

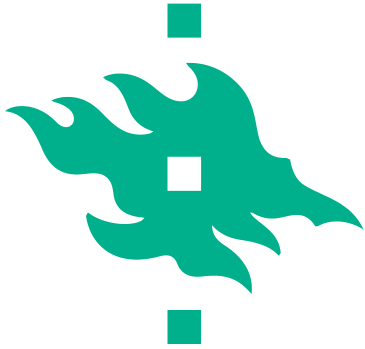


Using nitrogen-fixing crops

Fred Stoddard

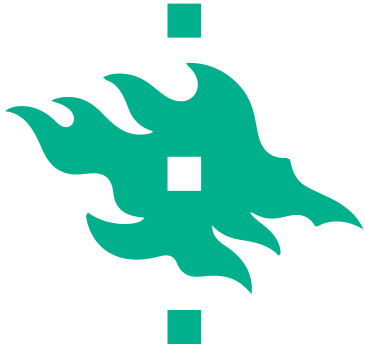


Euroopa Maaelu Arengu
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Contents

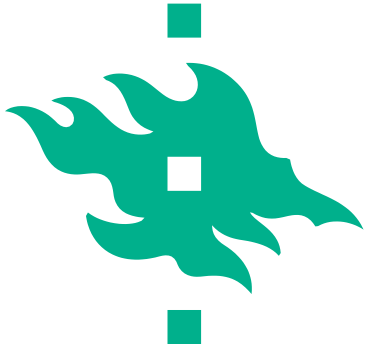
- What is BNF and who cares?
- Legumes for BNF and other purposes
- Changes in use of legumes in Europe
- The future



Nitrogen is everywhere, but not available

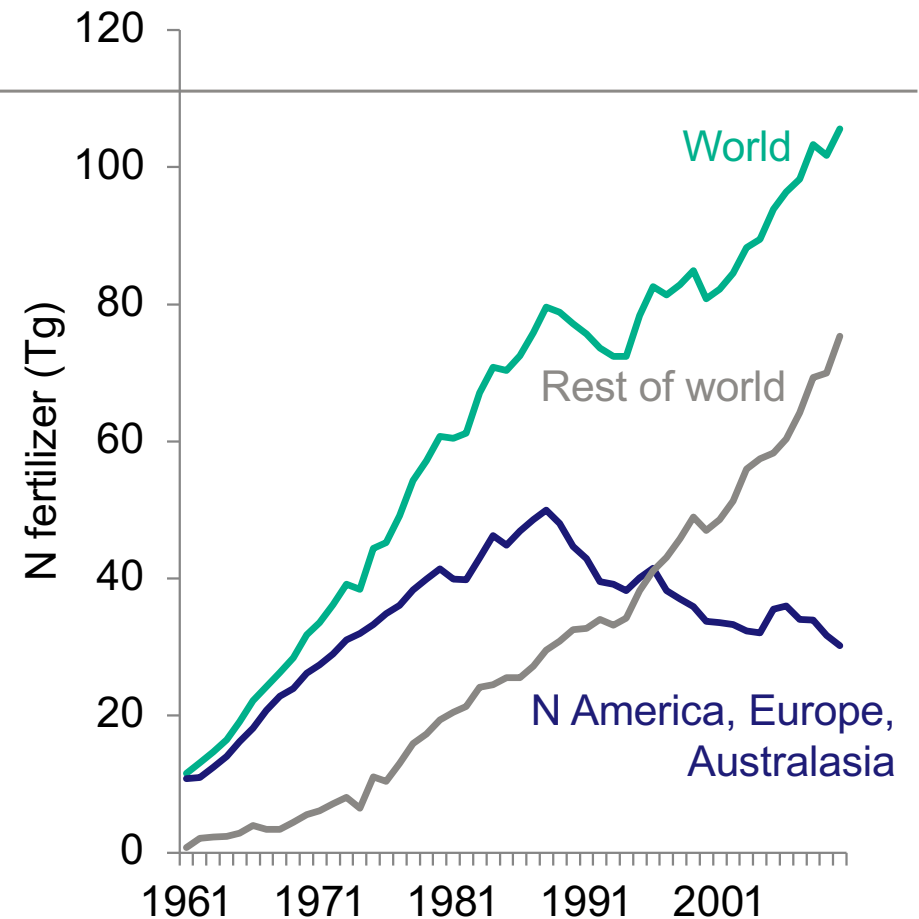
- Atmosphere is 78% N_2
- $N\equiv N$ is triple bond, hard to break
- Lightning does it
- Some bacteria do it
 - Nitrogenase enzyme
 - 16 ATP to fix $N_2 \rightarrow 2NH_3$
 - Legumes make symbiosis with some of these bacteria: BNF
- Organisms need *reactive* N to make their proteins

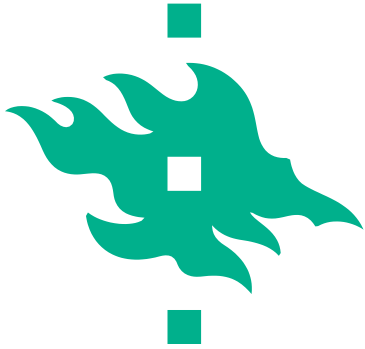




Who cares? You do!

- Total yearly natural nitrogen fixation = 90-130 x 10¹² g (Tg, million t) on land, 20-80 Tg in oceans
- 1909: Haber-Bosch process: 200°C, 200 atmospheres, Fe catalyst: $N_2 + 3 H_2 \rightarrow 2 NH_3$
- ~1 t fossil fuel per t fertilizer = 1.3% of total fossil fuel consumption
- ~1.2% escapes as N₂O, 250-310 x more powerful greenhouse gas than CO₂

