

Impacts of harvesting practise on base cation budgets of coniferous stands in Finland – a sustainability study

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Background

- Binding obligations to reduce fossil fuel emissions of GHGs (Kyoto protocol)
 - Substitution of the consumption of fossil energy with renewable energy
 - Intensification the utilization of forest bioenergy, regarded as carbon neutral energy source
- However, more intensive harvesting regimes **may increase the output of base cations from the site** in comparison to stem-only harvesting
 - Negative impacts to long-term sustainability of site fertility and productivity?

The amount of biomass and nutrients removed in harvesting vary

- Tree species
- The specific nutrients removed
- Developmental stage of the stand
- Site productivity & fertility
- Harvesting regime



Aim of the study

- To simulate the impacts of **final felling** harvestings on base cation (**BC: Ca^{2+} , K^{+} and Mg^{2+}**) budgets in boreal coniferous forests under the scenarios of:
 - stem-only harvesting (**SOH**)
 - whole-tree harvesting (**WTH**)
 - WTH + stump and root harvesting (**WTSR**)

Study approach

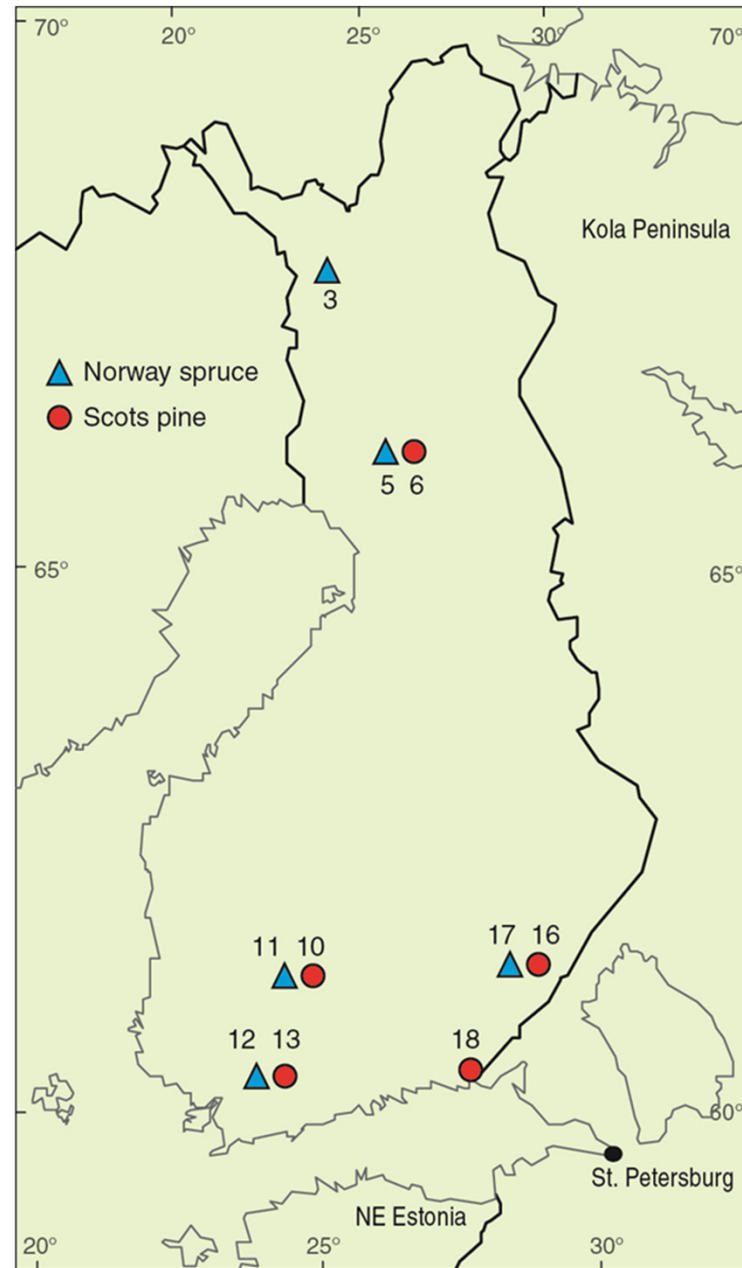
- Calculation of **BC exports** in the final fellings
- A mass balance approach was used:
base cations (BC) in **mean annual fluxes** of
 - TD = total deposition (wet and dry)
 - W = weathering (Olsson et al. 1993)
 - L = leaching, and
 - H = harvesting removals
- **Sustainability index (SI)** was calculated for each harvesting scenario and BC as net change in the base cation pool of the soil: **$SI = TD + W - L - H$** .

