Evaluating Agricultural Strategies for Groundwater Protection: Impact of Crop Rotations on Nitrate Leaching on Field Scale, Denmark

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INTRODUCTION

- **Surface and groundwater pollution** by NO_3-N is a major environmental issue on a worldwide scale.
- **Agriculture** contributes nitrate to the aquatic environment, groundwater, lakes, streams, and the marine environment.
- In **Denmark**, where **61% of the land is farmed**, nitrate risk is especially high.
- **Grassland rotations** are promising; they have a lower nitrate leaching level than monocultures.
- **Crop rotations** with a high share of grassland might mitigate nitrogen (N) leaching more effectively than monocultures.

OBJECTIVES

➢ **To analyze the effect of introducing a high share of grass-clover pastures in the cropping systems and measure the effects on field nitrate leaching.**

METHODS AND MATERIALS

Six fields (S1-S6) with different management strategies (Table 1) were monitored during 2022-2024. At each site, soil texture was analyzed (Fig. 1).

Suction cells were installed at a depth of 1 meter with eight replications (Fig. 2). Soil water samples were collected biweekly from autumn to spring and monthly during the summer.

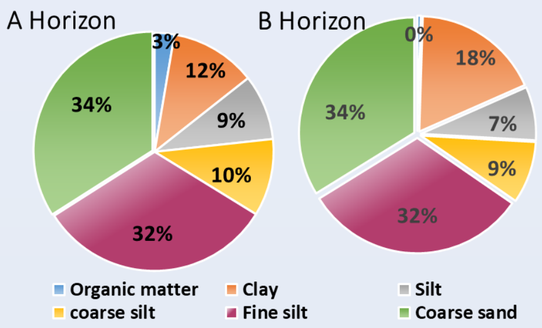

Fig. 1. An example of the soil texture from S4 in two horizons A and B

METHODS AND MATERIALS

Table1. Crop rotation in different fields during the study period

Fields	2022	2023	2024
S1	Spring barley undersown Grass-clover	Grass-clover	Grass clover
S2	Spring barley undersown Grass-clover	Grass-clover	Grass clover
S3	Spring barley	Spring barley-undersown grass	Grass clover
S4	Grass Clover	Maize (undersown grass)	Maize (undersown grass)
S5	spring barley (undersown grass)	rye grass for seed	Winter Wheat
S6	winter wheat	spring barely (undersown grass)	Spring Barley

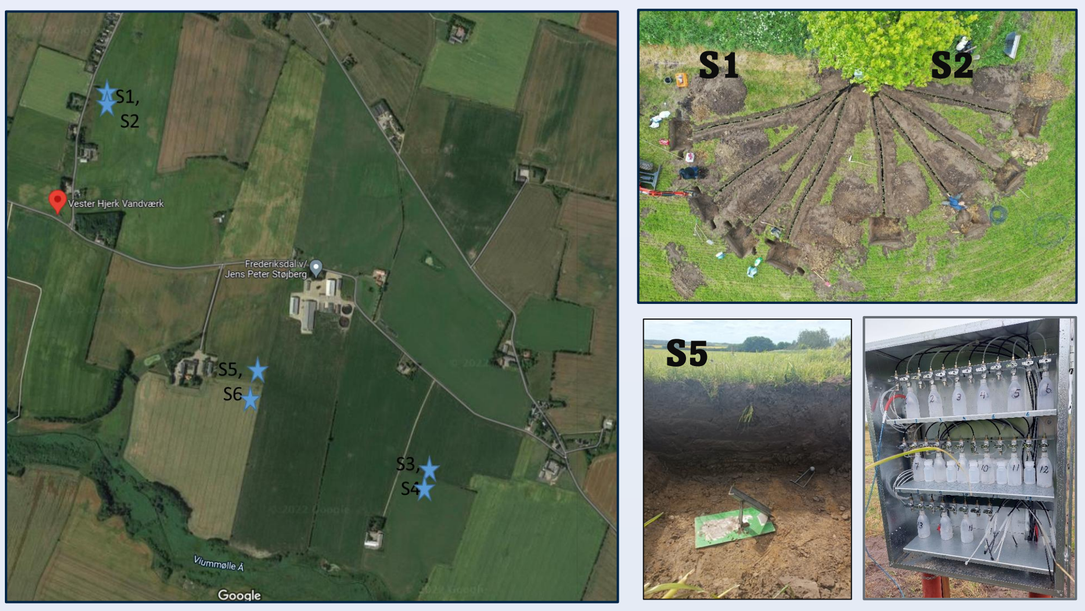

Fig. 2. Overview of the six monitored fields (S1–S6) located near Skive, Denmark, representing different cropping systems. The photos show site layout, installation of 8 suction cells at 1 m depth per site/field, and the water sampling.

RESULTS

➢ **S1 and S2 (Grass-clover):** Maintained consistently low nitrate-N levels (< 5 mg/L) throughout 2023–2024 (Fig.3), confirming strong nitrogen retention in long-term perennial systems(Li et al., 2024).

➢ **S4 (Maize with undersown grass):** Started with very high nitrate-N (30+ mg/L), dropped mid-2023 (Fig.3), but increased sharply again in late 2024, reaching the highest levels of all treatments (40 mg/L).

➢ **S3 (Spring barley) and S5 (Ryegrass, wheat):** Showed moderate nitrate-N concentrations (5–15 mg/L) with seasonal fluctuations (Fig.3).

➢ **S6 (Wheat, grass for seed):** Stable mid-range nitrate-N (10 mg/L), with modest fluctuations, but lower stability than S1 and S2 (Fig.3).