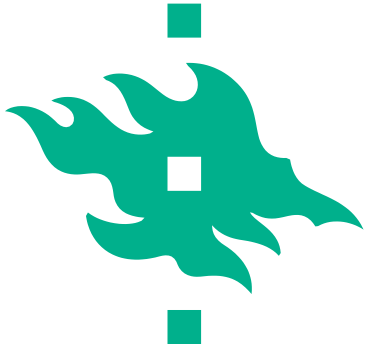




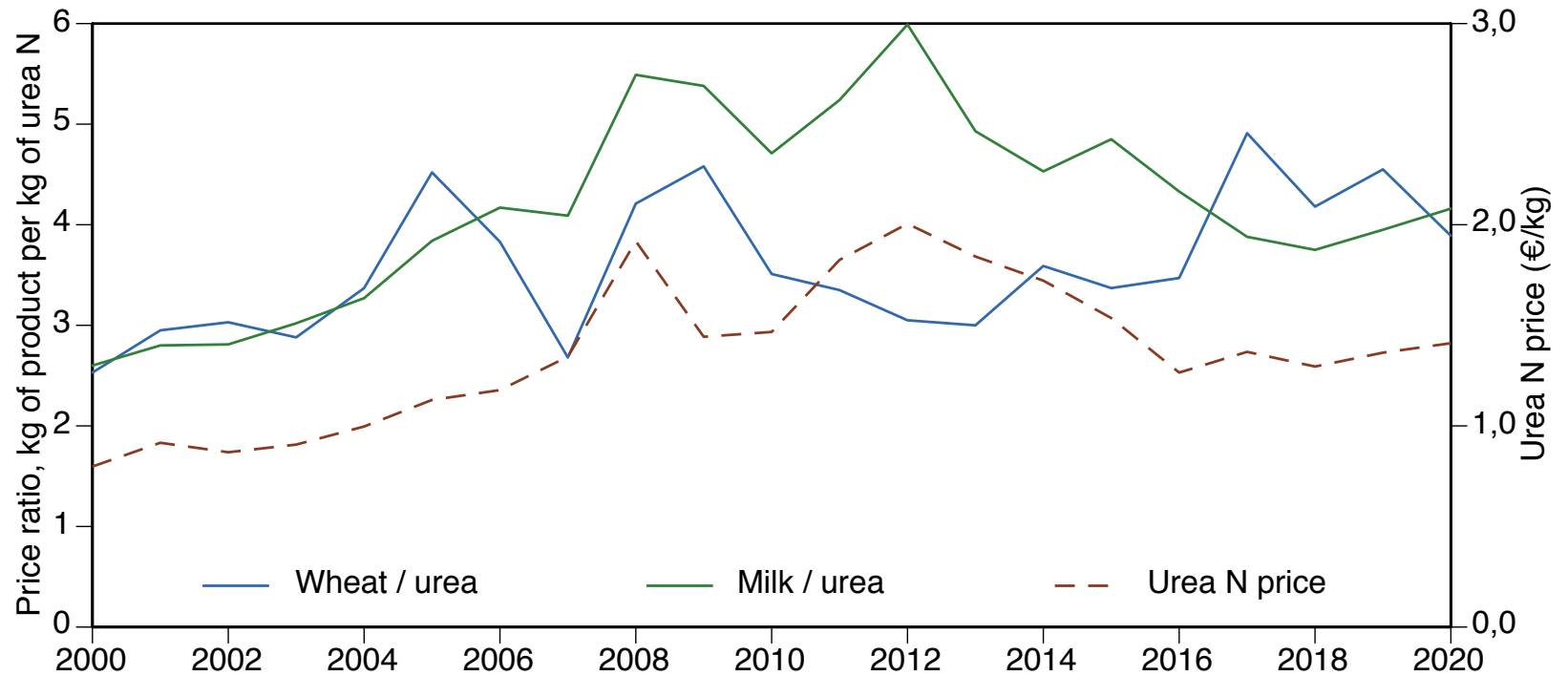
And now...



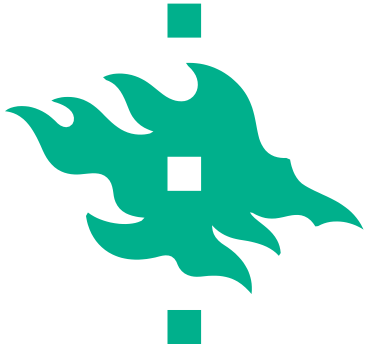
And *if* we can get N fertilizer, at what price?



How much wheat or milk does it take to pay for N fertilizer?



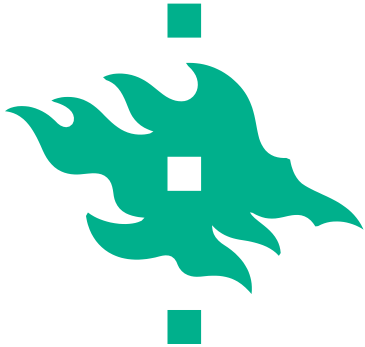
Data are EU means, weighted by production and use



Legumes fix N as they need it – and offer more besides

- FAO views legumes as one of the 5 pillars of Sustainable (or Ecological) Intensification
- BNF
 - And associated changes in soil biology
- Break-crop effects
 - Allow soil-borne diseases of cereals to die
 - Different biology allows use of alternative weed & pest control chemistry & methods
- Support of pollinator populations





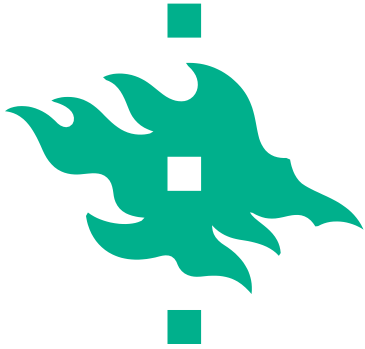
Result: legume seeds are rich in protein...

Species	Protein content (% dm)
Mung bean	17
Chickpea	22
Pea	23
Kidney bean	25
Lentil	27
Faba bean	29
Blue lupin	34
Soy	39

Soy arrives in the Netherlands



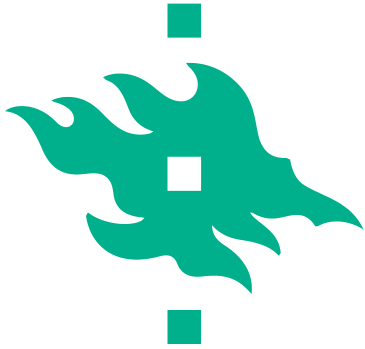
Cereals < 15%



Legumes now

- Food (ruoka)
 - “Pulse” = grain legume
- Feed (rehu)
- Fibre (kuitu)
- Fuel (polttoaine)
- Flavour (maku)
- Fragrance (tuoksu)

