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Supply of phosphorus and other nutrients in organic agriculture

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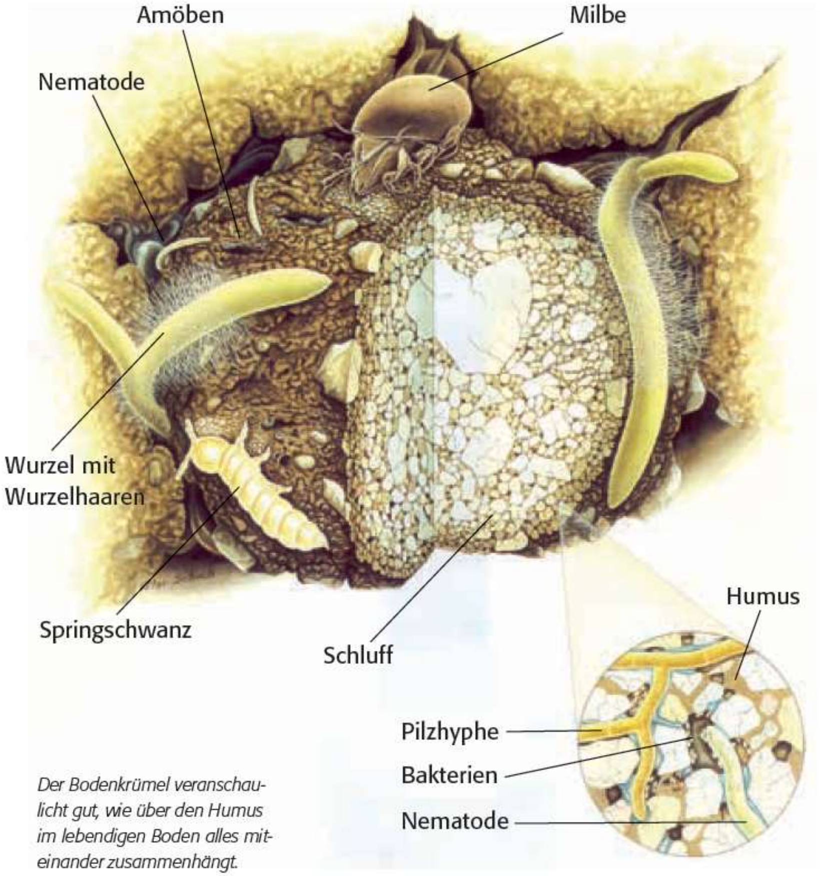
55th Annual Conference 2023 of the German Society of Plant Nutrition
Hohenheim, Germany; September 26, 2023

Plant nutrition in organic farming (I)



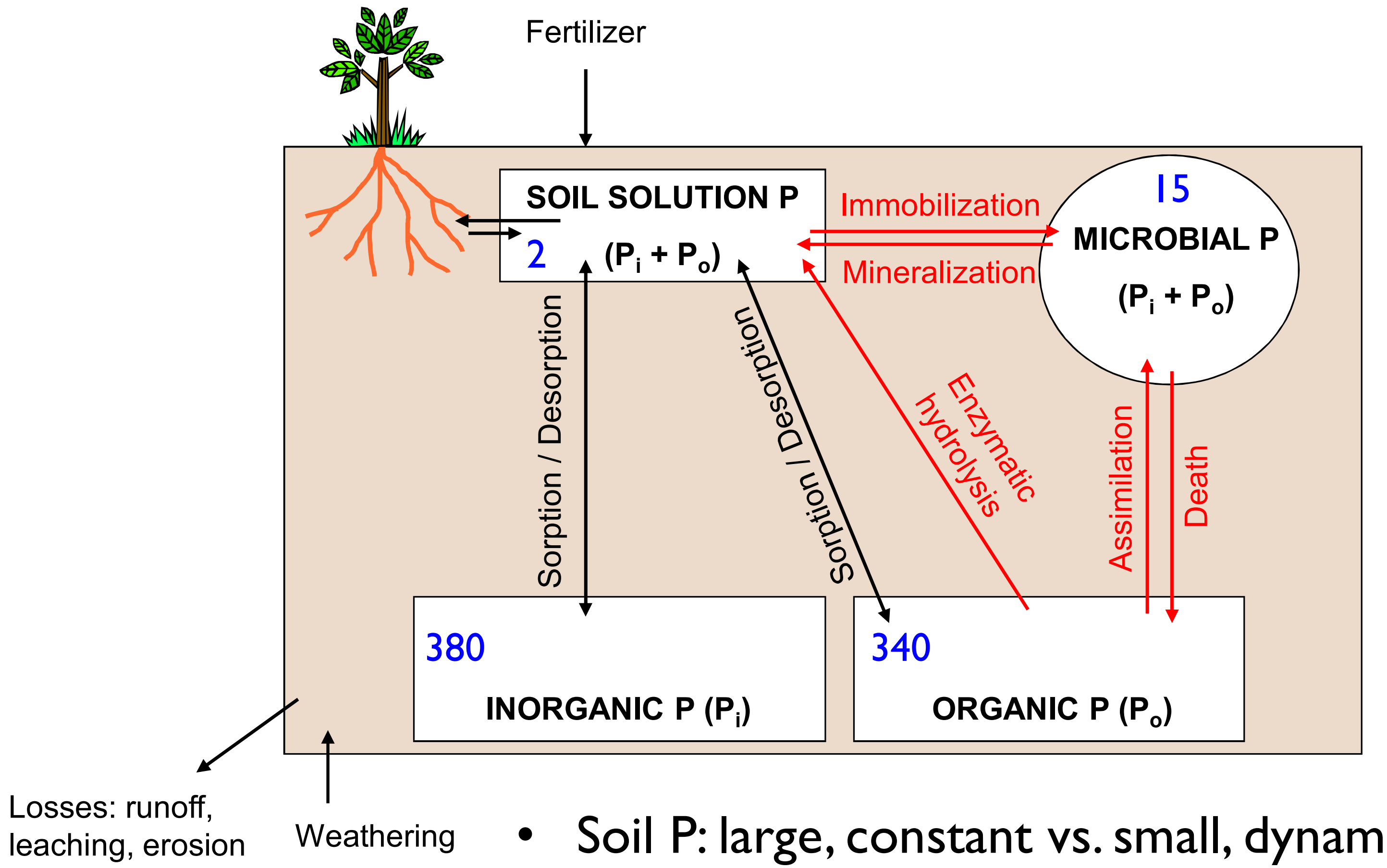
Soils are complex living systems

- Nutrient supply to plants primarily via the soil

⇒ Management of soil health is paramount.

