Nitrogen Use Efficiency in Nitrate Polluted Areas in Germany: How effective are regulatory measures?

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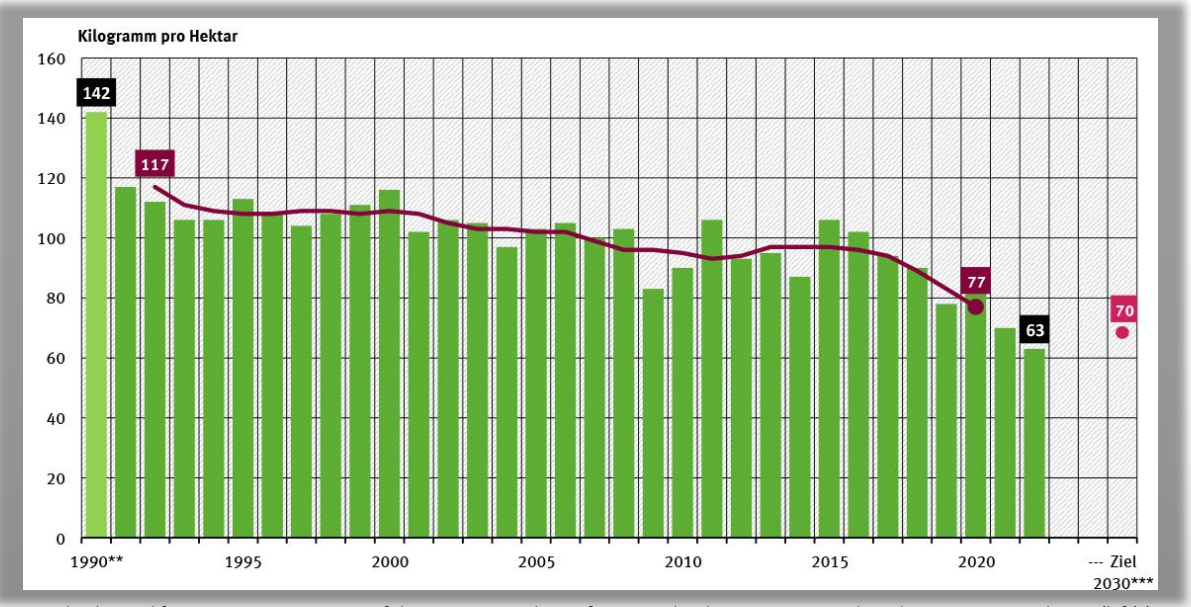
LuWQ2025: Aarhus, 3 – 6 June 2025

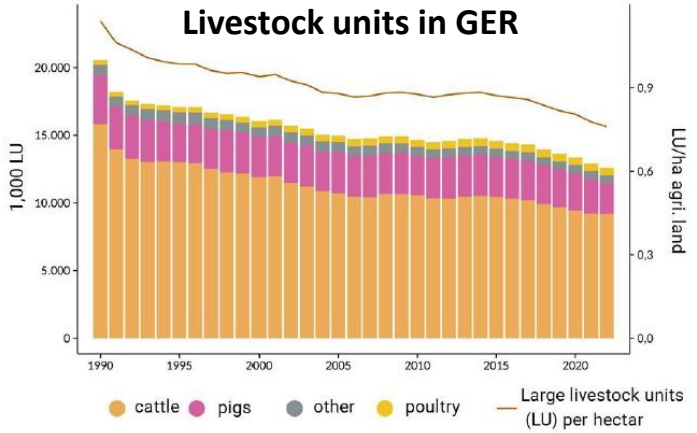
International Interdisciplinary Conference on Land Use and Water Quality: Agriculture and the Environment

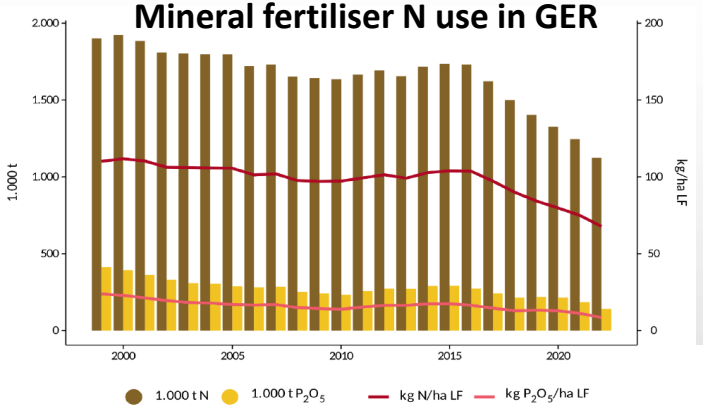
05.06.2025

Agriculture in Germany

- National N surplus, livestock numbers and mineral fertiliser consumption are substantially decreasing!