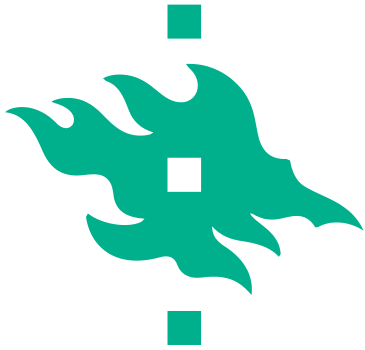




Importance in agri-food systems

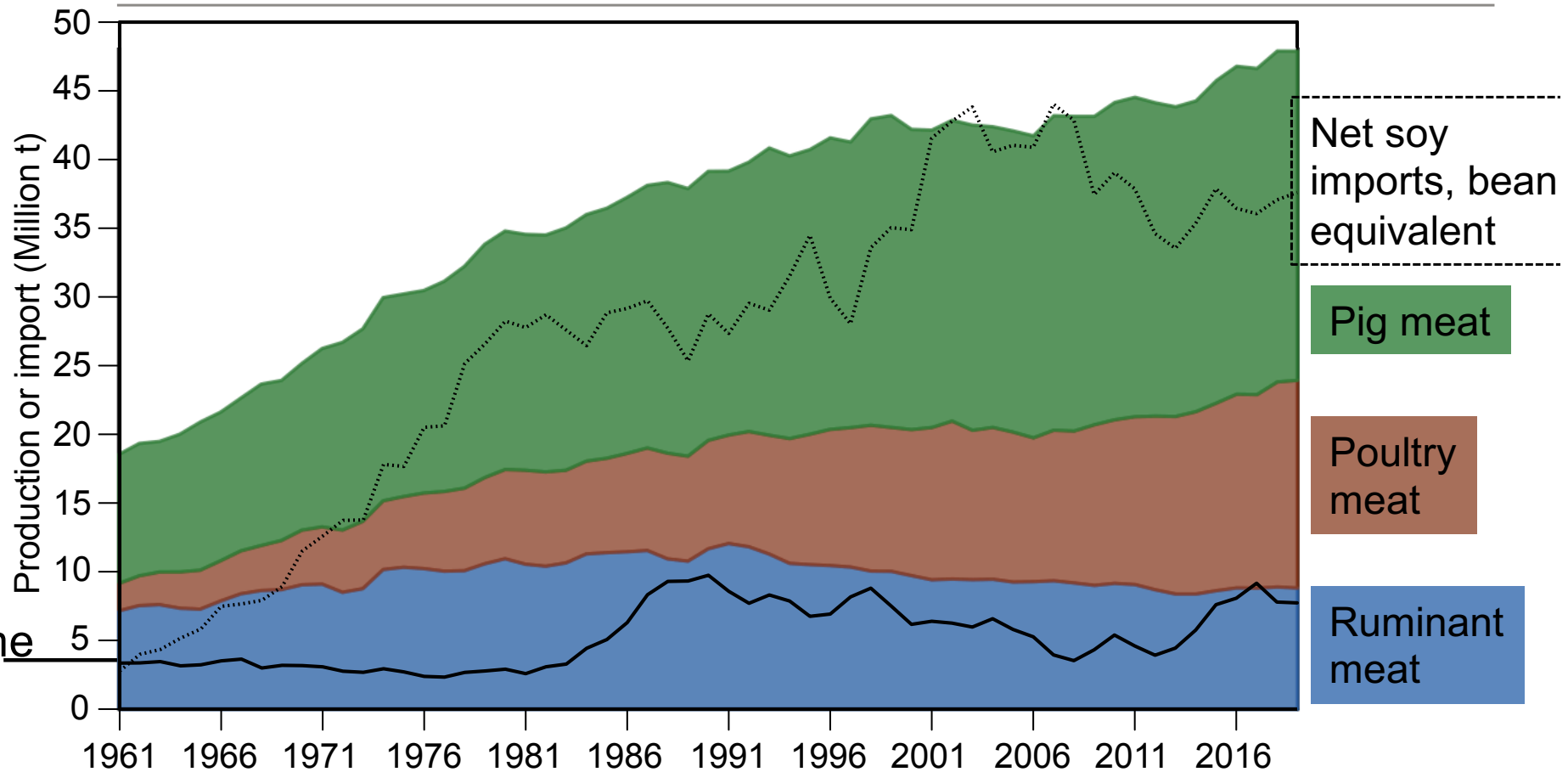
- Little N fertilization needed
 - Clover – grass pastures can be more profitable than fertilized grass
 - Food / feed protein with little NO_3^- leaching or N_2O
- Residual fixed N usable by next crop
- Protein-rich
- Good for pollinators
- Good for soil microbes

