Session: Nutrient mining and input output balances

Potassium Dynamics in Soil under different Cropping Systems and Nutrient Management Practices

Ingrid Öborn

Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden

ingrid.oborn@vpe.slu.se

SLU

Acknowledgement

Collaborators

Stefan Andersson[1], Helena Bengtsson[1], Ylva Andrist Rangel[1,2], Anthony C Edwards[2], Stephen Hillier[2], Johan Holmqvist[3], Allan Lilly[2], Lennart Mattson[1], S Ingvar Nilsson[1], Ed Paterson[2], Magnus Simonsson[1], Bo Stenberg[1], Harald Sverdrup[3] & Willie Towers[2]

[1] Swedish University of Agricultural Sciences (SLU)
[2] Macaulay Land Use Research Institute, Aberdeen, UK
[3] Lund University, Sweden

Funders

The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas), SLU, Macaulay Land Use Research Institute, Macaulay Enterprise Limited, MISTRA (Food 21)

THE MACAULAY INSTITUTE

SLU

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Content

✓ Introduction

✓ Input-output K balances – different approaches, what do they tell?

✓ 'Nutrient mining' – how to assess soil K weathering rates and potential?

✓ Results from research combining (i) simulation modelling, (ii) long-term field experiments, (iii) qualitative and quantitative characterization of K sources and sinks, and (iv) GIS based maps

✓ Conclusions and challenges ahead

Swedish University of Agricultural Sciences
www.slu.se

Introduction - Why research on K?

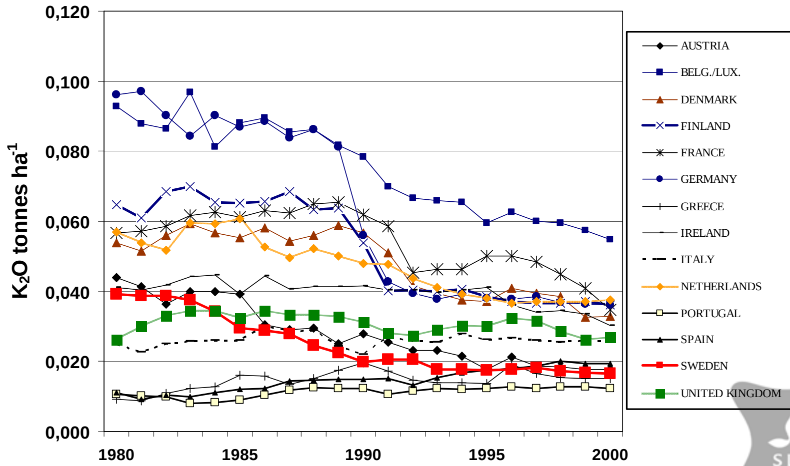
- Strong focus on N and P
- Decrease in K fertiliser application in many European countries *(see Fig)*.
- Negative K balances have been reported at farm and field level, especially in grass dominated low input systems (e.g. organic systems).
- Delivery of K from soil mineral sources can be of crucial importance for the long-term sustainability – how to assess?.
- There are areas where there will be a need for K-supplementation – but where?
- **Project: "K-dynamics in agricultural soils– quantifying K sinks and sources including mineral weathering and identifying soils (areas) in need of K-supplementation"**
-

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubanesw Management for Food Production, Quality and Reduced Environmental Damage.

K fertiliser sale/use in Europe 1982-2002

tonnes K_2O per ha and year

(International Fertilizer Industry Association 2004)

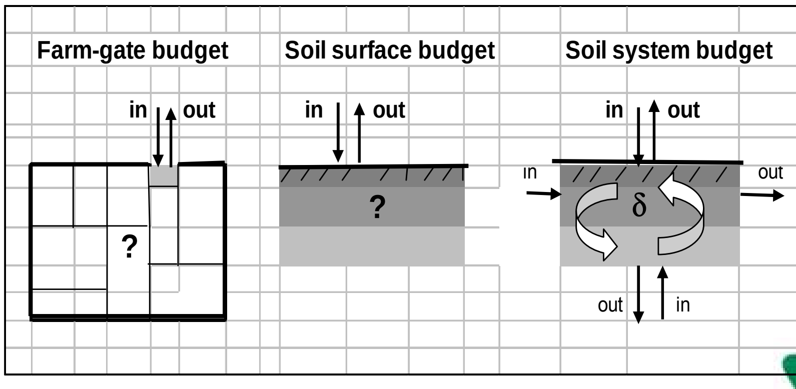


Öborn et al, 2005

Introduction - Why research on K?

- Strong focus on N and P
- Decrease in K fertiliser application in many European countries *(see Fig)*.
- Negative K balances have been reported at farm and field level, especially in grass dominated low input systems (e.g. organic systems).
- Delivery of K from soil mineral sources can be of crucial importance for the long-term sustainability – how to assess?.
- There are areas where there will be a need for K-supplementation – but where?

Nutrient balances – different approaches. What do they tell?