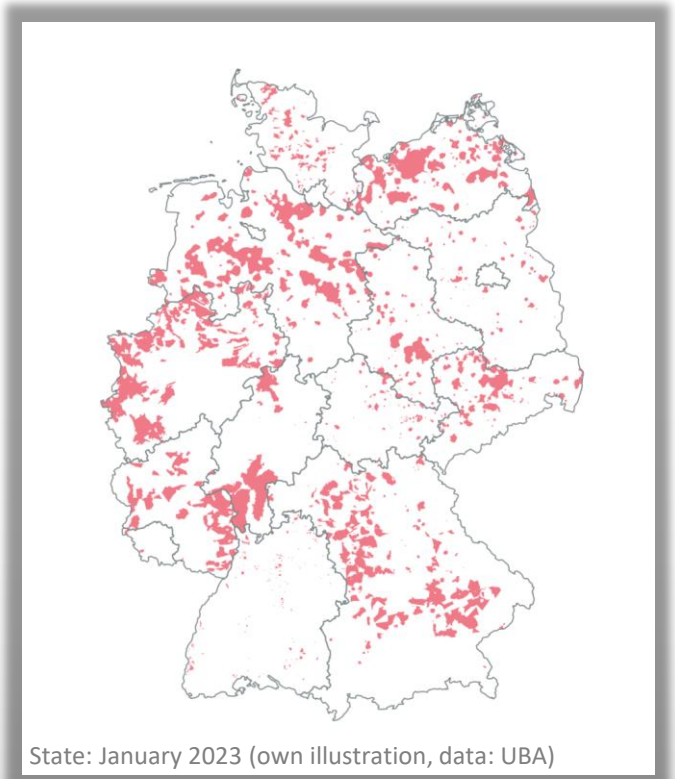






Annual value and five-year moving average of the nitrogen surplus on farm-gate level in German agriculture between 1990 and 2022 (left) (UBA, 2025), livestock units between 1990 and 2022 (right top) and mineral fertiliser use between 1999 and 2022 (right down) in Germany (Destatis, 2024)

Agriculture in Germany



State: January 2023 (own illustration, data: UBA)

Nitrate polluted „red“ zones according to AVV GeA in Germany in 2023

- Germany had to adapt its nutrient policy due to European Court of Justice ruling in the scope of Nitrates Directive in 2018:

(1) Abolition of soil surface N budgeting as regulatory approach

(2) Stricter frame for good farming practices in the DüV

(3) Implementation of a new national impact monitoring

(4) Harmonised designation of „nitrate polluted areas“ with stricter measures since 2021 (latest designation 2023)

- Urgent adaptations in German Fertilizer Law will address:
  - Water quality (EU Nitrates Directive)
  - Sustainability and climate goals (national programs)

Nitrogen use efficiency (NUE)

NUE

- Indicator for assessing N performance of agricultural systems (Sutton et al., 2013; Quemada et al., 2020)
- Ratio of N removal per N inflow
- Different system levels (e.g. soil, farm-gate) (EUNEP, 2015; Quemada et al., 2020)

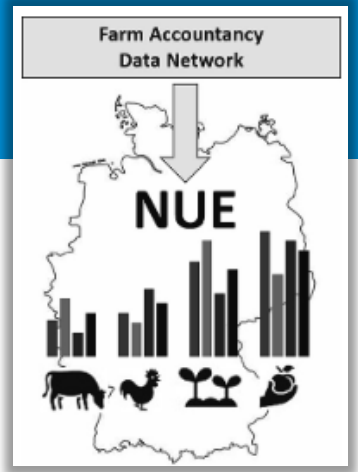
$$N\ use\ efficiency_{farm}\ (farm-NUE)[\%] = \frac{Exported\ N\ [kg\ N]}{Imported\ N\ [kg\ N]} \times 100\ [\%]$$

Research questions

- NUE *status quo* for farm types in Germany?
- Development of NUE *over time*?
- Differences for farms located in "*nitrate polluted areas*"?