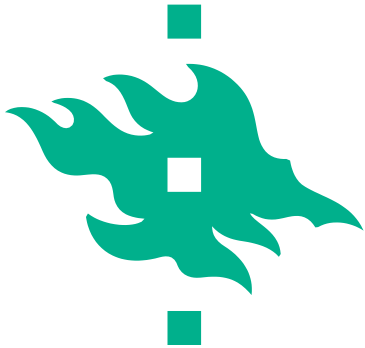




Europe's meat production and soy imports depend on each other

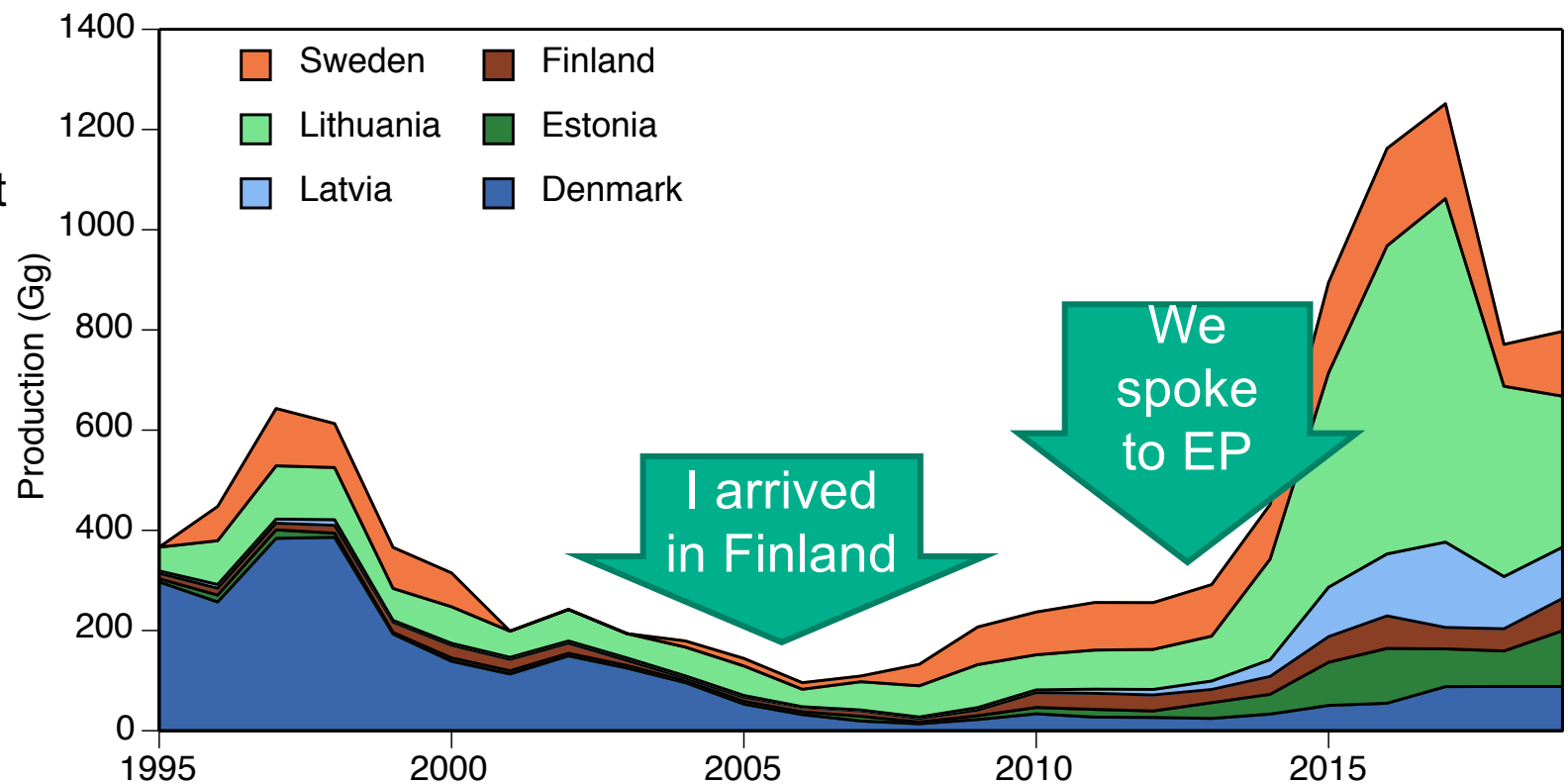
Grain legume production

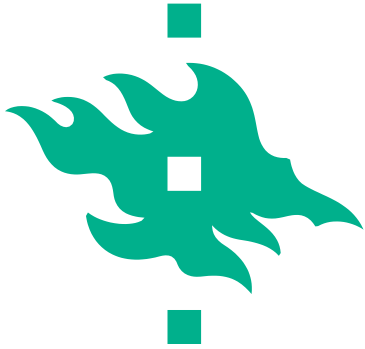




Pulse production in the Nordic – Baltic countries

- Data from Eurostat
- Maximum = 1/3 of imported soy
- Less, in protein terms

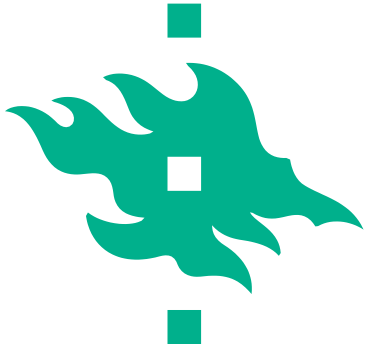




Forages

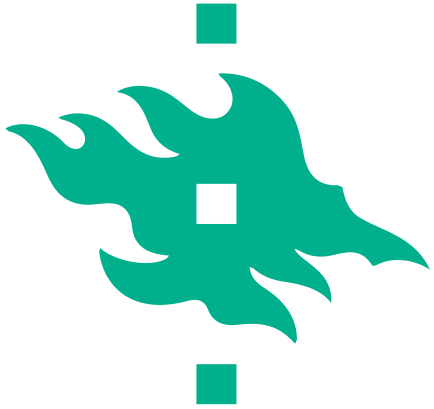
- Clovers
 - *Trifolium*
- Alfalfa, mediks
 - *Medicago*
- Trefoils
 - *Lotus*



