Research team develops new tool to help farmers make crop input decisions

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Reducing greenhouse gas emissions (GHGs) and nitrogen water pollution from agriculture are top environmental priorities in the United States. Key to achieving climate goals is helping producers navigate carbon markets, while also helping the environment and improving farm income.

A new tool developed by a University of Minnesota research team allows farmers to create a budget balance sheet of any nitrogen reduction plans and see the economic and environmental cost, return and margins, all customized to fields under their management.

"With these numbers in mind, farmers can make more informed decisions on nitrogen mitigation that not only saves them money, but also significantly reduces pollutants to the environment," said Zhenong Jin, who led the research and is an assistant professor in the Department of Bioproducts and Biosystems Engineering (BBE) in the College of Food, Agricultural and Natural Resource Sciences (CFANS).

Previous tools did not allow for customized predictions for every field in the U.S. corn belt, as the computational and storage costs of running these crop models at large scale would be very expensive.

As outlined in an article published in *IOPscience*, the research team built a series of machine-learning-based metamodels that can almost perfectly mimic a well-tested crop model at much faster speeds. Using the metamodels, they generated millions of scenario simulations and investigated two fundamental sustainability questions—where are the mitigation hotspots, and how much mitigation can be expected under different management scenarios.

"We synthesized four simulated indicators of agroecosystem sustainability—yield, N_2O emissions, nitrogen leaching, and changes in soil organic carbon—into economic net societal benefits as the basis for identifying hotspots and infeasible land for mitigation," said Taegon Kim, CFANS research associate in the BBE department. The societal benefits include cost savings from GHG mitigation, as well as improved water and air quality.

"By providing key sustainability indicators related to upstream crop production, our metamodels can be a useful tool for food companies to quantify the emissions in their supply chain and distinguish mitigation options for setting sustainability goals," said Timothy Smith, professor of Sustainable Systems Management and International Business Management in CFANS's BBE department.

The study, conducted in the U.S. Midwest corn belt, found that:

- Reducing nitrogen fertilizer by 10% leads to 9.8% fewer N_2O emissions and 9.6% less nitrogen leaching, at the cost of 4.9% more soil organic carbon depletion, but only a 0.6% yield reduction over the study region.
- The estimated net total annual social benefits are worth $395 million (uncertainty ranges from $114 million to nearly $1.3 billion), including a savings of $334 million by avoiding GHG emissions and water pollution, $100 million using less fertilizer, and a negative $40 million due to yield losses.
- More than 50% of the net social benefits come from 20% of the study areas, which thus can be viewed as hot spots where actions should be prioritized.

"Our analysis revealed hot spots where excessive nitrogen fertilizer can be cut without yield penalty," said Jin. "We noticed in some places that reducing nitrogen-related pollution comes at a cost of depleting organic carbon in soil, suggesting that other regenerative practices, such as cover cropping, need to be bundled with nitrogen management."

In the future, the team will expand the framework presented in this study and develop more advanced and accurate carbon qualification models through a combination of process-based models, artificial intelligence and remote sensing.

More information: Taegon Kim et al, Quantifying nitrogen loss hotspots and mitigation potential for individual fields in the US Corn Belt with a metamodeling approach, *Environmental Research Letters* (2021). DOI: 10.1088/1748-9326/ac0d21

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