Study sites

- 5 Scots pine stands
- 5 Norway spruce stands

ICP Forests Level II plots

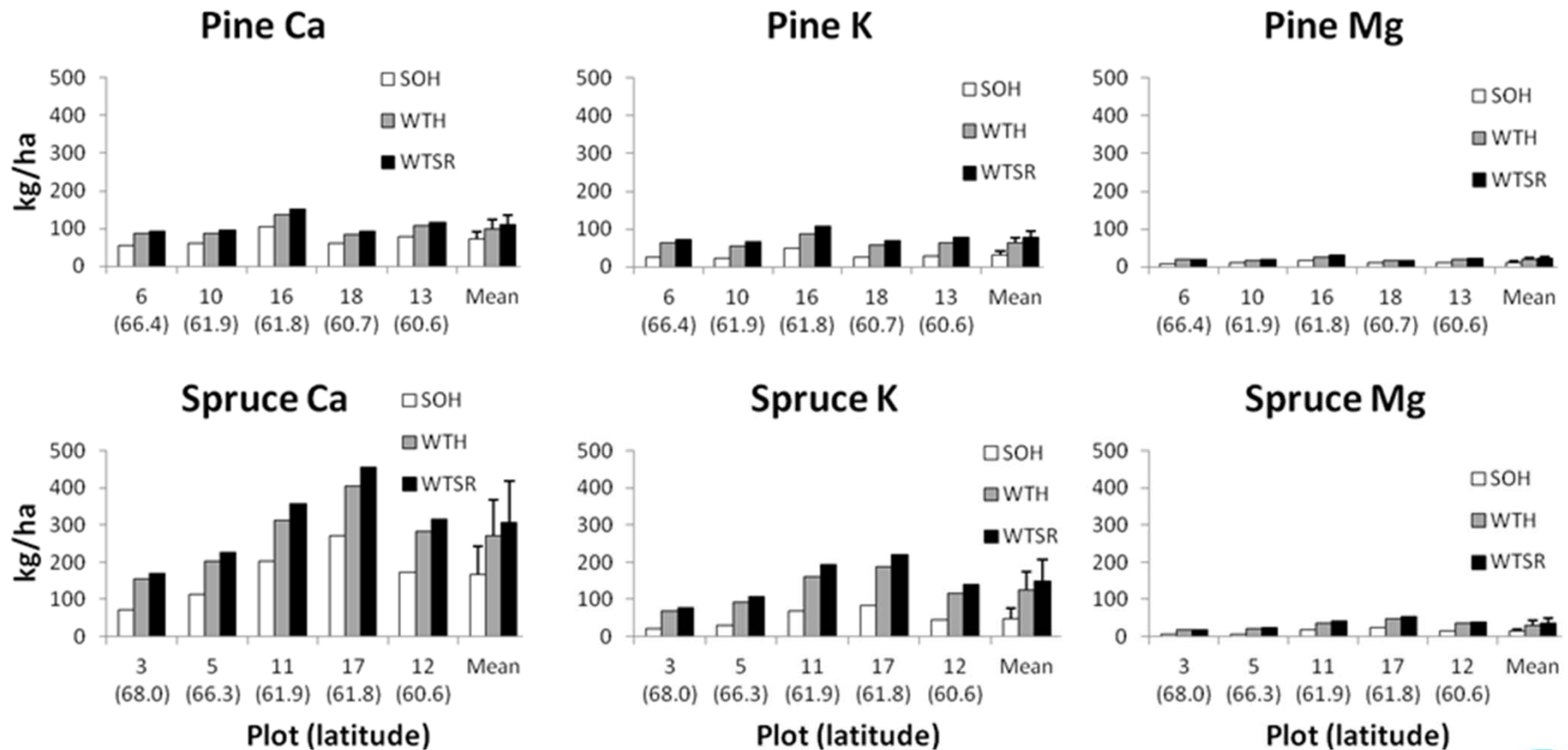
- managed forests
- age range of dominant trees 59-124 yrs



