Higher than expected: Nitrogen use efficiencies over 35 years of organic and conventional cropping

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Introduction

- Organic and conventional cropping systems differ in **type** and **amounts** of **nitrogen** (N) inputs

  Organic (manure) vs. synthetic mineral N fertilizers; possibly different amounts of symbiotically fixed N_2

  Organic and mineral N fertilizers differ in supply of available N over time

  → Effect on **efficiency** and **sustainability** of **N use?**

- Sustainability: **Time,** and **fertilizer** and **soil N** resource use

  - **Long term field experiment**
  - **N budgets over several decades**
  - **Incl. soil N stock changes**

DOK field experiment

- ***Goal:*** *comparison of bio-Dynamic, bio-Organic and conventional (Konventionell)* ***cropping systems***[1]*; since 1978; in Therwil (CH)*
- ***Soil:*** *Haplic Luvisol on loess; silt loam*[2]
- ***Treatments****:*

  CTRLNON *No fertilizer input*
  CTRLMIN *Conventional; exclusively mineral NPK fertilizers → stockless*
  BIODYN *Bio-dynamic, manure compost and slurry; 1 = low, 2 = typical*
  BIOORG *Bio-organic, organic manure and slurry; 1 = low, 2 = typical*
  CONFYM *Conventional, stacked farmyard manure, slurry, mineral NPK: 1 =* ***low****,* ***2 = typical***

  Reflecting mixed crop-livestock system

- *System specific* ***plant protection***
- Identical 7-year **crop rotation**, currently: maize[1] – **soybean** – wheat[1] – potatoes – wheat – grass **clover** 2 years; [1]followed by green manure
- Data records Agrocope → N **inputs fertilization**, N **exports harvests**, **soil** N conc, always all **per plot** → N budgets, **1985-2019** (5 crop rotation periods)