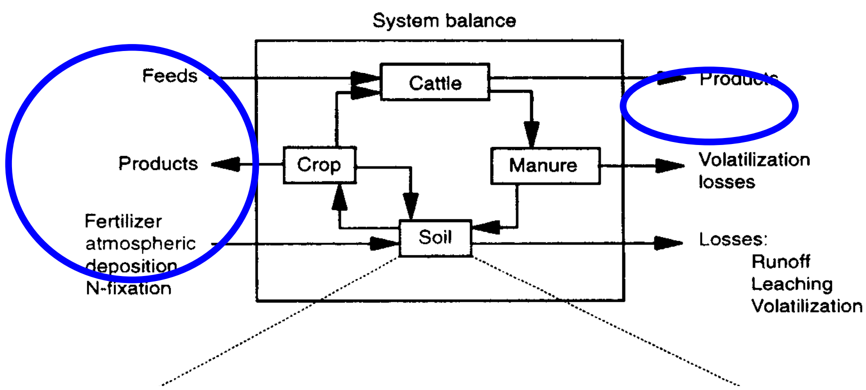


(Oenema et al., 2003)

Swedish University of Agricultural Sciences
www.slu.se

IO4

Input-output K balances – different approaches, what do they tell?



Farm-gate balance – following the 'cash-flow'

Barn balance

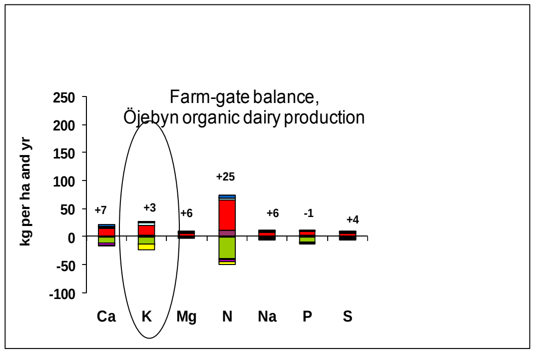
Field balance

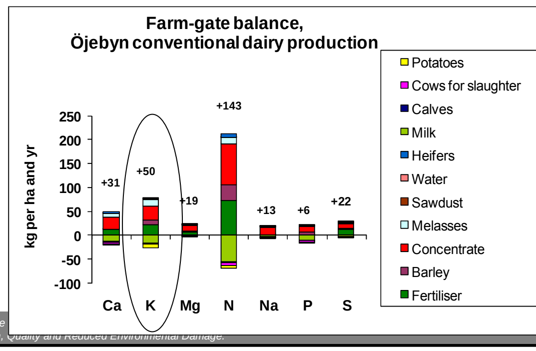
(Öborn et al., 2003)

