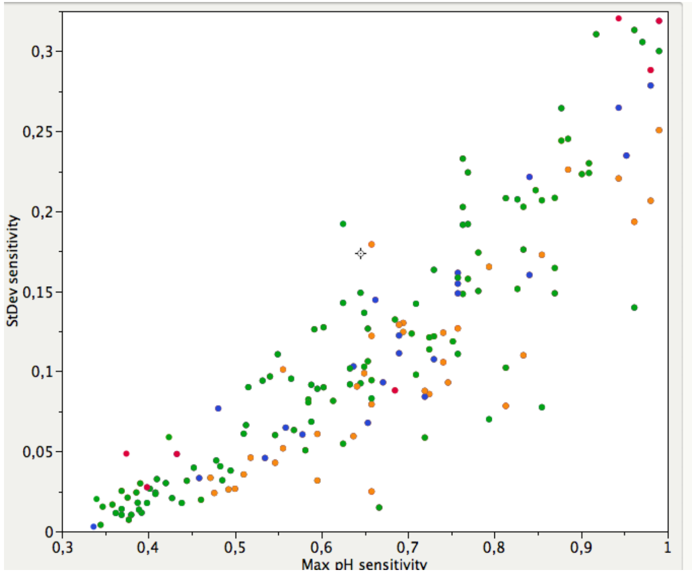


Difference between pH and pH sensitivity



Löfgren et al. 2017

pH sensitivity varies with season and the variation increases with sensitivity



Red = spring
Green = summer
Orange = autumn
Blue = late autumn

($-0.2 < ANC_{pH=5.6} < 0.2$)

Conclusions

- Forest growth produced acidity is to a large extent arrested in the soil due to restricted amounts of mobile anions, driving the leakage of BC, H^+ and Al^{n+} towards streams.
- pH-effects of forest growth and WTH are reduced along the groundwater flow path from clear-cut areas to streams.
- In a forest generation perspective, the pH-effect on surface water of WTH is most probably low (<0.1 pH-units).
- In a multiple forest generation perspective, the difference between CH and WTH may increase due to successive protonation of the organic matter in discharge areas.
- pH sensitive areas are distributed in a mosaic like pattern in the landscape
- The geographical location of them varies with season
- Organic soils (peat) and DOC are important parameters, where DOC acts both as acid and base

(Löfgren et al. 2017)


Varying pH-sensitivity!
Thanks for your attention!

Region	Selection	Landscape elements			Landscape elements + water chemical variables		
	-0.2<Alk<0.2 meq l^{-1}	Low pH-sensitivity	High pH-sensitivity	r^2	Low pH-sensitivity	High pH-sensitivity	r^2
Southwest (Rivers Viskan, Ätran, Nissan and Lagan catchments)	All seasons n=249	%Acid bedrock S-deposition N-deposition Precipitation Run off	%Coarse sediment %Thin soil %Basic bedrock %Intermediate bedrock %Lake area	0.17	TOC	pH Mg, K SO_4	0.43
	Summer n=84	%Rock outcrop %Thin soil %Norway spruce >70%	%Peat %Ombrogenic peat %Basal area >3m^2 ha^{-1} N-dep Vegetation period Mean temperature	0.45	pH ANC Ca, Mg	TOC	0.59
	Autumn n=83	%Acid bedrock S-deposition N-deposition Precipitation Run off	%Coarse sediment	0.40		Mg, K	0.62
Central (River Dalälven catchment)	All seasons n=281	%Forest land %Clear-cut %Agricultural land	%Wetland %Peat %Minerogenic peat %Basal area >3m^2 ha^{-1} %Deciduous trees>50%	0.22	pH ANC Ca, Mg, Na SO_4, NO_3	TOC	0.46
	Spring n=94	ns	ns	ns	pH ANC Ca, Mg	TOC	0.73
	Late autumn n=94	%Forest land %Clear-cut	%Wetland %Peat %Minerogenic peat %Basal area >3m^2 ha^{-1} %Deciduous trees>50% Mean temperature	0.33	pH ANC Ca, Mg SO_4, NO_3	TOC	0.65

Löfgren et al. 2017