Digging Deeper

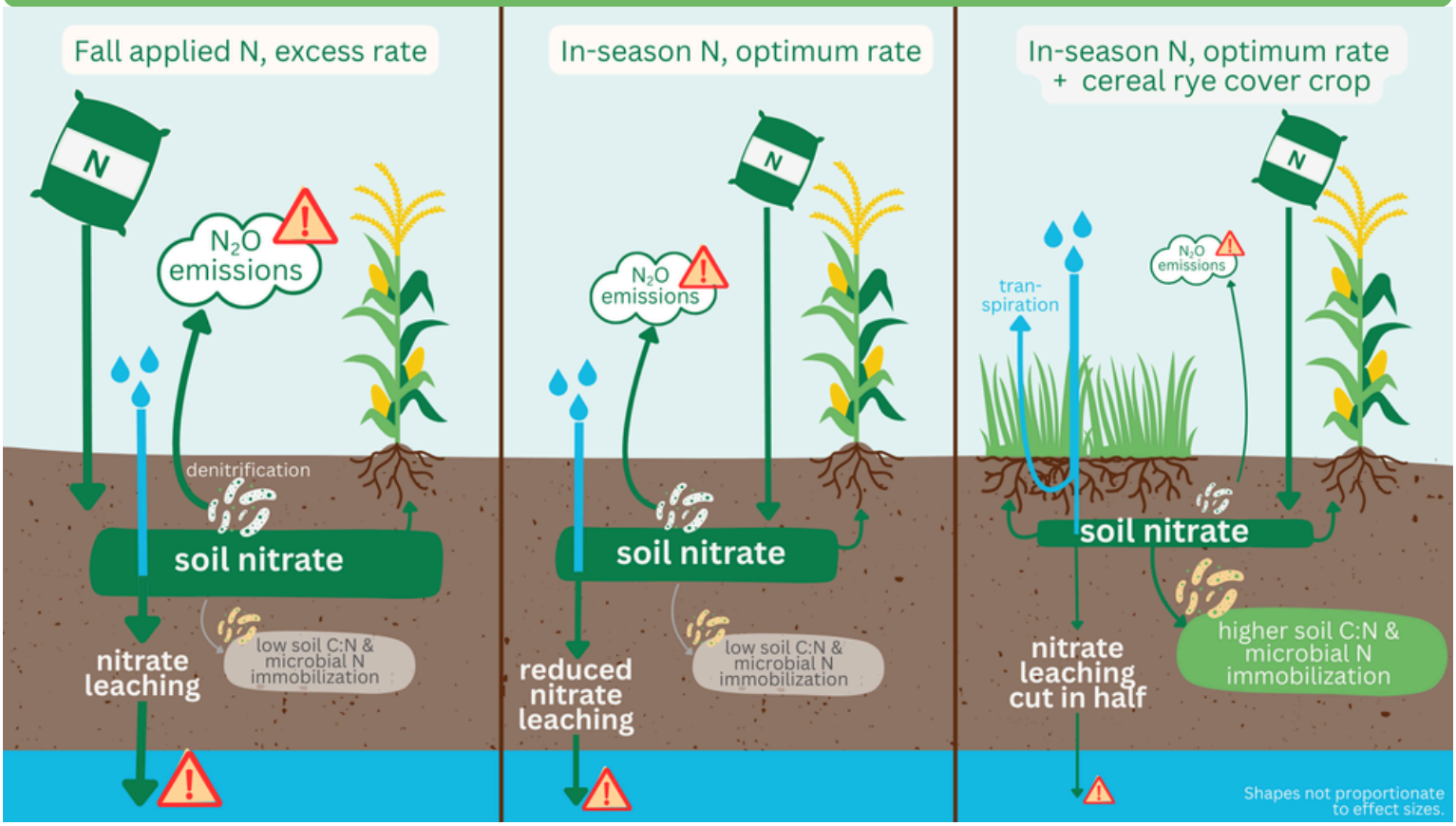
Cover Crops & N_2O Emissions

A pair of short-duration studies on Illinois fields suggested that cover crops reduce nitrate leaching (a win for water quality) but may increase nitrous oxide (N_2O, a greenhouse gas). We wanted to dig deeper into potential trade-offs and understand the environmental costs and benefits of cover crops.

Where does N_2O come from?