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

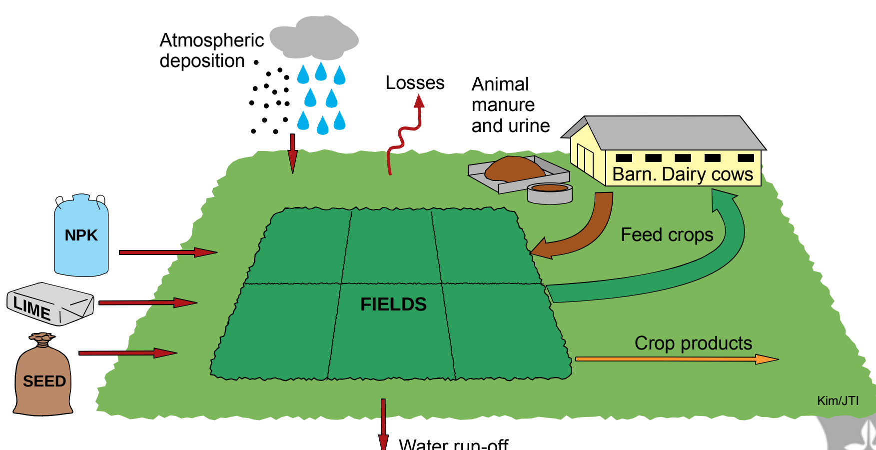
Slide 8

IO4 kan tas bort?
ingrido, 11/4/2009

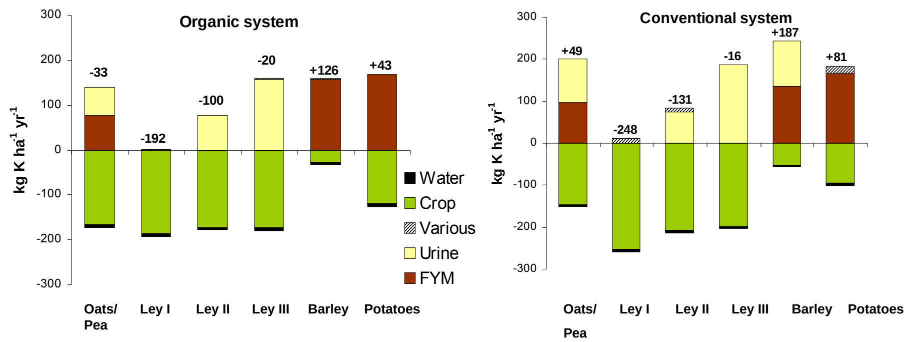




Field balance (soil surface balance) – including 'biophysical' flows

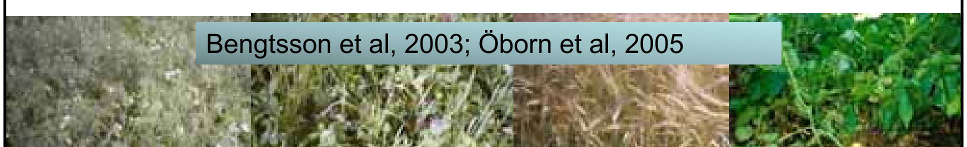


Field K balances in a 6-yr mixed rotation



Mean K balance -29 kg ha^{-1} yr^{-1}

Mean K balance -13 kg ha^{-1} yr^{-1}



Examples of soil pools of K Ap horizon (0- 25 cm), kg ha^{-1}

Soil type (FAO)	Tot-K	Aq reg K	2M HCl K	Ex-K
Loamy sand Dystric Cambisol	43 100	12 800	-	80
Loamy sand Eutric Regosol	**65 500**	**-**	**2 500**	**100**
Silt loam Thionic Gleysol	**66 000**	**-**	**6 800**	**220**
Clay(illitic) Eutric Cambisol	84 700	-	13 300	510

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

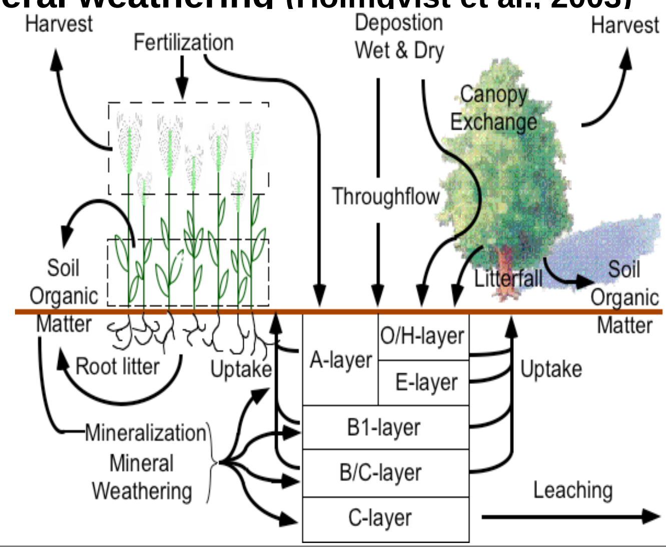
Project: “K-dynamics in agricultural soils– quantifying K sinks and sources including mineral weathering and identifying soils (areas) in need of K-supplementation

Photo C Watson

‘Nutrient mining’ – how to assess soil K weathering rates and potential?

(i) Simulation modelling to predict weathering rates

Application of the biogeochemical steady-state model PROFILE to estimate K release from mineral weathering (Holmqvist et al., 2003)



Estimated K release (steady-state) from mineral weathering using the PROFILE model

0-40 cm soil depth, soil temp. 2-10°C (Holmqvist et al., 2003)

- Sand and sandy till
  3-5 kg K $ha^{-1}yr^{-1}$
- Silt loam
  10-20 kg K $ha^{-1}yr^{-1}$
- Clay (illitic)
  50-80 kg K $ha^{-1}yr^{-1}$

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

The influence of temperature and moisture on K weathering rates

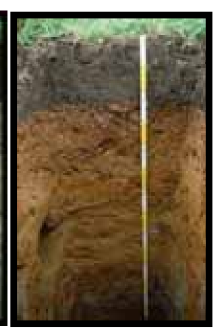
Soil moisture had a great influence:

	Field capacity →	**Wilting point**
Sa:	4-5 kgK/ha yr →	1-2 kgK/ha yr
Silt:	20 kgK/ha yr →	7-8 kgK/ha yr
Clay:	90 kgK/ha yr →	58 kgK/ha yr

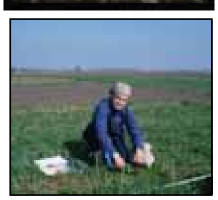
The weathering rate increased 5-10% at an average temperature increase on 1°C (interval 2-10°C)

‘Nutrient mining’ – how to assess soil K weathering rates and potential?

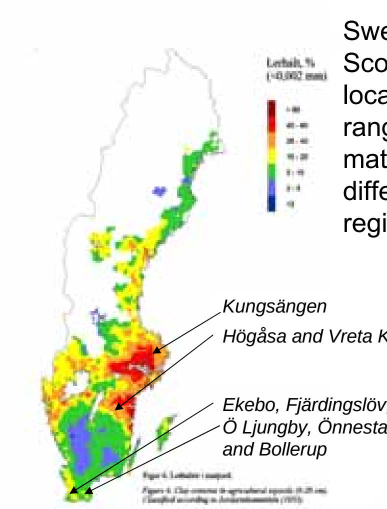




(ii) Long-term field experiments, historical data and re-sampling



Long-term field experiments and soil maps



Swedish and Scottish sites located on a wide range of parent materials and in different climatic regions