Löw & Osterburg (2024), Ag Sys 213 (2024) 103796

Data and statistics



Löw & Osterburg (2024)

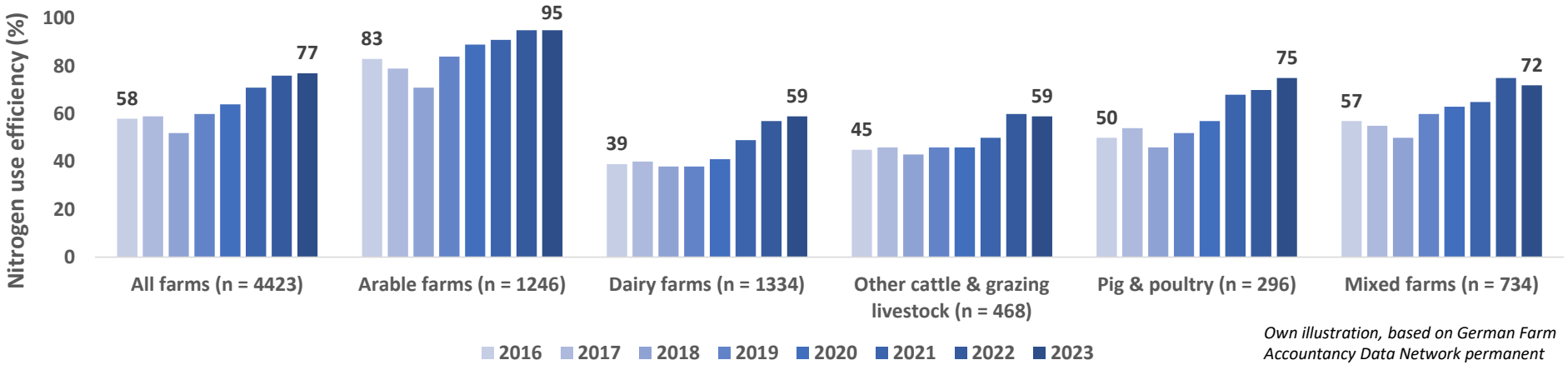
Farm Accountancy Data Network (FADN)

- Representative source of microeconomic data (BMEL, 2025)
- N = 4,423 permanent farms per year between 2016/17 and 2023/24
  → data on mineral fertiliser quantities, crop yields, livestock numbers,…)
- Grouping farm types according to common EU-typology and standard output
- Regional mapping according to municipality code and “nitrate polluted areas” (UBA, 2023)

Statistics

- Grouping: farms located in municipalities with >80% polluted area, descriptive statistics
- Mann-Whitney-Wilcoxon for non-parametrical statistical test
- Linear mixed-effects model with fixed effects

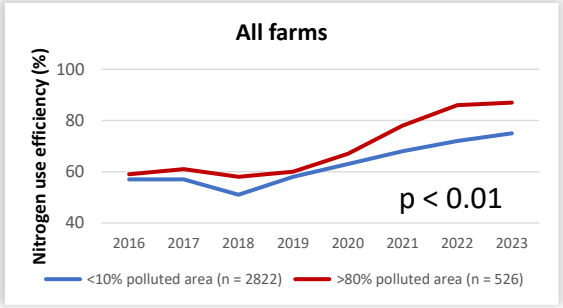
NUE development for farm types in Germany

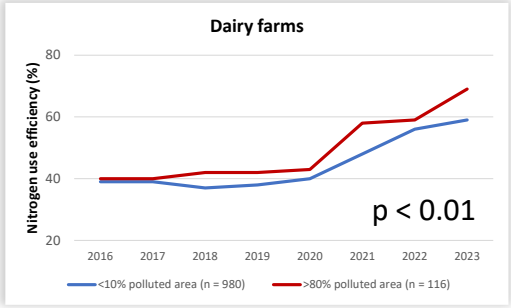


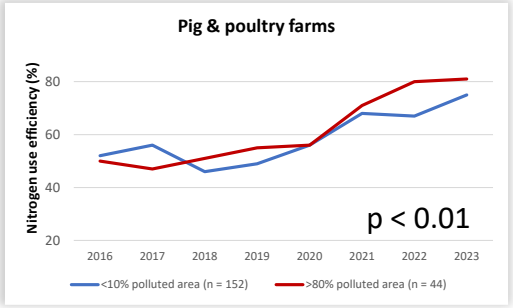
Own illustration, based on German Farm Accountancy Data Network permanent farms 2016/17 to 2023/24 (n = 4423)

