Nitrogen and phosphorus fertilization in crop production to help shaping sustainable futures

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14th Dhalia Greidinger International Symposium
Agricultural practices - towards environmental sustainability
Haifa, Israel, 27 & 28 February 2023

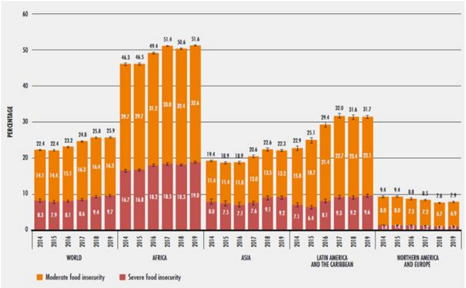
Background

Plants need 14 nutrient elements (in addition to C, H, O):

N, P, K, Mg, Ca, S, Fe, Mn, Zn, Cu, B, Mo, Cl (Ni)

Animals and humans need 22 nutrient elements:

N, P, K, Mg, Ca, S, Fe, Mn, Zn, Cu, Mo, Cl, Co, Na, Se, I, Cr, Ni, V, Sn, As, F



Uneven distribution on the globe:

1. Shortages lead to poor growth & development
2. Surpluses lead to pollution & ecosystem degradation
3. Easy accessible (P) reserves are being depleted

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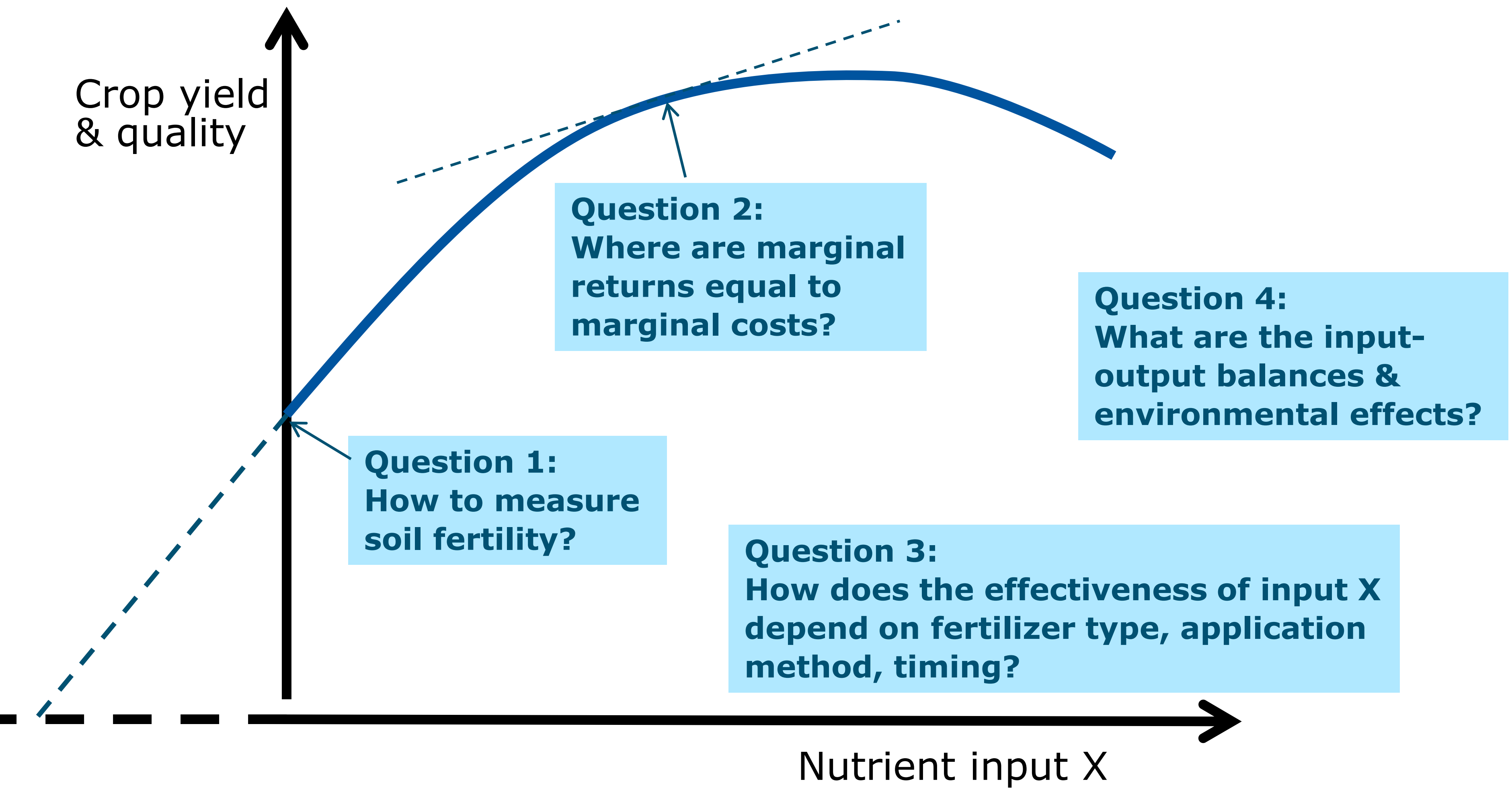
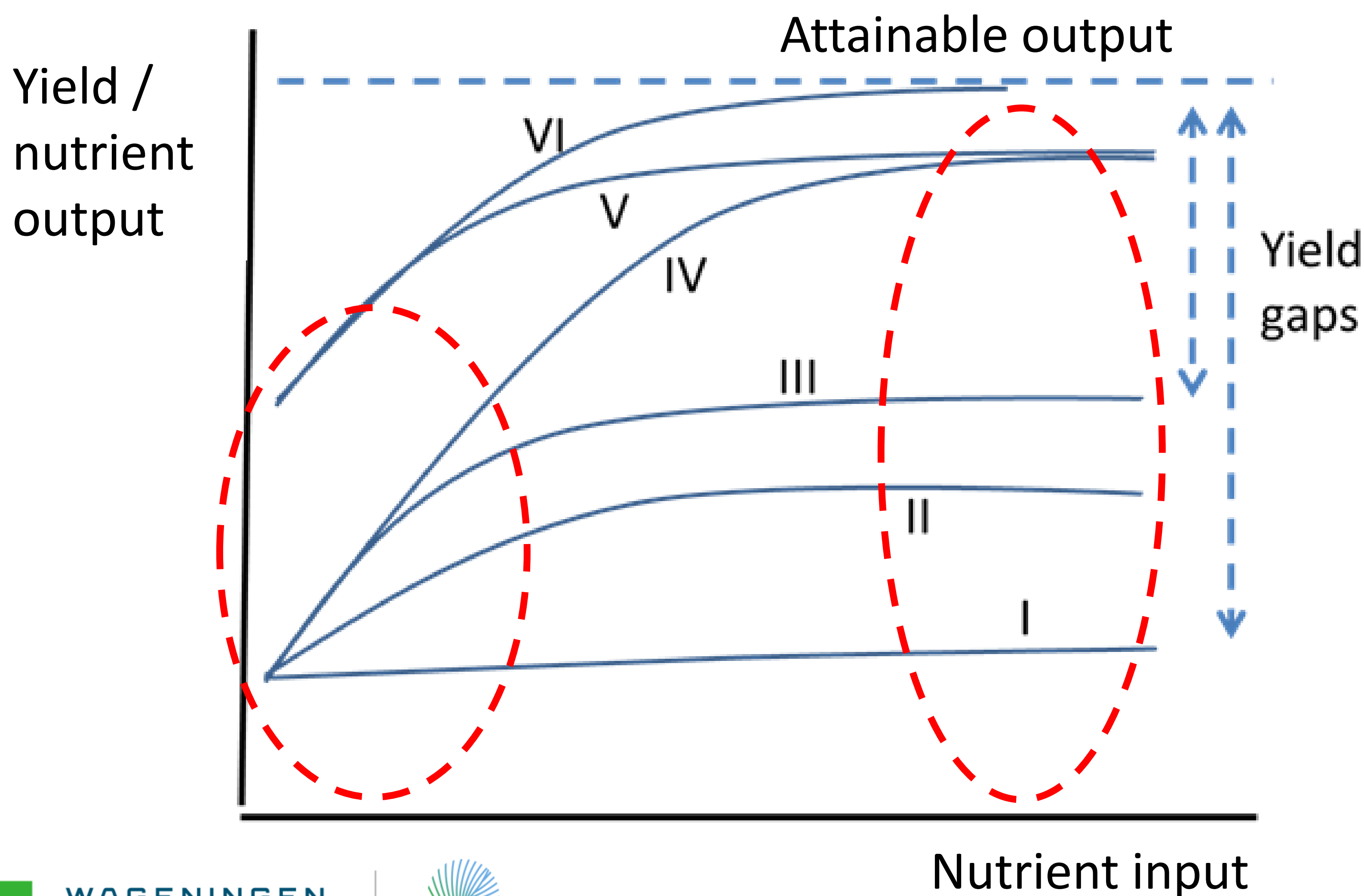
Classical questions in fertilization research



Yield gaps and different N response curves



Large differences between crops in financial loss with sub-optimal N fertilization

	Financial loss, euro per ha				
	N application, % of recommended amount				
Crop type	50%	60%	70%	80%	90%
Potato, sand	415	305	205	125	55
Potato, loess	695	500	335	250	90
Starch potato	120	80	45	20	5
Silage maize	105	75	50	25	10
Spinach	1300	830	475	210	70
Lilies	2070	1450	910	505	205

Based on a statistical analyses of many field experiments in NL. Note, fertilizer N savings are not included.
After Van Dijk et al. 2008