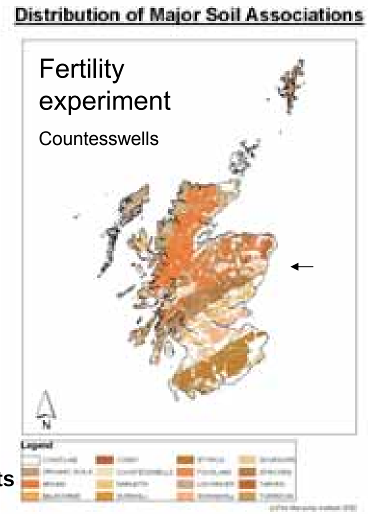
Kungsängen

Högåsa and Vreta Kloster

Fertility experiments

Ekebo, Fjärdingslöv, Ö Ljungby, Önnestad, and Bollerup

Cropping systems experiments



Swedish University of Agricultural Sciences
www.slu.se

Experimental site – Countesswells, Aberdeen, UK

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Experimental design, site and soil data

30 year field experiment

Rotations

Grass I perennial rye grass (*Lolium perenne*, L.) 11 yrs, 2 cuts yr^{-1}

Cereals 2 + 7 years (NPK fertilisers)

Grass II perennial rye grass 10 yrs, 3 cuts yr^{-1}

Treatments Grass I, Grass II

K0, K65 kg ha^{-1} yr^{-1}

N and P fertiliser added annually

Design

Randomized block design,
5 replicates

Parent material

Glacial till derived from granitic bedrock

Climate

Annual average 7.9°C, 791 mm

Soil type

Countesswells association, Dess series (freely draining iron humus podzol)

Dystric Cambisol (FAO)

Typic Fragiorthod (USDA)

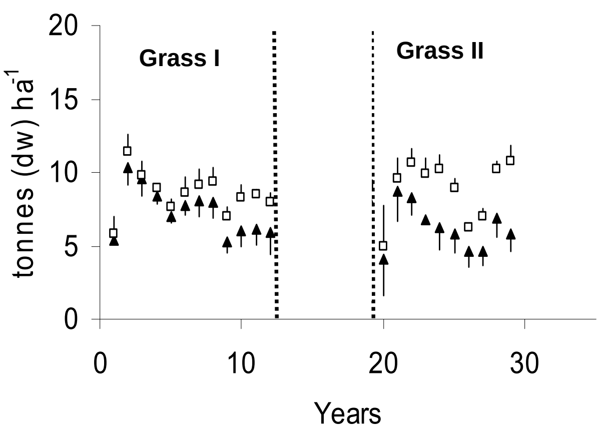
Soil characteristics

org C Ap 5.1%, Bs 1.5%

clay 1-4% silt 17-22% sand 75-82%

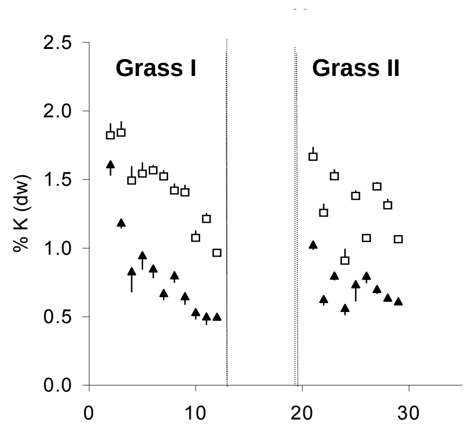
pH_{CaCl2} 4.9-5.2

Annual biomass harvest
❑ 65 kg K; ♦ 0 K

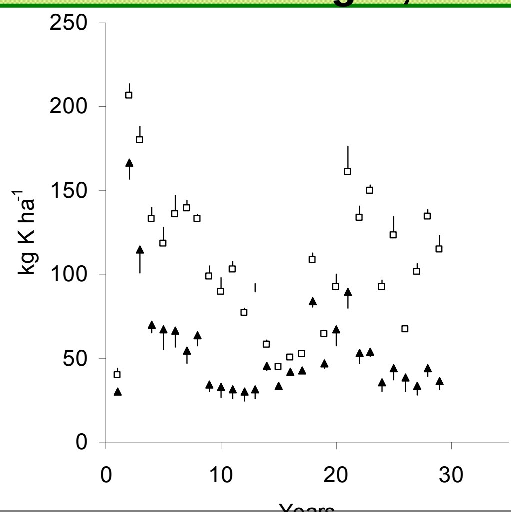


This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Mean annual K conc (%) in grass
❑ 65 kg K; ♦ 0 K

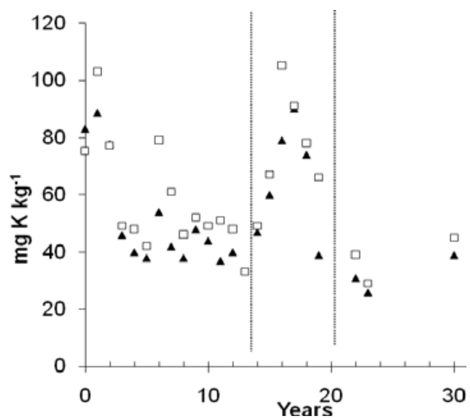


Mean annual K-off take in biomass harvest (kg K ha^{-1} yr^{-1}) in grass
❑ 65 kg K; ♦ 0 K