Denitrification is the microbial process that converts nitrate to N_2O and is responsible for most N_2O emissions from agricultural soils. Denitrification rate is influenced by the availability of nitrate, oxygen, and organic carbon. Soil temperature, moisture, and structure, which are all influenced to some extent by the use and management of cover crops, also play a role in denitrification rates. Plant residue from cover crops with high C:N ratios helps reduce the amount of nitrate available for leaching, but high carbon inputs from high C:N cover crops have been shown to stimulate N_2O emissions. So **we examined the scientific literature to put the two Illinois studies in the larger context of what is known about cover crops and N_2O emissions**.

The diagram below compares N cycling in a typical corn-soybean system with a high N rate and no cover crop (left), optimum N rate (middle), and optimum N rate with a cover crop (right).



In the left panel, soil nitrate is high even when there are no plants to use it. Denitrification and nitrate leaching occur throughout the year. In the middle panel, using an optimum N rate and applying the N when the crop needs it, reduces nitrate availability for denitrification and nitrate leaching. In the right panel, adding a cover crop reduces soil nitrate via plant uptake as well as soil carbon additions that encourage microbial N immobilization. Furthermore, the cover crop transpires soil moisture which reduces denitrification.

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Our analysis of 5 review papers and 3 experimental studies, summarizing results from nearly 200 studies, found that **nonlegume cover crops generally had no effect on N_2O emissions.** This was also true for studies in the Midwest, suggesting that the short duration studies in Illinois are an exception rather than the rule. Learn about each study below.

Article	No. of studies analyzed	Cover crops...	Recommendation for reducing N_2O emissions
Della Chiesa et al 2024	16 studies plus model for Indiana to Iowa region	...planted 30 days prior to corn harvest and before soybeans reduced N_2O emissions by 20%. Furthermore, a cover crop combined with early planting soybeans decreased N_2O emissions by 28% and **increased soybean yields by 16%**.	Plant nonlegume cover crop prior to corn harvest; plant longer maturity variety of soybeans early (e.g., April 24 rather than May 21); use recommended N fertilizer rates in corn years.
Muhammad et al 2019	48	...(nonlegume cover crops) decreased N_2O emissions compared to systems without a cover crop, while legume cover crops increased N_2O emissions. Compared to a no cover crop system, emissions were greater when residues were incorporated and lower when residues were left on the surface. Systems with greater cover crop biomass and/or higher C:N ratio had lower N_2O emissions.	Use a legume + nonlegume cover crop mix, keep residue on the surface instead of incorporating.
Basche et al. 2014	26	...(nonlegume cover crops and legume + nonlegume mixes) had close to zero effect on N_2O; however legume cover crops increased N_2O emissions. N rate was most responsible (statistically speaking) for N_2O emissions.	Leave cover crop residue on the surface (do not incorporate); use nonlegume or nonlegume + legume mixes rather than legume-only cover crops.
Abdalla et al. 2019	106	...decrease N leaching, increase soil carbon, had no impact on N_2O.	Grow cover crop mix including legumes to avoid yield drag.
O'Brien et al 2022	1 in Iowa	...had no detectable impact on N_2O, instead N_2O emissions driven by N application and wet weather.	Stack multiple practices to regulate nitrate and N_2O emissions.
Shcherbak et al. 2014	(78)	(Did not test effect of cover crops but found resounding evidence that N_2O emissions are driven by N fertilizer rate.)	Avoid excessive N fertilizer beyond crop N needs.
Preza-Fontes et al. 2023	1 in Illinois	...reduced nitrate losses but increased soil N_2O emissions in a continuous corn rotation. The year with the greatest N_2O emissions was the year N was fall-applied.	Pair cover crops with enhanced efficiency fertilizer, grow cover crops for longer in the spring to avoid cover crop residue promoting conditions favorable to denitrification when fertilizer is applied.
Johnson et al. 2024	1 in Illinois	...reduced nitrate losses, had zero effect on N_2O emissions.	None provided.

The Bottom Line:

Studies were in agreement that cover cropped fields led to a significant reduction in nitrate losses and recommended reducing potential N_2O emissions by planting a nonlegume cover crop or nonlegume-legume cover crop mix and leaving residue on the surface.
Remember that **nitrate availability is the key controller** of N_2O emissions from farm fields and following the 4Rs of nutrient management (Right Source, Right Rate, Right Time, Right Place) reduces potential for N_2O emissions regardless of cover crop adoption.

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