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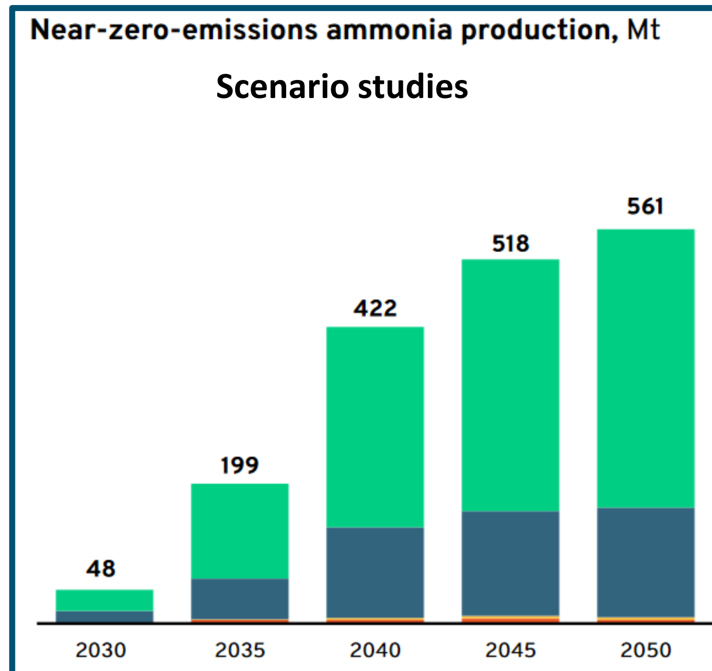
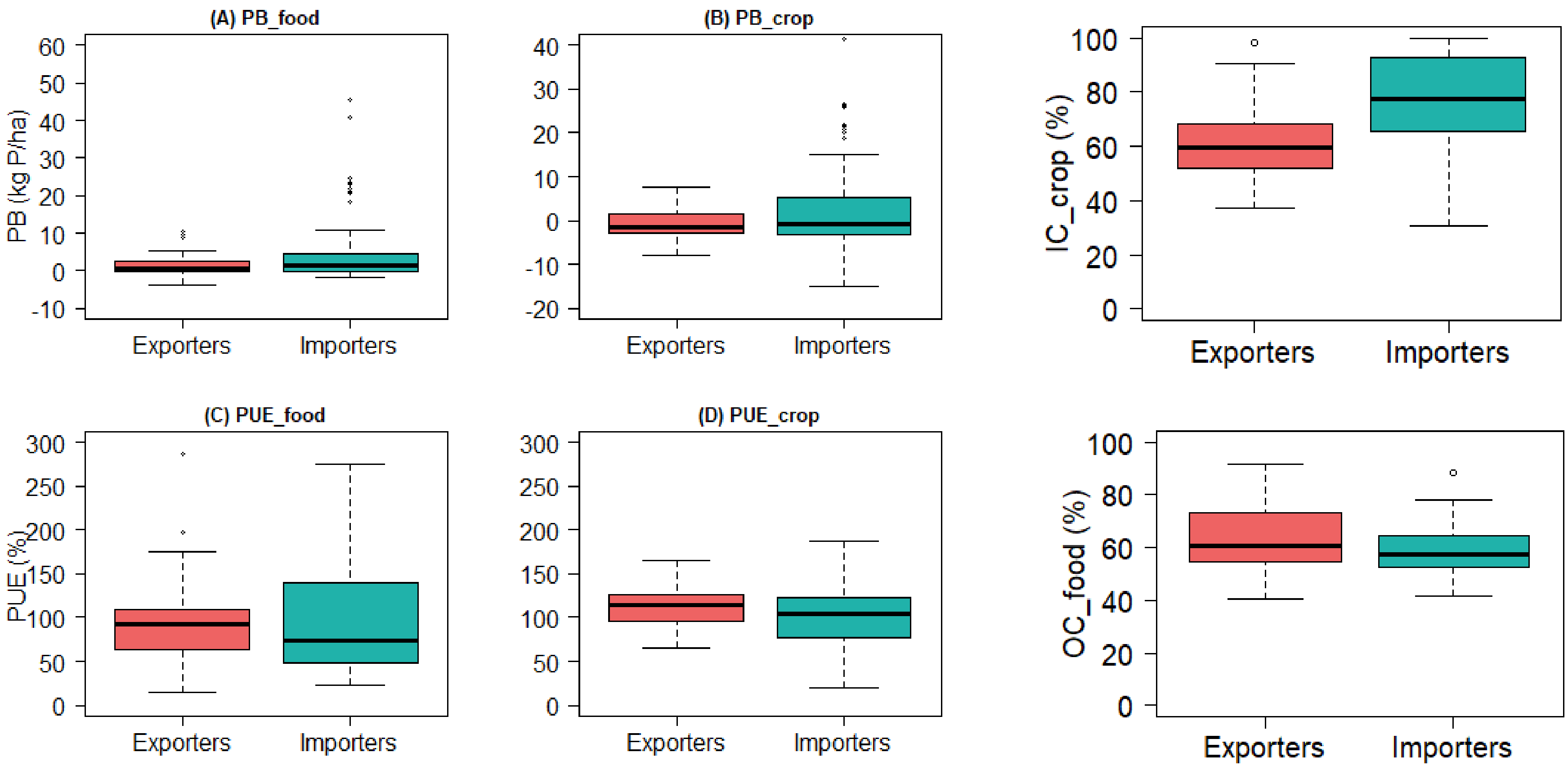
Soaring natural gas prices hit especailly EU producers of fertilizers & chemicals

- In October 2022 more than 70% of N fertilizer plants was off-line
- Increased fertiliser prices and increased imports of N fertilisers
- Increased incentives for producing green / bio-based ammonia



Food/feed exporting countries tend to have negative P balances, and low P input circularity



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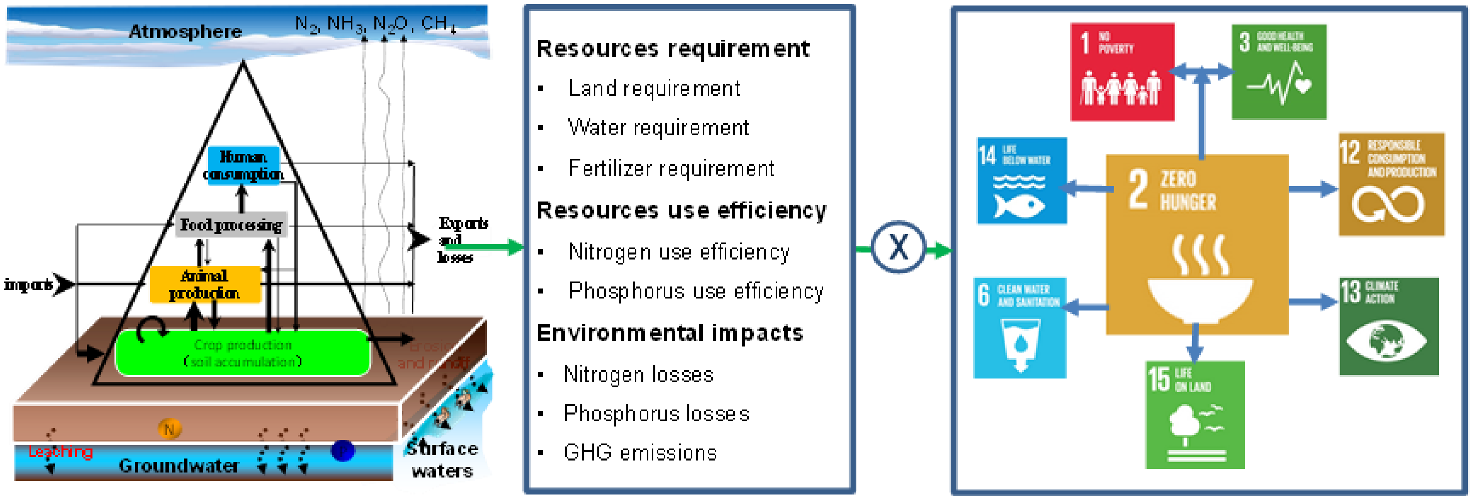
Wang et al., in prep.