⇒ To fertilize means to stimulate life in the soil.

Soil P pools and dynamics



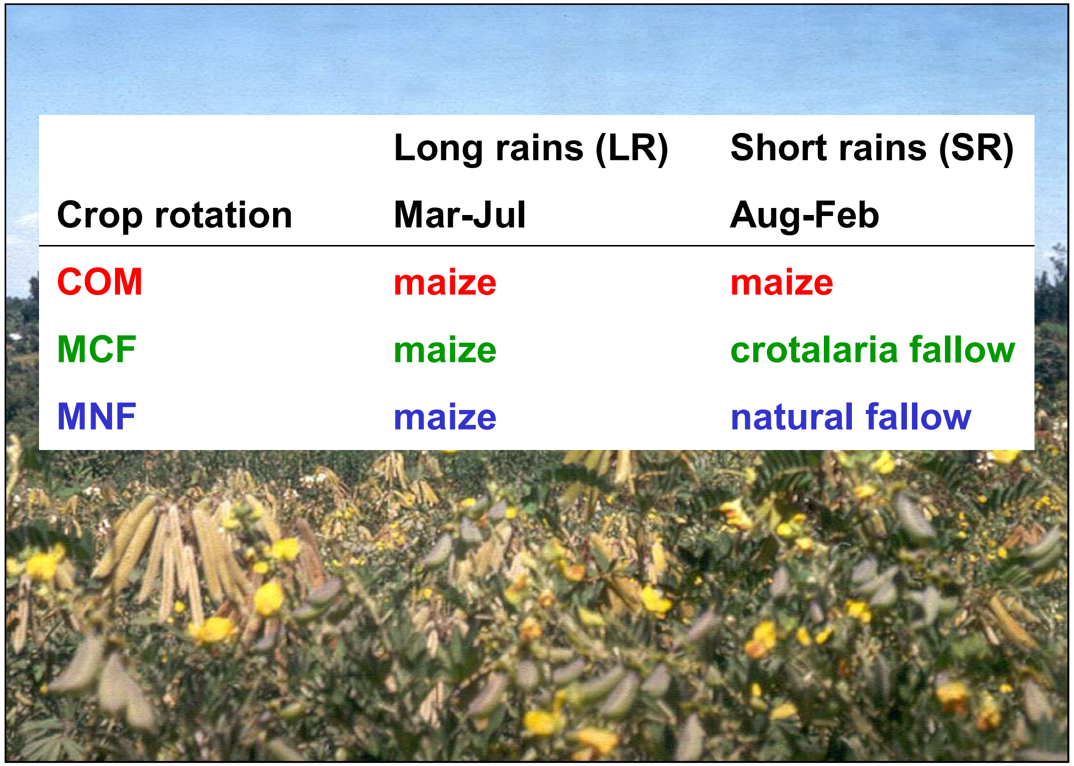
- Soil P: large, constant vs. small, dynamic pools
- Importance of physicochemical processes
- Role of microbial and enzymatic processes?

Legume fallows on P-limited soils in Western Kenya

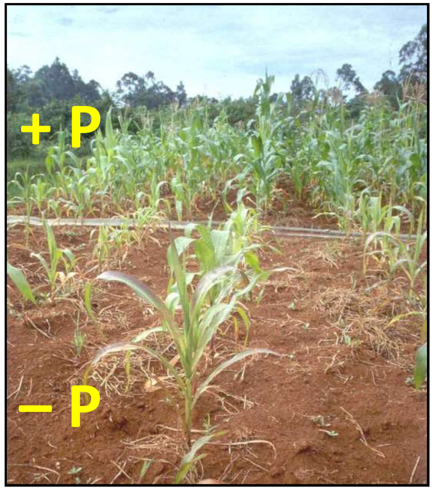
Soil type: Ferralsol (0-20 cm: pH_{H2O} 5.0, 37% sand, 39% clay)

Smallholders' cropping system: two rainy seasons per year,
maize-fallow or maize-~~maize~~ -legume fallow

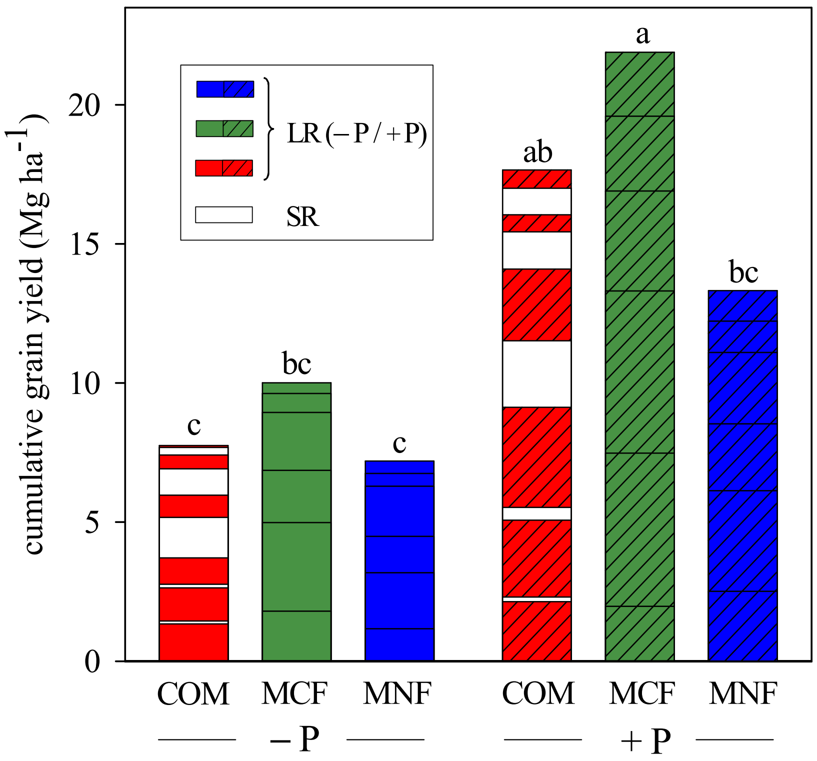
Legume: e.g. *Crotalaria grahamiana*



Crop rotation	Long rains (LR) Mar-Jul	Short rains (SR) Aug-Feb
COM	maize	maize
MCF	maize	crotalaria fallow
MNF	maize	natural fallow



