Adopting combined nitrogen and phosphorus management based on nitrate nitrogen threshold balances crop yield and soil nitrogen supply capacity

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Abstract

The appropriate combined nitrogen and phosphorus fertilization strategy is essential for obtaining higher grain yields while maintaining soil fertility. Here, a long-term split-plot design farmland experiment with five N fertilizer rates combined with four P fertilizer rates was established during 2016–2019 to determine an appropriate nitrate-N threshold in intensive managed winter wheat- summer maize cropping, and then propose the fertilization strategy based on NO3-N threshold to balances crop yield and soil nitrogen supply capacity. The results showed that N fertilizer increased accumulated NO3-N, while the combined phosphate fertilizer at each N rate reduced the accumulated NO3-N to different degrees. With the increasing of planting seasons, the residual soil NO3-N reached a steady-state balance of soil N pool when N application rate was 150–225 kg ha-1 combined 60–120 kg ha-1 P rate. The residual NO3-N threshold was determined as 100 kg ha-1 to maintain N supply capacity and prevent it leaching. Based on it, we recommend 154 kg ha-1 of N and 106 kg ha-1 of P fertilizer in the wheat season, and 162 kg ha-1 of N and 122 kg ha-1 of P fertilizer in the maize season. The optimized fertilizer strategy reduced the fertilizer by 67 kg N ha-1 per year and reduced the residual NO3-N by 34.2% in deep soil while only reducing average yield by 3.1% across crops and years. This study can serve as basis for sustainable solutions for balances grain yields and soil nitrogen supply capacity as well as preventing nitrate pollution in farmland.

Highlights

- Long-term N and P application led to different levels of nitrate residue.
- Residual nitrate increased by N but decreased by combined P to different degrees.
- Suitable N and P application reached a steady-state balance of soil N pool.
- NO_3-N threshold in 0–100 cm was 100 kg ha^{-1} can maintain soil N supply capacity.
- It also can prevent NO_3-N leaching into deep soil.

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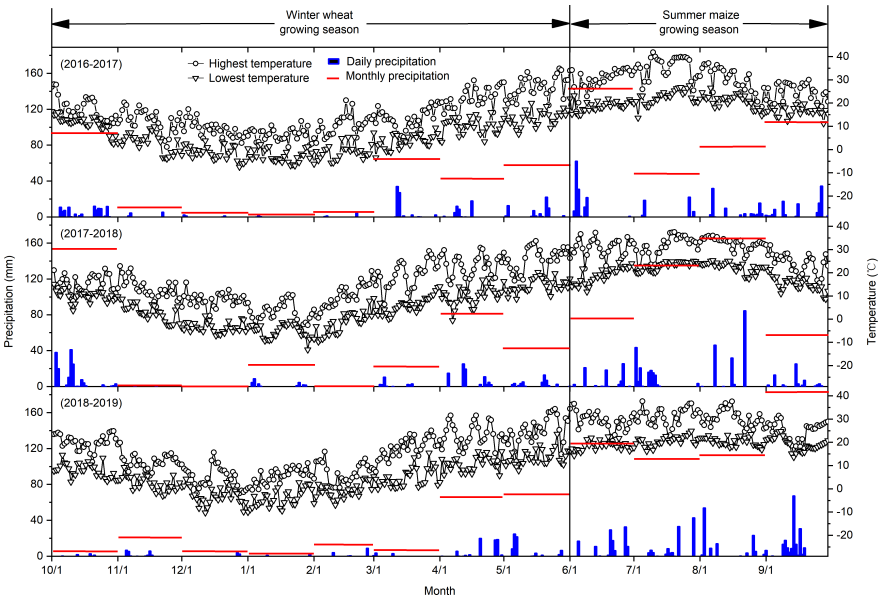
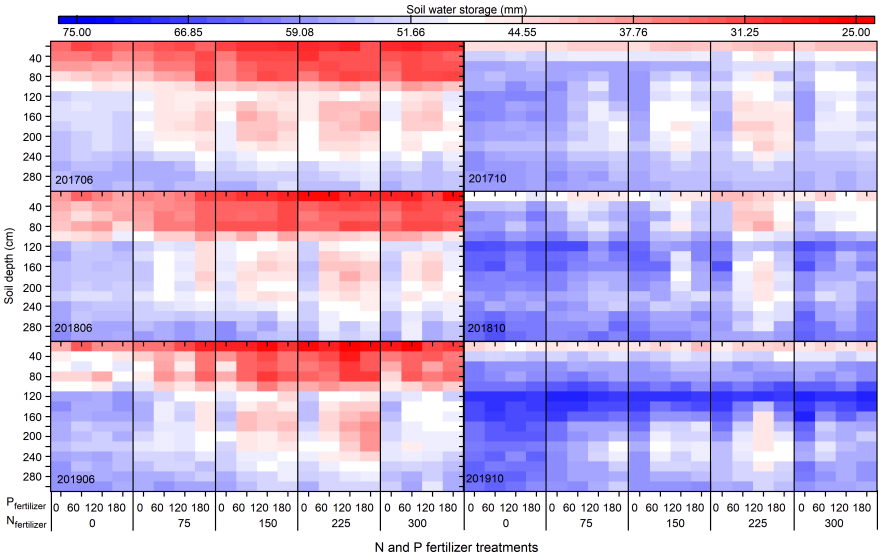
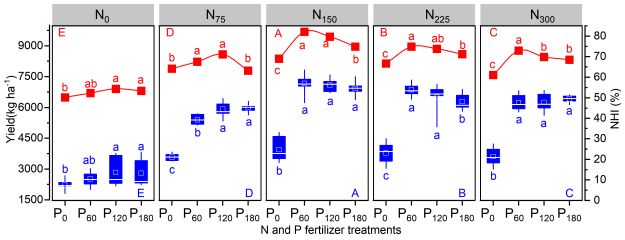
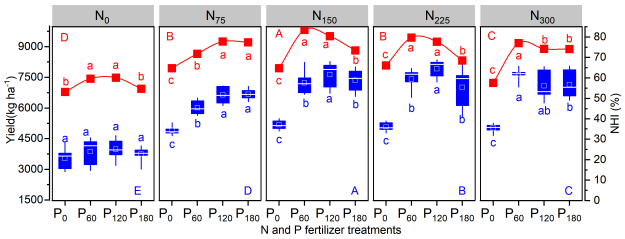