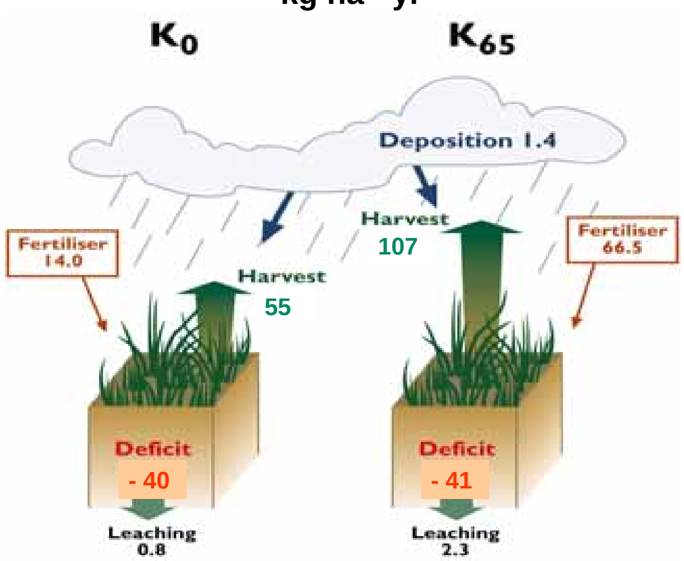


This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Exchangeable K (acetic acid extractable) 0-15 cm; ❑ 65 kg K; ♦ 0 K



Average K mass balances for a 30 year period, kg ha^{-1} yr^{-1}



This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Examples of soil pools of K Ap horizon (0- 25 cm), kg ha^{-1}

Soil type (FAO)	Tot-K	Aq reg K	2M HCl K	Ex-K
Loamy sand Dystric Cambisol	**43 100**	**12 800**	**-**	**80**
Loamy sand Eutric Regosol	65 500	-	2 500	100
Silt loam Thionic Gleysol	66 000	-	6 800	220
Clay(illitic) Eutric Cambisol	84 700	-	13 300	510

How does the K release rate relate to other soils under similar systems and climate?

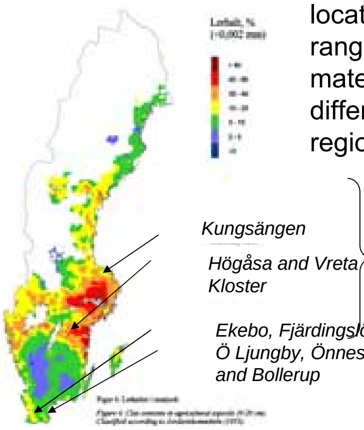
- Loamy sand (Hög) 8±10 kg ha^{-1}yr^{-1},
- Silty clay (Vre) 40± 8 kg ha^{-1}yr^{-1}
- Clay (Kun) 45±10 kg ha^{-1}yr^{-1}
- Loam (Eke) 51±12 kg ha^{-1}yr^{-1}
- Sandy loam (Fjä) 65 ± 7 kg ha^{-1}yr^{-1}

  0 PK, N fertiliser added, manure added (20-28 kg K ha^{-1} yr^{-1}) **(40 years; Simonsson et al., 2007)**

- Loamy sand, Countesswells, 38 ha^{-1}yr^{-1}
  (Öborn et al, under publication)

Long-term field experiments and soil maps

clay, %



Swedish and Scottish sites located on a wide range of parent materials and in different climatic regions

Kungsängen

Högåsa and Vreta Kloster

Ekebo, Fjärdingslöv, Ö Ljungby, Önnestad, and Bollerup

Fertility experiment

Countess-wells

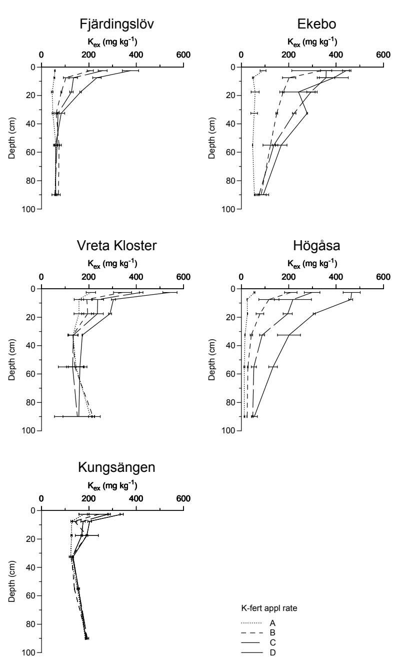
SLU's Soil Fertility Experiments (started 1957)