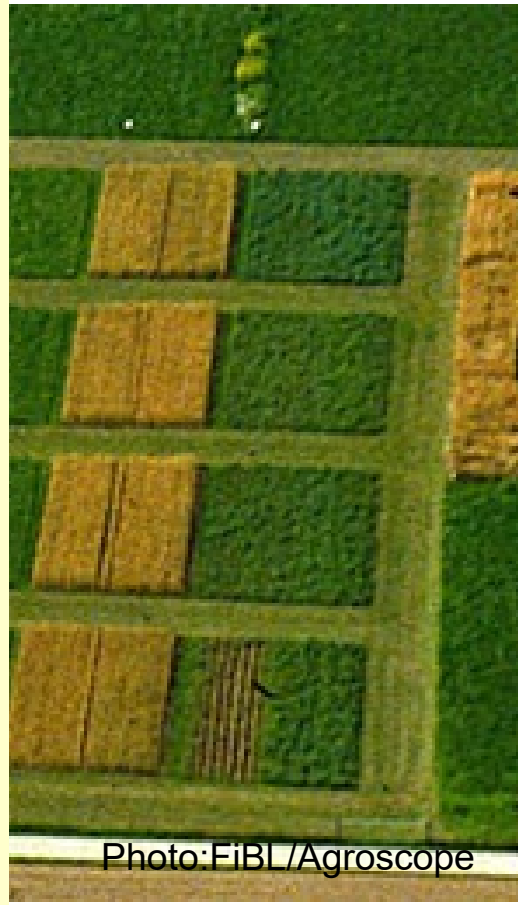


Photo:FiBL/Agroscope

[1]Mäder et al., 2002, Science; [2]Leifeld et al., Agr J

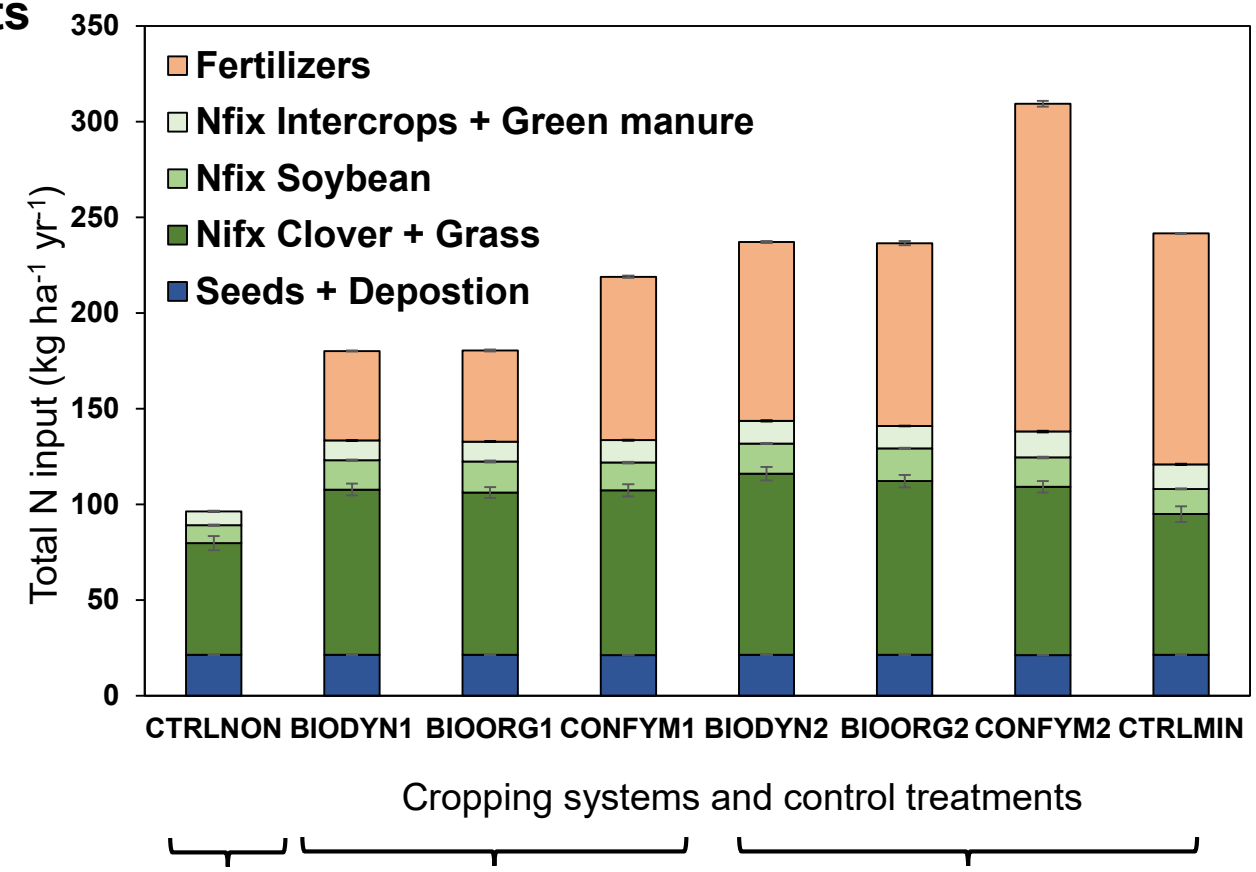
Nitrogen inputs

Symbiotic N_2 Fixation

- 75 to 120 kg N ha^{-1} yr^{-1} → **Important** in **all treatments**
- Most N fixed with **grass-clover leys**
- Incl. **fixed N** input into **soil** and **transfer** to **grass**
- **Minor reduction** under low fertilization
- **Reduced** under sole **mineral** fertilization