Cumulative yield during 5.5 years



	Soil P pools		
	Avail. inorg. P	Microbial P	Organic P
		mg P kg^{-1}	
COM	4.3 ns	3.5 b	264 b
MCF	4.0 ns	6.4 a	286 a
MNF	4.2 ns	5.3 a	272 ab
-P	1.7 b	4.9 ns	273 ns
+P	6.6 a	5.2 ns	275 ns

Maize yield:

- Increased by P fertilization
- Increased after incorporation of legume biomass

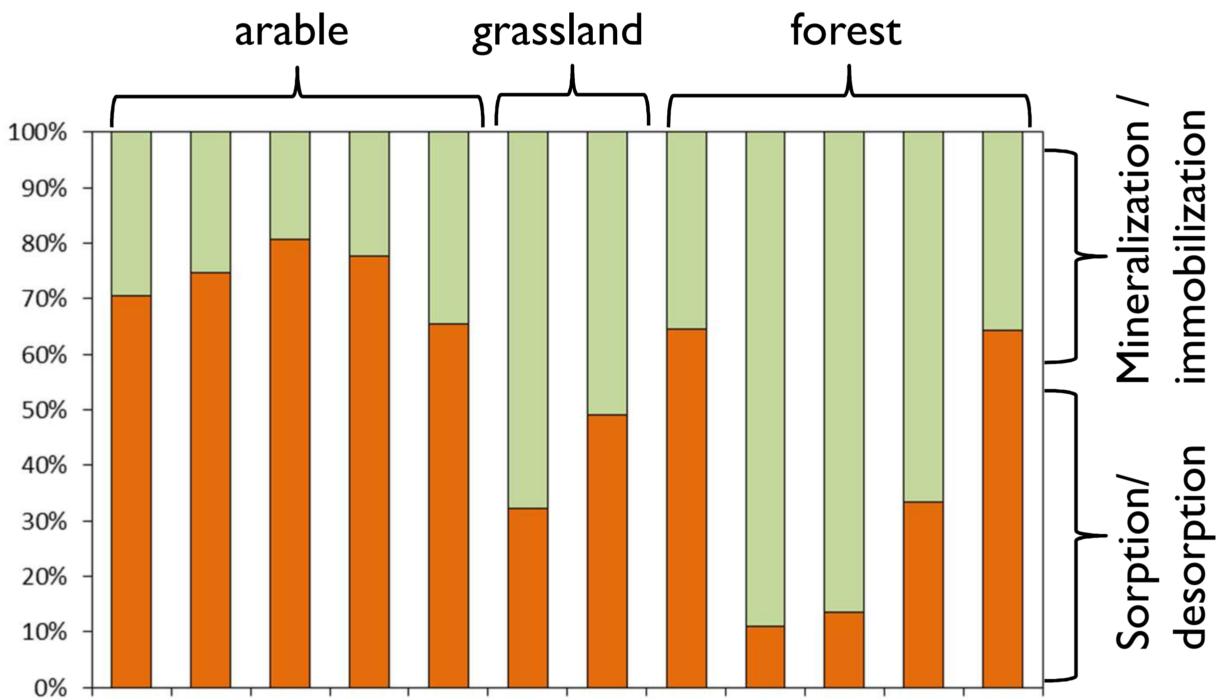
=> Effects of legume fallow on microbial and organic P, but not on availability of inorganic P

Bünemann et al. 2004 PLSO

Relative importance of gross P_o mineralization under different land-uses

Biological processes (as measured in laboratory incubations using P radioisotopes):

- more important in forest and grassland than in arable soils
- increase under P limitation (very fast microbial immobilization)

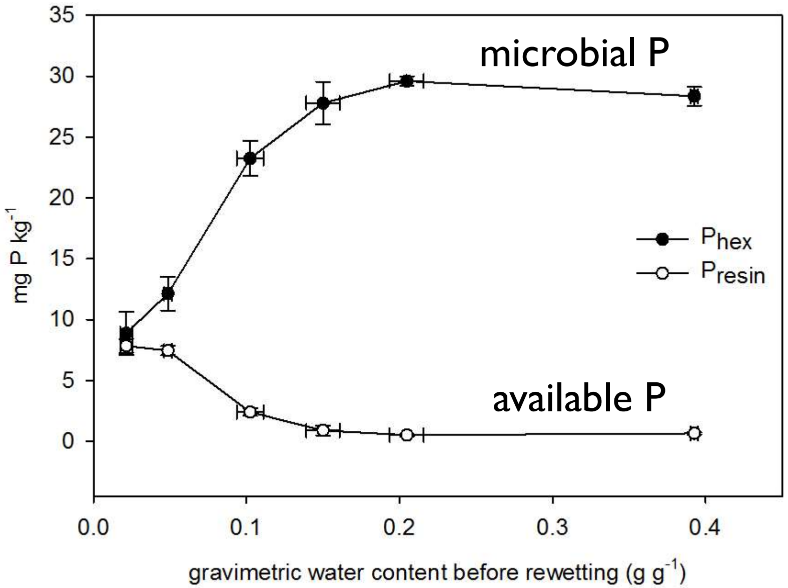


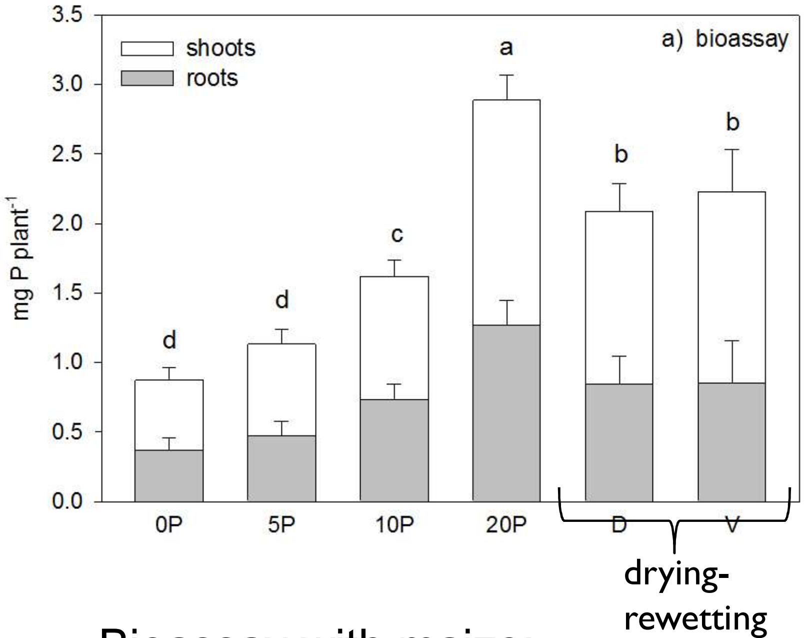
Oehl et al. 2004; Bünemann et al. 2007; Achat et al. 2009; Bünemann et al. 2012; Spohn et al. 2013; Randriamanantsoa et al. 2015

Bünemann 2015 SBB

=> Biological processes in soil P dynamics are not negligible!