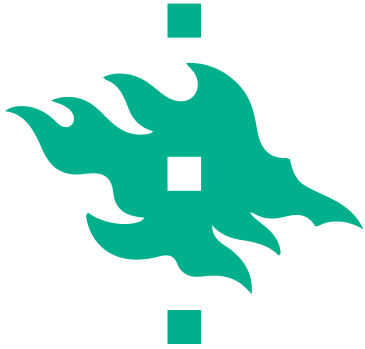


Legume forages

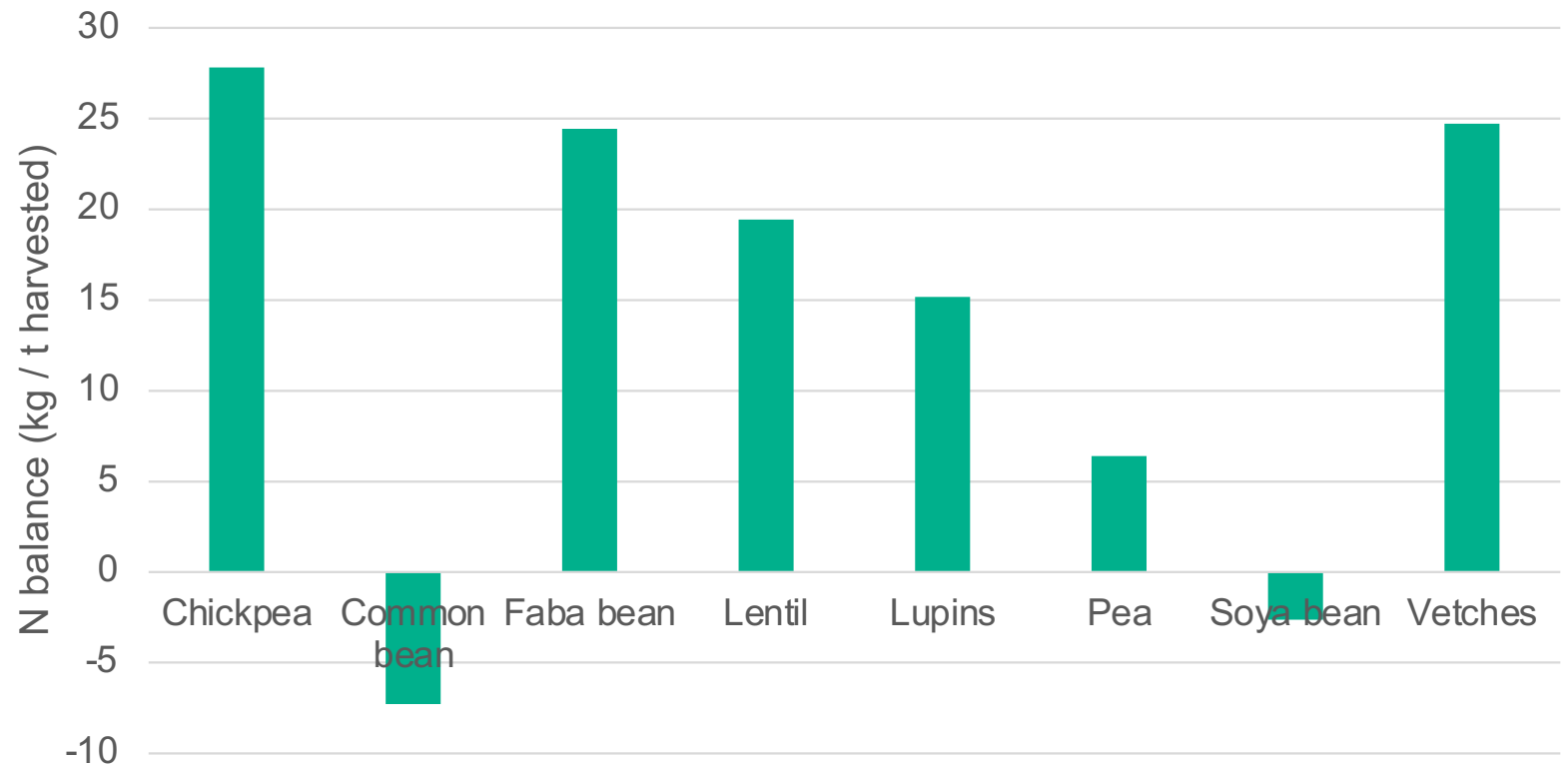
- Red clover lasts 2-3 years
 - Short-term leys good for soil C status
- White clover, alfalfa ~5 years
- Ireland, 2010:
Milk : N price ratio reached tipping point
Farmers increased profit with lower N fertilizer use,
white clover for N input, fewer cattle / ha

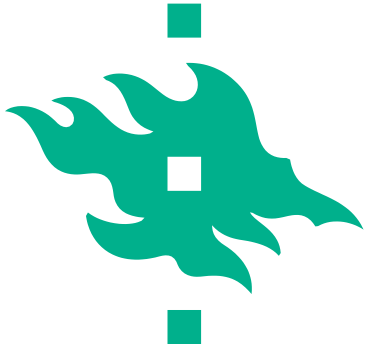


N impacts



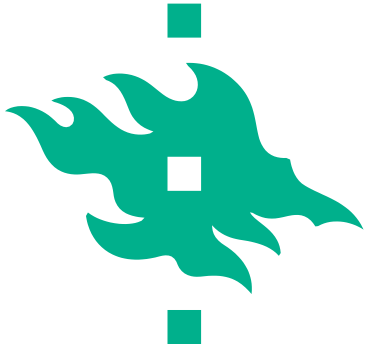
How much fixed N does a grain legume crop leave?





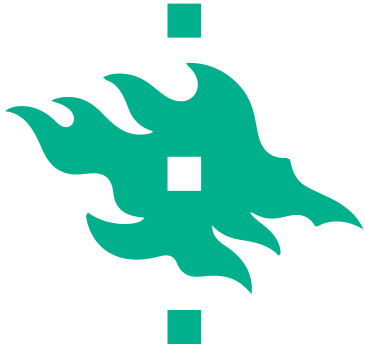
What does this mean in practice?

- Most European farmers view the residual as a bonus rather than a saving
- The N fixed is low-cost input into animal feed (forage) or feed and food (grain) with minimal usage of fossil fuel
- Can we increase protein security by producing more and importing less? What crops are displaced?
- What happens if diets change so less needs to be imported for feed?



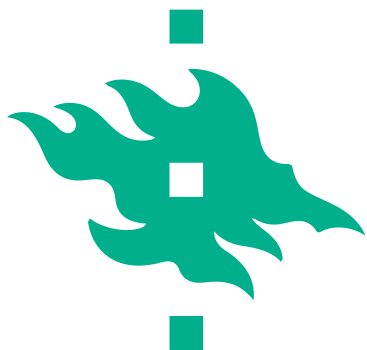
Could we be self-sufficient in plant protein? Calculations for Estonia

Scenario	Arable land needed for pulses
Using current faba : pea : lupin : soy ratio	27 000 ha more than now (48 k ha)
Using faba alone	23 000 ha more than now
Where to get it?	52 000 ha used for export barley



What if we reduce meat consumption?

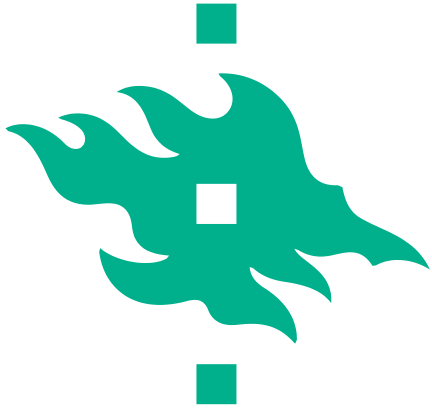
- Finns eat 15% more meat than the national dietary recommendation
 - Some nations eat a lot more!
- USDA (!) shows 72% of EU barley goes into feed
- $15\% \times 72\% = 10.8\%$ potential reduction in EU barley area



Assuming 15% less feed use of barley and soy (figures in k ha)

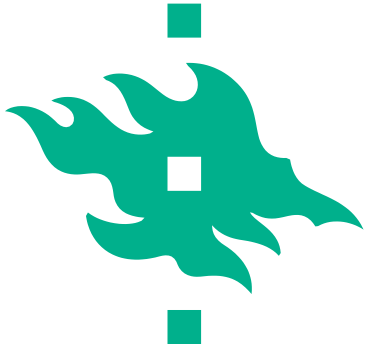
Our region (except Dk) could become a net exporter of plant protein!

