Potential to tighten P cycle in Finnish agriculture

Eila Turtola (1), Riitta Lemola (1), Jouni Nousiainen (2), Pekka Huhtanen (3), Risto Uusitalo (1) and Elena Valkama (1)

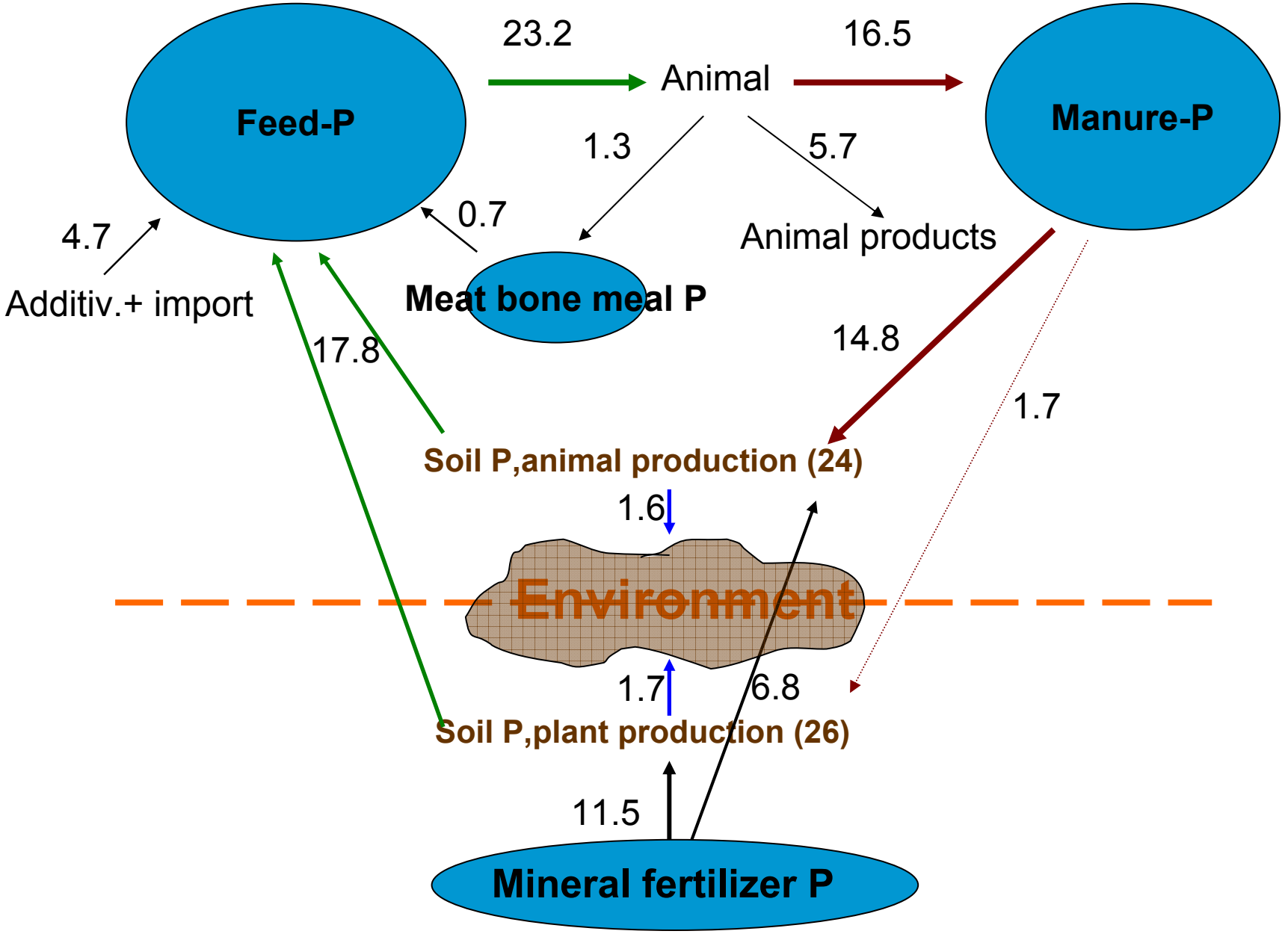
(1) MTT, Plant Production Research
(2) MTT, Biotechnology and Food Research
(3) SLU, Agricultural Research for Nothern Sweden

P-recycling in Agriculture
HELCOM and Baltic 21 Agriculture Seminar
Helsinki June 8-9, 2009

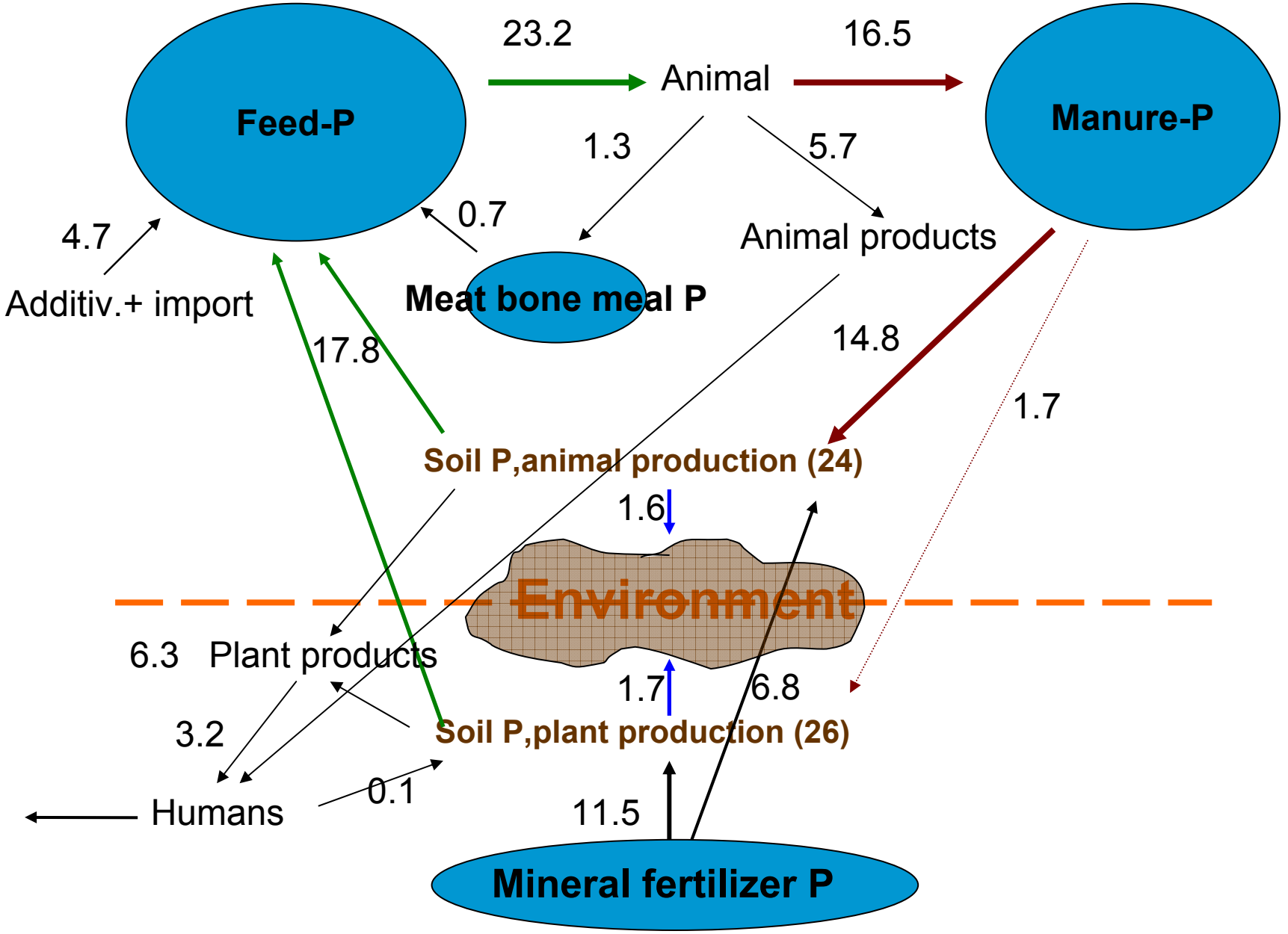
- When considering the potential to tighten P cycle of Finnish agriculture, we have to take a close look at 1) P fertilization and 2) P cycle as affected by animal husbandry

- Due to large share (80%) of cultivated land used to produce feed for livestock, the agricultural P cycle is dominated by animal husbandry

P cycle in Finnish agriculture in 2005, mill.kg y^{-1}



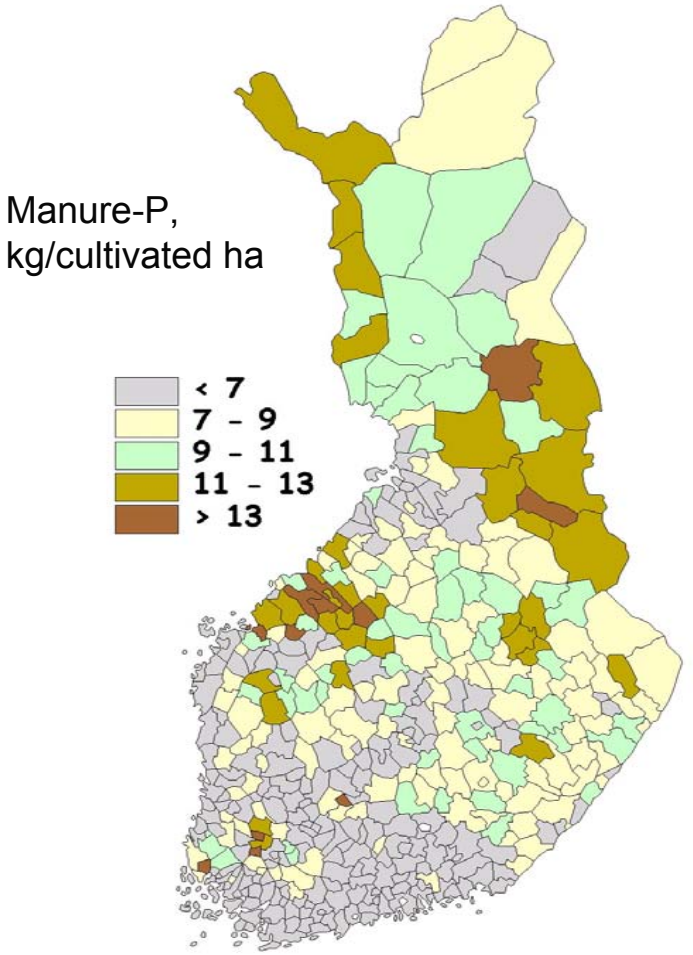
P cycle in Finnish agriculture in 2005, mill.kg y^{-1}



- In Finland, feed is transported from plant production areas to those of concentrated animal husbandry, from where manure P is not transported backwards (in Finland: long distances)

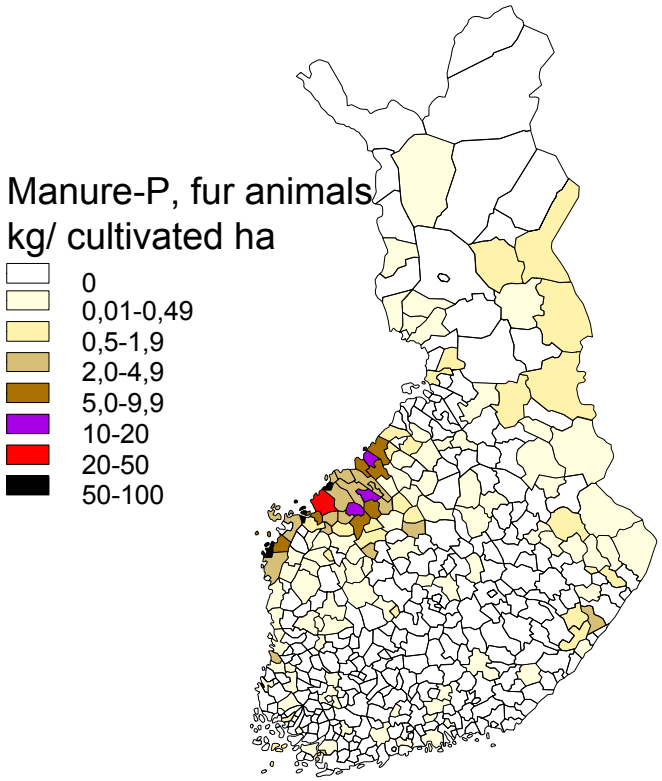
- In future, the development towards even larger units/more intensive regions of livestock will probably continue