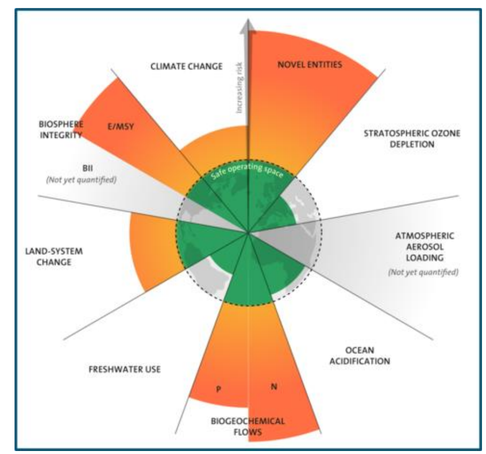
Increasing need to considering nutrient use and cycling in food systems' perspective



NUFER model | Indicators | Sustainable Development Goals (SDGs)

Ma et al., 2019

The EAT-Lancet Commission, 2019



Stockholm Resilience Centre, 2022

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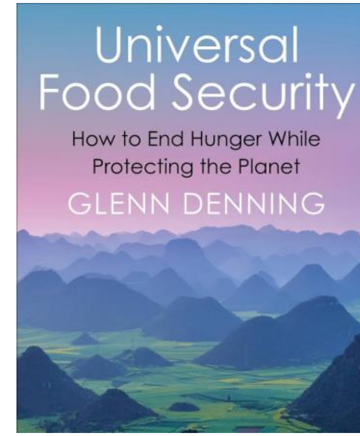
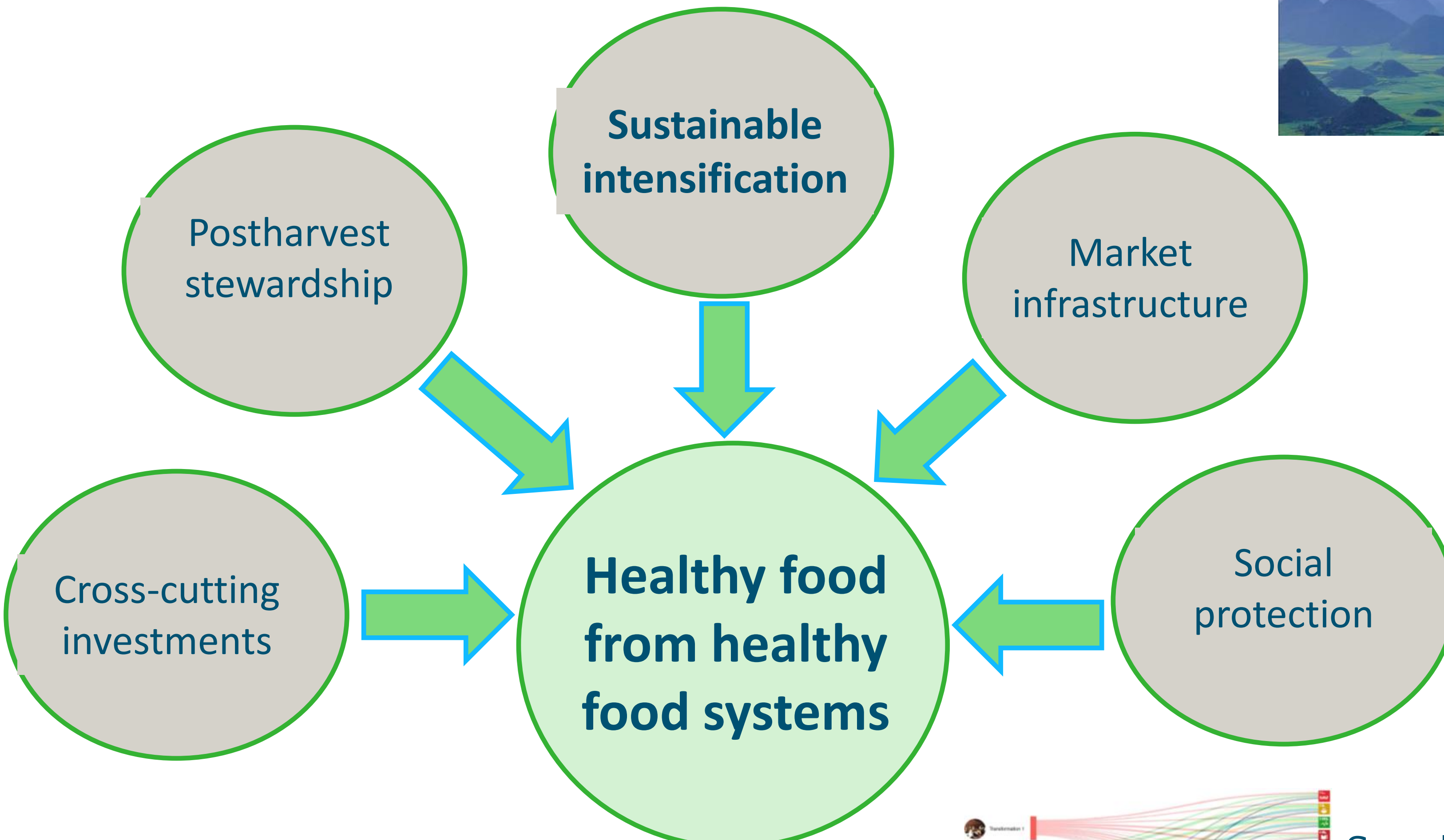
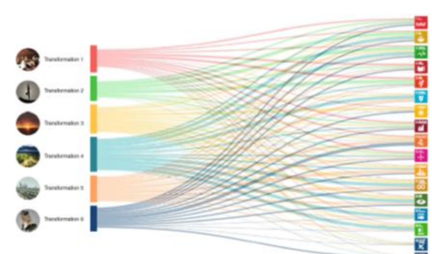
Universal Food Security - addressing all SDGs







See also Sachs et al., 2019

Law of the optimum

"The effect of N and/or P fertilization on crop yield & quality is largest when <u>all other</u> crop yield defining, limiting, or reducing factors are optimal".

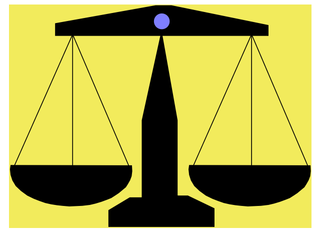
Response = G x E x M

Germplasm
* Crop variety

Environment:
- Climate
- Soil type
- Landscape

Management:
- crop rotation & management
- tillage
- drainage
- <u>fertilization</u>
- irrigation / fertigation
- weed management
- pest management
- residue management
- mechanization, and
- landscape management

The balance between nutrient supply and demand changes when nutrient loss limits need to be met too



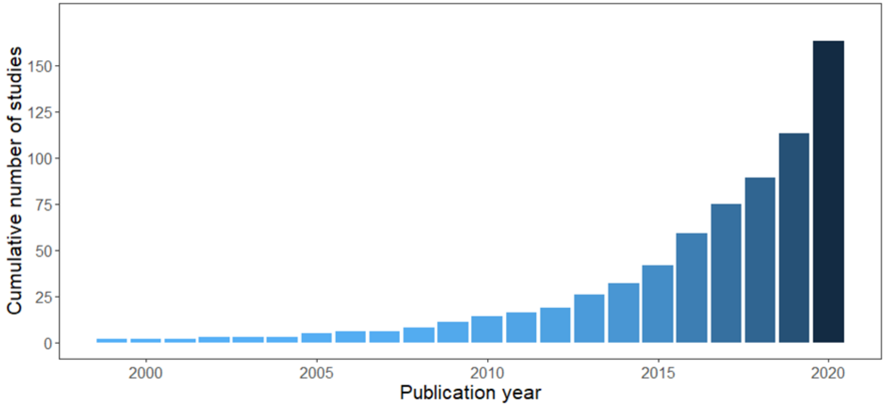
Need for new policies, business models, tools & advice:

- To guide farmers to achieve the conditions of the 'law of the optimum'
- To decrease nutrient losses further, through emission mitigation measures
- To increase the recycling of nutrients from residues, manures, and wastes
- To implement demand-side changes in food ingredients

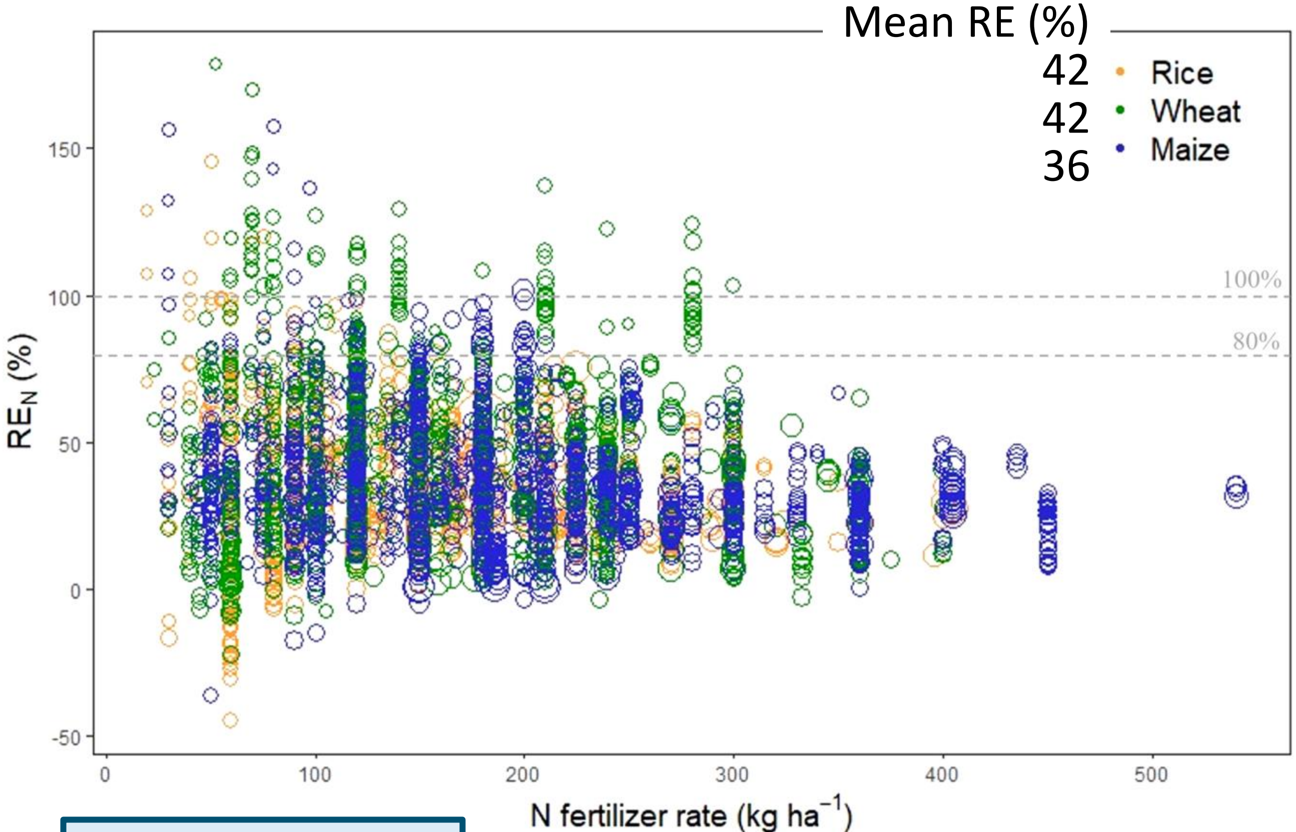
Review of 163 meta-analysis studies on crop husbandry and management practices