Non-steady state conditions





Rewetting after drying to below 15% gravimetric water content:

- decrease in microbial P
- increase in available P

Bioassay with maize:

- P uptake doubled after DRW, equivalent to mineral P addition of about 14 mg P kg^{-1}

Bünemann et al. 2013 PLSO

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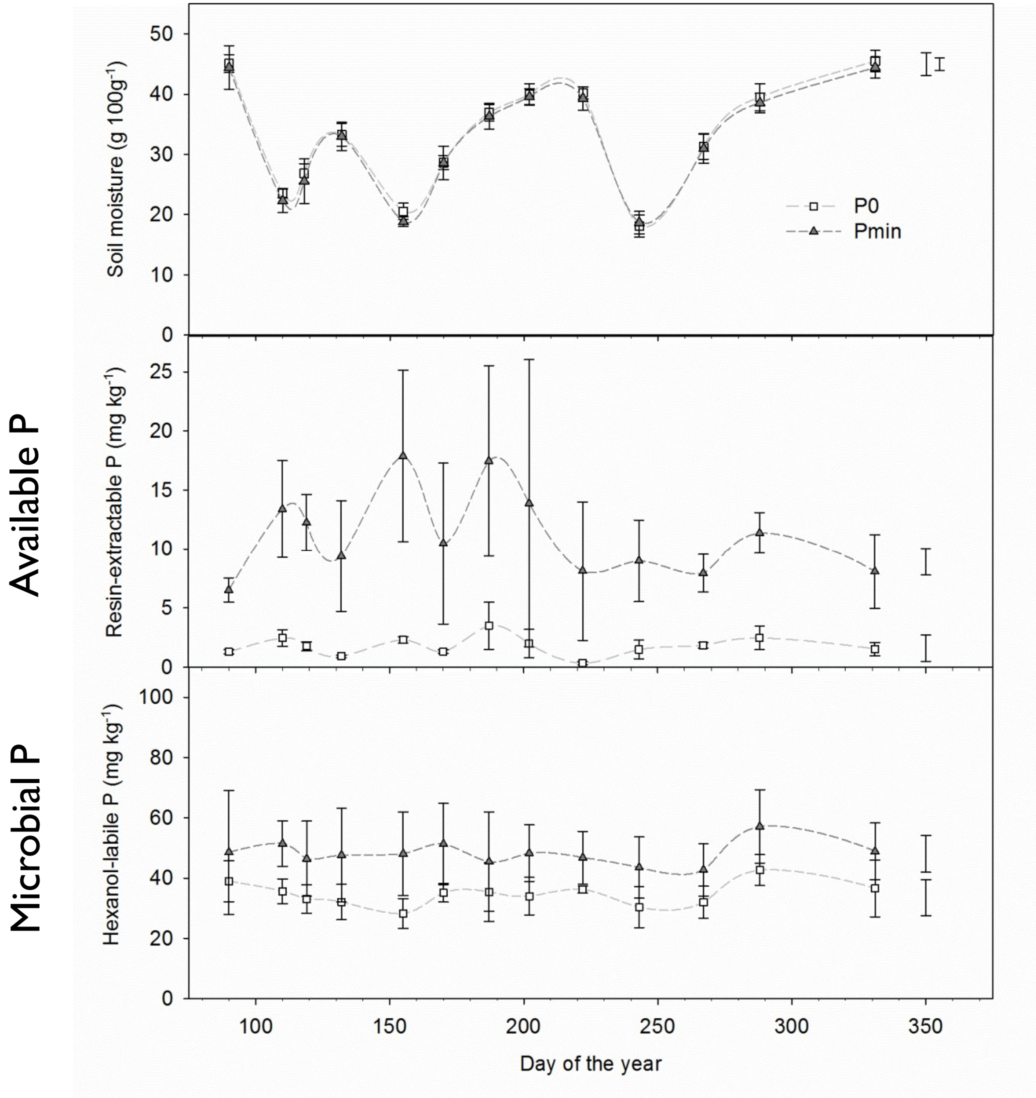
Seasonal dynamics in the field