- To facilitate efficient use of P and especially that of manure P in those regions, it is important to estimate whether there is <u>potential to adjust animal feeding in terms of P, and reach lower P contents in manure</u>



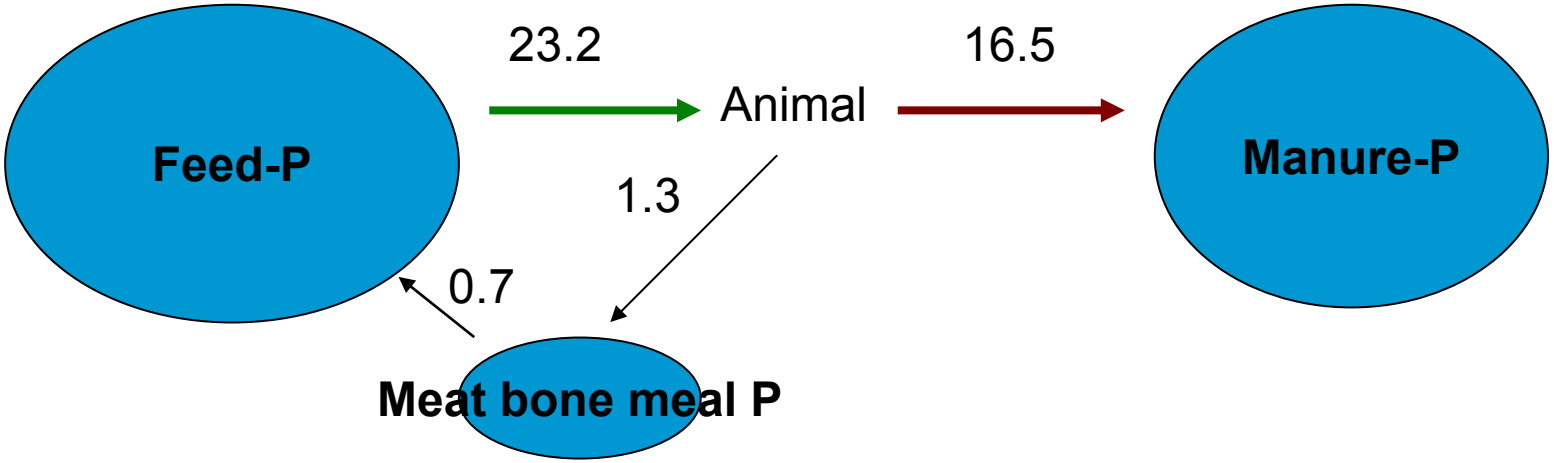
Maps: Kaarina Grek and Harri Lilja MTT

- A special case is feeding of fur animals with meat bone meal (side-product of animal production), leading to high P content of fox and mink manures. <u>Alternative routing as P source in plant production?</u>



Maps: Kaarina Grek and Harri Lilja MTT

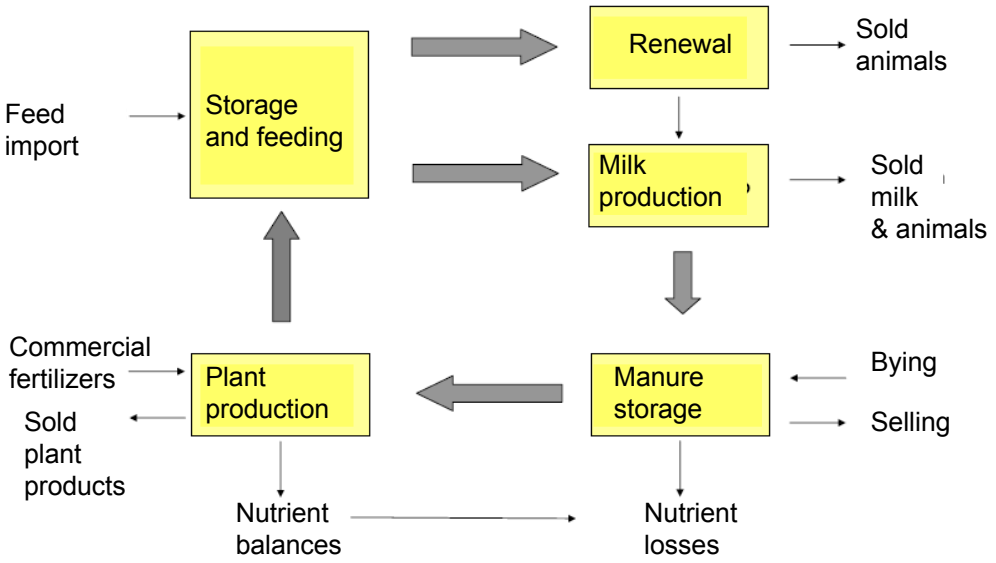
Potential to tighten P cycle in animal feeding?



Step 1: Comparison of current P feeding of animals to that justified by biological responses according to feeding trials, i.e. avoiding overuse

- The current P content of manure (year 2005) was estimated

- New P content of manures were then calculated with biological response functions, taking into account economic effects (no negative effects on the net income, Huhtanen et al.) and using specific options for different animals (cow, pig, poultry, fur animals)



Pekka Huhtanen SLU

Result (1): Adjustment of P feeding would result in 12% lower P content in manure

Area	Current manure-P mill.kg/year	Adjusted manure-P mill.kg/year
Whole Finland	16,5	14,5
Uusimaa	0,48	0,43
Varsinais-Suomi	1,9	1,7
Pohjanmaa	2,9	2,6

Jouni Nousiainen MTT, Pekka Huhtanen SLU

Step 2: Meat bone meal as P source in plant production

- Meat bone meal is the most important P containing side-product of livestock with annual content of 1.3 mill.kg P, most part of which is used as feed for fur animals

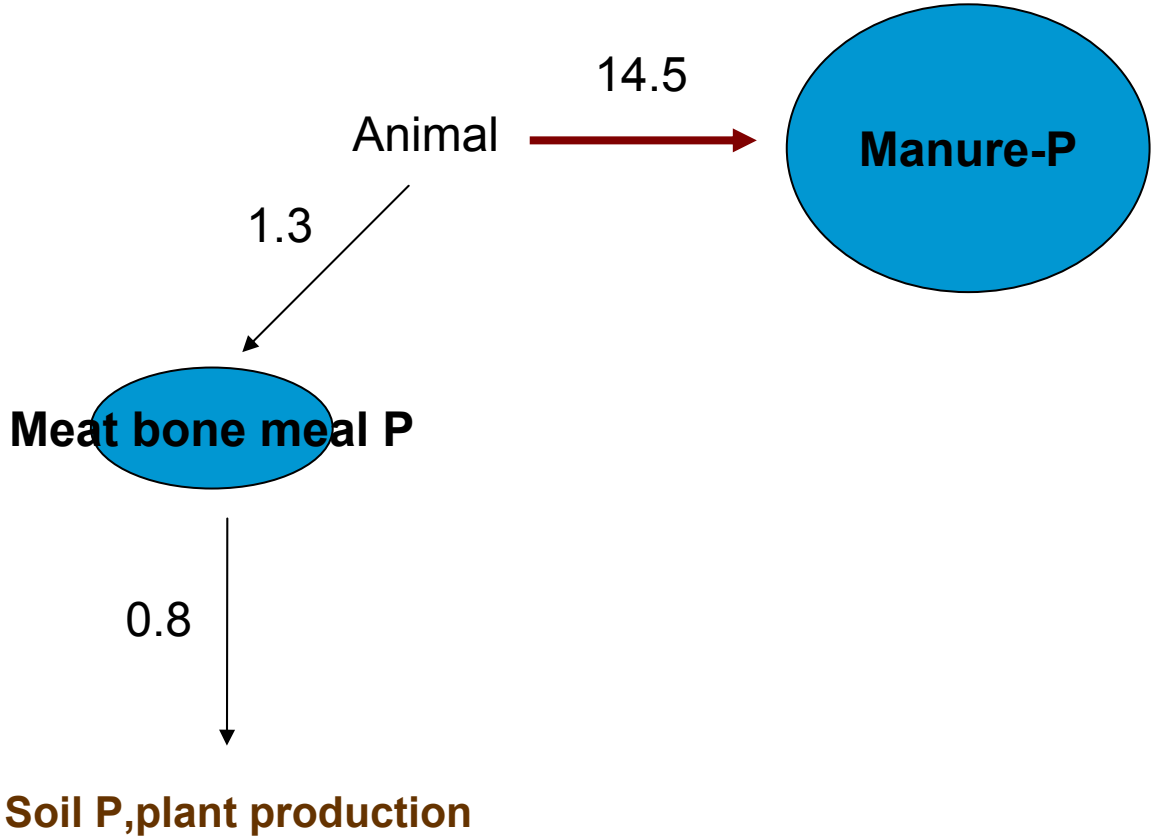
- Fertilizer value of meat bone meal was estimated by laboratory, pot and field experiments (Ylivainio et al)

Result (2): P availability of meat bone meal 20-60% (in first year-in 3-4 years) compared with superphosphate, with highest responses in grass cultivation

P source	Pot experiment 3 years	Field experiment 3-4 years
Meat bone meal	63	13-45
Fur animal manure	55-78	32
Cow manure	100	100

Ylivainio et al. 2008, Ylivainio & Turtola 2009

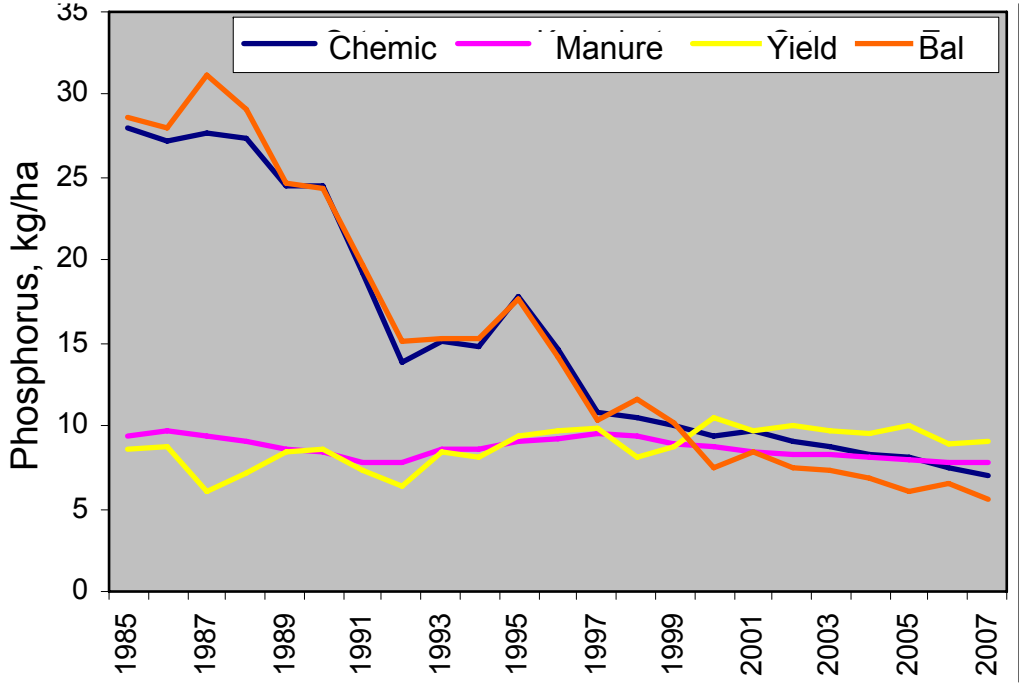
Adjusted feeding and use of meat bone meal, mill.kg y^{-1}