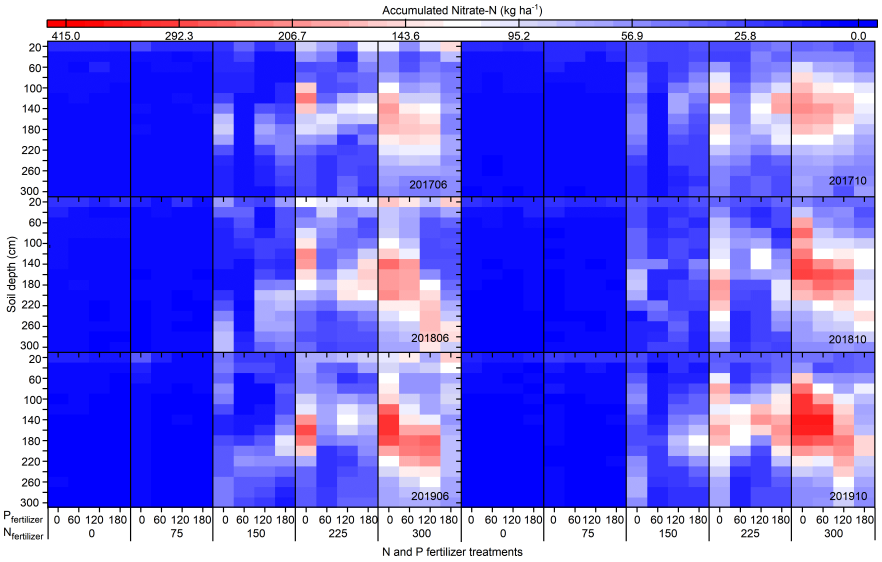
Analysis of variance (ANOVA)

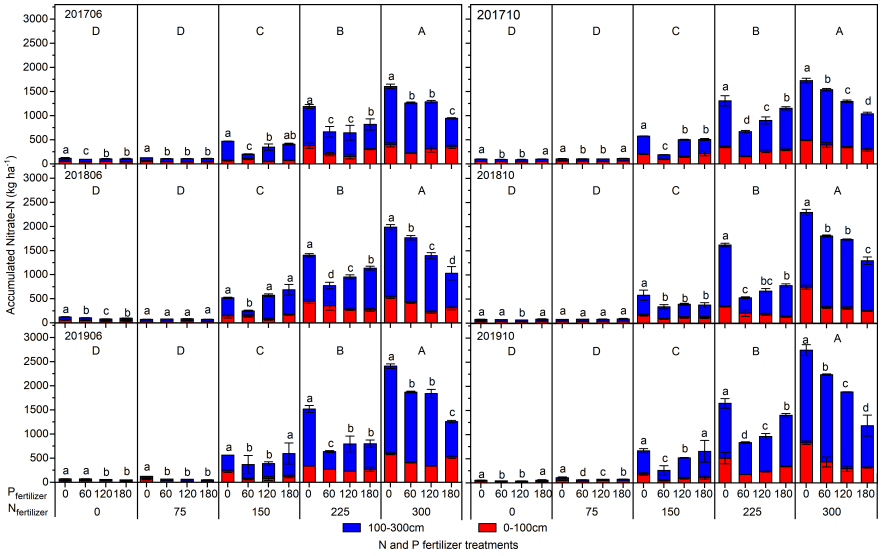
Factor	Yield F-value	NHI F-value
Y	35.1***	41.6 ***
N	1492.6***	300.1***
P	1107.2***	61.1***
Y × N	10.4***	13.8***
Y × P	20.6***	8.6***
N × P	54.1**	5.2***
Y × N × P	5.9***	4.0***