	Needed for 100% replacement	For 85% replacement	Export barley	10.8% reduction in non-exported
Denmark	788	670	448	88
Estonia	23	20	52	22
Finland	116	98	27	49
Latvia	38	32	46	15
Lithuania	93	79	59	27
Norway	12	11	0	0
Sweden	135	115	80	42
EU28	17317	14720	2813	1461

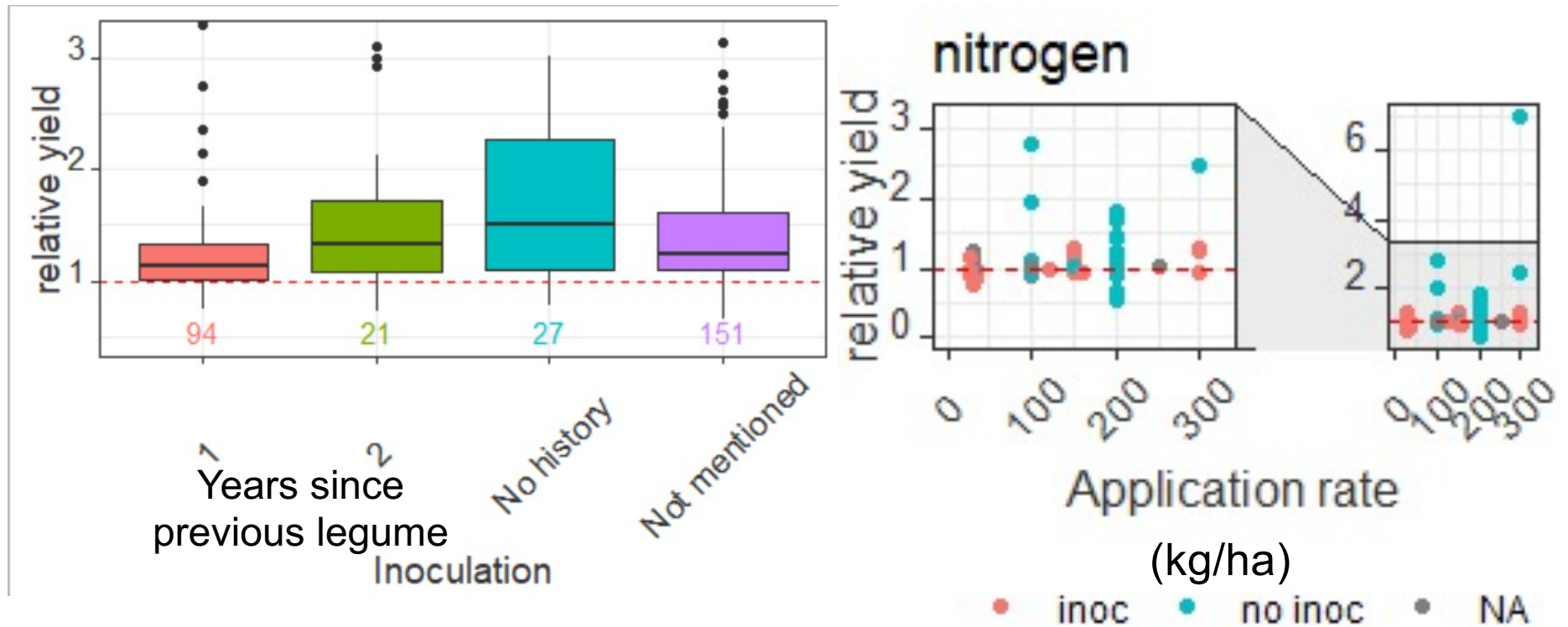


How can we grow faba better?

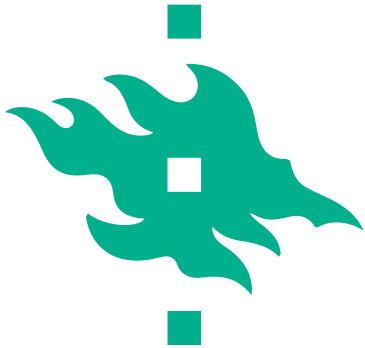
A few highlights of a meta-analysis in LegumeGap