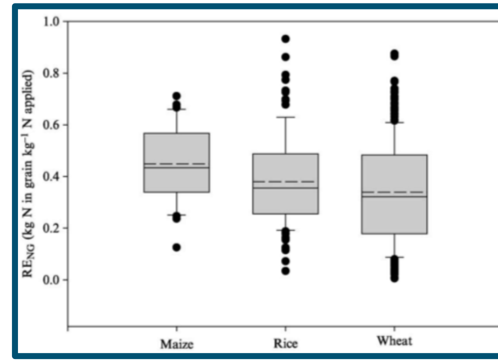
Crop husbandry and soil management practices	Total	Number of meta-analysis studies per aspect: Crop yield & quality	Soil quality	Resource use efficiency	Economic aspects	Environ-mental impacts
1 Crop type & crop rotations	32	12	12	2	1	14
2 Nutrient management	25	12	9	0	1	7
3 Irrigation + fertigation	18	12	2	11	0	4
4 Drainage	6	1	1	0	1	4
5 Tillage	55	19	36	5	2	14
6 Pest management	7	3	3	0	0	1
7 Weed management	4	2	2	0	0	0
8 Crop residue & mulching	19	14	5	6	1	8
9 Mechanization & technology	2	3	1	0	1	0
10 Landscape management	6	3	2	0	0	4
Total	174	81	73	24	7	56

Rietra et al., 2020



Fertilizer N recovery efficiency and N fertilizer rate





Ladha et al., 2016

$RE_N = (U_T - U_0)/F_N.$

Meta-analysis of 3586 observations from 261 papers

"We believe there is much opportunity to increase REN through fertilizer management without causing significant yield losses"
Yu et al, AGEE 338 (2022) 108089

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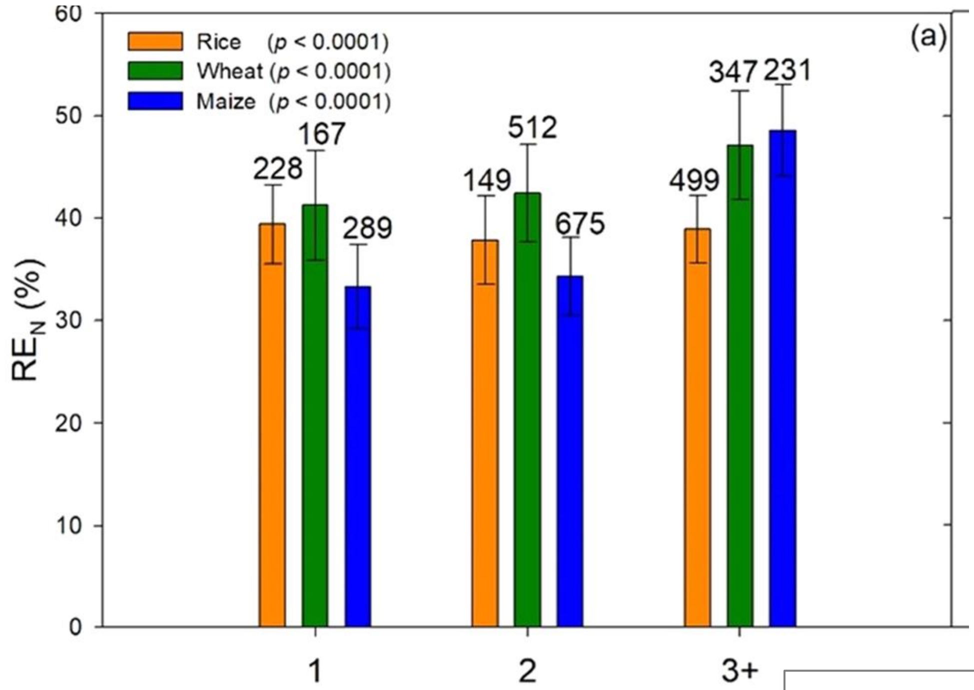
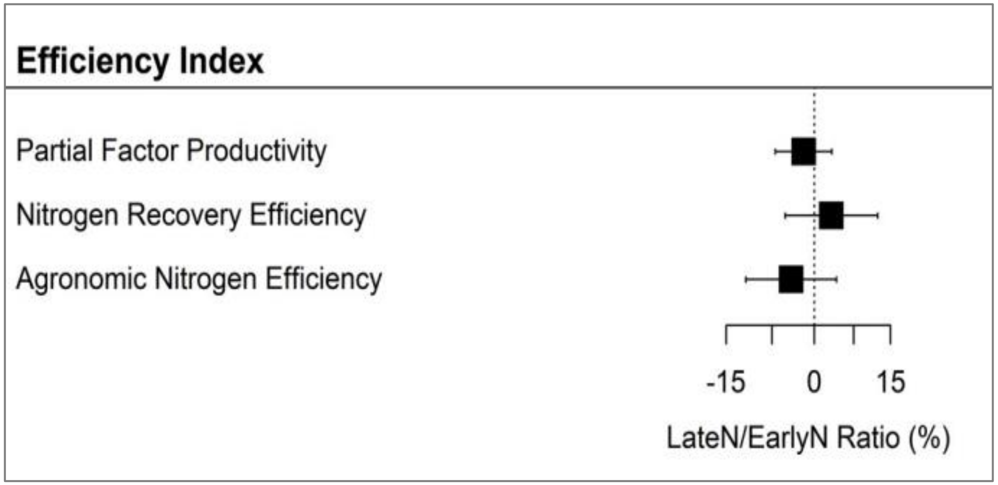
Only small effects of split applications



Fernandez et al., Late-season nitrogen fertilization on maize yield: A meta-analysis. Field Crops Research 247 (2020) 107586

Yu et al, Global meta-analysis of nitrogen fertilizer use efficiency in rice, wheat and maize. AGEE 338 (2022) 108089



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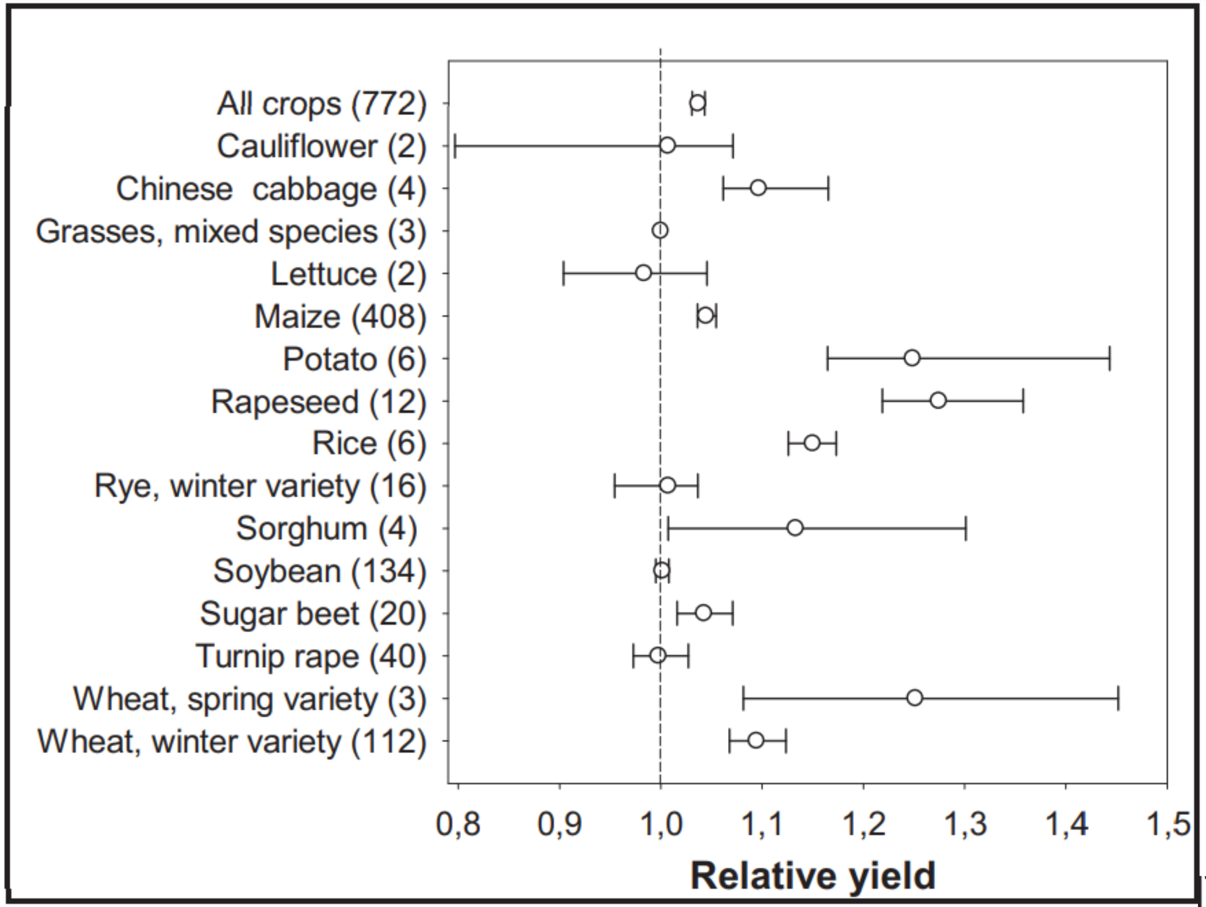
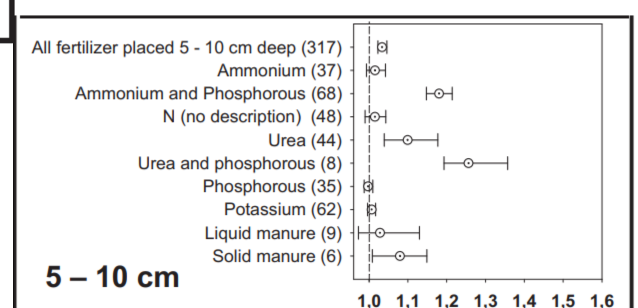
Modest benefits of fertilizer placement relative to broadcasting