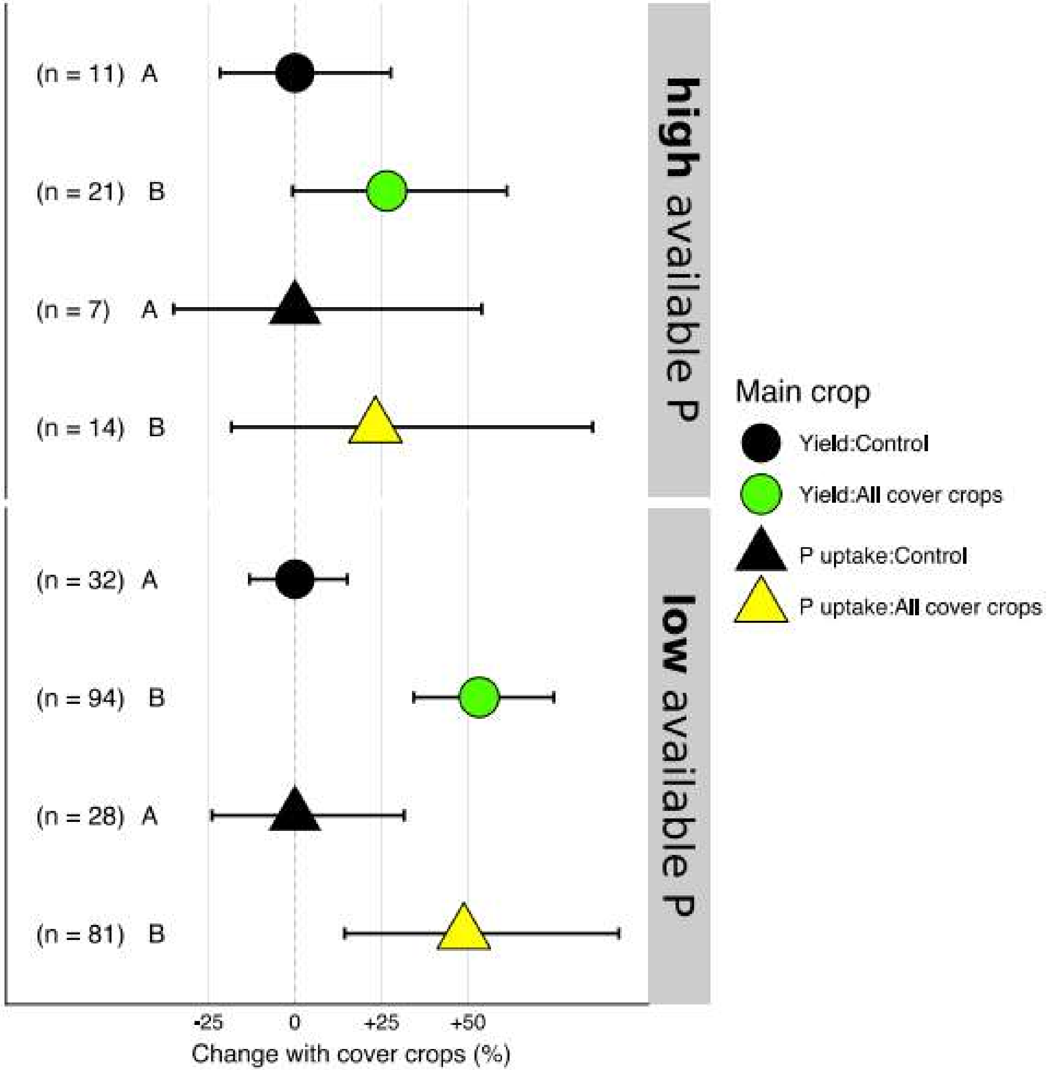


Fluctuations in available and microbial P related to

- soil moisture
- competition between plants and microorganisms for available P

Liebisch et al. 2014 BFS

Increase in crop yield and P uptake after cover crops



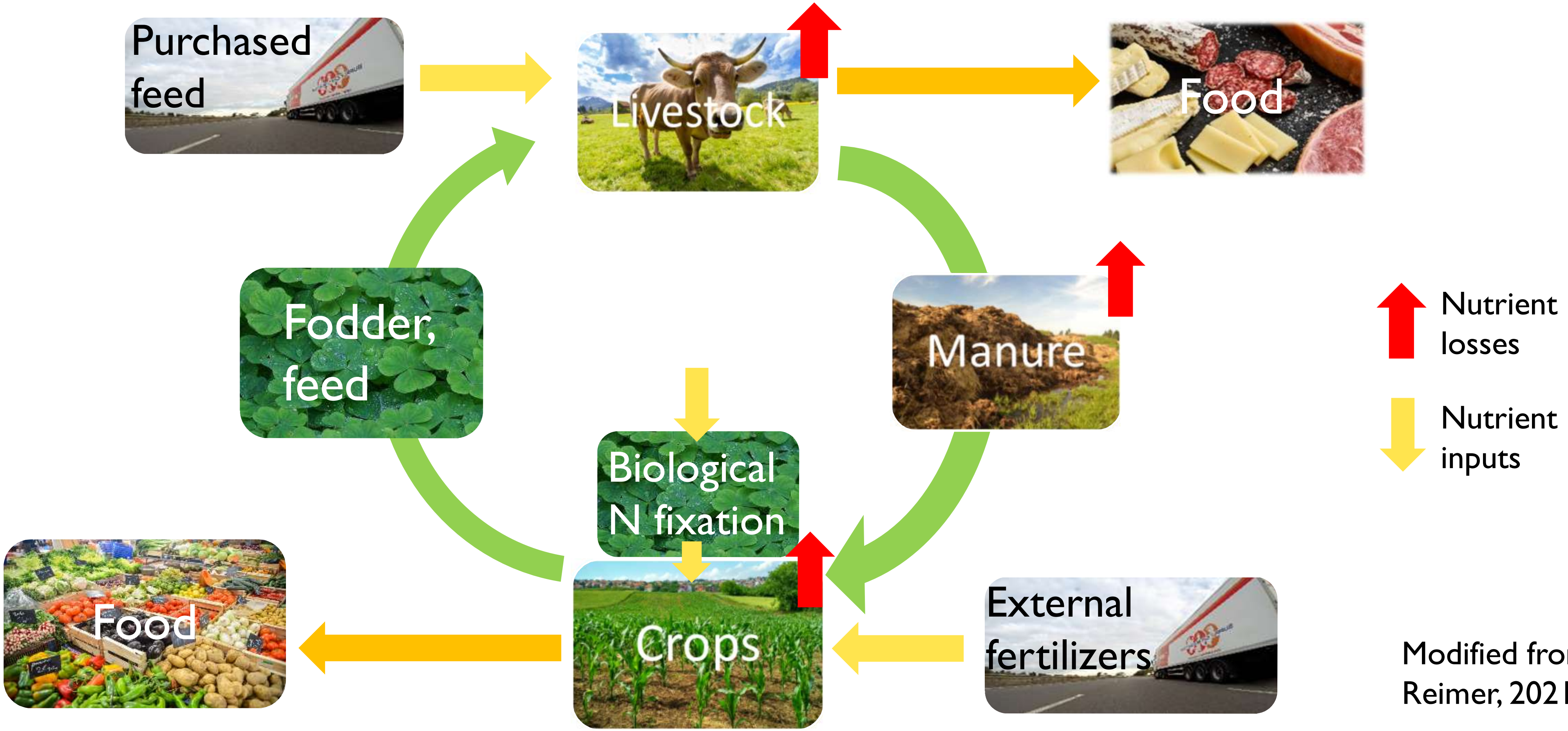
- Greater increase in yield and P uptake after cover crop incorporation on low-P than on high-P soils

- Mechanisms:

  P mobilization
  Decomposition (dynamics depend on C:P)
  Increased mycorrhizal abundance
  Increased microbial biomass P
  Increased phosphatase activity

Hallama et al. 2019 PLSO

Plant nutrition in organic farming (II)