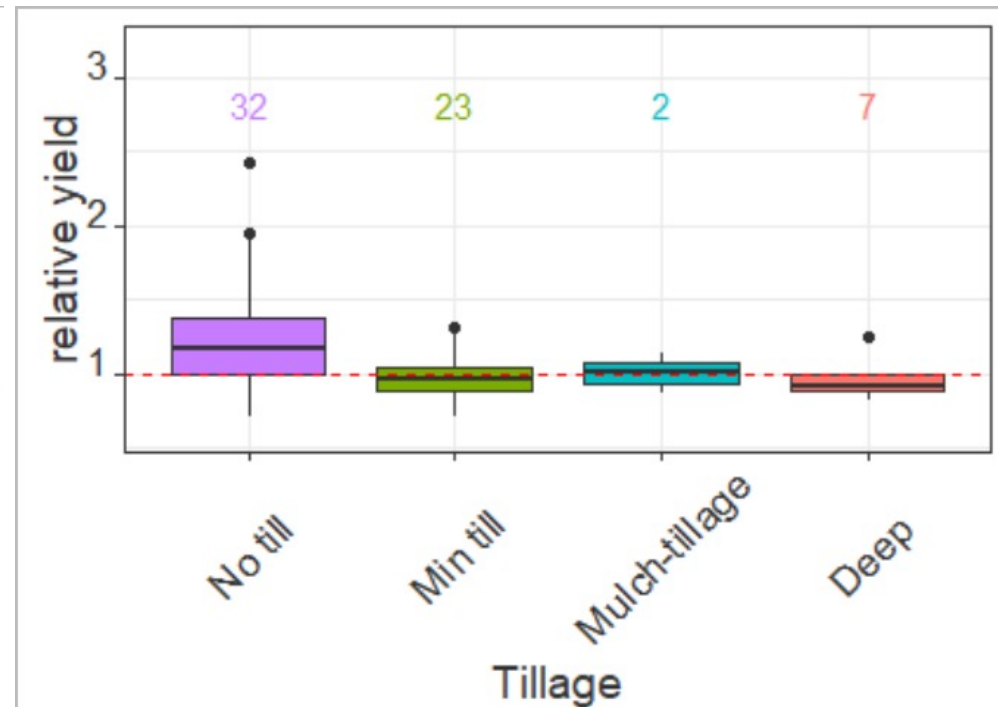
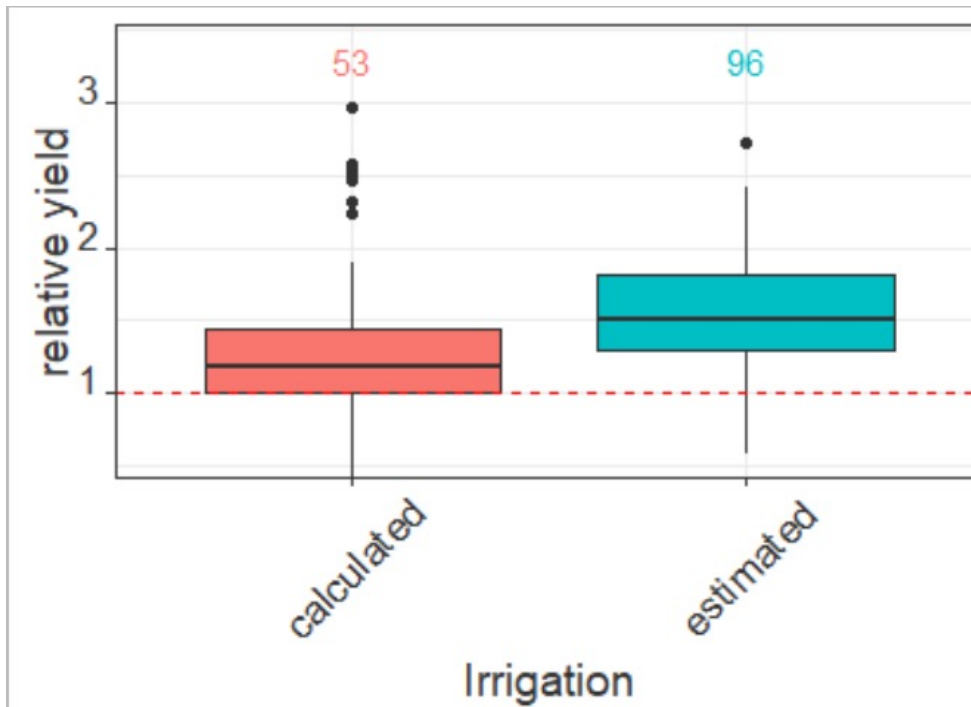
Rhizobium inoculation usually pays, N fertilization does not

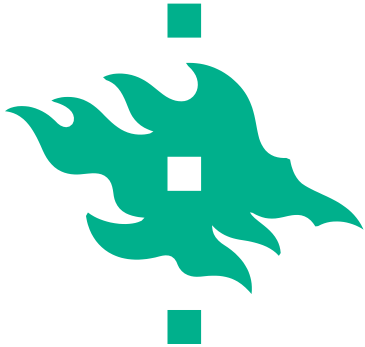


Nevertheless, most farmers prefer to start with 20 – 40 kg/ha

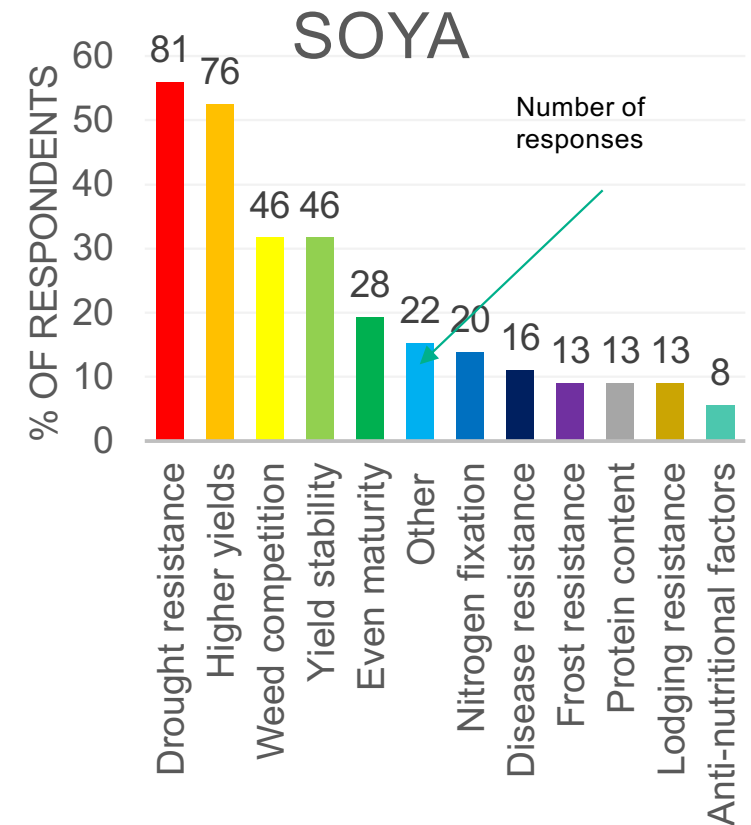
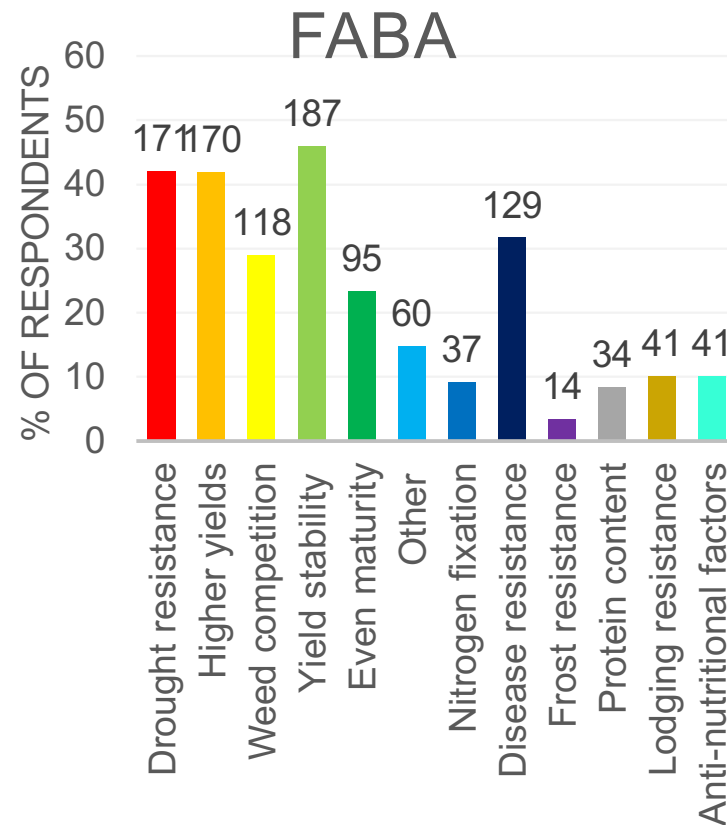