BC in harvested biomass in final felling

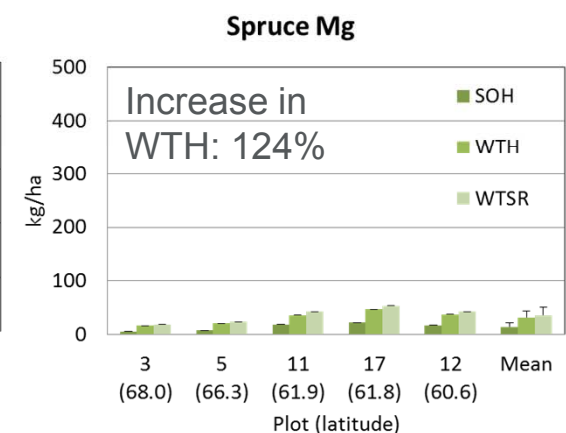
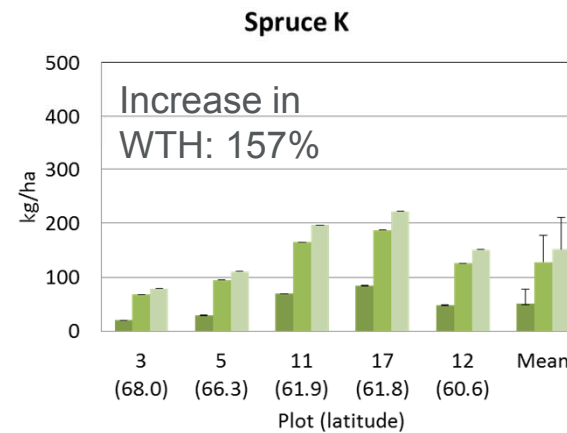
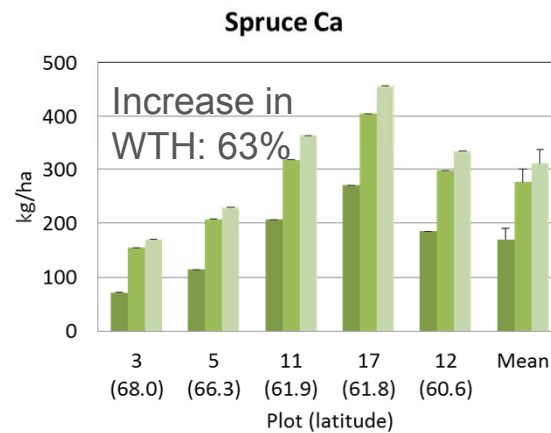
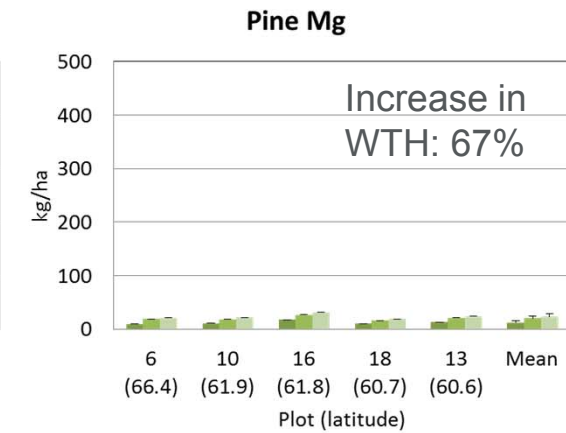
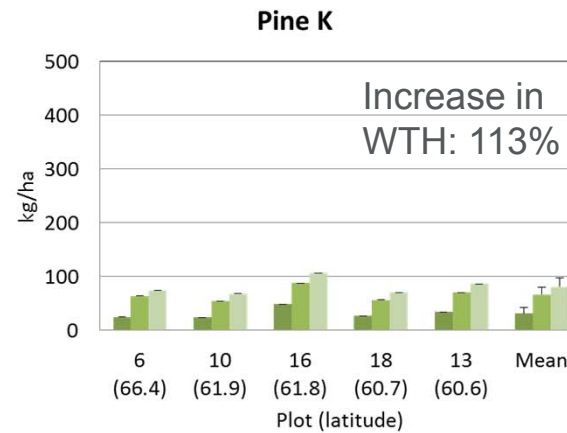
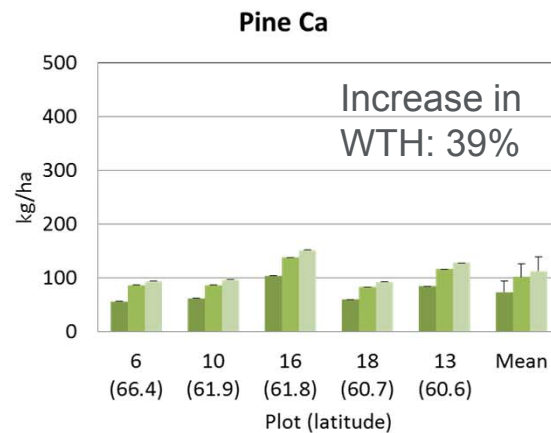
- One final felling only considered
- Biomass functions of Repola et al. (2007) applied to estimate stocks of tree compartments: stem wood, bark, dead & living branches, needles, roots, stumps
- K, Ca, Mg concentrations in tree compartments measured in earlier studies were applied
- Calculation of BC stocks removed:
 - Sum of BC stocks in biomass compartments in each harvesting scenario (SOH, WTH, WTHRS)
- Removal estimates applied in WTH and WTHRS:
 - 60% needles
 - 70% stumps and large roots,
 - 80% living and dead branches