- In plant production, P fertilization (mineral + manure) has decreased from the highest levels in late 1980s by 20 kg/ha to the present level of 16 kg/ha

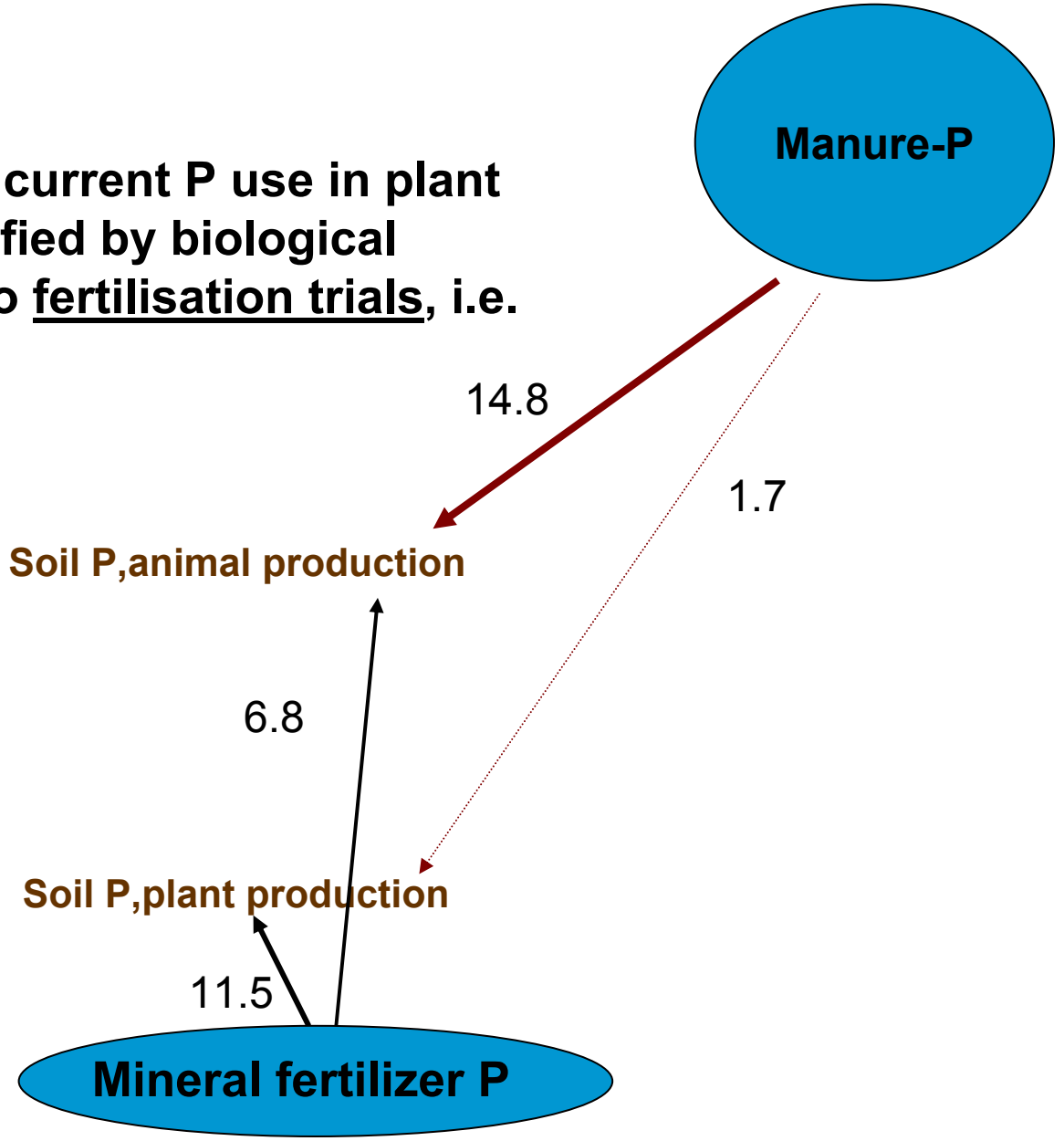
- P inputs in manure and outputs in yield have remained stationary

- Since crop yields, at least in the national and regional levels, have not been affected by the recent, lower P fertilisation, is there further potential for reduction?

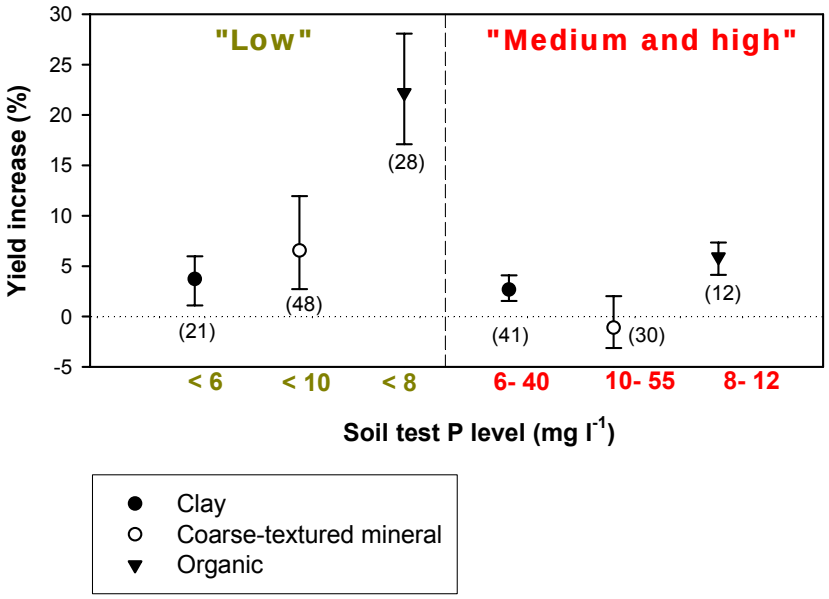


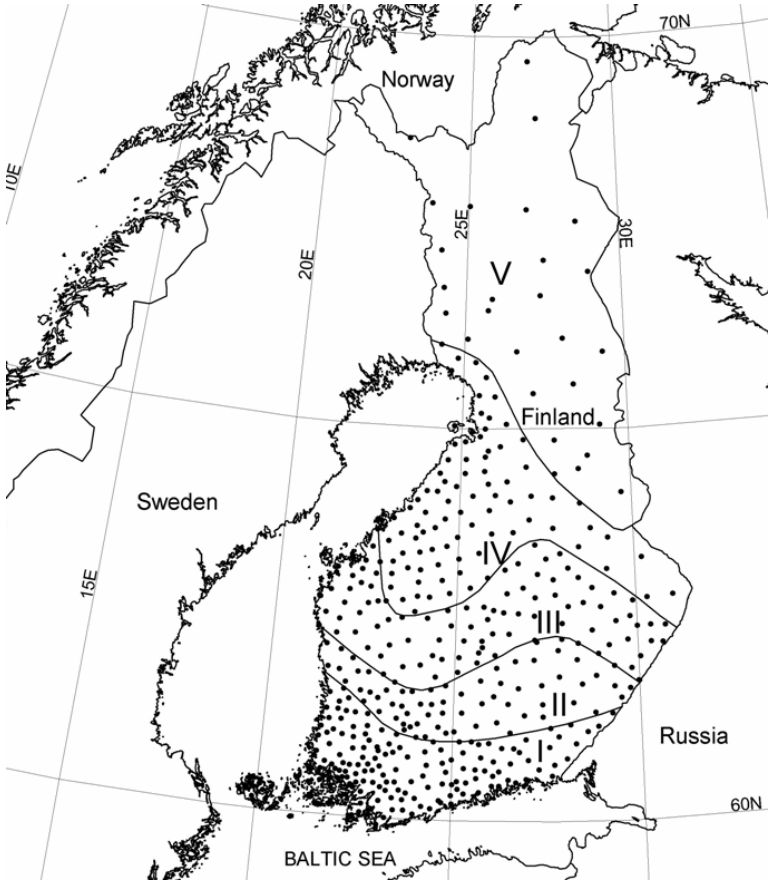
P application in mineral fertilizers and manure in Finnish agriculture in 2005, mill.kg y^{-1}

Step 3: Comparison of current P use in plant production to that justified by biological responses according to <u>fertilisation trials</u>, i.e. avoiding overuse



- Need of P fertilisation was estimated according to amounts giving maximum yields (meta-analysis of Finnish fertilisation trials, Valkama et al. 2009)



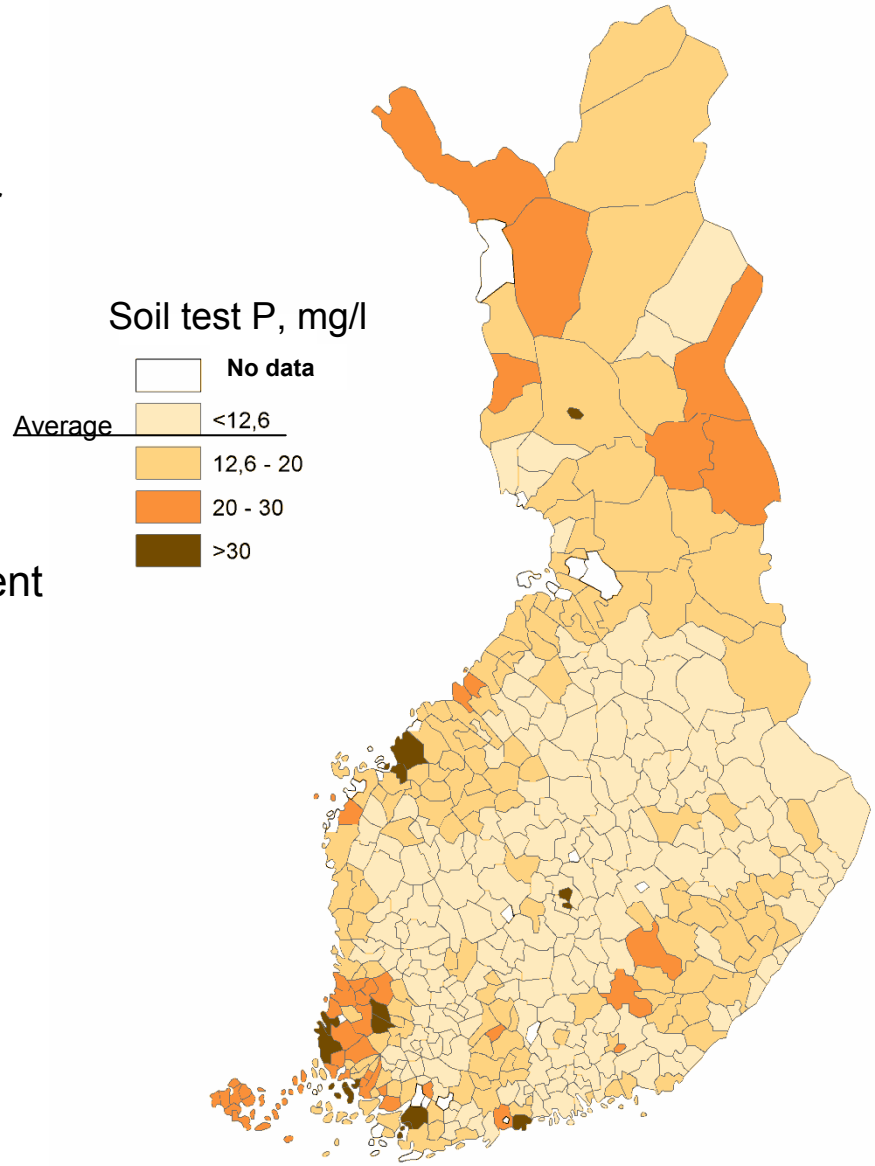


Map: Harri Lilja MTT

Valkama et al. 2009

- Current soil test P of the plough layer was considered (data for years 1997-2002) with >90% coverage of all fields (one sample representing max 5 ha)