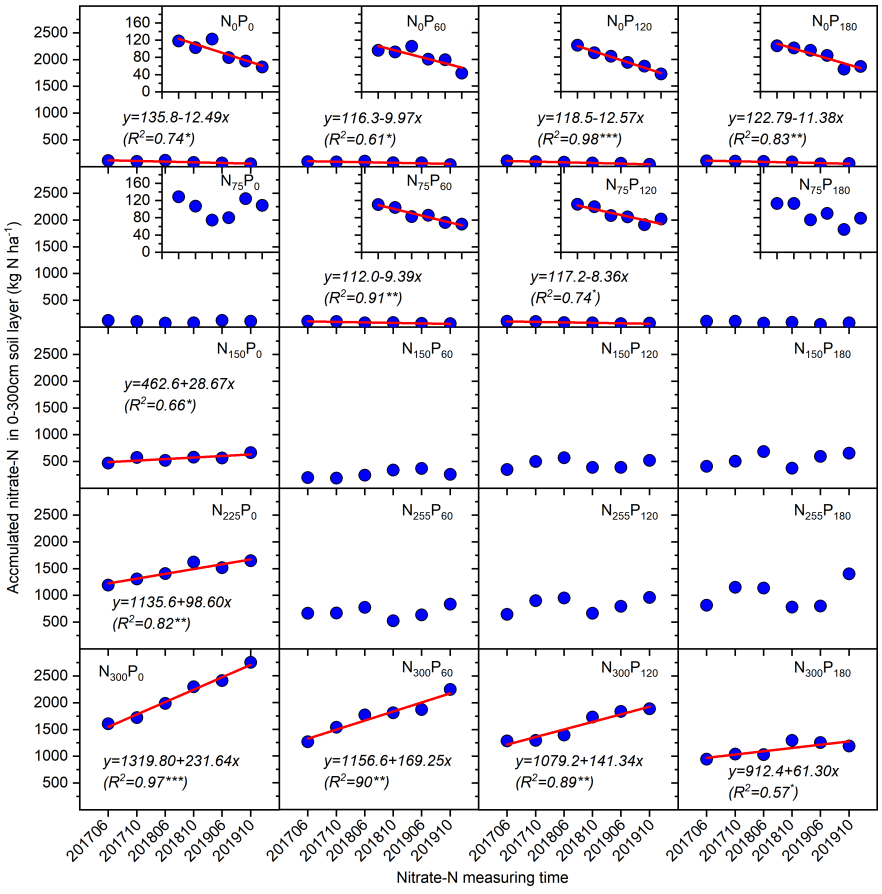


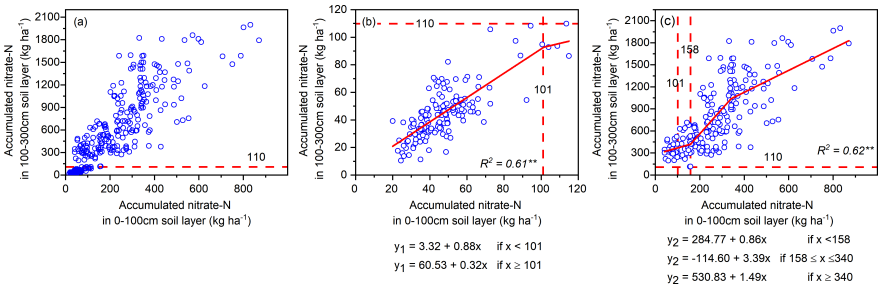
Analysis of variance (ANOVA)