- **NUE increasing since 2016**, farm type-specific differences
- High NUE values, efficiency reserves seems widely to be depleted → **further increase uncertain**
- **Partially retrogressive**

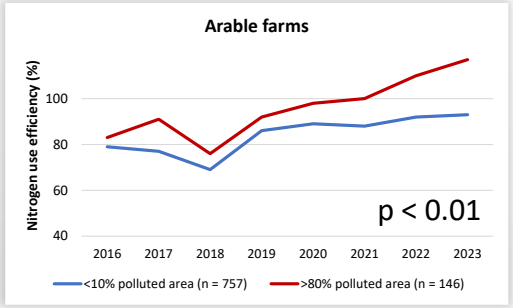
NUE of farms in nitrate polluted areas

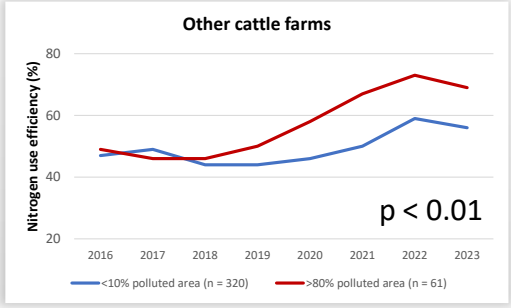


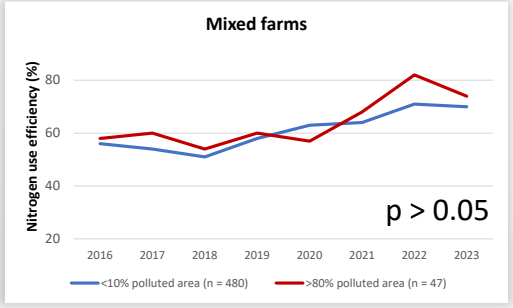




P < 0.05 → the distribution of NUE differs significantly between the groups

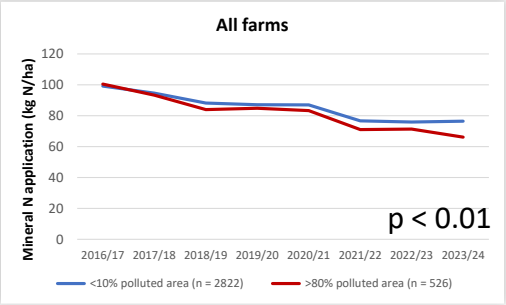


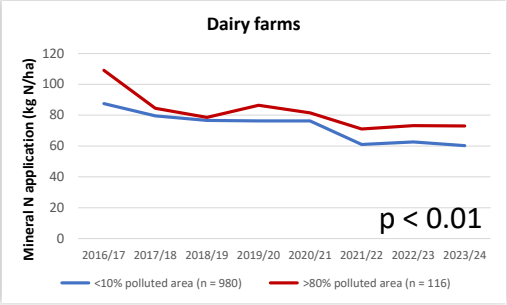


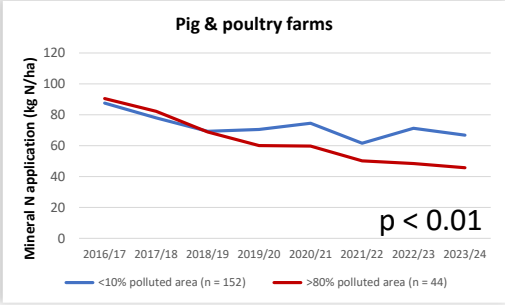


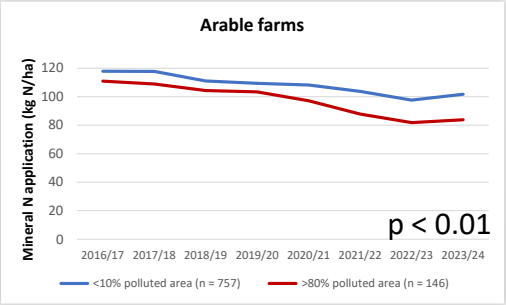
- All farm types show **higher NUE** in municipalities with high share of polluted areas (mostly significant)
- **Gap increases** until 2023 in all farm types