Nkebiwe et al. Meta-analysis of fertilizer placement. Field Crops Research 196 (2016) 389–401

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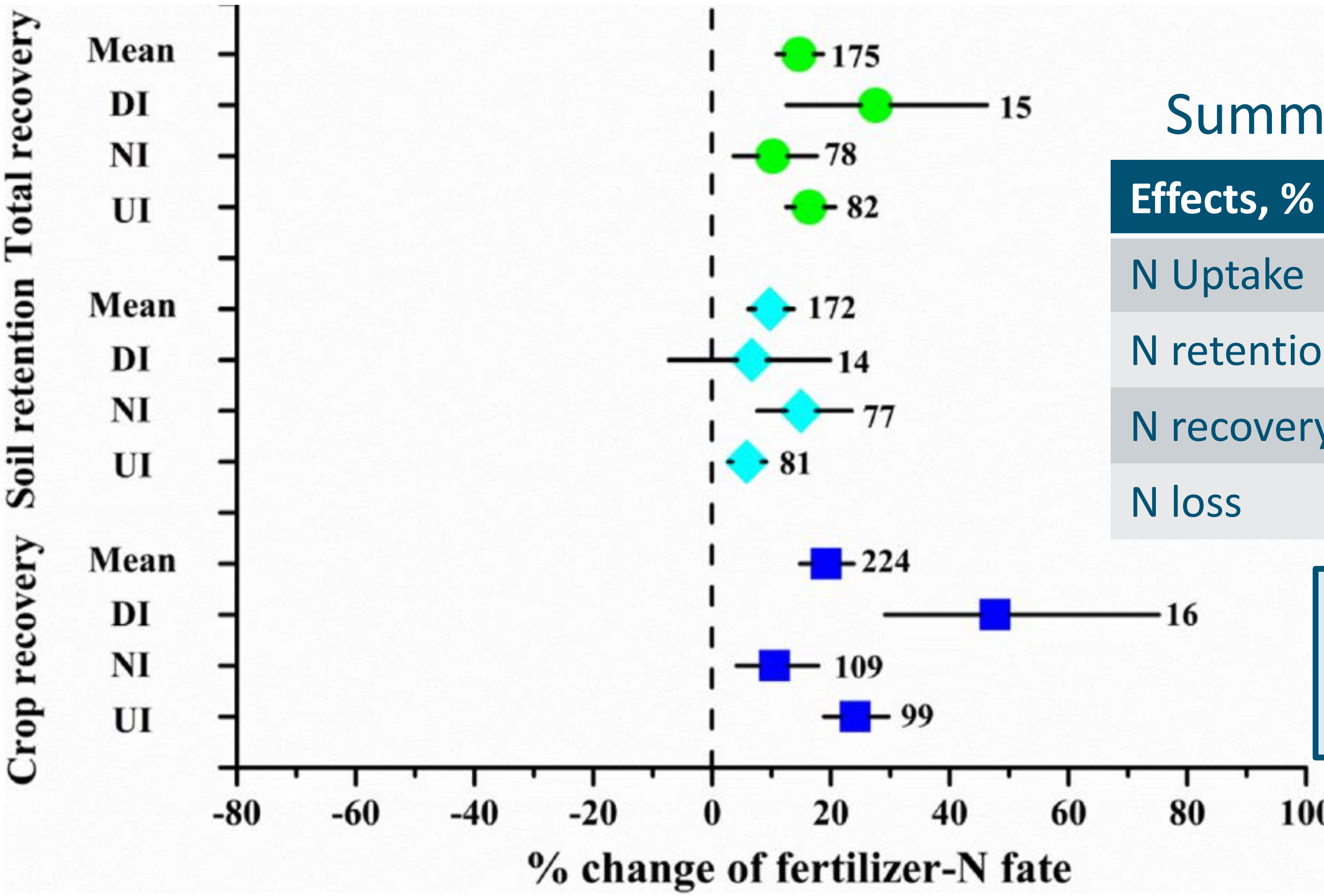
Large benefits of using fertilizer inhibitors



Summary overview

Effects, %	UI	NI	DI
N Uptake	+24	+11	+48
N retention soil	+6	+15	+15
N recovery	+16	+10	+28
N loss	-33	-15	-38

72 papers with 227 observations, all using the ^{15}N tracer method

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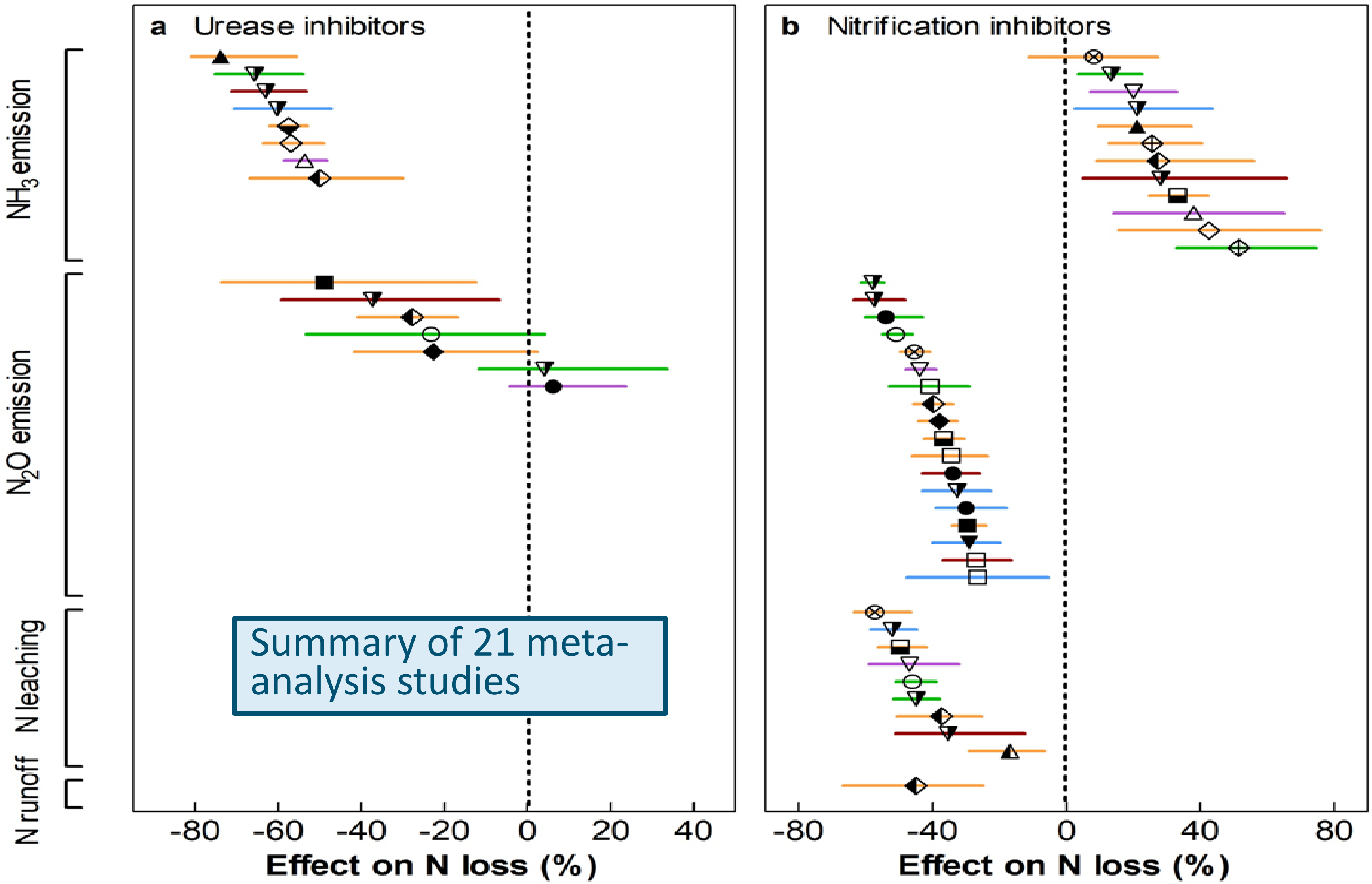
Sha et al., Meta-analysis of N stabilizers on fertilizer-N fate. AGEE, 290 (2020) 106763