A. No K

B. K replacement

C. K repl + 40kg K

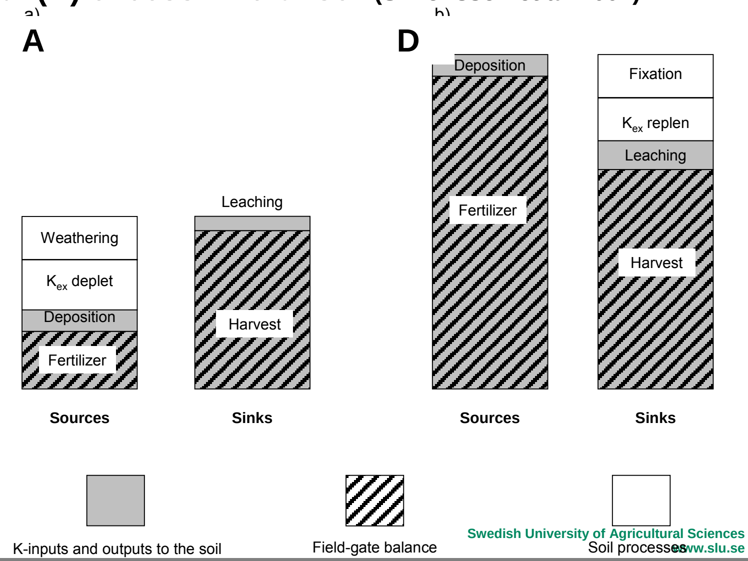
D. K prel + 80 kg K



Concentrations of exchangeable K (K_{ex}) in the soil profiles (0-110 cm) (*n* = 2).

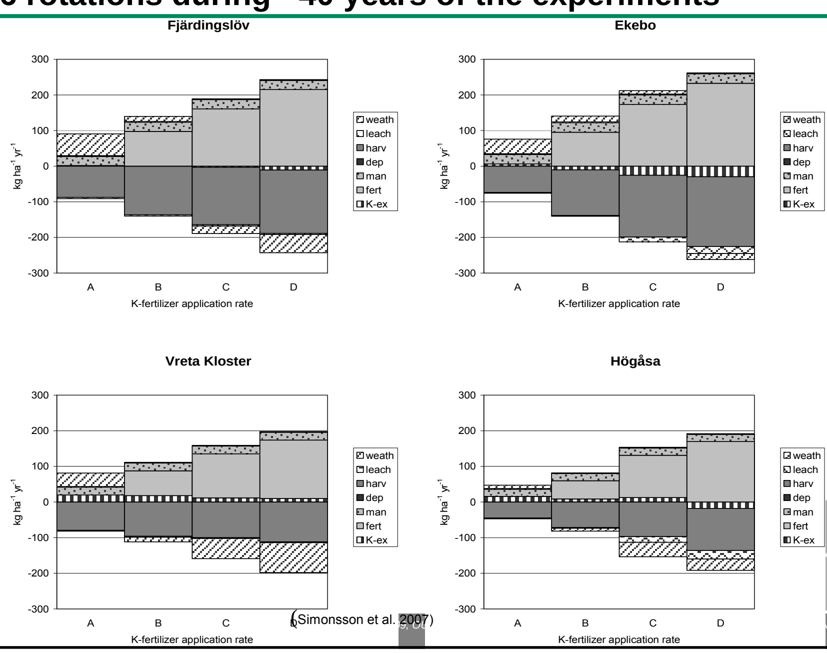
This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Schematic visualization of sources and sinks (kg ha^{-1}) of K in field balance for (A) low K input (only manure), and (D) excess K fertiliser (Simonsson et al. 2007)



Swedish University of Agricultural Sciences
www.slu.se

Average sources (positive) and sinks (negative) of K, over 4–6 rotations during ~40 years of the experiments



(Simonsson et al. 2007)

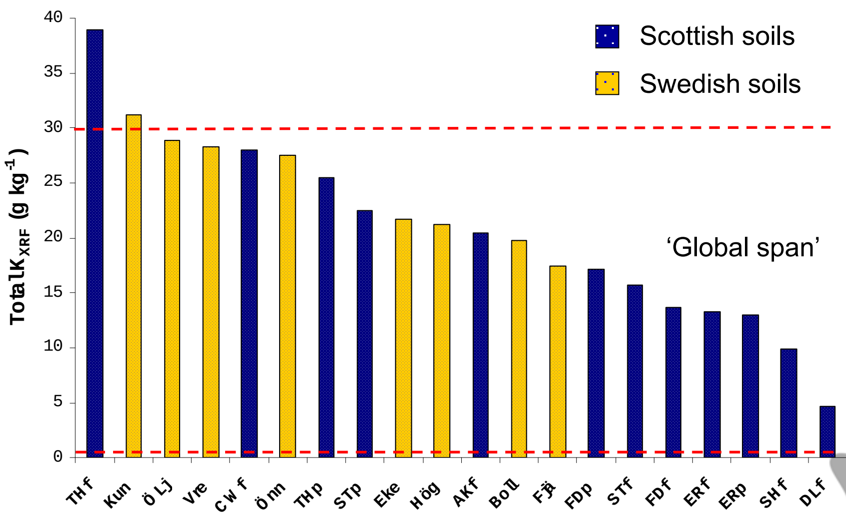
‘Nutrient mining’ – how to assess soil K weathering rates and potential?