- The soil test P data was divided according to the soil type (clay, coarse textured mineral, organic) due to different P distributions and responses to P fertilisation



Viljavuuspalvelu Oy and
Ålands Försöksstation 2001-2005

- Year 2005 was used as starting point in the calculations

- The calculations were done with 5-year intervals for 20 years

- New soil P status (after 5-year intervals) were calculated, by considering P status at the starting point and annual P balances, when the P fertilisation was adjusted as described earlier

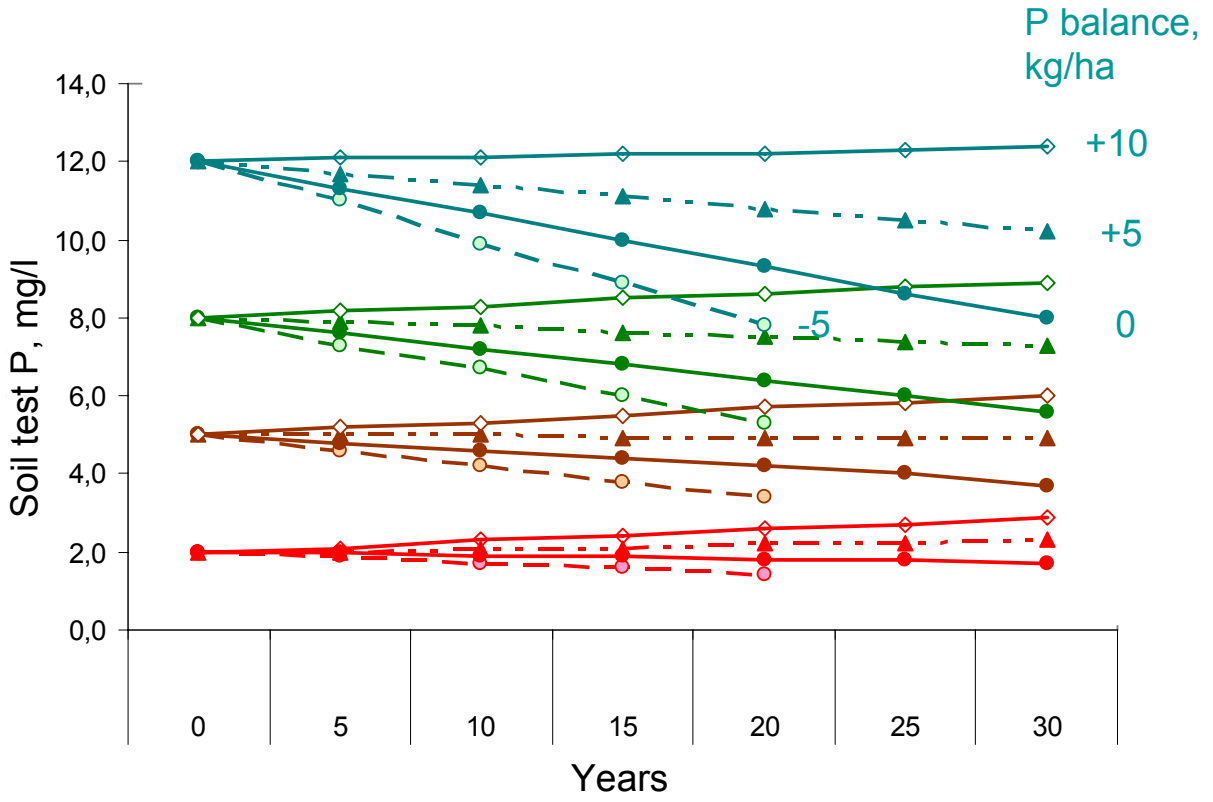
- The new P status were calculated using equation based on long-term fertilisation trials (Saarela et al. 2004)

$P_1 = -0{,}0031*(P_0)^2+0{,}887*P_0+0{,}12$

$P_2 = P_1 + \text{balance}*((0{,}0013+0{,}001325*P_1-0{,}0000161*(P_1)^2))$

Saarela et al. 2004

- P fertilisation was re-adjusted after each 5-years according to the decreasing P status

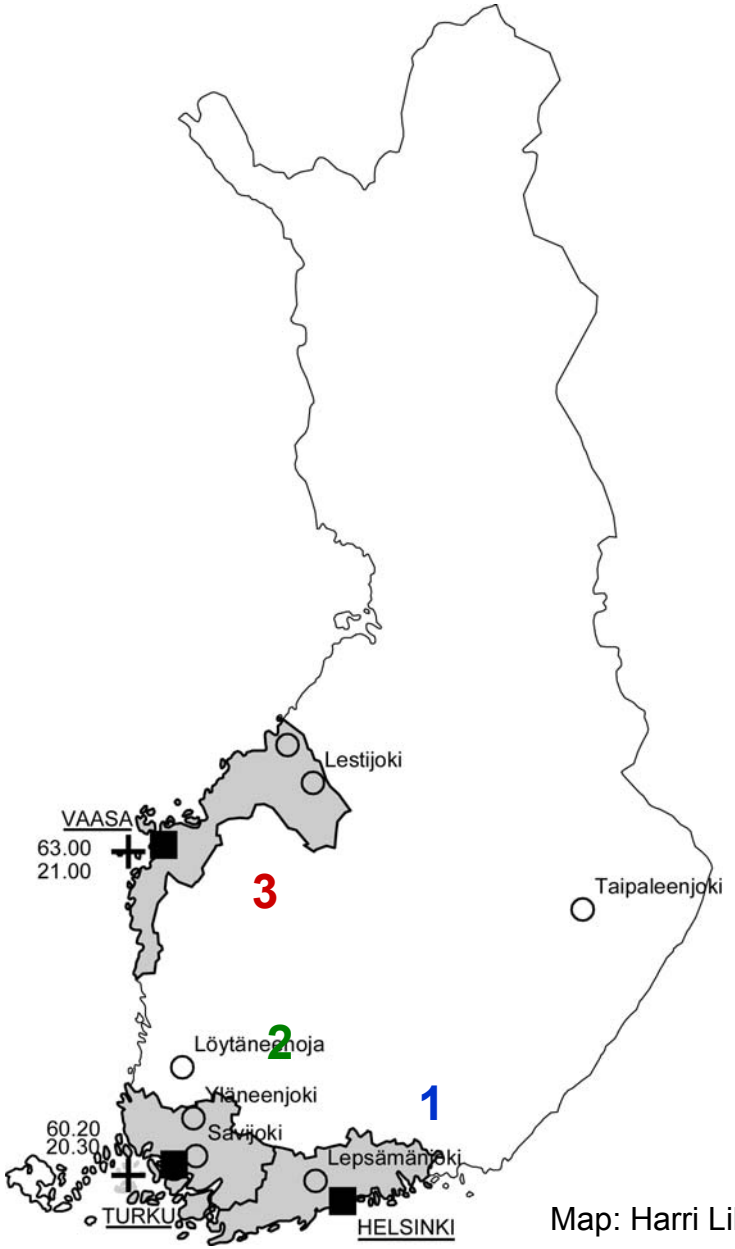


The calculations were done

- for <u>whole Finland</u>
- for smaller regions

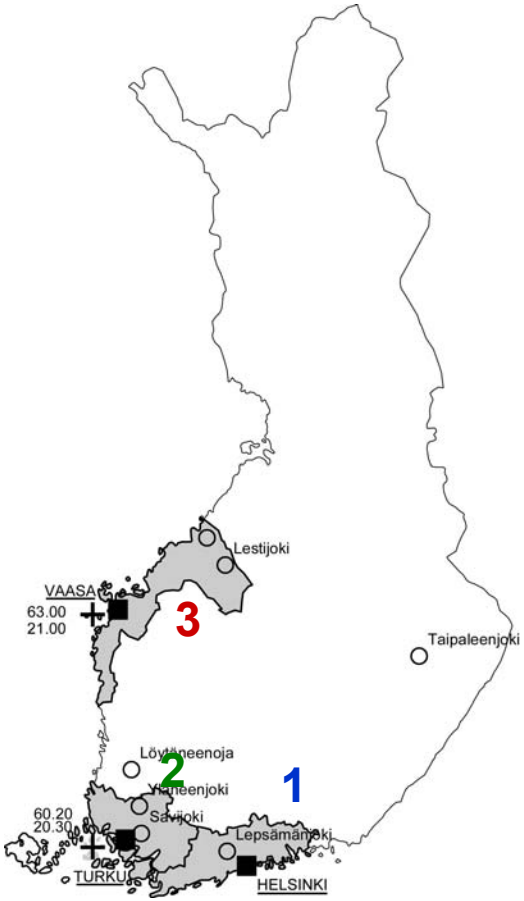
<u>having different intensities of animal production:</u>

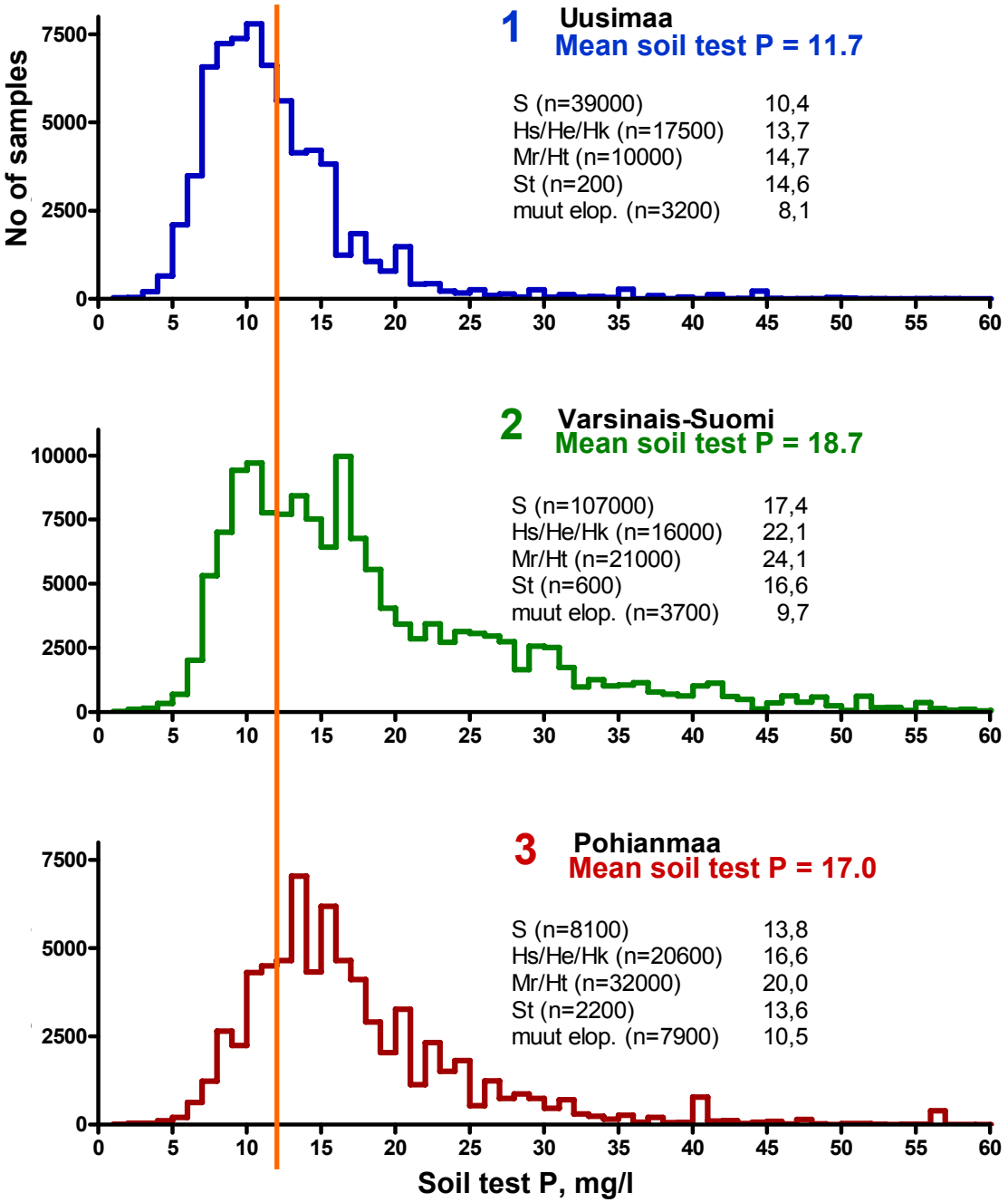
1 Uusimaa (0.13 lu/ha)
2 Varsinais-Suomi (0.29 lu/ha)
3 Pohjanmaa (0.46 lu/ha)