Again, large benefits of using fertilizer inhibitors



Summary of 21 meta-analysis studies

Shu Kee Lam et al 2022 Nature Food 3, 575–580

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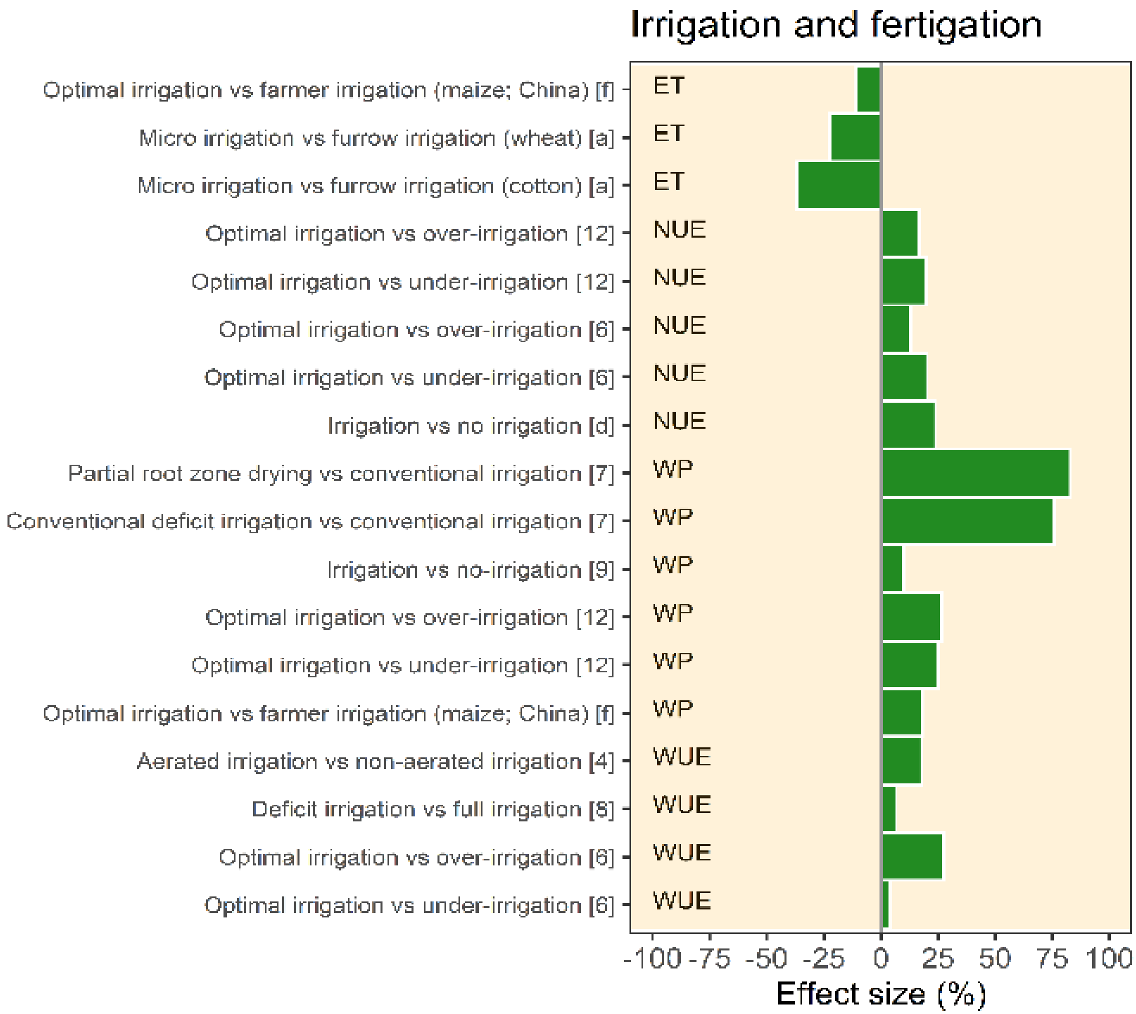
Large benefits of optimizing irri/fertigation on NUE, WUE



Summary of 18 meta-analysis Studies. Effect sizes ranged from 20 to 80%.

Rietra et al. Review of Crop Husbandry and Management Practices Using Meta-Analysis Studies: Land 2022, 11, 255

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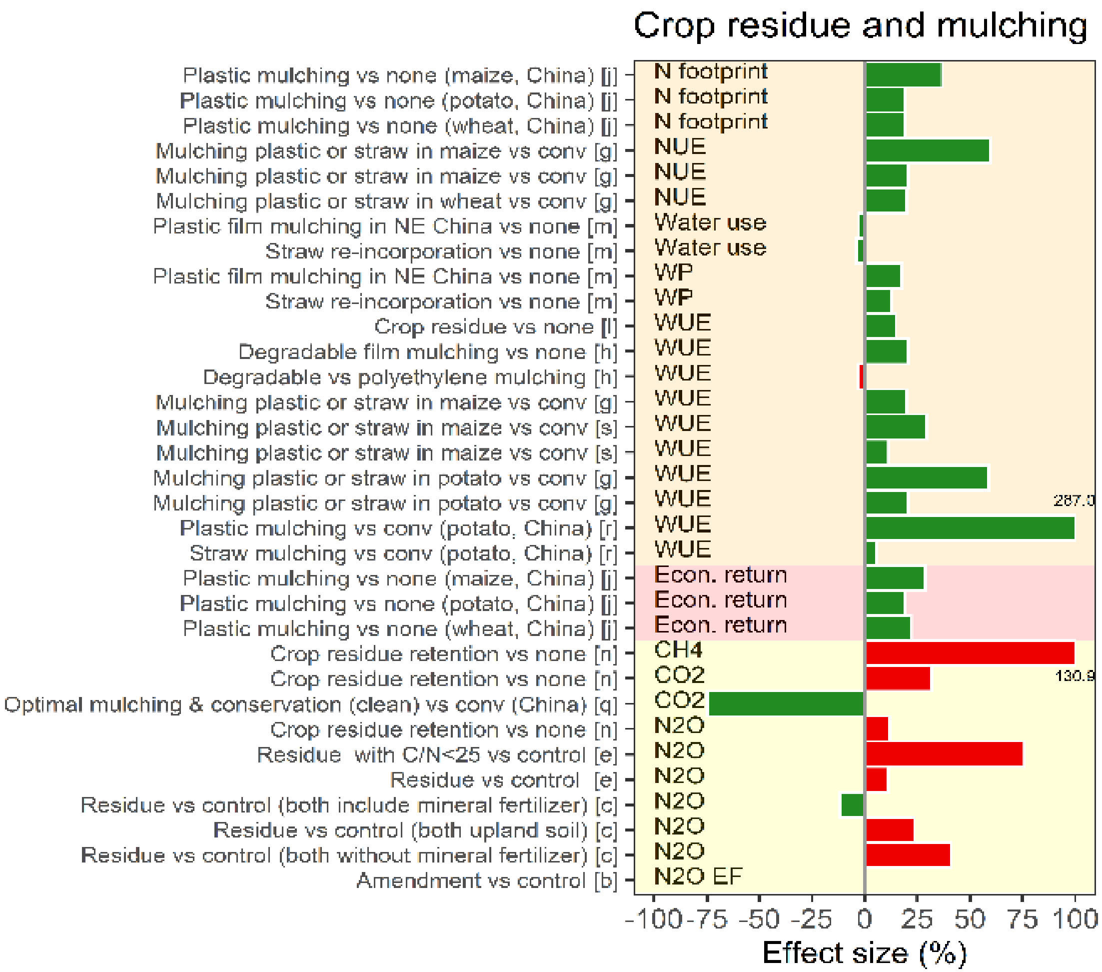
Surface mulching increases yield and resource use efficiency, but increases N_2O emissions too



Summary of 19 meta-analysis Studies. Effect sizes ranged from 0 to 100% for NUE,WUE. Emissions of N_2O increase

Rietra et al. Review of Crop Husbandry and Management Practices Using Meta-Analysis Studies: Land 2022, 11, 255

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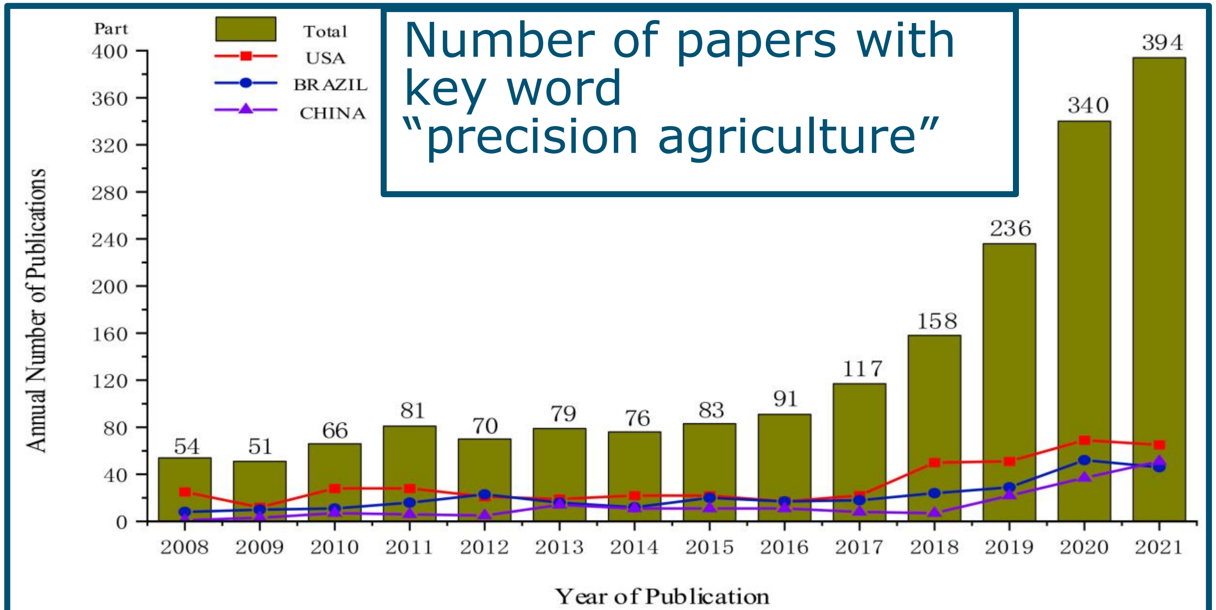
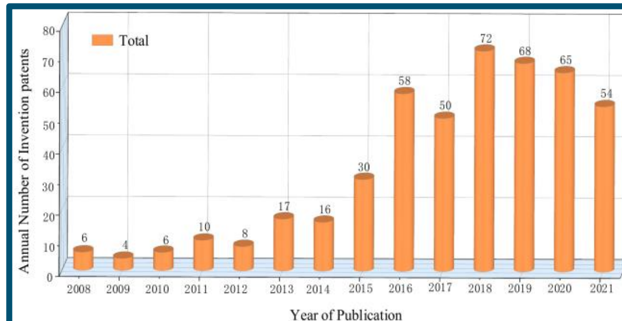
Precision agriculture is driven by technology



Number of papers with key word "precision agriculture"



Lu et al., AgriEngineering 2022, 4, 626–655.