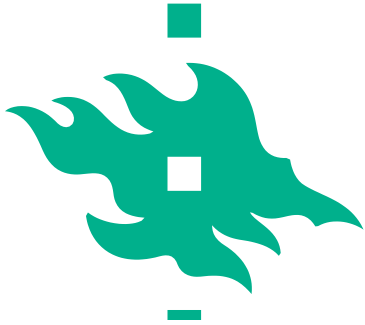
Irrigation is almost always useful, zero tillage brings benefits





In what ways do we need to improve faba and soy cultivars?

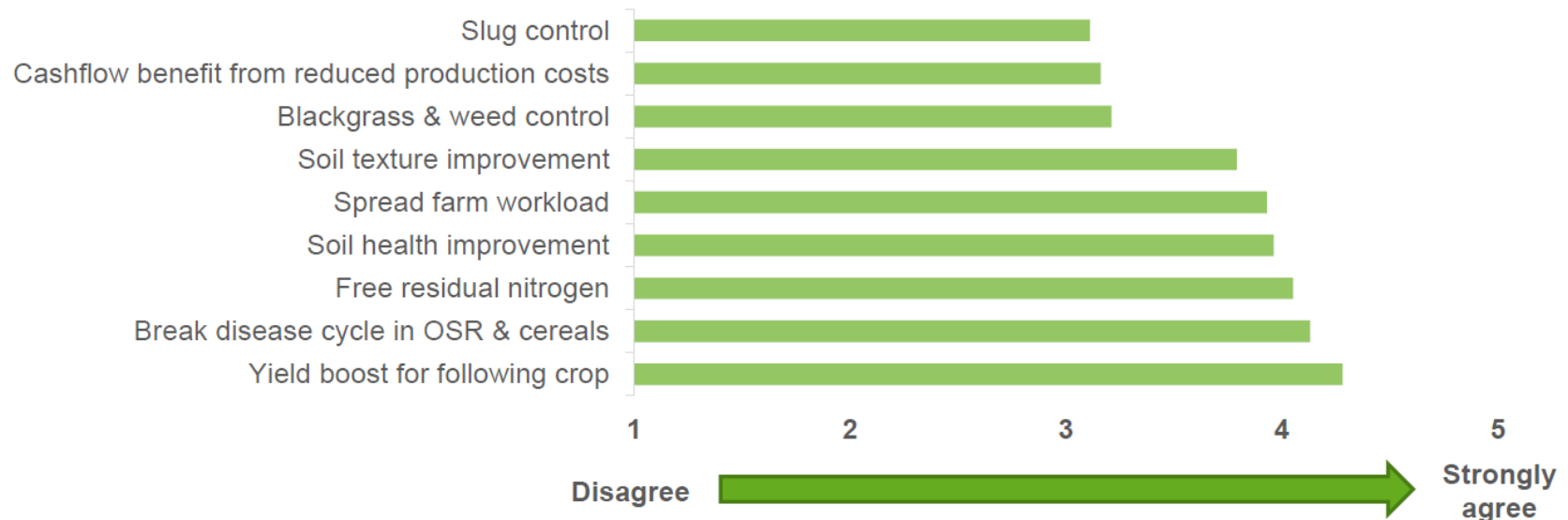


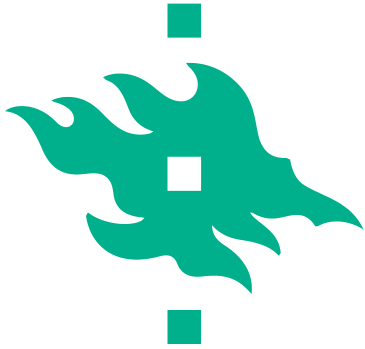


What is the biggest benefit of growing a grain legume?

‘Yield boost for following crop’ most strongly agreed with as benefit

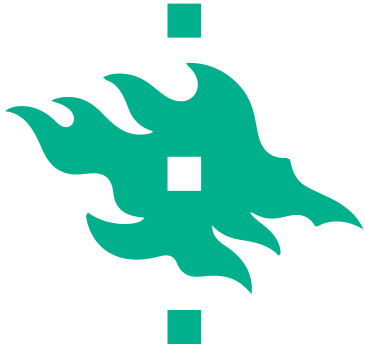
Agreement with agronomic benefits of pulses identified by PGRO





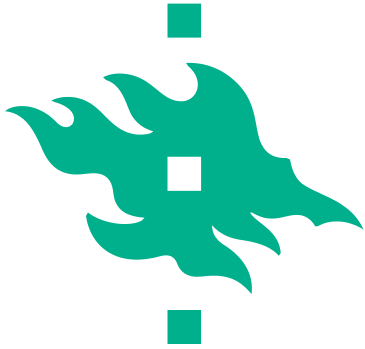
Drawbacks and trade-offs

- Legume residues have a high N content
- → High potential for NO_3^- leaching, N_2O emission after the crop
- Need to trap the N
- Prices are often too low to compensate for the currently low yield
 - Food use usually commands a higher price than feed use



How to trap more of the biologically fixed N or prevent emission

- Cover crops or winter crops to take up N as it mineralizes
- Application of C-rich material to alter the C:N balance: cereal straw or biochar
- Rhizobium bacteria with the nosZ gene for Nitrous oxide reductase reduce N₂O release as residues break down
 - So do some other denitrifying bacteria: inoculate?
- Root exudates affect N₂O release: scope for breeding or management
- Investment in breeding for yield, stress resistance, disease resistance, quality



Conclusion

- Legumes need little or no N fertilizer
- Profit margins low, war may change this
- Break-crop effect valuable for next cereal
- Novice must learn about the crop: managing weeds, pests and diseases
- Legume forages reduce need for fertilizer on pastures