Fertilizers

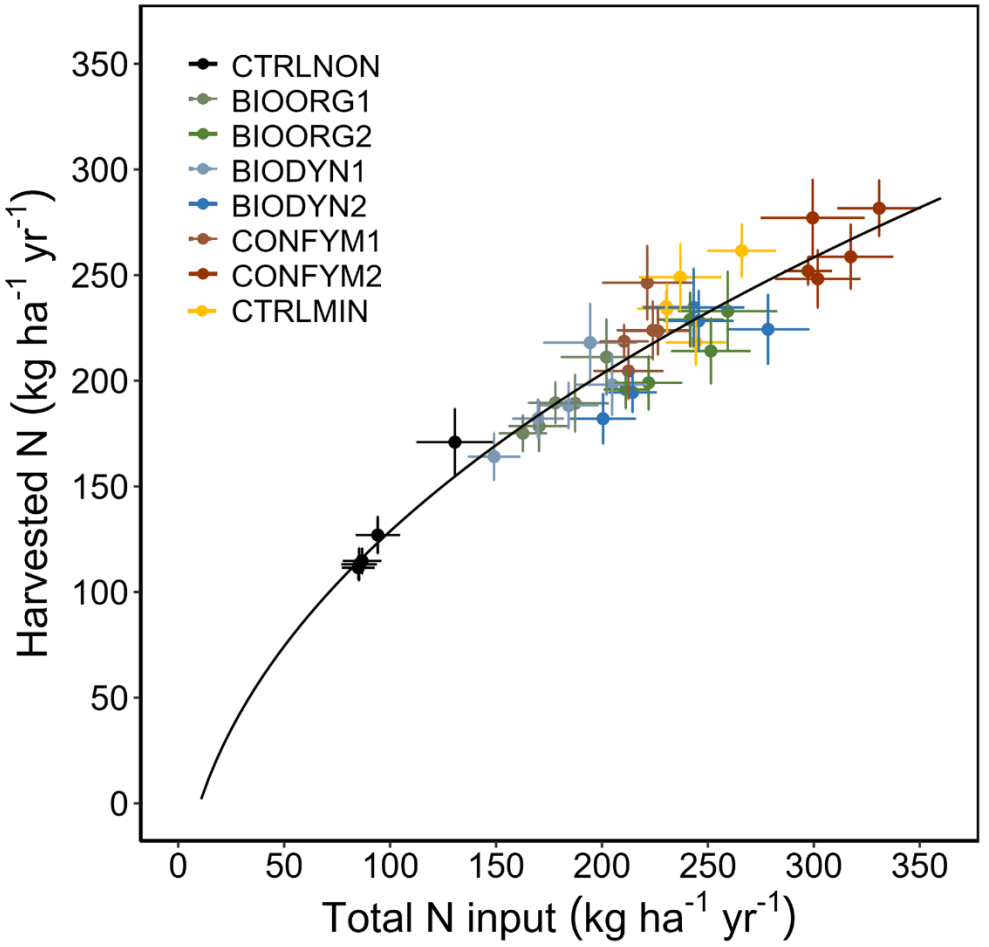
- **Main** N input in **conventional** treatments
- In organic systems **~55%** of CONFYM
- In CONMIN ~ **70%** of CONFYM
- Level 1 always half of level 2



Oberson et al., under revision

Harvested N in function of total N inputs

- **Strong correlation** (R^2= 0.81, with square root model equation)
  → **N responsive** conditions
- **Harvested N** under typical organic cropping by **~19%** less than typical conventional
  → **Reflecting overall yield difference**[1]
- CONFYM1 close to Bio2 level → **Plant protection**[1]



[1]Knapp et al., 2023, Field Crops Res.

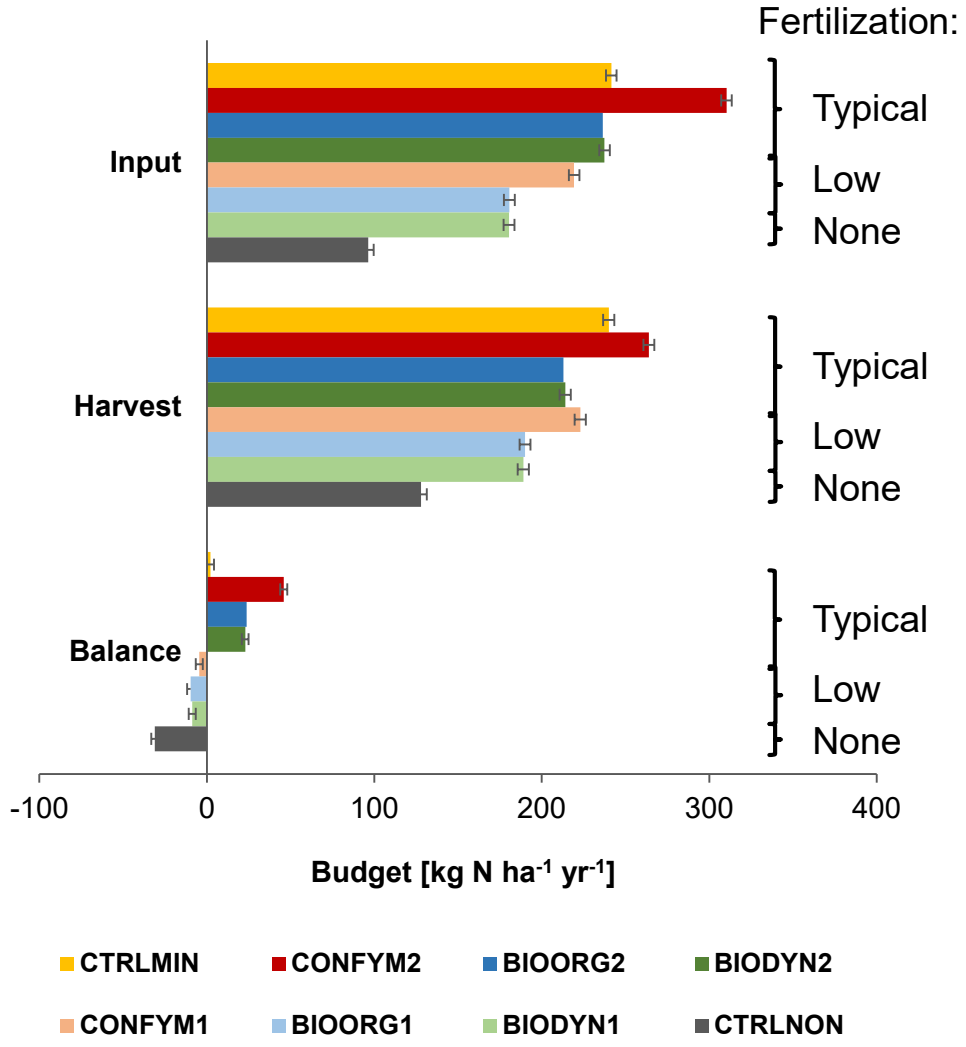
Soil surface budget and N use efficiency (NUE)