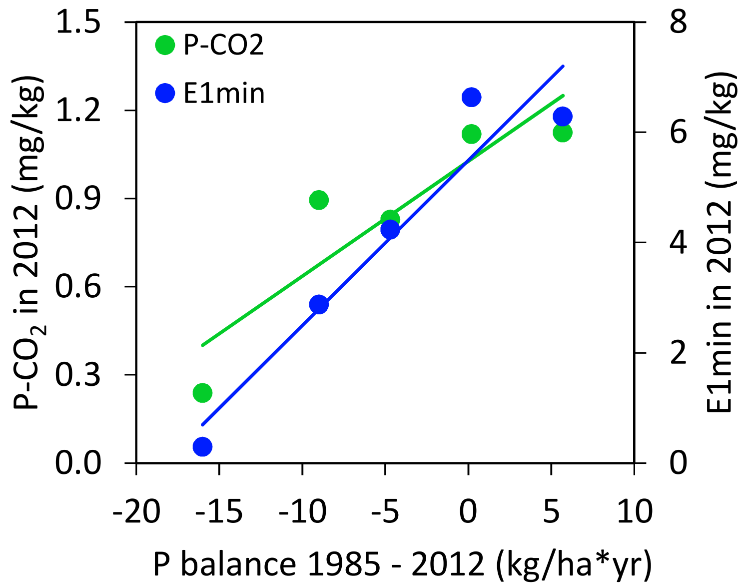
Modified from Reimer, 2021

- Farm considered as an agroecosystem with **largely closed nutrient cycles** and **few external inputs**. Self-regulation.
- Synthetic N fertilizers and easily soluble P fertilizers not allowed.

P dynamics in the DOK (Dynamic Organic (K)Conventional) trial

- Therwil (near Basel), haplic Luvisol (15% sand, 70% silt, 15% clay), since 1978

Treatment	Fertilizer type	Input	Output	Balance
		kg/ha*yr		
NONFERT	-	0.3	16	- 16
BIODYN2	Composted Manure	22	31	- 9
BIOORG2	Rotted Manure	27	32	- 5
CONFYM2	Fresh Manure + Mineral fert.	37	37	+ 0
CONMIN	Mineral fertilizer	39	33	+ 6

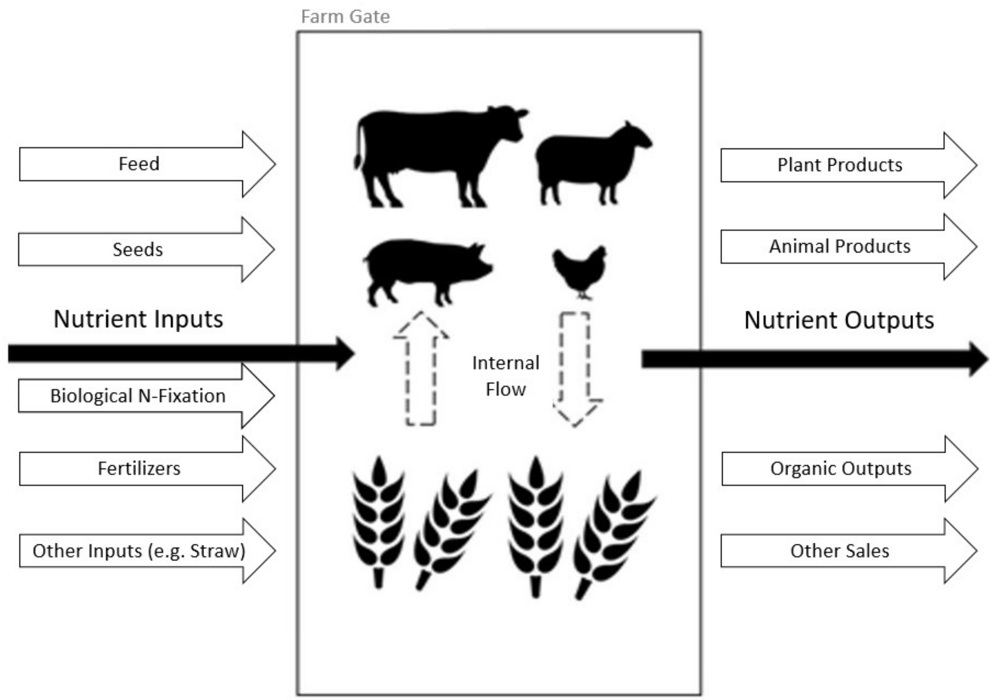


- Negative P budgets in organic systems
- Available P is related to the P budget

Jarosch, Oberson et al., in preparation

Current use of and need for external nutrient sources in organic farming in Europe

RELACS
IMPROVING INPUTS FOR ORGANIC FARMING



Survey of 71 organic farms in 7 European countries: Interviews and farmgate budgets covering 3 years

Reimer et al. 2023 Nutr. Cycl. Agroecosyst.

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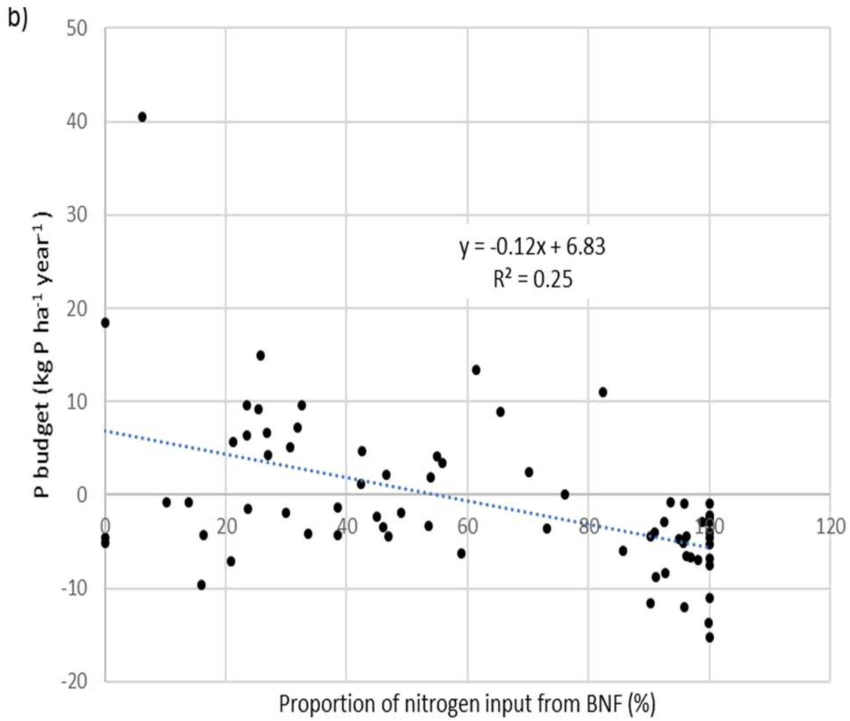
Reliance on BNF affects P and K budgets

- 24% of farms with negative N budgets; on average 61% of N derived from BNF
- 66% and 56% of farms with **negative budgets for P** and **K,** respectively
- **Farm type most important factor** →Stockless farms have highest deficits
- **High reliance on BNF correlated with low output, and with negative P and K budgets**
- «Some organic farmers believe having sufficient legumes in the rotation is sufficient to meet soil fertility needs"