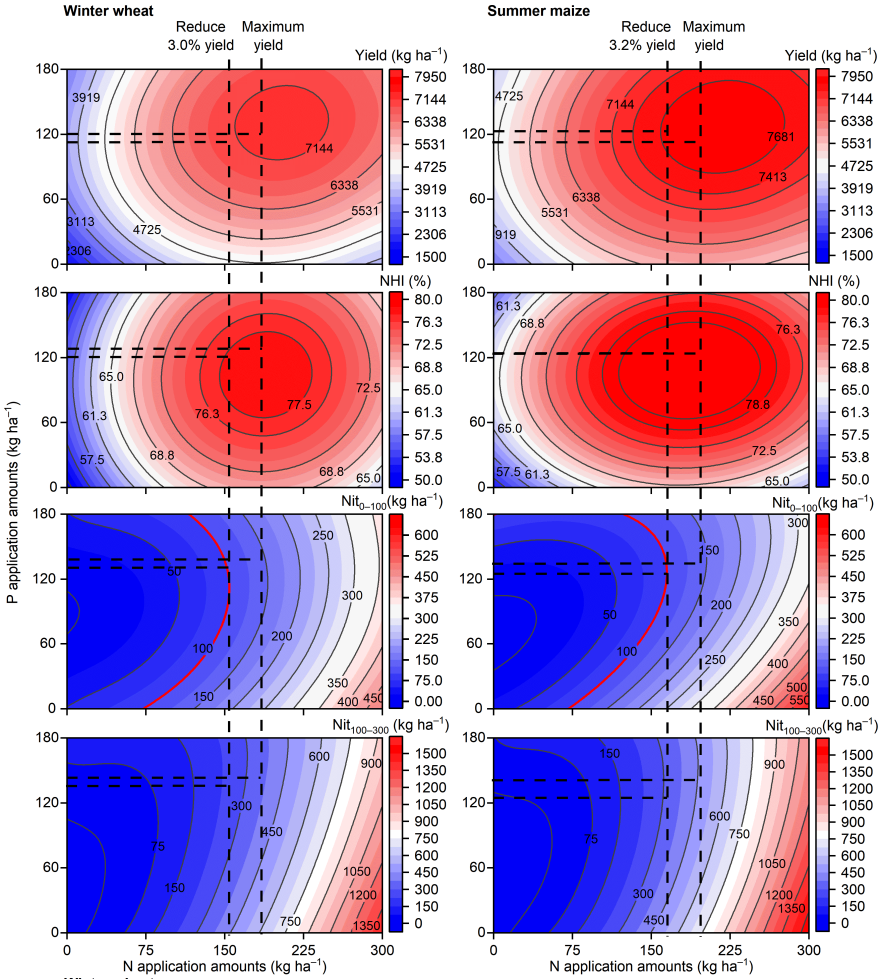
Factor	Yield F-value	NHI F-value
Y	88.8***	13.7 ***
N	1413.0***	143.8***
P	795.6***	121.1***
Y × N	35.8***	13.5***
Y × P	20.1***	15.3***
N × P	50.8**	9.5***
Y × N × P	5.4***	3.0***











Winter wheat:

Yield = 1518 + 33.98N + 35.45P – 0.092N^2 – 0.156P^2 + 0.027NP (R^2 = 0.85**, n = 180) (1)

NHI = 48.94 + 0.232N + 0.150P – 0.632N^2 × 10^{-3} – 0.775P^2 × 10^{-3} +0.611NP × 10^{-4} (R^2 = 0.70**, n = 180) (2)

Nit$_{0-100}$ = 59.12 + 0.29N – 1.36P + 0.004N^2 + 0.008P^2 – 0.002NP (R^2 = 0.86**, n = 180) (3)

Nit$_{100-300}$ = – 23.47 + 0.95N – 0.54P + 0.013N^2 + 0.008P^2 – 0.013NP (R^2 = 0.93**, n = 180) (4)

Summer maize:

Yield = 2969 + 28.19N + 29.54P – 0.071N^2 – 0.136P^2 + 0.023NP (R^2 = 0.83**, n = 180) (5)

NHI = 51.49 + 0.189N + 0.246P – 0.536N^2 × 10^{-3} + 0.122P^2 × 10^{-2} +0.985NP × 10^{-4} (R^2 = 0.60**, n = 180) (6)

Nit$_{0-100}$ = 35.74 + 0.60N – 1.34P + 0.004N^2 + 0.009P^2 – 0.006NP (R^2 = 0.86**, n = 180) (7)

Nit$_{100-300}$ = – 13.40 + 0.76N – 1.22P + 0.015N^2 + 0.011P^2 – 0.011NP (R^2 = 0.89**, n = 180) (8)