Soil surface budget[1] (kg N ha^{-1} yr^{-1})
Balance = Fertilizer + Fixation + Depos. + Seed – Harvest
= Input – Harvest

- **Positive N balance** under **level 2**, negative for other treatments[2]

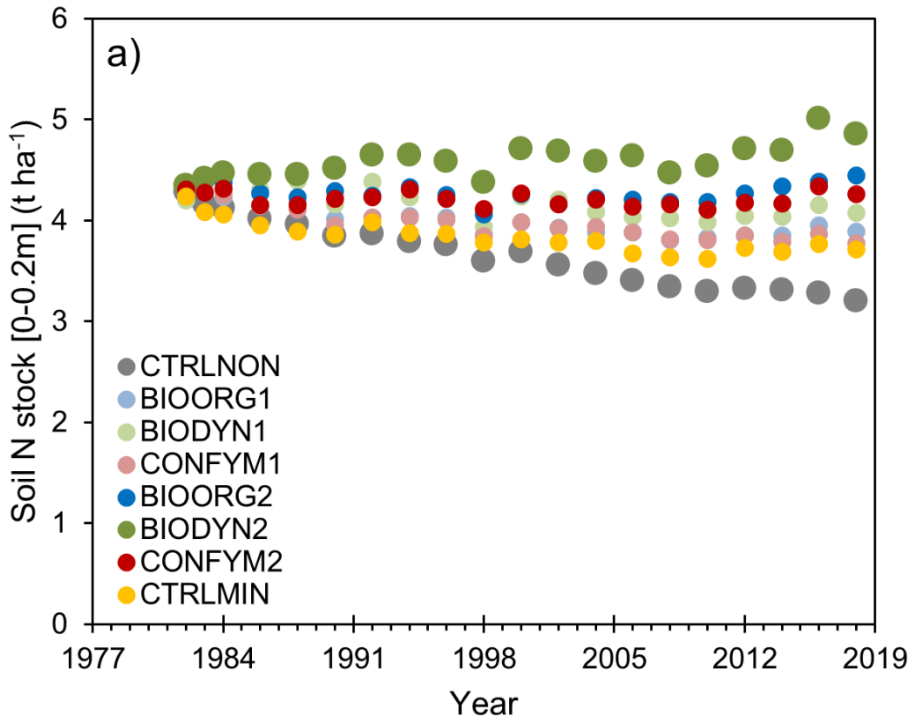
Surface budget derived NUE (Nharv/Ninput), %

