Adoption analysis of edge-of-field treatment wetlands in the Corn-Soy belt of the US: Application of TOA-MD and SIMPLE model coupling

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Introduction

The Mississippi river basin supports one of the most productive farming regions in the world. However, intensive agricultural activity in the region, with high fertilizer use, has led to excess nutrient leaching to surface and groundwater, leading to hypoxia in the Gulf of Mexico (Goolsby et al. 2001) causing adverse ecological and economic impacts in the region. Nutrient leaching also contributes to biodiversity loss, crop yield loss as well as adverse human health impacts across the basin (Liu et al. 2018). The EPA Hypoxia Task Force set an interim target of a 20 percent reduction in nutrient load in the Mississippi river by 2025 along with a longer-term goal to reduce the average hypoxic zone to a more manageable level of 5000 square kilometers on average by 2035.

Recent multi-scale research shows that establishment of wetlands are a key to reduce the nutrient load in surface and groundwater leaching in combination with other agronomic and environmental management techniques (Liu et al. 2022). Wetlands contribute towards denitrification of surplus nitrogen, via microbial respiration in anoxic conditions in hydric soils. It also lengthens the duration of nutrient laden water and encourage deposits of sediment material into the wetland and reduces the nutrient load of water reaching rivers and oceans. Wetlands also provide other ecosystem services such as species habitat, biodiversity and flood protection (Watson et al. 2016).

Small edge-of-field wetlands, comprising of 3 percent of tile-drained farmland reduced 15 – 38 percent of nitrogen leaching midwestern US (Lemke et al. 2022). Liu et al. (2022) find a similar wetland restoration policy when combined with higher nitrogen taxation and improved efficiency of nitrogen absorption, can reduce nitrate leaching by 30.2 percent which is two third of the reduction necessary to achieve the EPA's 2035 target. Establishment of edge-of-field wetlands is distinct from current conservation policies such as Wetland Reservation Program that focus on the conservation of larger areas. There is increasing evidence that edge-of-field treatment wetlands could provide similar benefits of nutrient reduction while removing fewer hectares out of production (Gordon, Lenhart, and Nieber 2021; The Nature Conservancy 2021).

In this paper, we evaluate the potential adoption of edge-of-field treatment wetlands in the Corn Belt of the US. We focus on corn-soy growing farmland since it is the dominant crop in the Mississippi River basin contributing to a majority of the leached nutrients. We use a model coupling approach to model farmers' adoption decision of edge-of-field wetland and its impacts on crop production, input and output prices as well as changes in land and nutrient use. This analysis helps us understand the potential adoption rate of edge-of-field wetlands.

Methodology

In this paper we couple the TOA-MD (Trade-off Analysis Model for Multidimensional Impact Assessment) model (Antle 2011) and the SIMPLE (Simplified International Model for agricultural Prices, Land use and the Environment) (Hertel and Baldos 2016) model to estimate the potential adoption rate for edge-of-field treatment wetlands and evaluate the its impact on agricultural production, input use and water quality.

We use the Trade-off Analysis (TOA) approach to model farmers' decisions to adopt edge-of-field treatment wetlands (Antle and Valdivia 2021; Antle, Stoorvogel, and Valdivia 2014). TOA is best suited for this analysis, since it combines foresight analysis and simulation modelling while incorporating potential uncertainties. One major area of uncertainty in this study, is the wide variation in the cost of establishment of wetlands which can depends on bio-physical characteristics such as type of soil and topography of the land as well as existent infrastructure such as controlled and tile drainage. Estimates for the establishment and maintenance costs of wetlands in the Midwestern states range between $660 to $4076 per hectare (Bravard et al. 2022; Christianson, Tyndall, and Helmers 2013). Further, the TOA approach is designed to study different policy designs incentivizing the adoption of edge-of-field treatment wetlands. The TOA approach has been widely used to study complex systems such as the use of sustainable production practices in the dryland wheat systems of the US (Antle et al. 2019), integrated pest management in rice production in the Philippines (Antle and Pingali 1994) and mixed crop-livestock systems in Kenya (Claessens, Stoorvogel, and Antle 2008). In this study, we use the TOA-MD model to estimate the potential adoption rate for edge-of-field treatment wetlands under different policy scenarios.

SIMPLE is a partial equilibrium model for agricultural production that has been designed around the principle that a model should be no more complex than is absolutely necessary to understand the basic forces governing the supply and demand for crops, cropland and food prices. It has been applied to analyze the long run drivers of future food production, prices and land use change (Baldos and Hertel 2013; Hertel, Baldos, and van der Mensbrugghe 2016), adaptation to climate change (Lobell, Baldos, and Hertel 2013; Baldos, Fuglie, and Hertel 2020), and the role of R&D and productivity growth in ensuring food security and environmental sustainability (Baldos and Hertel 2014). In this paper, we leverage the two-input (Land and Non-land inputs) framework underlying the model. We use the potential adoption rate estimated from the TOA-MD model, to shock the land supply equation in the SIMPLE model. The SIMPLE model outputs the change in commodity price which is used to update the potential adoption rate from the TOA-MD model. We run this model coupling exercise until we arrive at an equilibrium.

Data

We will use data from the Census of Agriculture (from USDA) and Food and Agricultural Organization (FAO) to calibrate both the TOA-MD and SIMPLE models. Further, we will use existent information on the cost of establishing wetland from the literature to calibrate the TOA-MD model.

Potential for discussion

This research evaluates different policy options to incentivize the adoption of edge-of-field treatment wetlands with the aim to improve water quality and reach the EPA's target of minimizing the Hypoxic zone. This is a novel methodology and will benefit from discussions at this meeting, to understand critical aspects of policy design for the adoption of wetland by agricultural producers. It will also generate discussion on critical aspects of farm-wetland production systems that should be the focus of such policy design.

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Motivation

- Excess nutrient leaching leads to Hypoxia in the Gulf of Mexico leading to adverse ecological and economic impacts.
- Recent multi-scale research (Liu et al. 2022), show that edge-of-field treatment wetlands are key to reduce nutrient load in run-off water by 30.2%. This is also confirmed by others (Gordon, Lenhart, and Nieber 2021; The Nature Conservancy 2021).
- Current policies for conversion of agricultural land into wetlands adopts a full field approach where an entire field is converted to wetlands.
- In this paper, we study ex-ante, the potential adoption of edge-of-field treatment wetland policy based on the findings of recent reseach i.e., conversion of 3% of tile-drained farmland reduced 15-38% of nitrate leaching in the mid-west.

Methodology

- Model coupling approach with the TOA-MD (Trade-off Analysis Model for Multidimensional Impact Assessment) model (Antle 2011) and the SIMPLE (Simplified International Model for agricultural Prices, Land use and the Environment) (Hertel and Baldos 2016)
- We use Trade-off Analysis (TOA) approach to model farmers' decisions to adopt edge-of-field treatment wetlands (Antle and Valdivia 2021; Antle, Stoorvogel, and Valdivia 2014). TOA is best suited for this analysis, since it combines foresight analysis and simulation modelling while incorporating potential uncertainties inherent in ex-ante policy evaluation.
- SIMPLE is a partial equilibrium model for agricultural production that has been designed around the principle that a model should be no more complex than is absolutely necessary to understand the basic forces governing the supply and demand for crops, cropland and food prices. We use the SIMPLE approach to model the economy wide effects of the policy.

(references available on request)