(iii) Soil pools of K – how much K and in which form?

YAR2

RESULTS

Total K g kg^{-1} (XRF) in surface soil (Ap-horizons)

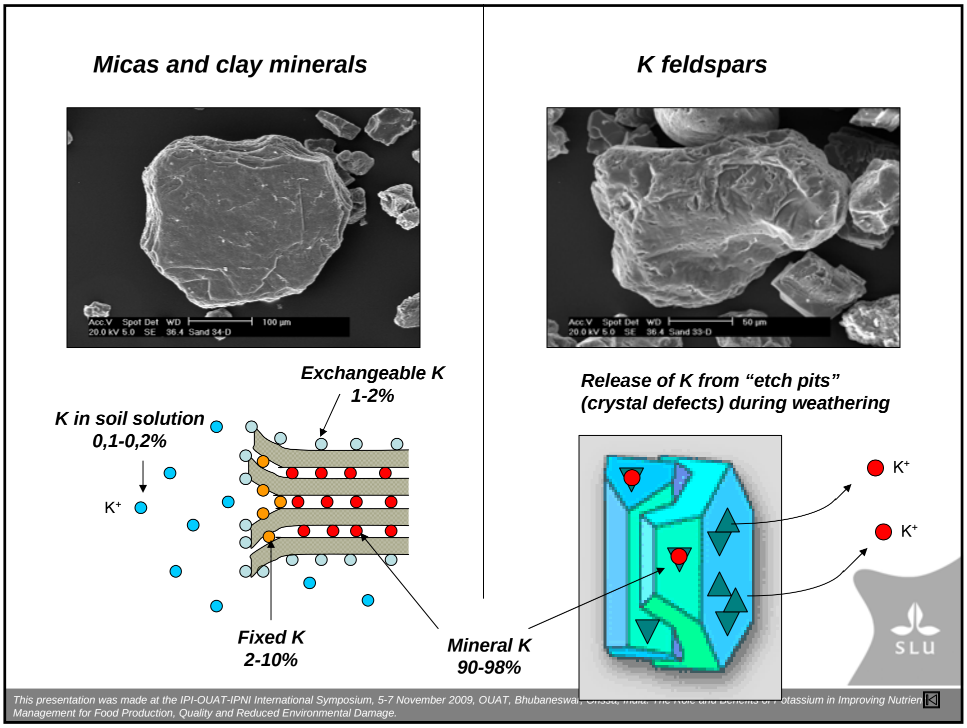


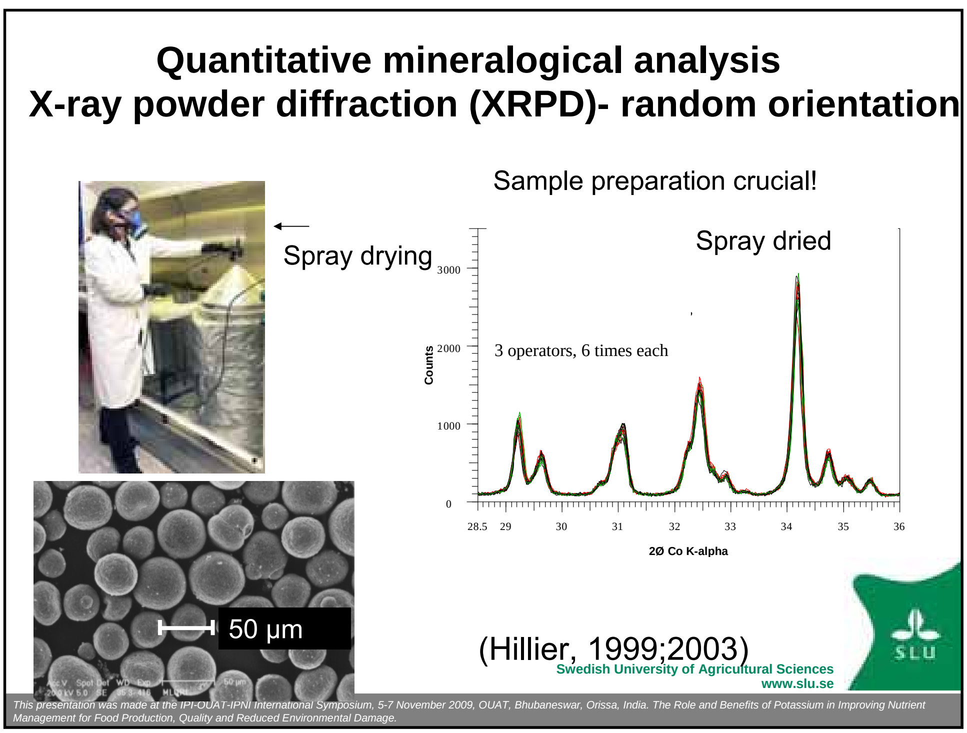
(Andrist Rangel, 2008)