Map: Harri Lilja MTT

…and different distributions of soil test P



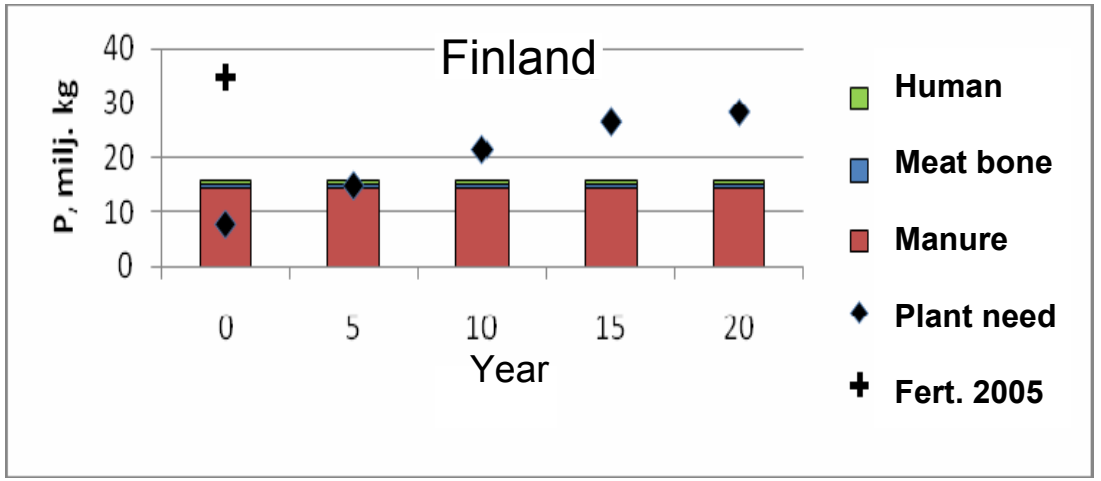


Result (3): Current fertilisation compared to biologically justified fertilisation and P content of manure in the next 20 years

In whole Finland, P fertilisation was 4.5-fold compared to biologically justified fertilisation in 2005.

Even after adjustment in feeding, there would be enough P in manure for fertilisation during next 5-10* years

* excess manure of the first years saved for later use

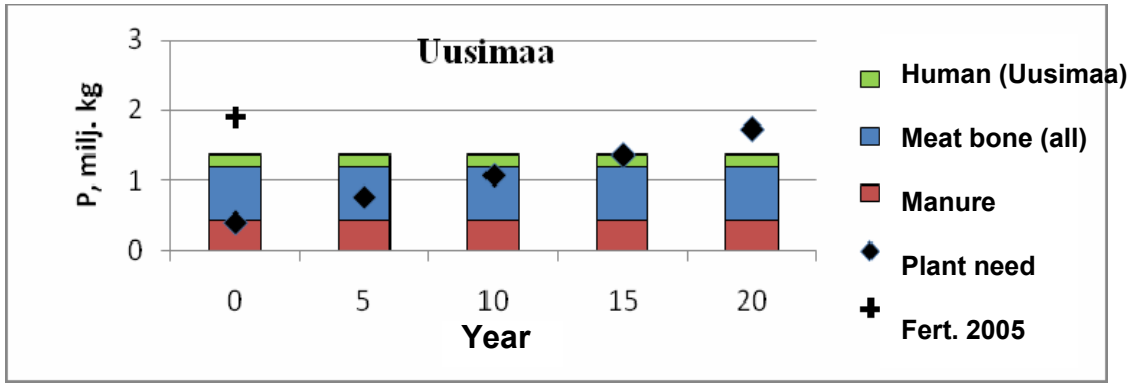


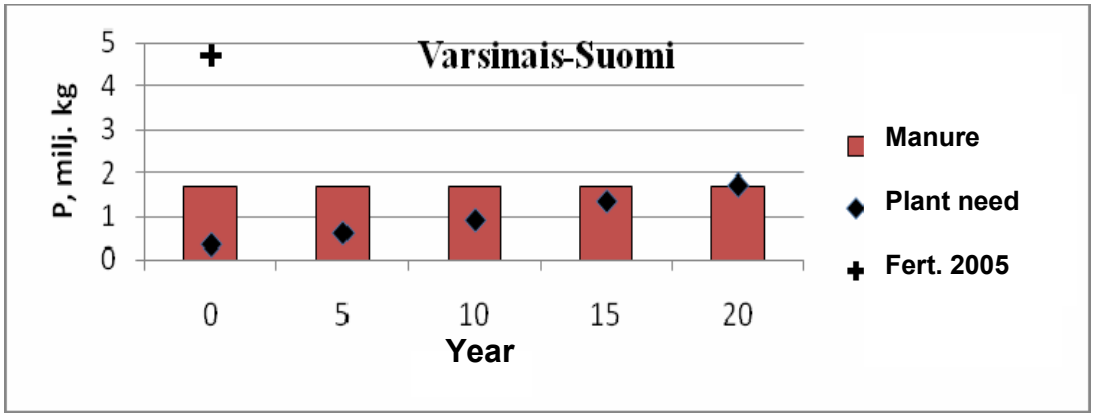
Need for P fertilisation (♦) and P available for crops in manure, meat bone meal and human feaces in 5-year intervals during next 20 years, and P fertilisation in 2005 (+).

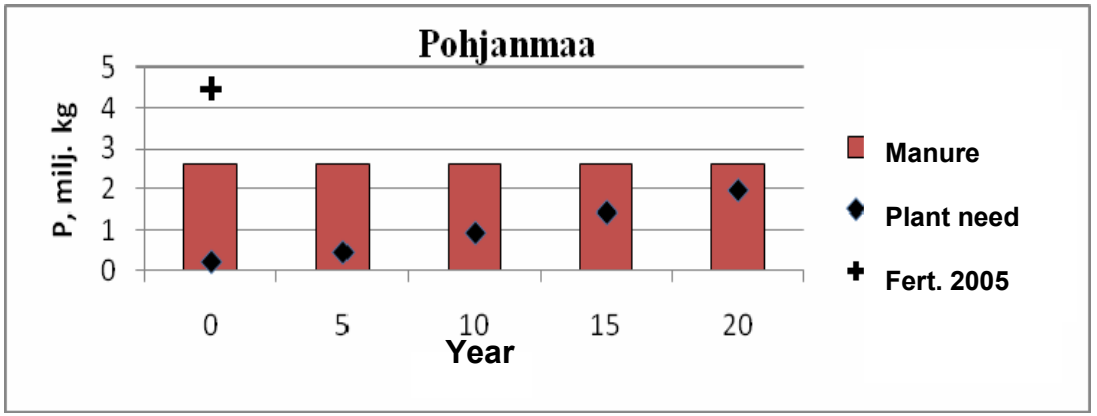
In the different regions, current P use is 4-21 –fold compared to the need

Presently in Uusimaa region, manure-P would be just enough

In Varsinais-Suomi, manure P alone would last 20 years, and in Pohjanmaa more than 20 years







Riitta Lemola MTT

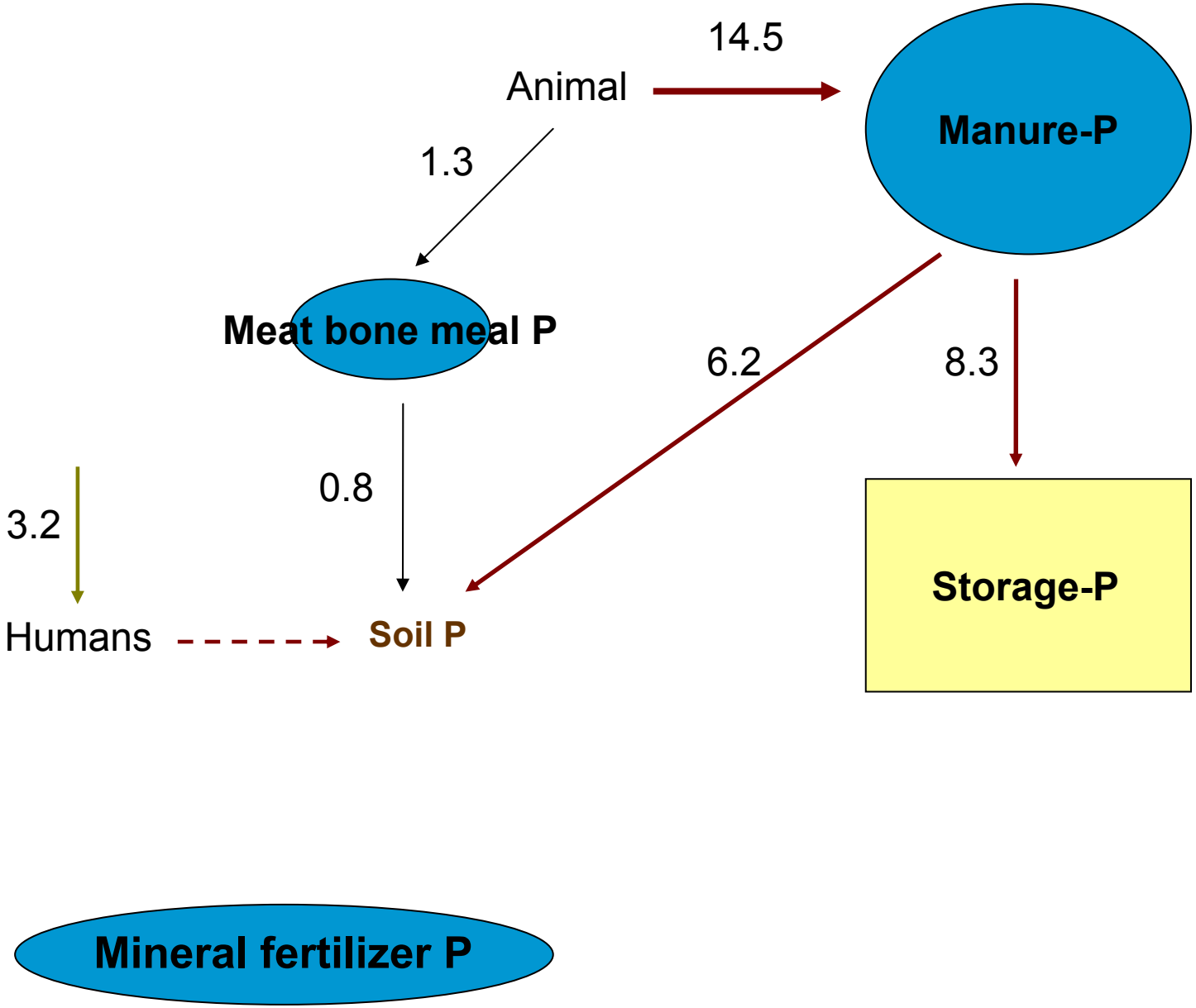
Distribution of P use between manure and chemical fertilizers and saving in total use of P