Ca, K and Mg stocks in harvested biomass



Ca, K and Mg stocks in harvested biomass

spruce/pine			
	SOH	WTH	WTRs
Ca	2.3	2.7	2.7
K	1.6	1.9	1.9
Mg	1.2	1.6	1.5



WTRs: further increase of 10-22%

27.5.2015

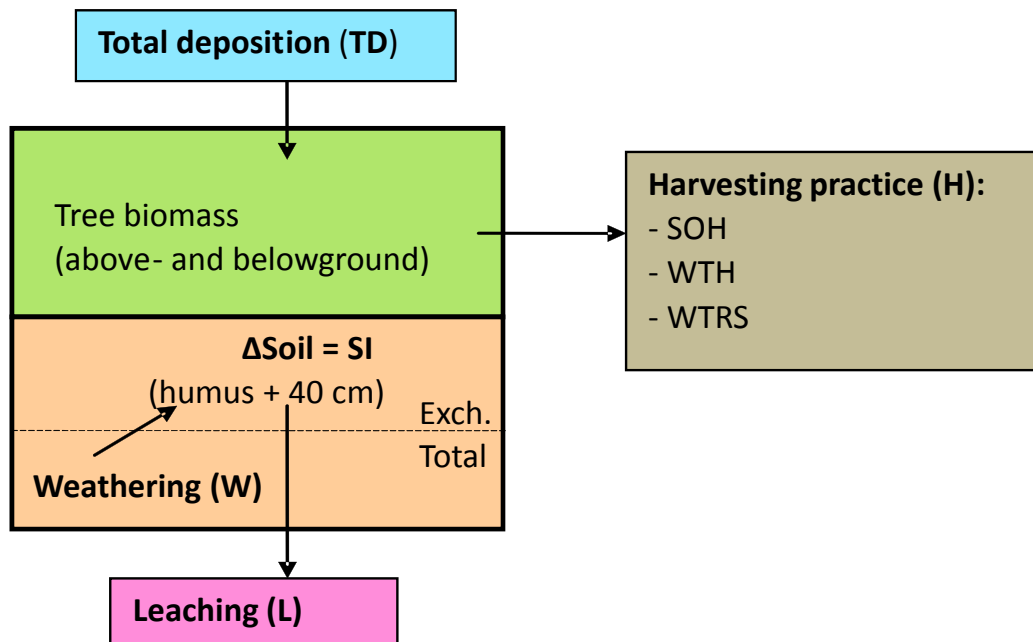
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A mass balance approach

Sustainability index = net change in soil base cation store on an annual basis (**kg/ha/yr**)

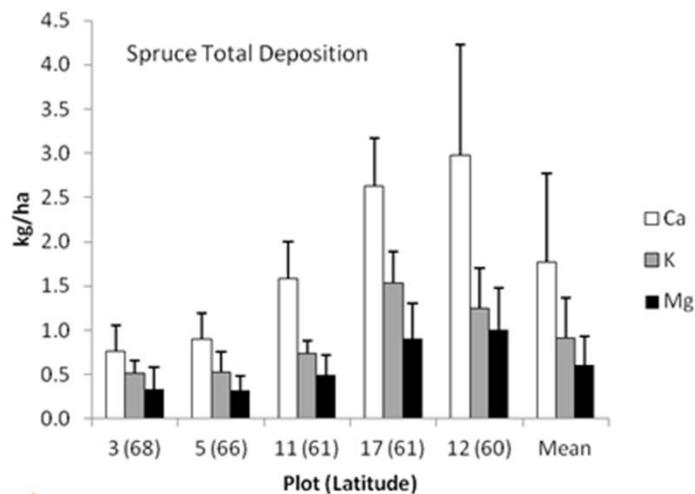
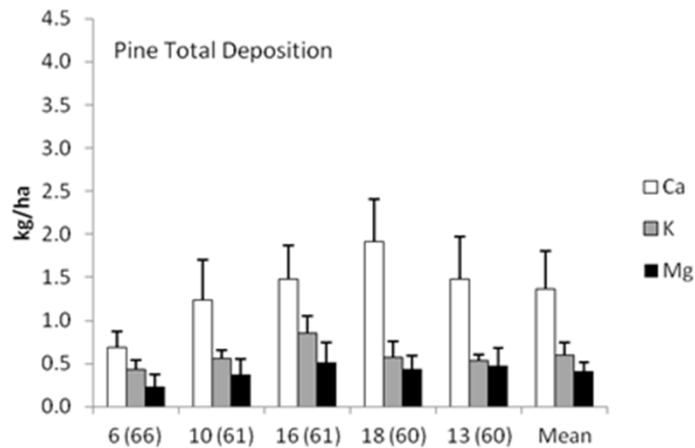
$$SI = TD + W - L - H$$

Index for hypothetical harvesting impacts on soil base cation sustainability i.e., negative if outflux > influx



$$SI = TD + W - L - H$$

Annual Total Deposition TD



- Annual average of 1999 – 2007
 - Throughfall TF
 - Bulk deposition BD
 - Dry deposition estimated using sulphate in TF as an inert tracer:
 - Enrichment factor: $EF = \frac{TF_{SO_4}}{BD_{SO_4}}$
 - $TD = EF \times BD_{K/Ca/Mg}$
- (Ukonmaanaho 2001)