➢ **Seasonal Trends:** Most treatments exhibit lower concentrations during summer, rising in autumn/winter, highlighting post-harvest leaching risk (Wey et al., 2022).

➢ Across all treatments (S1–S6), nitrate consistently comprised 77 -89% of total nitrogen measured in the soil water (Fig.4).

➢ The strong proportionality suggested nitrate is the dominant form of nitrogen in these systems, regardless of crop rotation or season, and indicated that nitrate alone provides a reliable estimate of total nitrogen leaching risk (Fig.4)

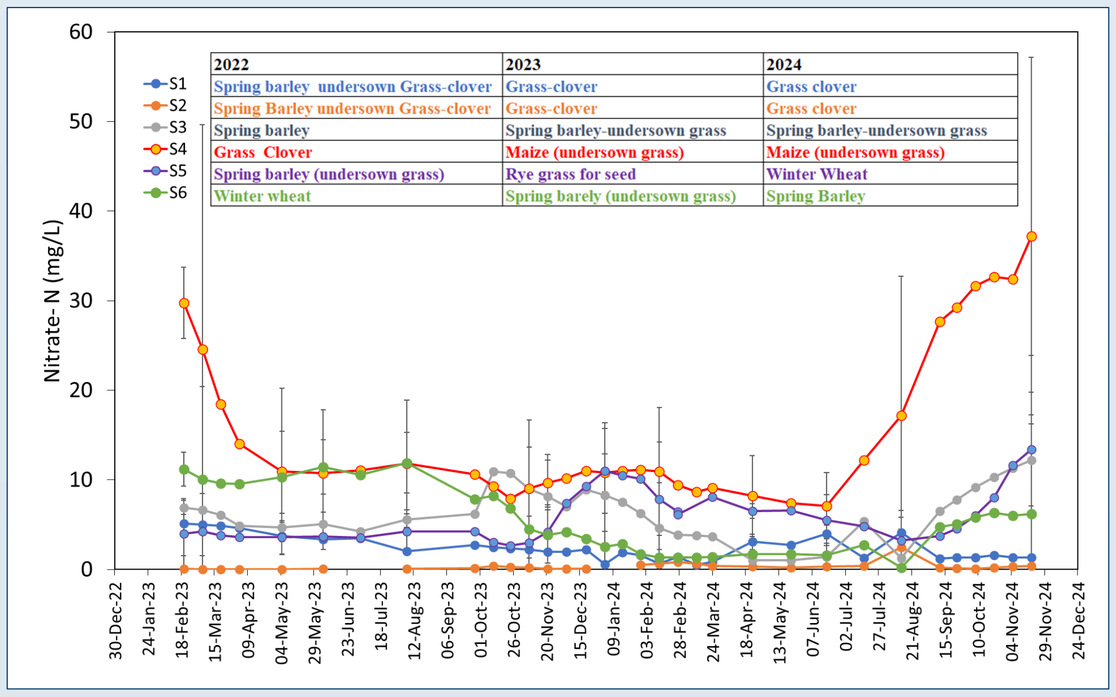

Fig. 3. Nitrate-N concentrations (mg/L) measured in drainage water from six cropping systems (S1–S6) over two years.

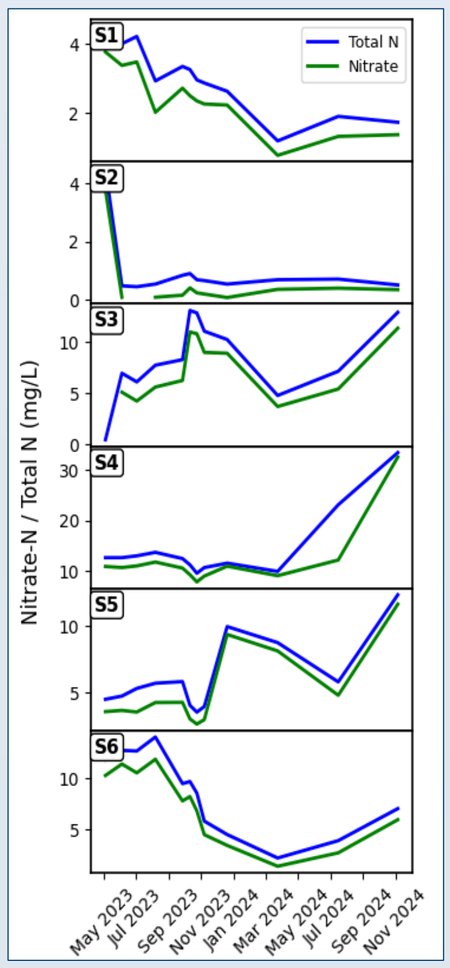

Fig.4 . Comparison of total nitrogen and nitrate-N concentrations for each cropping system (S1–S6).

CONCLUSION

Grass-clover systems (S1, S2) consistently minimized nitrate losses, while maize systems (S4) showed the highest leaching level. Nitrate accounted for 77–89% of the total N, confirming that monitoring nitrate alone is sufficient for estimating N leaching risk, supporting its continued use as a cost-effective proxy in field and regular monitoring. Seasonal peaks highlight the need for targeted post-harvest management (e.g. cover crops).

REFERENCES

Li, D., Wang, J., Chen, R., Chen, J., Zong, J., Li, L., Hao, D., & Guo, H. (2024). Review: Nitrogen acquisition, assimilation, and seasonal cycling in perennial grasses. *Plant Science*, *342*, 112054.

Wey, H., Hunkeler, D., Bischoff, W. A., & Bünemann, E. K. (2022). Field-scale monitoring of nitrate leaching in agriculture: assessment of three methods. *Environmental Monitoring and Assessment*, *194*(1)

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