	Manure-P % of use	Chem.fert-P % of use	soil test P (P_{Ac}) ** mg/l
current, year 2005			
Whole Finland	47	53	12,7
Uusimaa	25	75	12,0
Varsinais-Suomi	40	60	18,6
Pohjanmaa	65	35	17,5
during next 20-25 years ('biologically adjusted')			year 2025
Whole Finland	82	18 *	9,0
Uusimaa	54	46	8,0
Varsinais-Suomi	100	0	11,0
Pohjanmaa	100	0	10,7

*Saving in P use 90 %

**5-12 mg/l enough for crop growth without P fertilisation

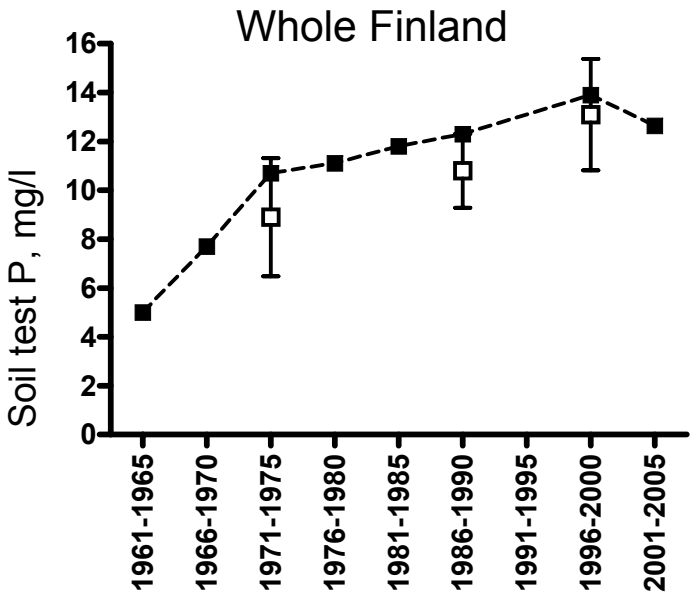
Adjusted P application in Finnish agriculture, mill.kg y^{-1}

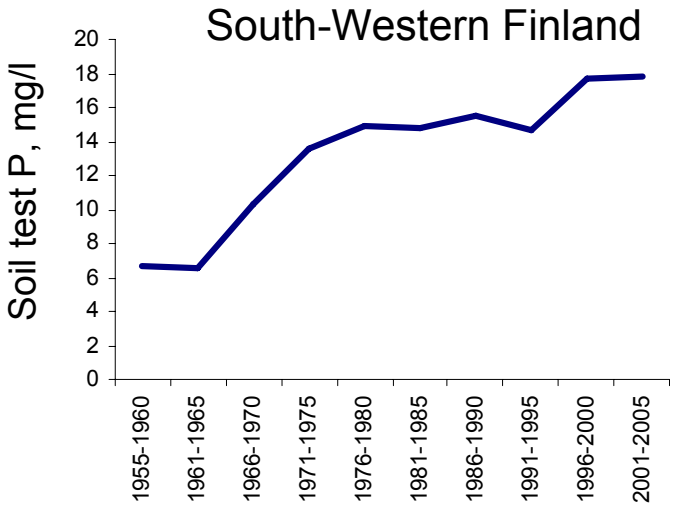


- In Finland, the average soil test P (P_{Ac}) was raised from 5 mg/l ('moderate') to 12-14 mg/l ('satisfactory') by the surplus P balances of 20-30 kg/ha

- Due to still positive balances, soil test P has not decreased considerably during the last 15-20 years, or has remained stationary ('good') in regions with intensive animal production as in South-Western Finland

- National monitoring studies have found only small or no decrease in P concentrations of agriculturally loaded rivers

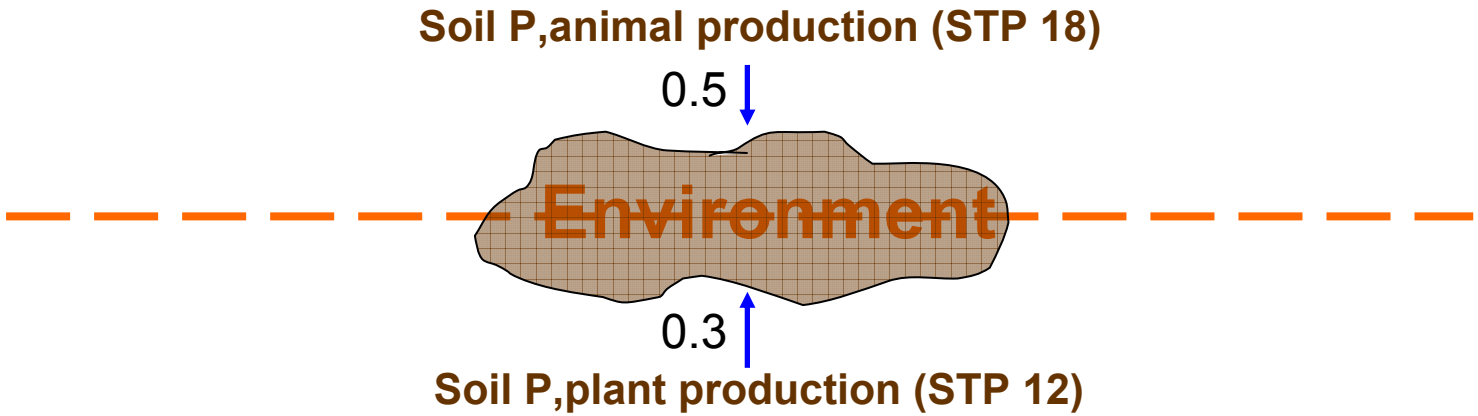




Uusitalo et al. 2007

Dissolved P losses from Finnish agriculture, mill.kg y^{-1}

Step 4: Estimation of the effect on DRP losses to waters when tightening the P cycle as described

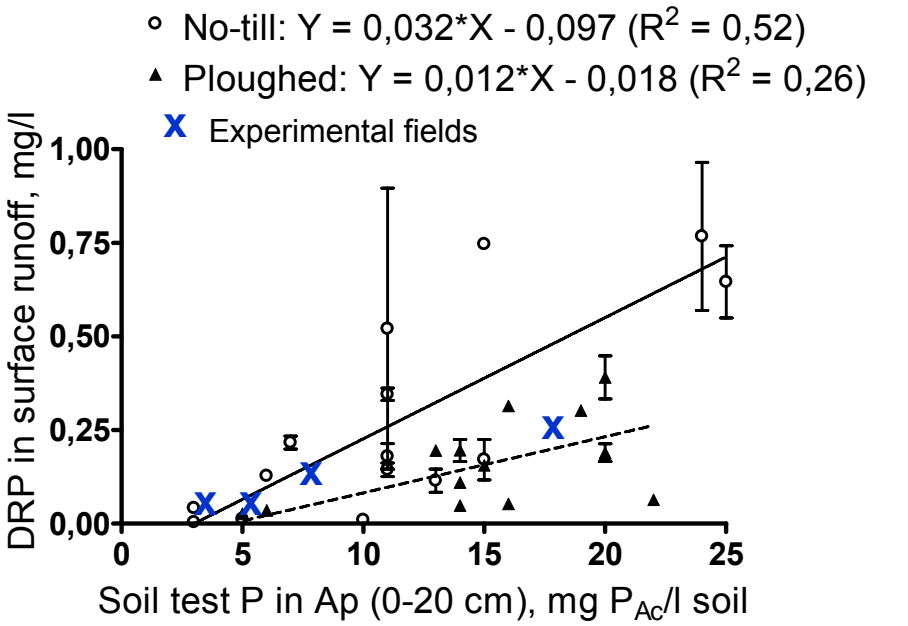


- According to experimental results in Finland, soil test P (Finnish method: acid ammonium acetate, pH 4.65) is one of the most important factors affecting potential DRP losses from a field

- We estimated tentatively the potential effects on P losses by

DRP (mg/l) = 0.01 x (Soil test P)

and assuming a standard total runoff of 270 mm

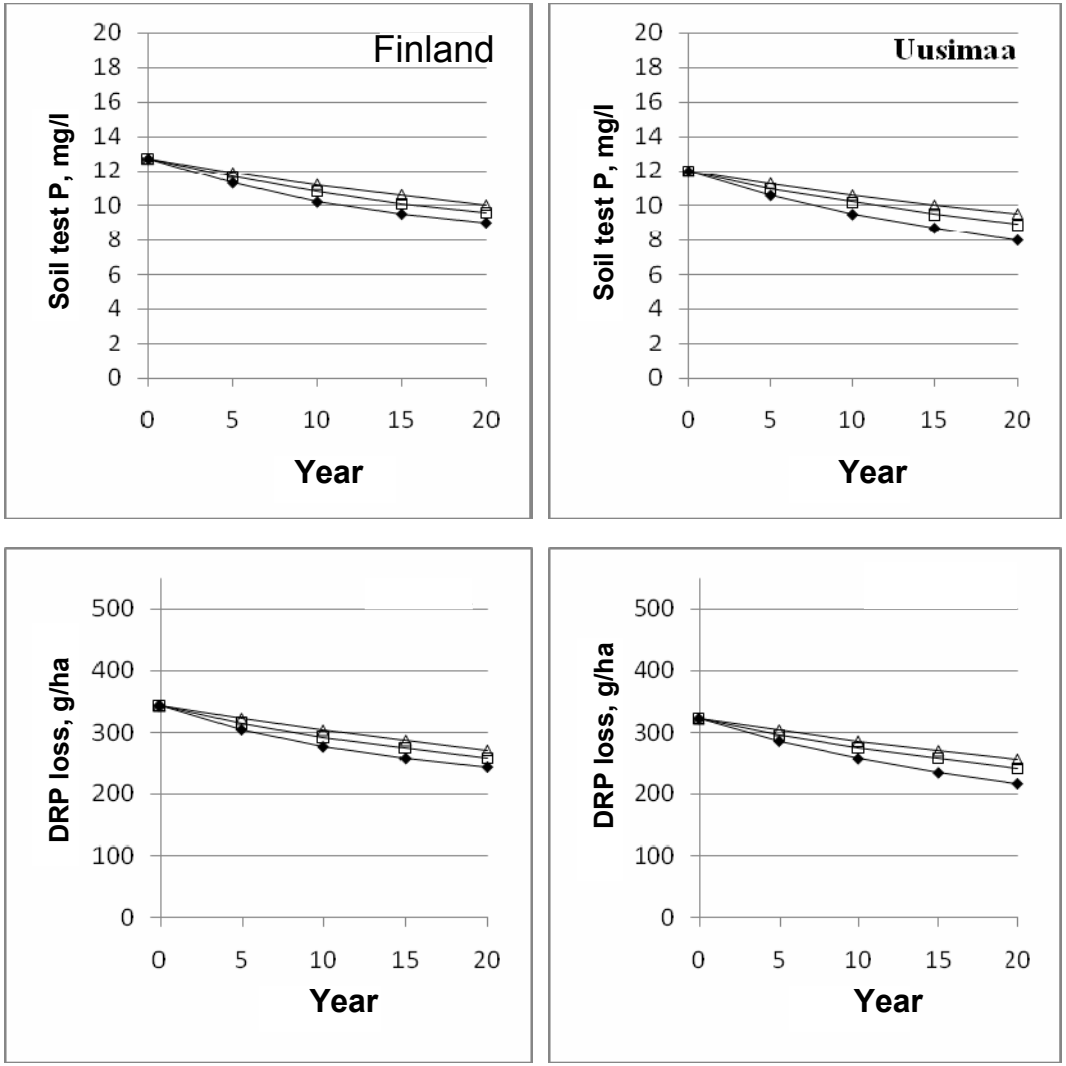


Uusitalo & Aura 2005

Result (4): Change in soil test P and DRP loading potential

Soil test P would decrease in 20-25 years:

Whole Finland - 29 %
Uusimaa - 33 %

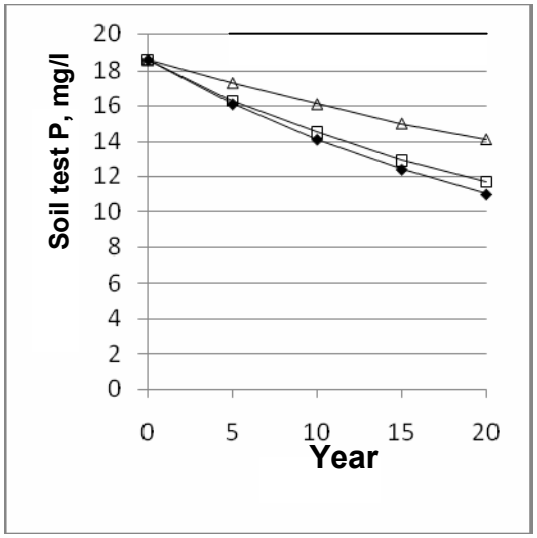


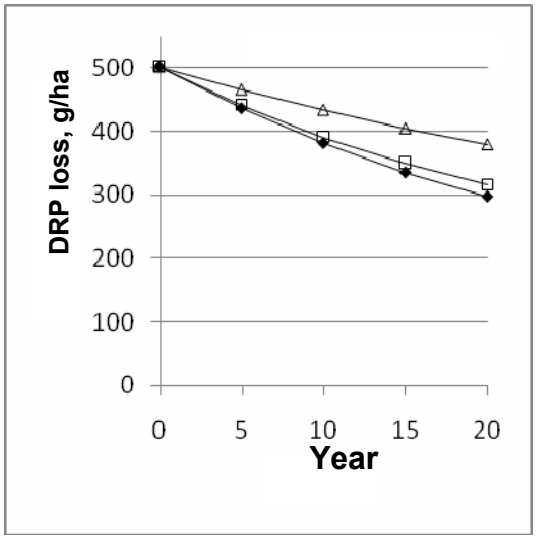
The decrease would be largest in regions, where soil test P and DRP loading potential are highest:

Varsinais-Suomi - 41 %
Pohjanmaa - 39 %

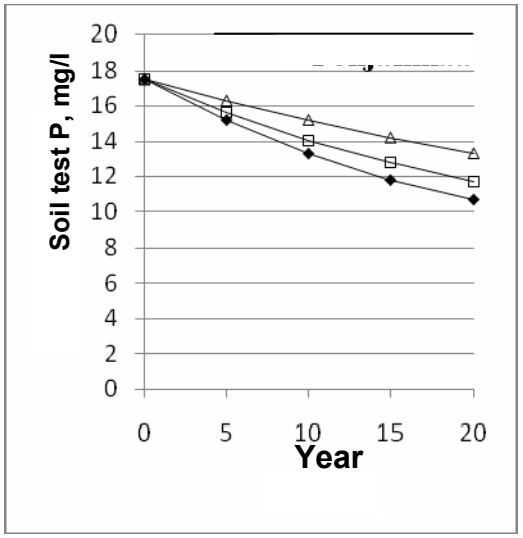
!! The decrease would continue also after that

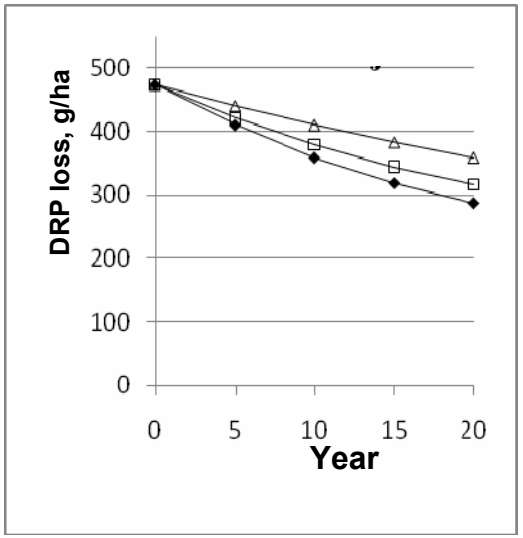
Varsinais-Suomi





Pohjanmaa





P fertilisation adjusted

Conclusions

- Concentrated animal husbandry is challenging for efficient P recycling. Presently regionally imbalanced structure of the production is one of the main reasons that manure-P is not distributed according to actual plant need.

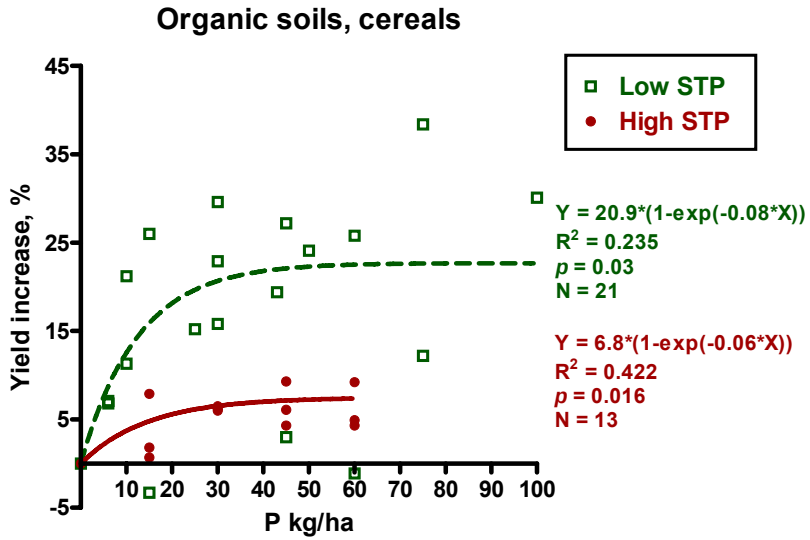
- Adjustments in animal feeding would decrease the P content of manure by >12% and thus facilitate the reasonable use of manure locally

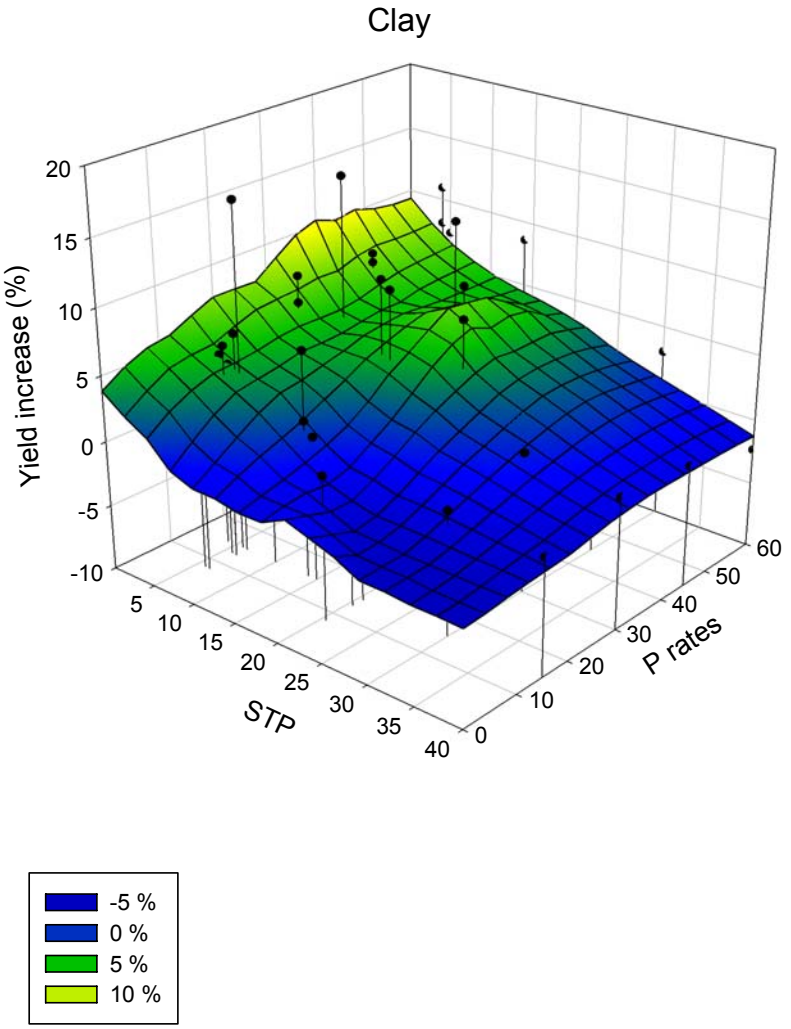
- However, for manure to comprise larger share of P use in national scale (manure-P would be enough as P fertilizer for up to 10 years), we need innovations to process and transport manure-P

- By efficient use of manure-P and considering the biological responses, P fertilization can be markedly reduced (at present >75%). This means that there is a large potential to cut the P losses e.g. to the Archipelago Sea by adjusting the P applications

…conclusions

- In critical river basins, farmers need simple calculation tools to determine sufficient and economic P feeding of animals and P fertilisation for their fields. We develop these tools





Elena Valkama & Risto Uusitalo MTT

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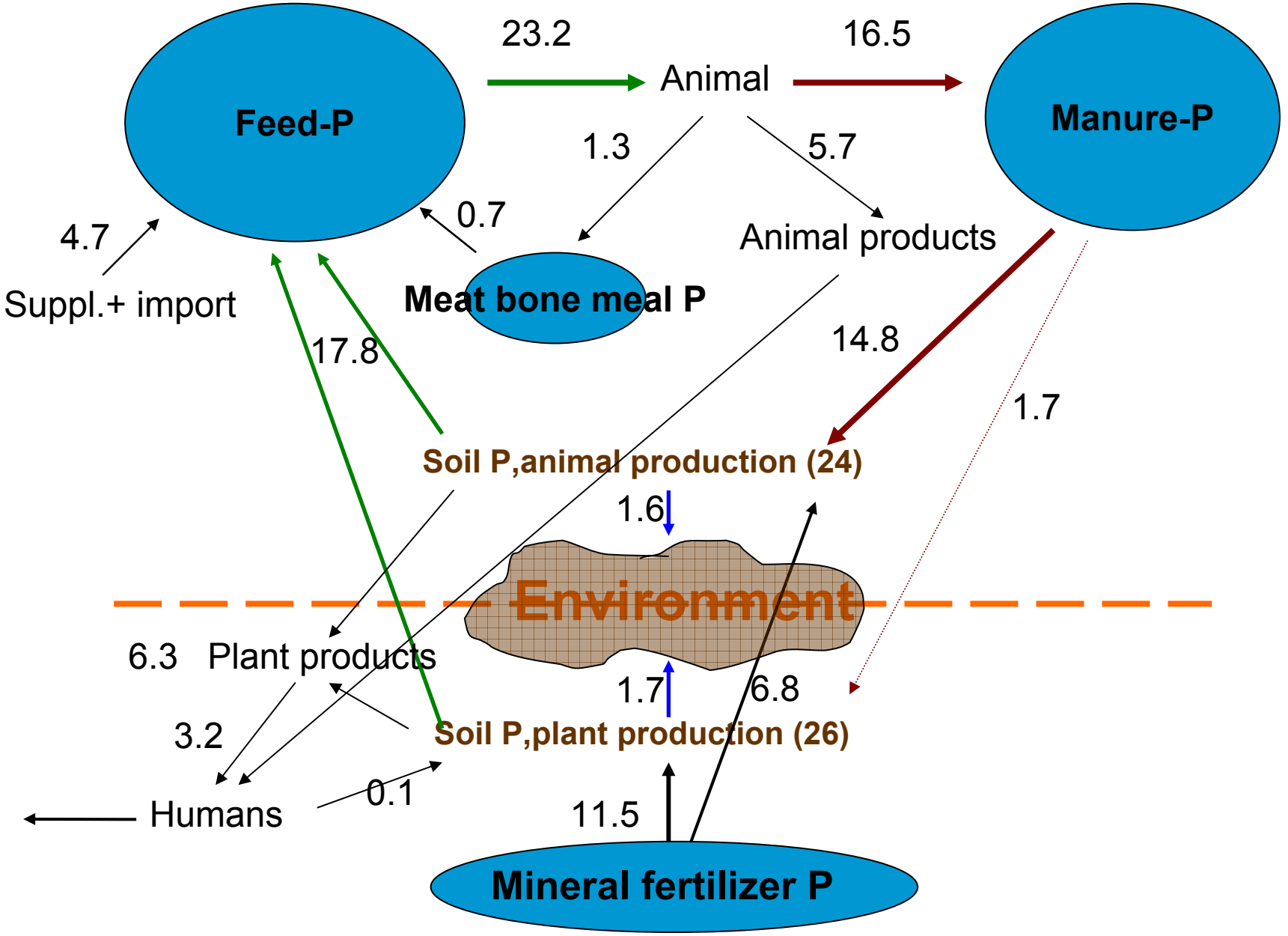
P cycle in Finnish agriculture in 2005, mill.kg y^{-1}



P fertilisation is obviously the most important background factor for DRP (bioavailable PP) losses from fields to waters

In modern agriculture, inputs of commercial fertilizers have been large

P fertilisation rates in Finland were high starting from the beginning of 1960s.