$$SI = TD + W - L - H$$

Annual Weathering flux W

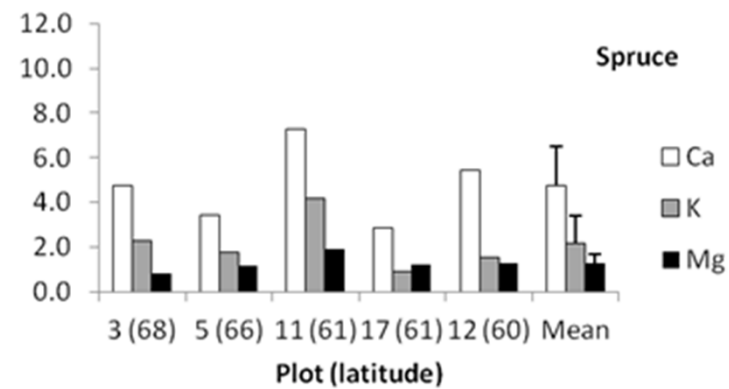
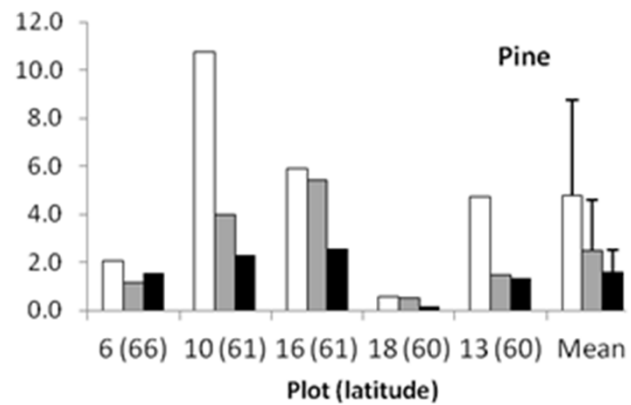
- Estimated by the weathering functions by Olsson et al. (1993):

Function	r
$W_{Ca} = -111.16 + 260[X_{Ca}]$	0.86
$W_{Mg} = -29.28 + 0.285[X_{Mg}]$	0.89
$W_K = -311.89 + 0.208[X_K]$	0.81

- $X_{Ca/Mg/K}$ = effective temperature sum * Ca/Mg/K conc. in C horizon
- Functions derived from measured Zr depletion estimates

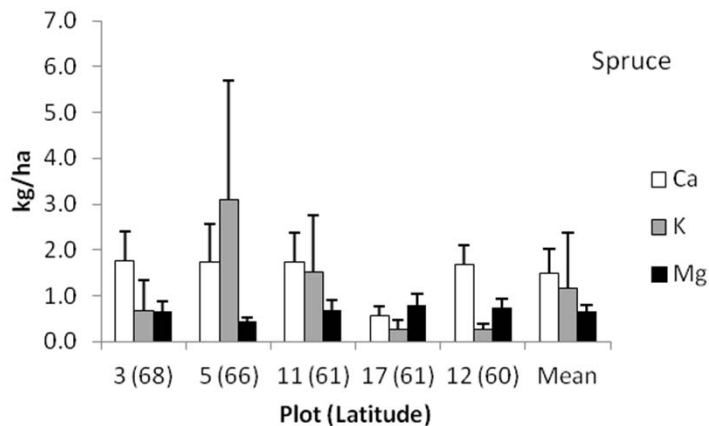
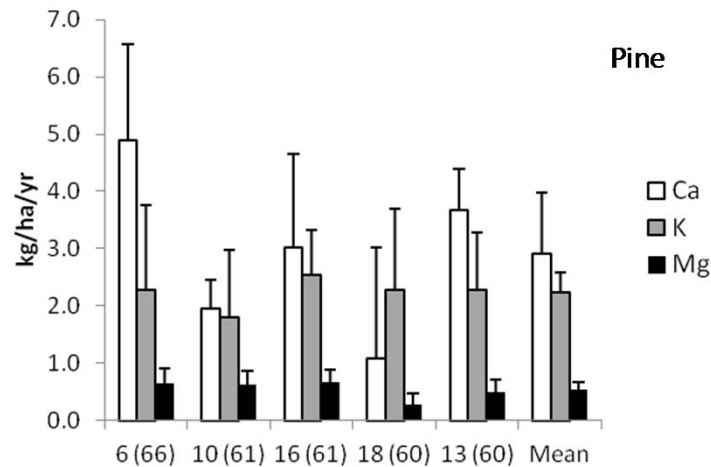
*Olsson M., Rosén K. and Melkerud P.A. 1993. Regional modelling of base cation losses from Swedish forest soils due to whole tree-tree harvesting. Applied Geochemistry, Suppl. Issue No. 2: 189–194.

