**Paper #3: Using Targeted Policies to Manage Nitrogen for Sustainable Agriculture in the US**

**Background**

Nitrate leached from agricultural fertilizer has created a host of environmental problems (Tilman et al. 2002). Improving nitrogen management can decrease its harmful effects on the environment (Socolow 1999). However, behavioral change rarely takes place automatically. Interventions are necessary to induce or require polluters to internalize the cost of pollution (Shortle and Horan 2017). Various instruments have been considered such as taxes on chemical fertilizer, subsidies for conservation practices, and regulatory restrictions to reduce the over-use of nitrogen. Some of these interventions can be expensive and have been increasingly criticized as inefficient or ineffective due to the one-size-fits-all approach to achieve the specified goals (Ribaudo 2011). With the assistance of spatially explicit data that identify the locations with the greatest potential for reducing nitrate leaching at least cost, targeted policy measures may substantially improve the cost-effectiveness of abatement efforts (Konrad et al. 2014). This paper aims to assess the impacts of a variety of such policy measures on agriculture in the U.S.

**Method**

Assessing the costs and benefits of reducing N-loss requires knowledge of yield response to Nitrogen use and the resulted nitrate leaching. In order to capture the spatial heterogeneity in these relationships, a grid-resolving model SIMPLE-G-US-CS is developed. SIMPLE-G-US-CS is a global partial equilibrium model where the U.S. is divided into numerous 5 arcmin resolution grid-cells and each of the fifteen non-US regions is represented by an individual 'grid'. It is a gridded version of the SIMPLE model that has been widely employed to study long run sustainability issues in agriculture (Baldos and Hertel 2014; Hertel, Ramankutty, and Baldos 2014; Liu et al. 2017). Like its aggregate version, the core of the gridded model describes the demand for and supply of crops. The increasing regional demand for food is shaped by growing population, income per capita, biofuels demand and total factor productivity. On the supply side, crop production follows a CES function but each grid cell has a distinctive cost structure and an elasticity of substitution between Nitrogen fertilizer and other inputs.

Cost shares and elasticities are derived from a set of transfer functions that are separately fitted based on the simulated yield responses to Nitrogen use from a biophysical agroecosystem model AgroIBIS. These grid-specific transfer functions significantly improve the representation of local biophysical characteristics in the economic model. Given that AgroIBIS is geographically confined to Mississippi Basin and simulates only major field crops in this area, SIMPLE-G-US-CS focuses on two dominant crops -- corn and soybeans whose combined planted area accounts for 54% of total area planted in the U.S. in 2017. They also play a critical role in shaping the long-run sustainability of agriculture given the bio-energy goals and the diet transition by the middle of the century. In terms of nitrate leaching, corn specifically 'requires the most nitrogen per acre' according to USDA.

## Experimental Design and Preliminary Results

While continuing to refine the experimental design, in this abstract we consider two stylized experiments to demonstrate the function of the model: (a) A nationwide 40% fertilizer tax that targets leaching indirectly by constraining Nitrogen use, and (b) reducing nitrate leaching by 45% in Illinois, Indiana, Iowa and Ohio, a regulatory restriction that targets nitrate loss directly. The baseline of the model features the economy of 2010. Figure 1 shows the impacts of these policies on crop (corn and soybeans composite) output and Nitrogen use. Not surprisingly, the nationwide fertilizer tax reduces Nitrogen application and thus crop output in the central corn belt. The changes can be as large as 25kg/ha reduction in Nitrogen use and 0.8 tons/ha reduction in output. Nationally, total crop output decreases by 3.2% and crop price increases by 2.5%. The reduction in nitrate leaching resulted from the suppressed use of Nitrogen fertilizer is 15.5%.

In the other experiment, the resulted output reduction mainly occurs in the four regulated states, while corn and soybeans production expands in the other states, especially in Nebraska and southern Minnesota. Although nitrate leaching is reduced by 45% in Illinois, Indiana, Iowa and Ohio, this regional achievement is diluted by the leakage to the non-regulated regions, leading to a much lower nitrate loss reduction of 6.6% at the national level. The impacts on national total output and price again are minor, -2.1% and 1.6%, respectively.