Rank	Journal	TC
1	*Computers and Electronics in Agriculture*	1843
2	*Remote Sensing*	880
3	*Sensors*	798
4	*Agronomy (Basel)*	391
5	*Precision Agriculture*	634
6	*Transactions of the Asabe*	488
7	*Agriculture (Basel)*	183
8	*Applied Engineering in Agriculture*	256
9	*Engenharia Agricola*	224
10	*IEEE Access*	798

Abbreviations: TA = total articles; TC = total citations; A

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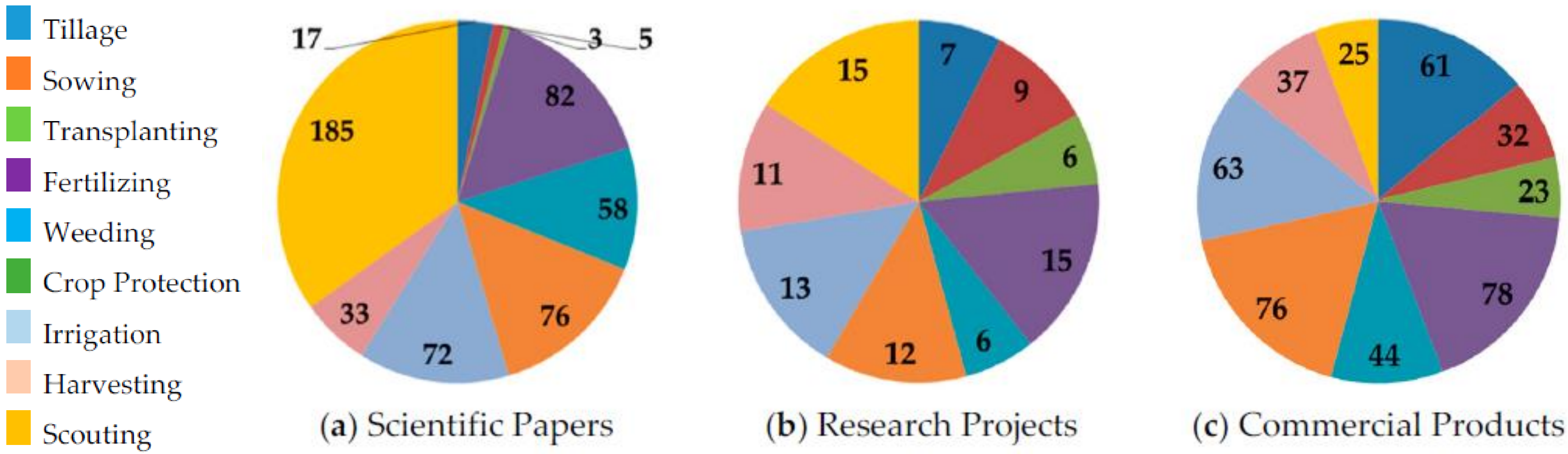
Assessment of 1064 Smart Farming Technologies (SFTs)



531 SFTs | 94 SFTs | 439 SFTs

- SFTs do not bring major changes in agricultural systems
- Commercial SFTs were indicated to increase productivity, revenue, and quality
- Main claims on input reduction (fertilizers, pesticides, and irrigation water
- Little attention for gaseous emissions

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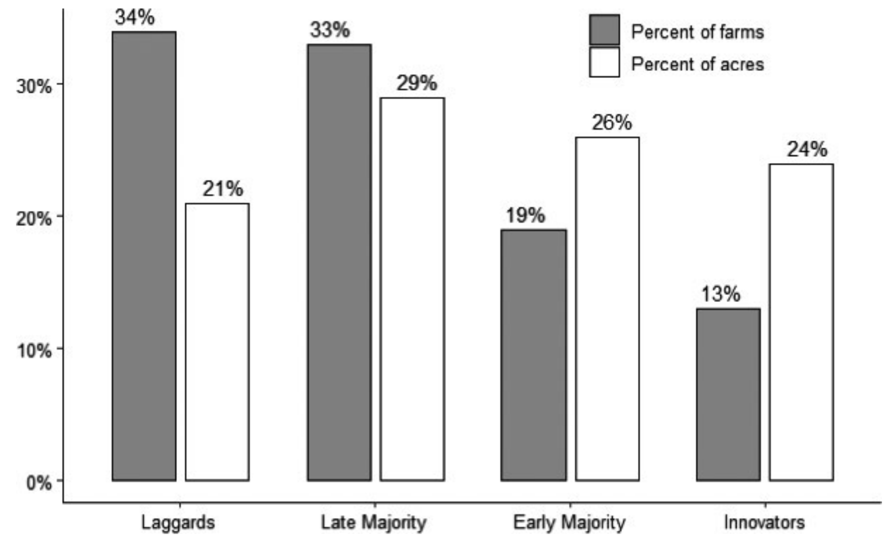
Balafoutis et al., Smart Farming Technology Trends. Agronomy 2020, 10, 743

Adoption of Precision Agriculture in US – survey & analysis of 1594 farms

- Farm size matters; early adopters were large farms
- Farms with advanced PA technology were technically more efficient than non-adopters.
- Differences in technical efficiency were driven by inefficiencies in input usage at the farm level
- Yield monitors were the most popular data collection tool (55%)
- VRT for seeding, fertiliser or pesticides used on 26% of farms

DeLay et al. Precision agriculture technology adoption and technical efficiency. J Agric Econ. 2022;73:195–219



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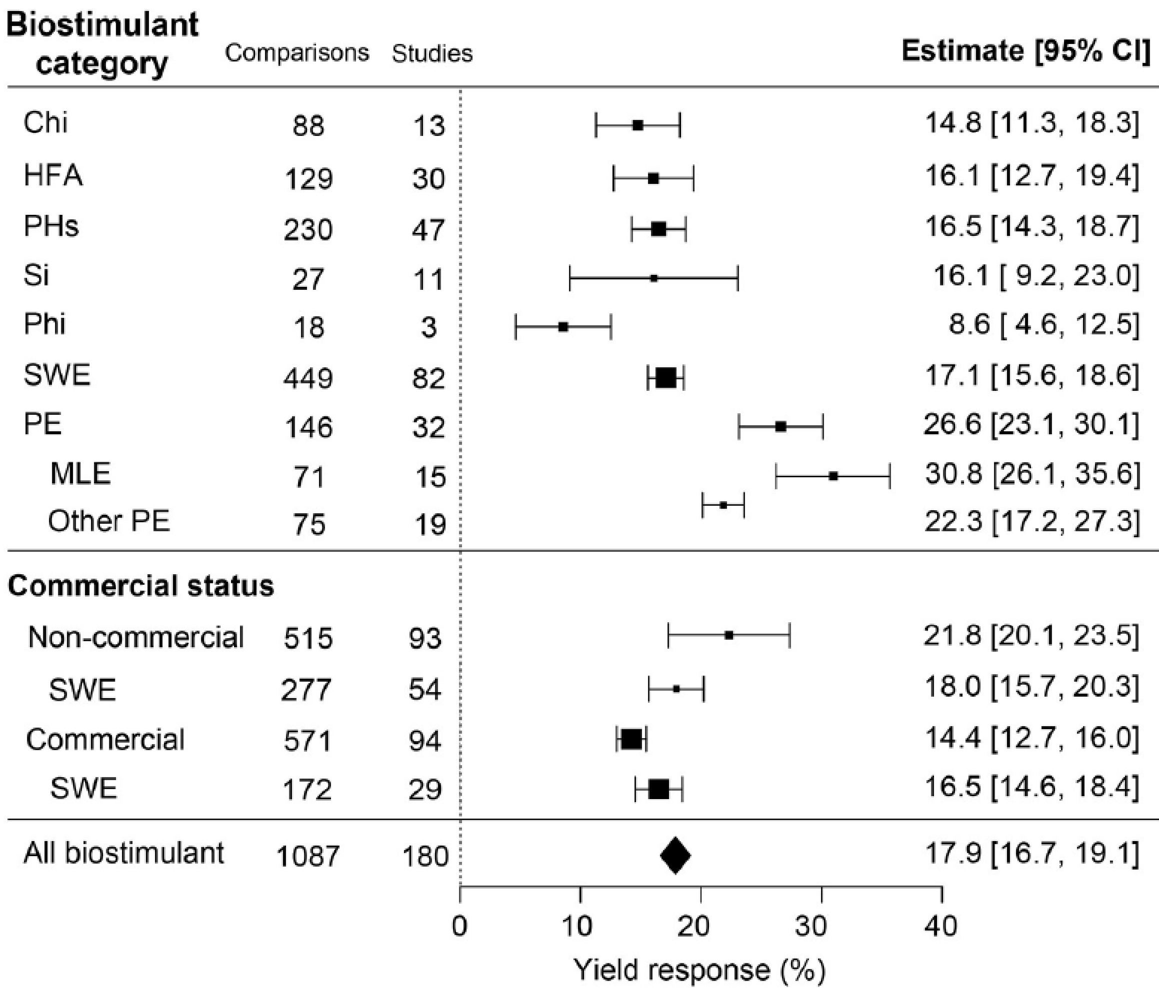
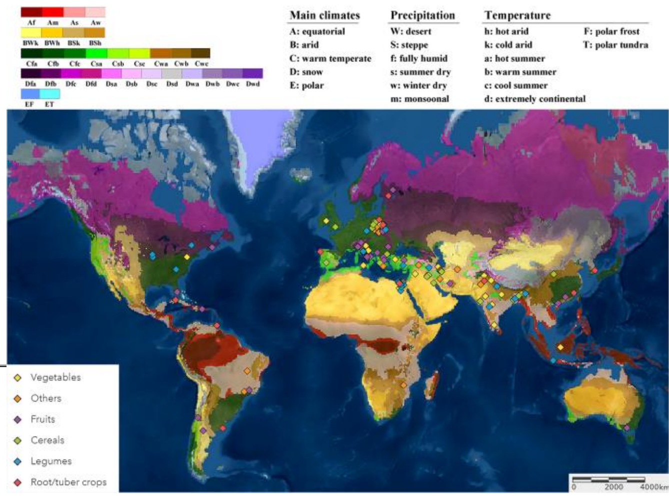
Plant biostimulants increase crop yields by ~17%;