Weathering rates kg/ha/yr



$$SI = TD + W - L - H$$

Annual Leaching flux L



- Annual average of 1999-2007
 - Percolation water sampling, depth 40 cm

$$L = SW_{mm} * SW_{Ca / K / Mg}$$

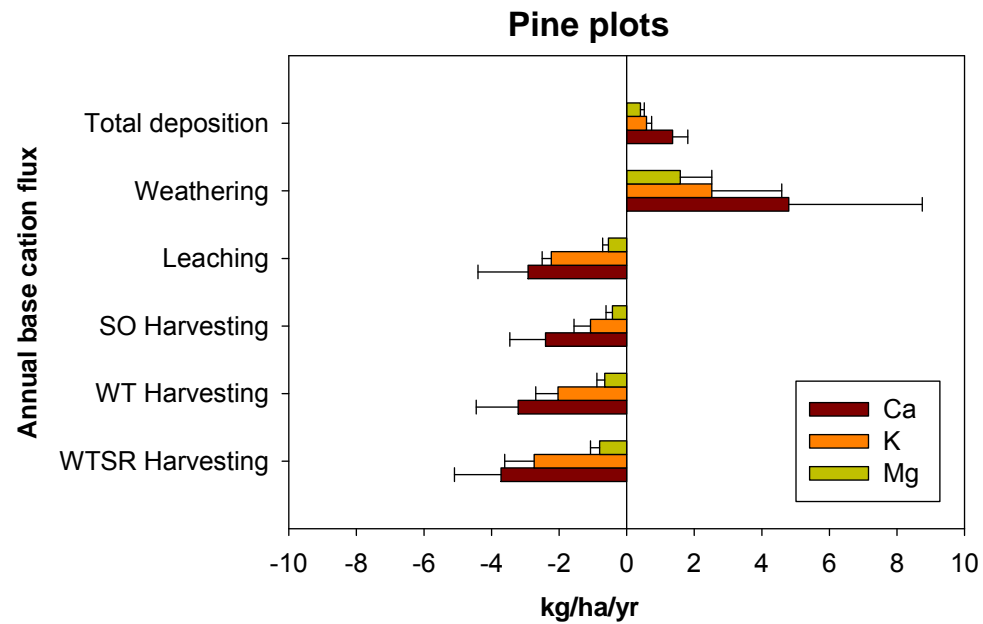
- Estimation of water flux by sulphate budget method:

$$SW_{mm} = TF_{SO4} \times TF_{mm} / SW_{SO4}$$

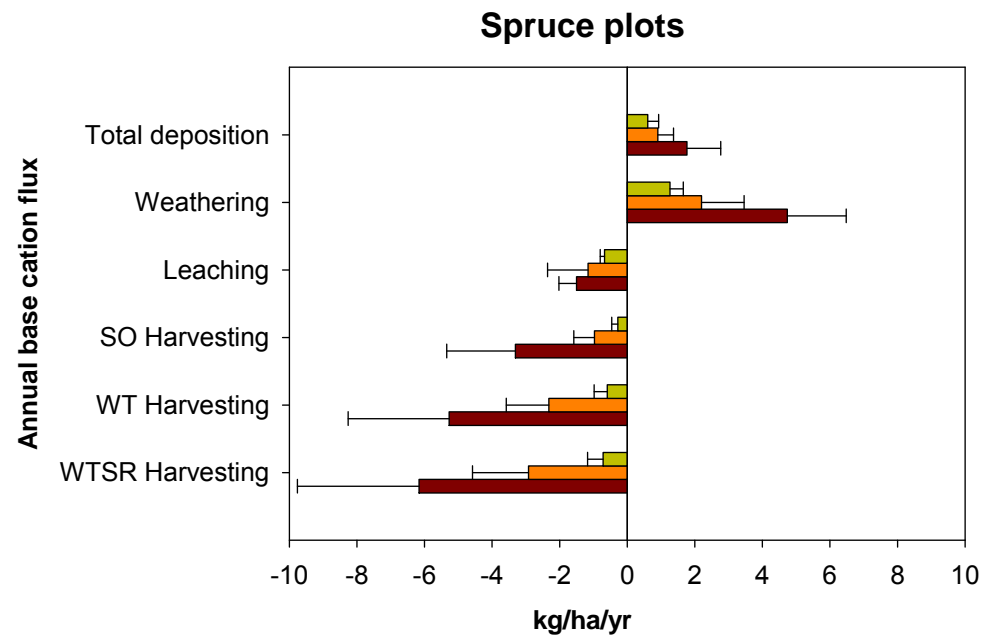
$$SI = TD + W - L - H$$

Annual Harvesting flux H

- Current mean annual increment (CAI) during 2000-2005 was used to represent the annual harvesting flux
- $H \text{ flux} = \text{CAI} * \text{BC conc. in each tree biomass compartment}$



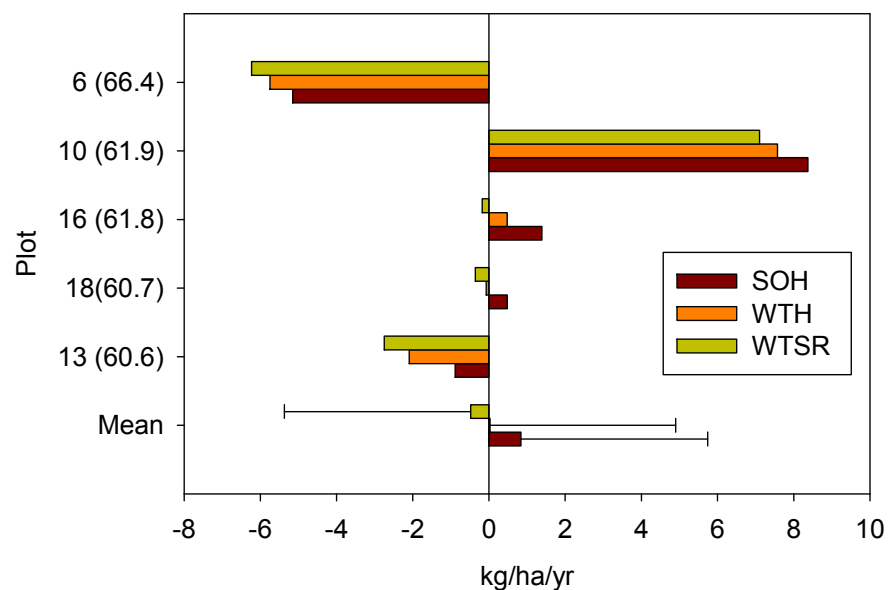
SUMMARY of annual base cation fluxes
- means for tree species