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

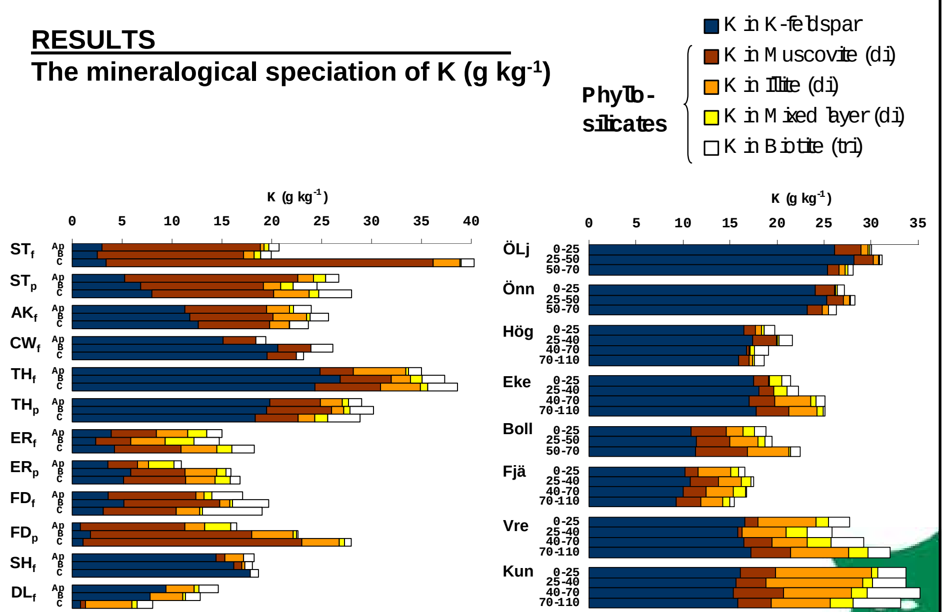
Slide 34

YAR2 based on sugbeswunt quatitative mineralogical analysa and normative calcutaion. useing the same set of mineral forlul afor all soils, a minrertalogical bugeting appraoch was ......next slide...were the speciation of total K could be reveals. , something that is imotrtaint ti tnks to be able to extimate the potential K deliver capacit of teh soils.
Andrist Rangel, 8/23/2008


Micas and clay minerals
K feldspars
Acc.V Spot Det WD 100 µm
20.0 kV 5.0 SE 36.4 Sand 34-D
Acc.V Spot Det WD 50 µm
20.0 kV 5.0 SE 36.4 Sand 33-D
Exchangeable K
1-2%
K in soil solution
0,1-0,2%
K+
Fixed K
2-10%
Mineral K
90-98%
Release of K from "etch pits"
(crystal defects) during weathering
K+
K+
SLU
This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.


Quantitative mineralogical analysis
X-ray powder diffraction (XRPD)- random orientation
Sample preparation crucial!
Spray drying
Spray dried
3 operators, 6 times each
Counts
3000
2000
1000
0
28.5
29
30
31
32
33
34
35
36
2Ø Co K-alpha
50 µm
(Hillier, 1999;2003)
Swedish University of Agricultural Sciences
www.slu.se
SLU
This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

RESULTS
The mineralogical speciation of K (g kg^{-1})



(Andrist Rangel, 2008)

Swedish University of Agricultural Sciences
www.slu.se

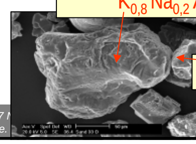
Conclusions

- ✓ In a K deficient grass system the total net K off-take (30 yrs) was 1100 kg K ha^{-1} (38 kg ha^{-1} yr^{-1}) being released from non-exchangeable sources.
- ✓ The Ex-K pool in the rooting zone (0-40 cm) was ~100 kg ha, i.e. Ex-K is a dynamic pool that has been replenished 10 times during the experimental period.
- ✓ Evaluation of long-term field experiments showed K release rates in the range 8-65 kg K ha^{-1} yr^{-1}
- ✓ Model simulations estimated a weathering of 3-80 kg K ha^{-1} yr^{-1} depending on e.g. soil mineralogy, soil texture, climate.

Swedish University of Agricultural Sciences
www.slu.se

Conclusions cont. and challenges

- ✓ There is a need to integrate site specific properties such as weathering potential in nutrient management (based on science).
- ✓ This requires quick quantitative methods (mineralogical and chemical) to characterize K sources and sinks
- ✓ Better understanding of and use of knowledge about the mechanisms and processes in the soil-plant-microb system
- ✓ Further development and testing of simulation models including weathering, e.g. in relation to particle size
- ✓ K-feldspars in agricultural soils: importance as K source for plants? How can we increase the utilization of feldspar K?



Expected outcomes

- ✓ Identification of soil types / areas and cropping systems in need of K-supplementation.
- ✓ User-friendly tables and/or GIS based maps showing the potential K-delivering capacity for different soil types (tables) and geographical areas (based on dominating soil type within an area).
- ✓ Inclusion of the potential K delivering capacity of different soils in extension/advisory, e.g. in K field balance calculations and for fertiliser recommendations

Thank you for your attention!