meta-analysis of 1,108 paired observations from 181 empirical studies





Li et al., 2022)

"Due to possible publication bias, we assume that the average yield increase reported here is an over-estimation of what can be expected in a commercial context" (Li et al., 2022)

European Green Deal: transforming the economy for a sustainable future

- Response to the UN SDGs
- Tackling climate and environmental-related challenges
- Main policy areas:
  - Climate-neutral by 2050
  - Clean energy, industry, mobility
  - Circular economy, resource efficient
  - Farm to fork, i.e., a food system approach
  - Preserving biodiversity
  - Zero pollution

New EU Fertilising Products Regulation, more type of products & more quality control

Product Function Categories

1. Fertilizers (solid / liquid):
   a. Organic
   b. Organo-Mineral
   c. Inorganic (Mineral)
2. Liming material
3. Soil improver
4. Growing media
5. Inhibitors
6. Plant Biostimulants
7. Blends

Component Material Categories

1. Virgin Material
2. Plants and plant parts
3. Compost
4. Fresh crop digestate
5. Other Digestate
6. Food industry by-products
7. Micro-organisms
8. Nutrient-polymers
9. Other polymers
10. Animal byproducts
11. Industrial byproducts
12. Ashes
13. Struvites
14. Biochar
15. High purity substances

New EU Fertilizer Product Regulation – gives a boost to recycling

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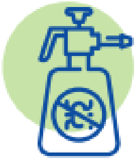
Farm-to-Fork strategy; 6 priorities

A healthy and plant based diet reduces the risk of life threatening diseases and the environmental impact of our food system.

- Ensuring sustainable food production
- Ensuring food security
- Stimulating sustainable food processing & practices
- Facilitating the shift to healthy, sustainable diets
- Reducing food loss and waste
- Combating food fraud along the food supply chain



The use of pesticides in agriculture contributes to pollution of soil, water and air. The Commission will take actions to:

✓ **reduce by 50%** the use and risk of chemical pesticides by 2030.

✓ **reduce by 50%** the use of more hazardous pesticides by 2030.

The **excess of nutrients** in the environment is a major source of air, soil and water pollution, negatively impacting biodiversity and climate. The Commission will act to:

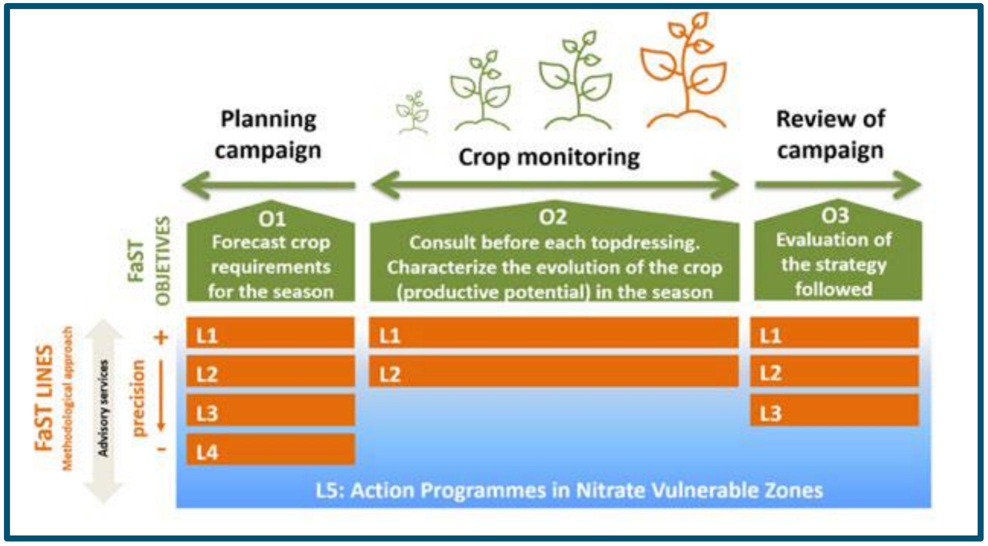
✓ **reduce nutrient losses by at least 50%**, while ensuring no deterioration on soil fertility.

✓ **reduce fertilizer use by at least 20%** by 2030.

Farm Sustainability Tool – FaST Navigator

- Part of a new CAP strategic plan
- an electronic tool for on-farm decision support:
  - For optimizing economic performance
  - For nutrient management planning and N, P, K balances
  - Quantitative advice for N, P, K fertilization
  - Mitigation of GHG emissions

Osann et al., 2022
Development of a common framework for the quantitative advice of crop nutrient requirements and greenhouse gas emissions and removal assessment at farm level - FaST-Navigator



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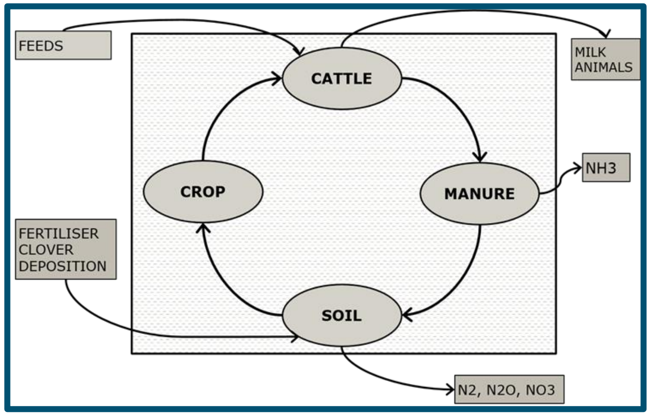
KringloopWijzer – management / accounting tool in NL

- Developed as management tool for grassland-based dairy farms
- From 2016 implemented on all dairy farms as monitoring / accounting tool by the milk processing industry.
- Data are owned by farmers and industry
- Used for monitoring / accounting of:
  - Milk production and feed use (efficiency)
  - N and P balances and use efficiencies
  - Emissions of NH_3, CH_4, N_2O, CO_2 emissions
  - 'On the way to Planet Proof Milk'

Oenema & Oenema, 2021, 2022



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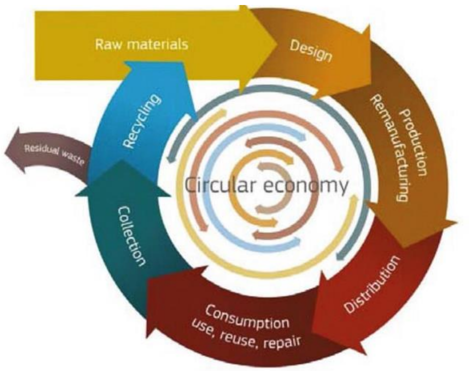
Nitrogen Crisis in NL

The battle is about:

- Distribution of limited emissions rights
- Legitimicy of emission mitigation
- Buy-out of livestock farms
- Changes in the crop rotation
- Trust

Summary & Conclusions

- From fertilization of crops to nutrient use & recycling in food systems
- Law of the optimum is guiding:
  - all yield defining, limiting and reducing factors have to be addressed
- Meta-analysis useful method to synthesise published research findings
- Precision tools have to deliver greater impact on nutrient use efficiency
- More efforts needed to address situations with
  - too little nutrient inputs
  - too much nutrient inputs
- Need for new policies, business models, tools & advice



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Thanks for your attention!!

Questions?

Plant biostimulants

Plant biostimulants are products that stimulate plant growth and improve one or more additional functions:

- nutrient use efficiency,
- abiotic stress tolerance,
- crop quality traits, and
- availability of confined nutrients in the soil or plant rhizosphere.

EU Fertilising Products Regulation 2019/1009 distinguishes two types:

- microbial (mycorrhizal fungi, and rhizobacteria)
- non-microbial (6 complex mixtures of extracts)