⇒ N needed to increase productivity

⇒ P and K needed to prevent soil mining

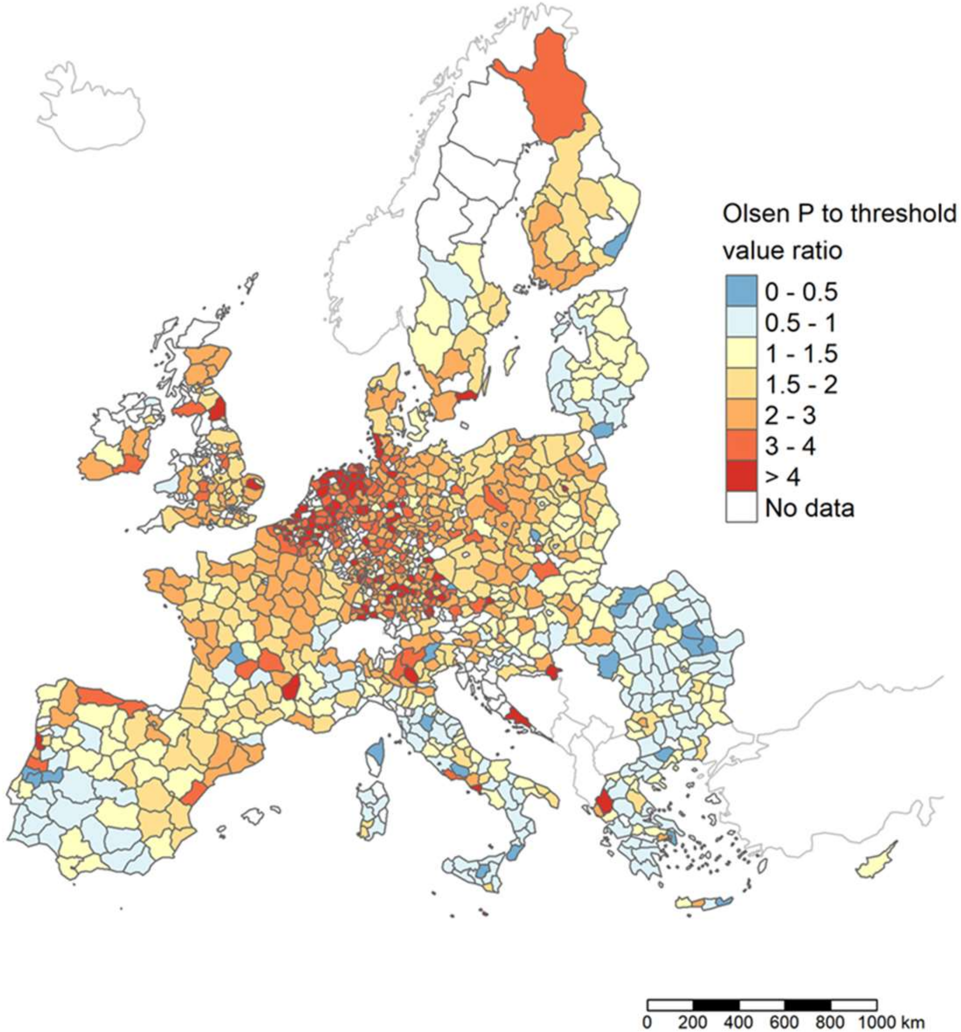
Reimer et al. Nutr. Cycl. Agroecosyst., 2023

Soil P status of European soils

- Improved model for estimating Olsen P threshold values:

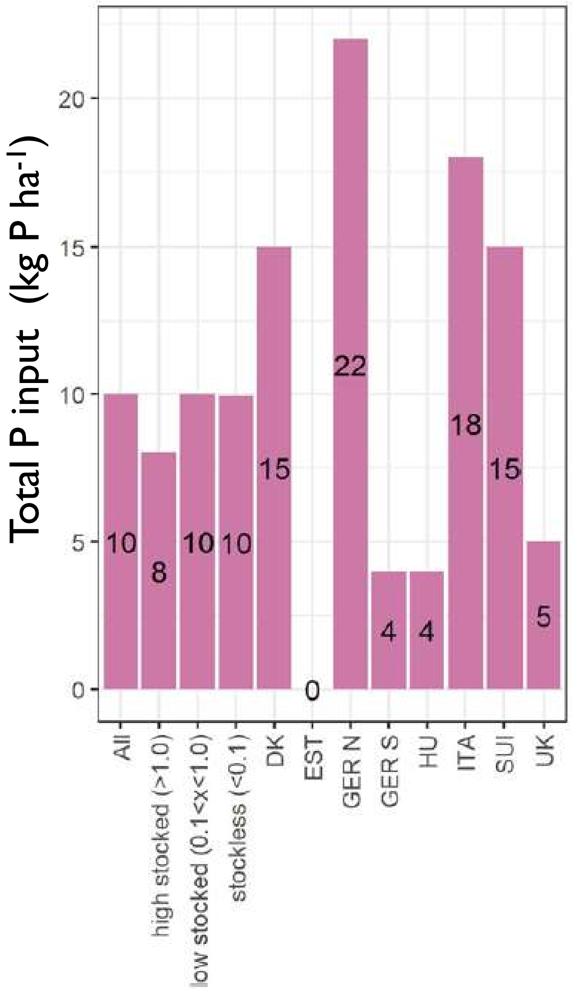
only 27.8% of EU cropland soils and 42.7% of grassland soils are P-responsive