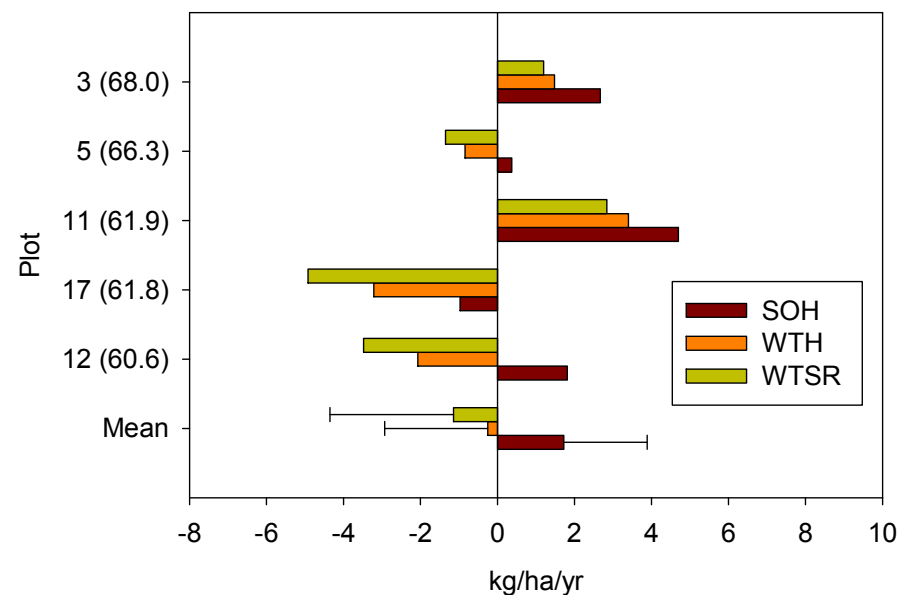
Sustainability index = TD + W – L – H

Calcium

Pine



Spruce

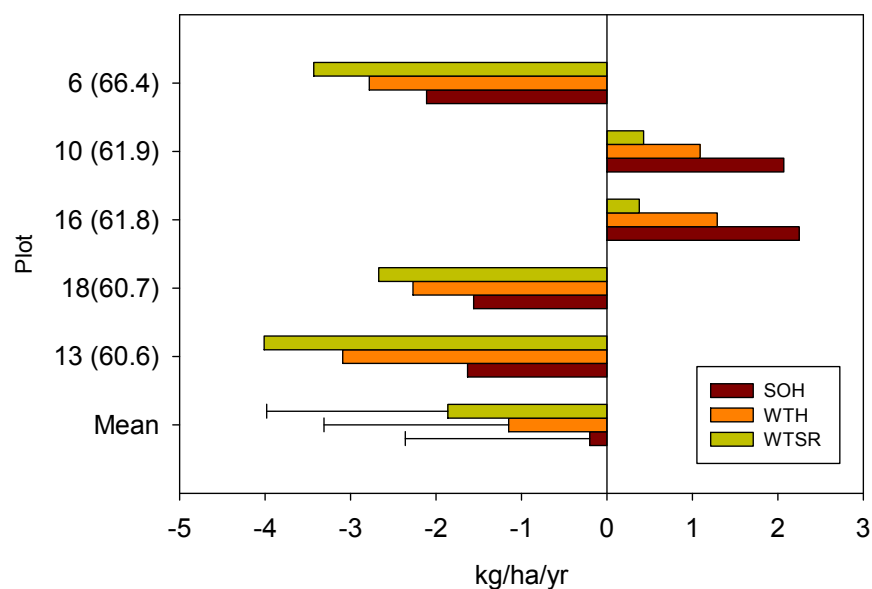


Averages: SOH +, WTH -, WTSR -

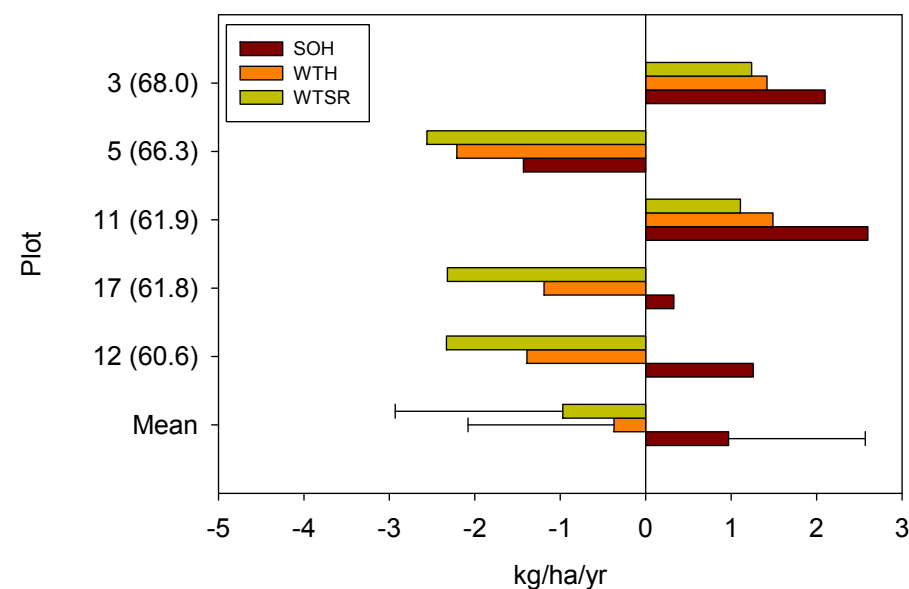
Sustainability index = $TD + W - L - H$

Potassium

Pine



Spruce

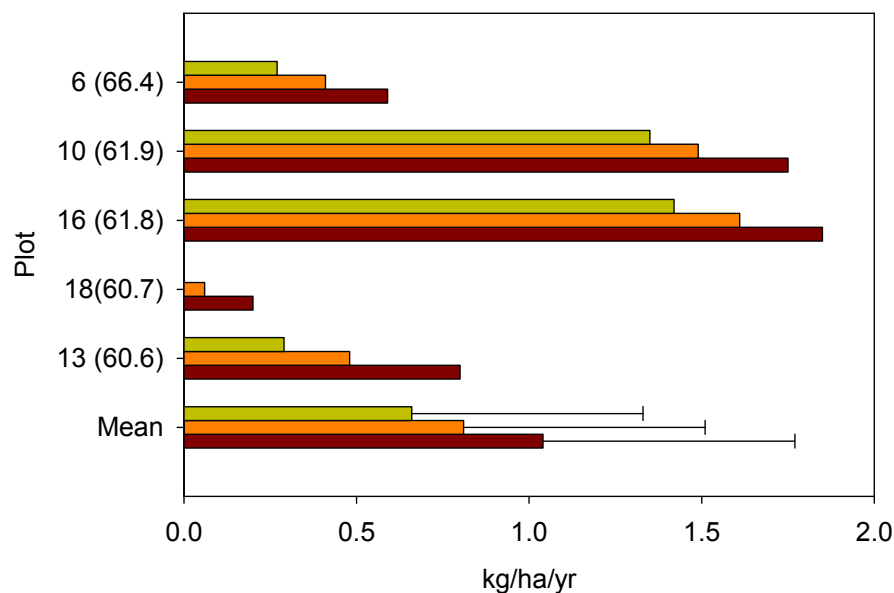


Averages: SOH - for pine, WTH -, WTSR -

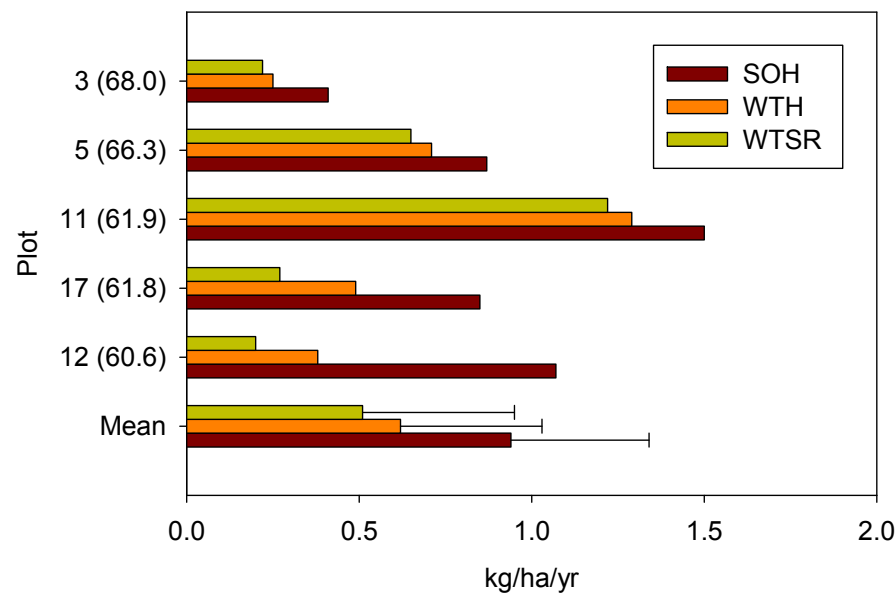
Sustainability index = TD + W – L – H

Magnesium

Pine



Spruce



Averages: SOH: +, WTH: +, WTSR: +

Conclusions

- Total deposition of BC: **spruce stands > pine stands**
- Total deposition and harvesting removals of BC decreased northwards for spruce
- BC amounts in the final fellings **spruce > pine** in all scenarios
- BC removals in **WTH and in WTSR did not differ** significantly from each other
- The sustainability index for **pine K, spruce K, spruce Ca** were **negative** under WTH and WTSR
- **SI for Mg** on average **positive** in all harvesting scenarios

Thank you!