Fertilisation has been reduced considerably in the last 15-20 years

The average P balance was +30 kg/ha in the end of 1980s, but is now +6 kg/ha (Sweden +2, Norway +13, Denmark +11, Netherlands +16, Hungary -15 kg/ha)

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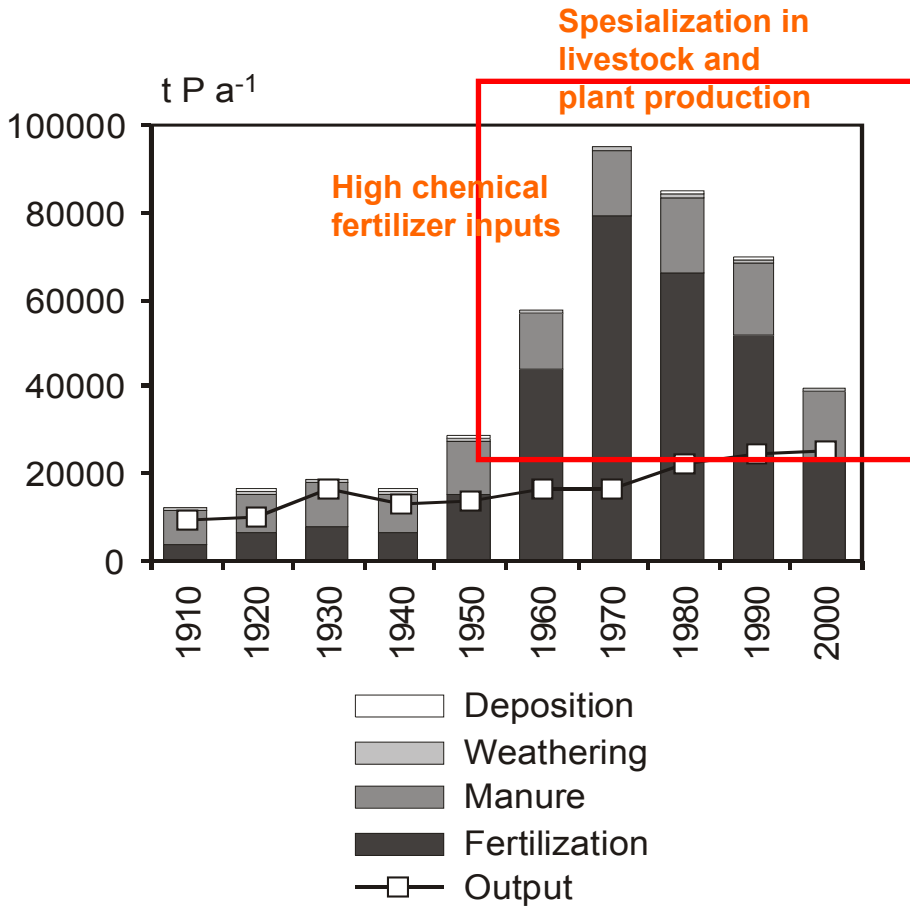
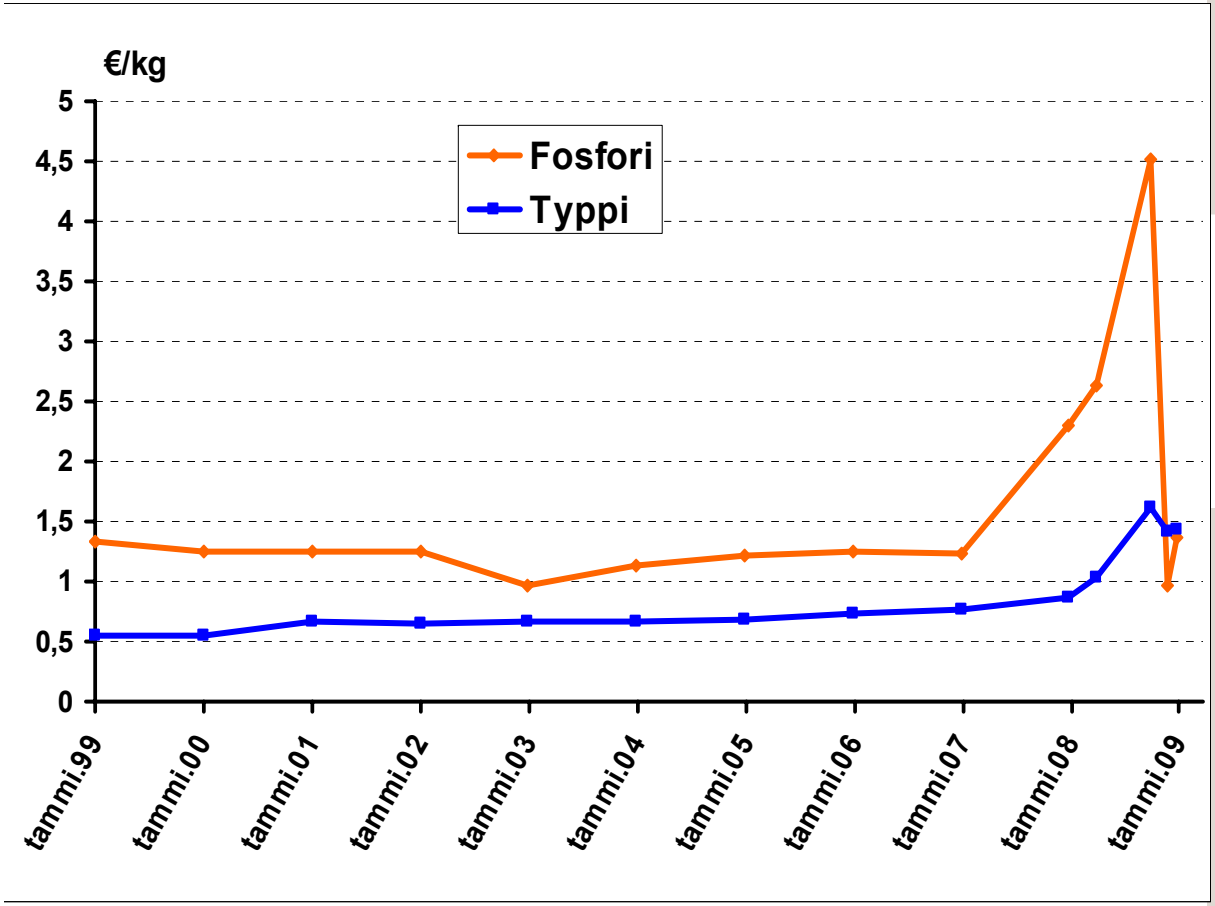
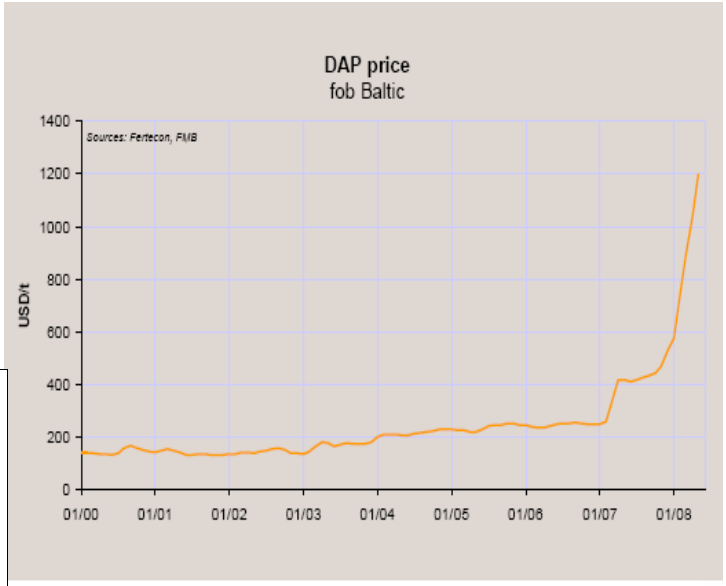
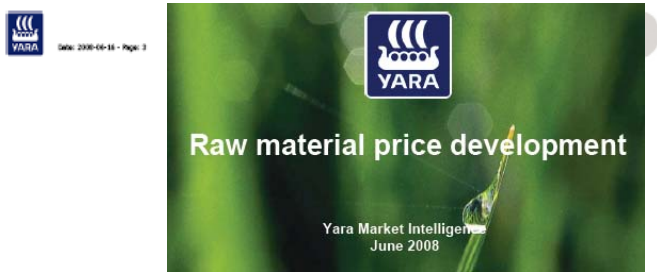


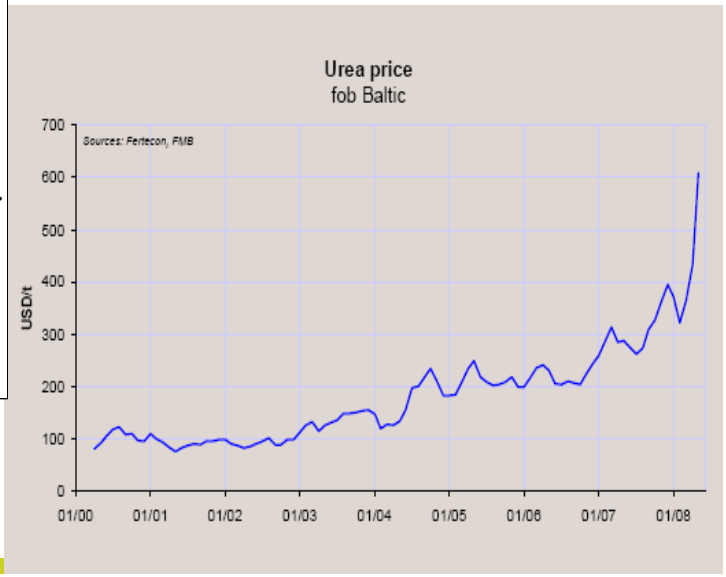
Antikainen et al. 2005

Lannoiteravinteiden hintakehitys 1999-2009









- Tutkimustarpeeksi nousee vähitellen myös hyvän kasvun aikaansaaminen fosforiköyhässä maassa. Arviot fosforimineraalien riittävyydestä vaihtelevat 60-130 vuoden välillä. Maatalouskäyttöön menee 80 % tuotannosta, ja hinta tulee nousemaan
- SCOPE 54 -Phosphorus in the Global Environment - Transfers, Cycles and Management (1995), http://www.icsu-scope.org/downloadpubs/scope54/TOC.htm
- Steen, I. 1998. Phosphorus availability in the 21st century: Management of a non-renewable resource. Phosphorus and potassium 217: 25-31, http://www.nhm.ac.uk/mineralogy/phos/p&k217/steen.htm