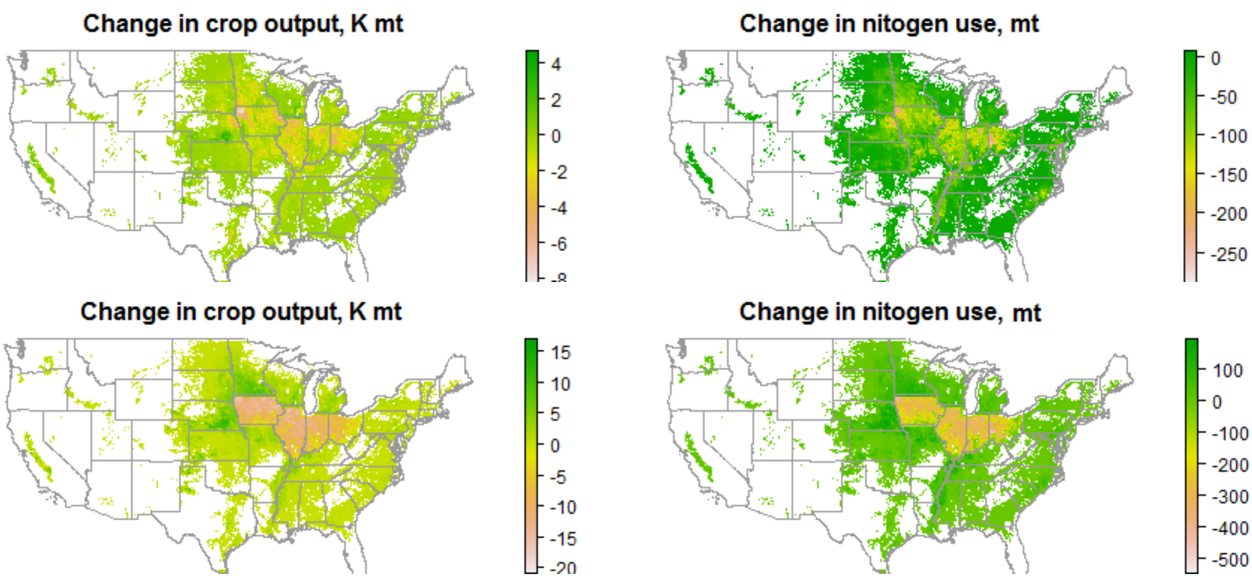


Figure 1. Change in crop output (in 1000 metric tons per 5 arcmin grid-cell) and change in Nitrogen use (in metric tons per grid), resulted from a nationwide 40% Nitrogen fertilizer tax (top panel) and 45% reduction in nitrate leaching in IN, IL, IA and OH (bottom panel).

## Discussion and Next Steps

Several insights are learned from these stylized experiments. First, the tradeoff between agricultural yields and leaching management is anticipated. Nonetheless, the impacts on production and crop price are modest, not only because commercial fertilizer use is substitutable, but also because of the improvable Nitrogen use efficiency, as well as the expansion of corn and soybeans area to other crops. Second, targeted policies match the extent of interventions with the tradeoffs and thus could be more cost-effective. At a finer scale, the policy can target directly the location where the physical characteristics are related to high leaching (e.g. subsurface drained) and low Nitrogen use efficient (low output value per unit of nitrate leaching). Alternatively, a broader area (watershed or state) can be targeted, with the expectation that the low-cost (less punishing) acre contributes a greater share to achieving the nitrate load reduction goal. The next step of the research is to formulate realistic Nitrogen management policies and analyze their impacts on production, food price, land use, nitrogen use efficiency, and nitrate leaching. We will further compare these impacts against the case of uniform polices and assess the potential gains from implementing more efficient nitrate leaching reduction strategies.

**References**

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