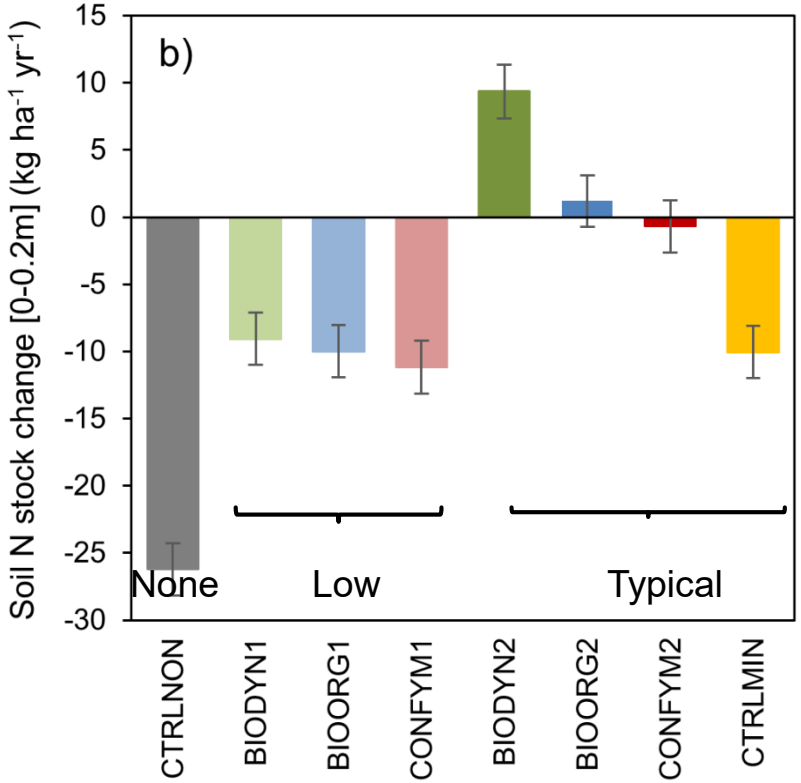
- Typical level **85 to 99%**[2]
- >100% in others[2]
- **Soil N stock** changes and **N losses not** yet **included**



[1]Oenema et al., 2003 Europ J Agr; Oberson et al., 2023, under revision

Changes in soil N stocks





- N stocks in **topsoil (0-0.2 m)** decrease except in treatments with **manure level 2**
- **Positive surface N balance** needed to maintain soil N --> **N losses cannot be fully avoided**
- **>100% NUE** at none and level 1 → **Soil N mining,** but also under **sole mineral fertilization**
- Importance of **animal manure**, positive effect of **composting**[1,2]

[1]Mayer et al., 2022, Geoderma; [2]Krause et al., 2022, Agr Sust Dev

Soil system budget and NUE

Soil system balance (kg N ha^{-1} yr^{-1}) = Inputs – Harvest – ΔSoilN

Treatments	CTRLNON	BIODYN1	BIOORG1	CONFYM1	BIODYN2	BIOORG2	CONFYM2	CTRLMIN	LSD
Fertilization	None	Low			Typical				
kg N ha^{-1} yr^{-1}									
Soil surface balance	-31	-9	-10	-5	23	24	46	2	6
Topsoil stock change	-26	-9	-10	-11	9	1	-1	-10	14
Soil system balance	**-5**	**0**	**0**	**7**	**14**	**23**	**47**	**12**	**6**
%									
Soil surface NUE	133	105	106	102	91	90	85	99	3
Soil system NUE	104	100	100	97	94	91	85	95	3

- At typical level not entire soil surface balance surplus reflected in topsoil N changes → Losses
- Soil system balance surplus indicates moderate N losses: 12 to 47 kg N ha^{-1} yr^{-1} at typical level
- Overall **high NUE of combined N inputs** confirmed
- Subsoil N not considered

Oberson et al., 2023, under revision

Fertilizer N use efficiency

Difference method corrected (%) = $\frac{NharvF - NharvCTRLNON}{Nfert + NfixF - NfixCTRLNON - \Delta soilNF + \Delta soilNCTRLNON} \; x \; 100$

Budget method corrected (%) = $\frac{Nharv - Nfix - Nseed - Ndeposition + \Delta soilN}{Nfert} \; x \; 100$

	BIODYN1	BIOORG1	CONFYM1	BIODYN2	BIOORG2	CONFYM2	CTRLMIN	LSD
	Low			Typical				
Difference method	91	92	87	82	73	70	86	7
Budget method	101	101	93	87	78	73	91	8

- High NUE for both, mineral fertilizer and animal manure
- Animal manure compost and mineral fertilizer with similarly high NUE

Oberson et al., 2023, under revision

Conclusions

- **High NUE** of **combined N inputs** and **fertilizers** in **all treatments** → Optimal management, deep soil profile, climatic conditions
- **Positive N balance needed** to maintain or increase **soil N stocks** → Losses cannot be fully avoided
- **Negative balance with >100% NUE** → Soil N mining → Animal manure at low level cannot sustain soil organic N and C → Need for **alternative organic matter** and **nutrient inputs**
- Both, **mineral N** and **animal manure N** used at **high efficiency**, but sole mineral N fertilization **cannot maintain soil organic N**
- **The unique value of Long Term Field experiments**!

Thanks!

Field and lab teams of Agroscope and FiBL for 45 years of DOK experiment

Many students and scientist on this long-lasting way

You for your attention

Photo:FiBL/Agroscope