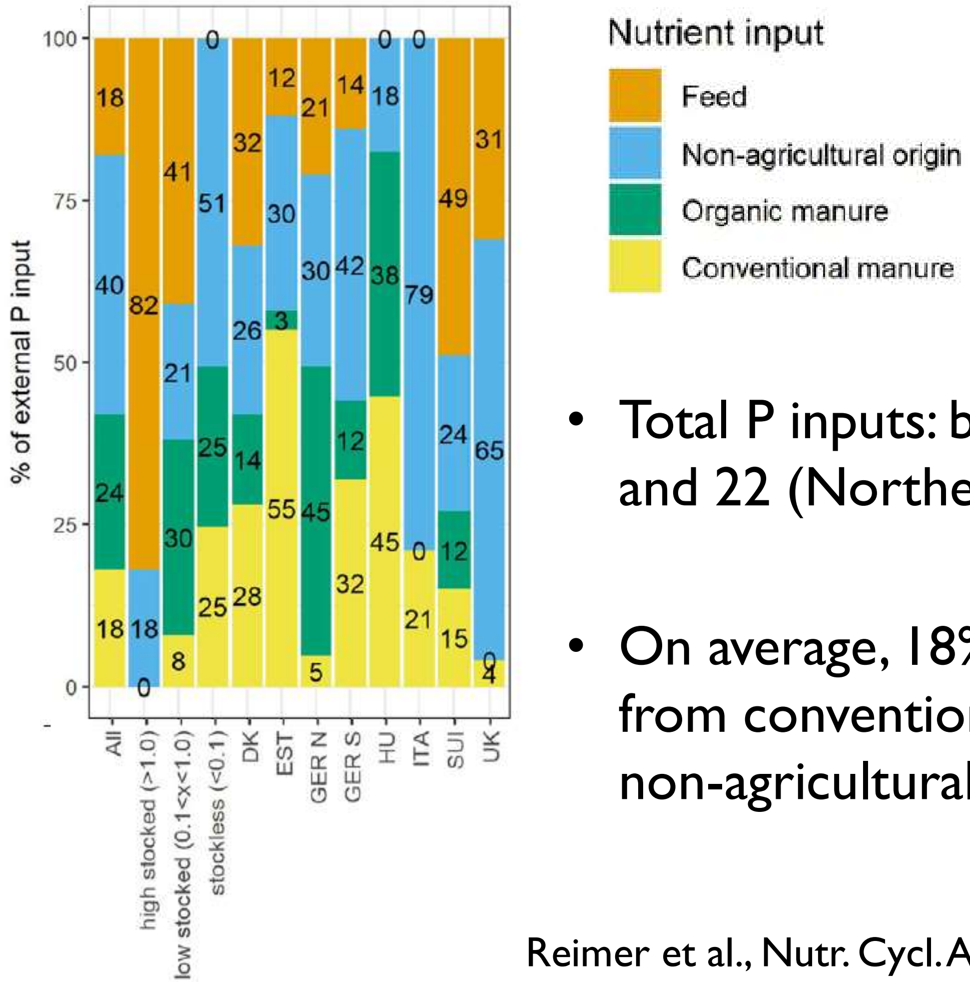
- A large proportion of NUTS3 regions in the EU has a build up component of zero, i.e. P fertilizer should (at most) compensate for crop P export.



Recena et al. 2022 J. Cleaner Prod.

External P inputs used on organic farms in Europe





- Total P inputs: between 0 (Estonia) and 22 (Northern Germany) kg P ha^{-1}
- On average, 18% of external P input from conventional manure, 40% from non-agricultural origin, 18% from feed

Reimer et al., Nutr. Cycl. Agroecosyst., 2023

Interviews with organic farms: State the main rationale why you consider using a given nutrient input or not

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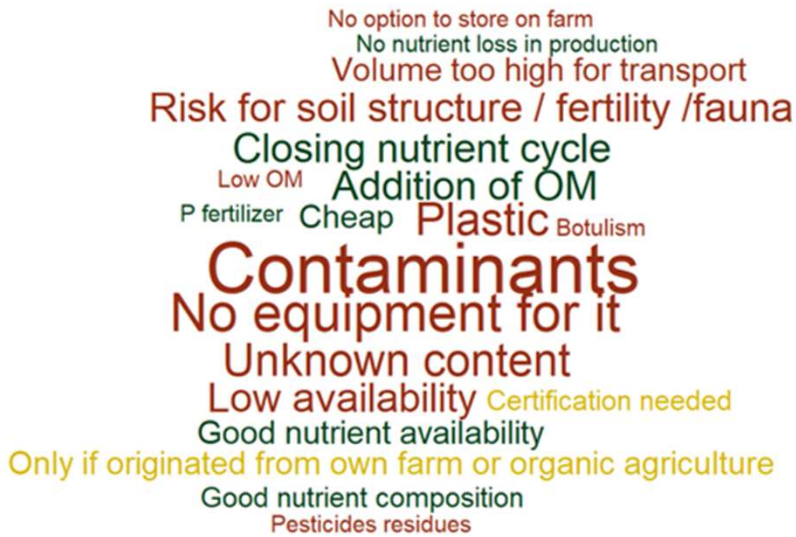
Household waste compost

Biogas digestates



Sewage sludge

Green: reason for
Red: reason against
Yellow: condition

- Main benefits: addition of OM, closing nutrient cycle
- Main obstacles: contaminants, plastic

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P recycling: navigating between constraints

	P recovery	P fertilizer value	Organic matter	PTEs	Organic Pollutants	Env. impact	Overall Score
Bio-waste compost	green	green	green	red	grey	red	grey
Bio-waste digestates	green	dark blue	green	grey	grey	green	dark blue
Meat and bone meal	green	grey	dark blue	green	green	green	dark blue
- ashes	green	red	red	green	green	green	dark blue
Sewage sludge	green	green	green	grey	red	green	green
- Struvite (AirPrex)	red	green	red	green	green	green	dark blue
- Struvite (Stuttgart)	dark blue	green	red	green	green	red	dark blue
- AshDec Rhenanite	green	green	red	grey	green	dark blue	dark blue

IMPROVE

2013-2016

CORE organic II

P availability
Risk assessment
LCA
Acceptance

Scale: 4 3 2 1

Further information: Möller et al. 2018 Advances in Agronomy Volume 147

www.improve-p.uni-hohenheim.de www.youtube.com/watch?v=LBKmgw5LjLA

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A way forward

***Principle of* HEALTH**

Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.

***Principle of* ECOLOGY**

Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

***Principle of* FAIRNESS**

Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.

***Principle of* CARE**

Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

IFOAM

A multi-criteria assessment of nutrient inputs for organic farming could follow these criteria:

1. Maximize farm-internal recycling and/or cooperation between organic farms before sourcing external fertilizers.
2. External fertilizers should originate from nutrient recycling.
3. The fertilizer production process should have a low environmental impact.
4. The fertilizer should not harm the soil and ideally be beneficial for soil quality.

Take home messages

- Organic farms try to close nutrient cycles within the farm as much as possible and to use as little external inputs as necessary
- Maintenance and build-up of soil fertility is central to nutrient management in organic agriculture
- Biological processes in soil P dynamics are important => more research needed (under field conditions)
- Maximising N input by legumes bears risks of P and K depletion => balanced nutrient inputs more challenging in organic agriculture
- Closing nutrient cycles between society/consumers and agriculture/producers is mandatory as well as challenging