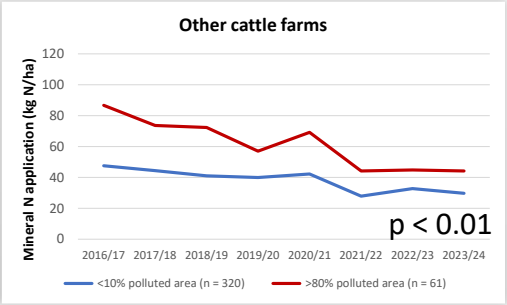
Mineral fertiliser use of farms in nitrate polluted areas

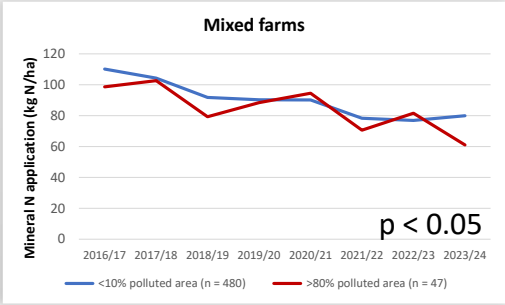












P < 0.05 → the distribution of mineral N use differs significantly between the groups

- Erratic levels and gaps for mineral fertiliser N use between farm types
- All farm types show **higher N reduction** in municipalities with high share of polluted areas (up to 50 %)

Share of farmland for farms in nitrate polluted area

Greenish = farms in areas <10 % polluted;
Red = farms in areas >80 % polluted

Arable farms	Years			
	2017	2024	2017	2024
Maize (% UAA)	12	12	16	23
Wheat (% UAA)	33	30	29	28
Grassland (% UAA)	11	12	6	7

- Slightly interannual differences, but **across pollution groups**!
- **Share of maize higher in polluted areas**
  → Significant effect on NUE
- Effect of pollution groups depends on farm type

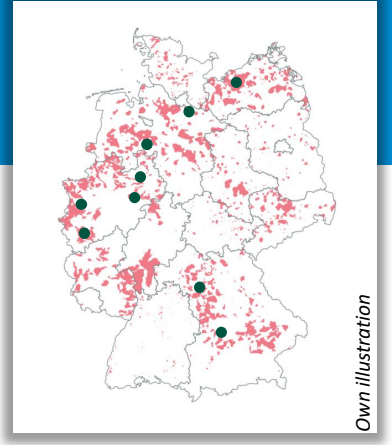
Dairy farms	Years			
	2017	2024	2017	2024
Maize (% UAA)	29	30	50	47
Wheat (% UAA)	11	11	16	15
Grassland (% UAA)	65	65	36	35

Other cattle farms	Years			
	2017	2024	2017	2024
Maize (% UAA)	20	18	54	51
Wheat (% UAA)	12	12	10	9
Grassland (% UAA)	68	69	44	35

Pig & poultry farms	Years			
	2017	2024	2017	2024
Maize (% UAA)	19	20	35	41
Wheat (% UAA)	27	26	20	18
Grassland (% UAA)	9	10	4	7

Mixed farms	Years			
	2017	2024	2017	2024
Maize (% UAA)	14	16	30	33
Wheat (% UAA)	24	27	20	20
Grassland (% UAA)	23	24	11	12

Discussions and outlook


Own illustration

- Increasing efficiency while shrinking mineral fertiliser use = adapting to **efficiency reserves**

- Location in with nitrate polluted area show significant effects on NUE **in combination with farm type and with share of maize**

- **Patterns regarding crop selection and extent with focus on maize:**
  - Maize can handle high manure loads
  - Manure management more challenging than mineral N (Oenema et al., 2007)
  - (Excessive?) High N demand values defined in regulatory framework (Albers et al., 2021; Bukowiecki, 2024; DüV, 2020)
  - Maize comparably N efficient with high N leaching risk, long cropping time in autumn (Dieser et al., 2023; Taube, 2021)

Discussions and outlook

- **FSDN as part of the European Green Deal in preparation:**
  Further important N-management related variables
  (e.g. application technique, traded manure quantities)

EU-COM

- **Dynamics and interaction** between N management, crop management and soil-climate characteristics (in nitrate polluted areas) need to be better understood for targeted policy measures

- **Further research:** Considering longer time series after the designation of polluted areas to identify adaptation measures and assess effectiveness, as well as extension of the mixed-effects model with further predictors

Federal Ministry of Agriculture, Food and Regional Identity

THÜNEN

RessortForschtKlima

Thanks a lot for your attention!

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