Assessing a pay-for-performance conservation program using an agent-based modeling framework

Seungyub Lee
U.S. Environmental Protection Agency
lee.eric@epa.gov

Matthew Heberling
U.S. Environmental Protection Agency
heberling.matt@epa.gov

Christopher Nietch
U.S. Environmental Protection Agency
nietch.christopher@epa.gov

Amr Safwat
Aptim Federal Services
amr.safwat@aptim.com

Selected Poster prepared for presentation at the 2022 Agricultural & Applied Economics Association Annual Meeting, Anaheim, CA; July 31-August 2

Assessing a pay-for-performance conservation program using an agent-based modeling framework

[1]Seungyub Lee, [1]Matt Heberling, [1]Chris Nietch, and [2]Amr Safwat

[1]U.S. Environmental Protection Agency, Office of Research and Development, Center for Environmental Measurement and Modeling, Cincinnati, OH • [2]Aptim Federal Services, LLC, Milford, OH

Seungyub Lee | lee.eric@epa.gov | | Matt Heberling | heberling.matt@epa.gov

Pay-for-Performance (PfP)

- Water quality trading, a market-based approach, has been studied in the Upper East Fork of the Little Miami River in Ohio
  - Point sources, or wastewater treatment plants, are unlikely to purchase enough nutrient pollutant reduction from agricultural producers to make a difference in water quality
- Other approaches exist that can help distribute conservation funds to agricultural producers. One gaining interest is Pay-for-Performance (PfP), compared to pay-for-practice.
- PfP is based on nutrient reduction performance
  - Has a potential advantage on improving water quality
  - Potentially more cost-effective approach
- Integrated ABM-SWAT[1] model can provide estimated spatial and biophysical dynamic nutrient reduction based on farmer's BMP[2] decision
  - ABM based on PfP can potentially find cost-effective/efficient and more flexible options under limited resources
- We are interested in understanding the potential benefit of using PfP

[1] Soil and Water Assessment Tool; 2 Best Management Practice

Agent-Based Model (ABM)

- ABM is a bottom-up modeling approach
  - Fosters improved understanding of the dynamics of complex systems that consist of various types of autonomous agents (e.g., farmers) having different behaviors and interactions
  - In comparison, optimization/aggregated approaches typically assume one/similar type of agent
- SWAT can help to predict crop yields and loading dynamics affecting water quality based on land uses and agricultural BMPs

➔ Combining these two modeling approaches allows us to understand coupled human and natural systems dynamics while examining various factors and interactions

➔ We can compare pay-for-practice type program (e.g., EQIP[1]) to one based on PfP

[1] USDA's Environmental Quality Incentives Program

Model setup

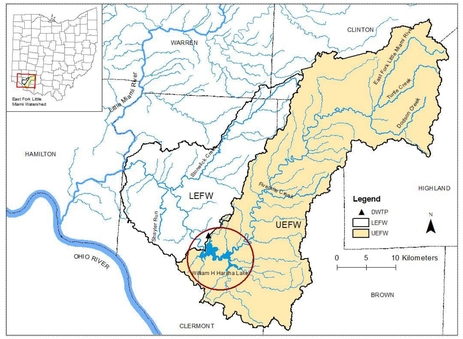

Figure 1: Map of the East Fork of the Little Miami River Watershed (EFW) in Southwestern Ohio. The EFW is 1293 km² and located within five Ohio Counties : Clermont, Brown, Highland, Clinton, and Warren. The current study includes the Lower East Fork Watershed (LEFW) with plans to expand to the entire EFW.

- Created 50 farmers in the SWAT model
- A random portion of potential BMP area will be assigned to each farmer, which is drawn from N(0.10, 0.05)
  - This is drawn from normal distribution with mean area equal to 10% and 5% standard deviation. Farmers will make production and BMP decisions based on their expected profit
  - Compare every possible BMP adoption scenario including no adoption
- If a farmer decides to adopt BMP(s), it will be decided by
  - Cost-efficiency ($/lb Total Phosphorus reduction)
  - Total conservation program budget (currently, $75,000)
  - If farmers adopt BMP(s) in year *t* with PfP program,
    - Then in year, *t*+1, farmers will compare their profit with 1% more BMP area vs. their current BMP area, to decide if they change BMP area
- Each scenario is run with 30 iterations to obtain reliable results

Agent (farmer)

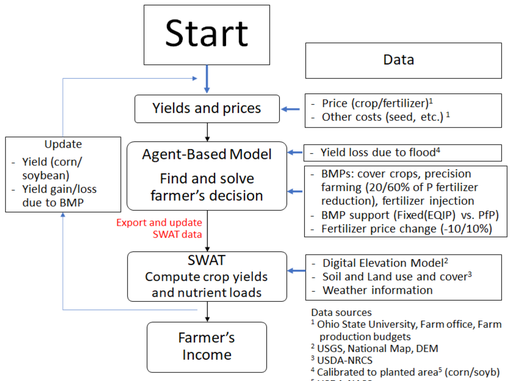

Figure 2. Flow chart showing ABM process including data needs and sources

$$E(\text{Profit}) = P_{c,t} \times E(Yld_{i,c,t,b}) - Cost(seed_{c,t}, fertilizer_{f,t}) + d_{i,b,t} \times (CS_b - Cost(BMP_b))$$

- $P_{c,t}$ - crop price
- $Yld_{i,c,t,b}$ - estimated by the SWAT model
- $E(Yld_{i,c,t,b})$ - farmers consider field condition based on April and May precipitation
- CS_b - Cost-share$_{BMP}$, which will vary by BMP
- BMP types: cover crops, precision farming (20 or 60% of Phosphorus fertilizer reduction), fertilizer injection
- ***c***: crop (corn/soybean), ***t***: year (2010-2020), ***i***: farmer, ***b***: BMP types, ***f***: fertilizer types (nitrogen/phosphorus)

Results

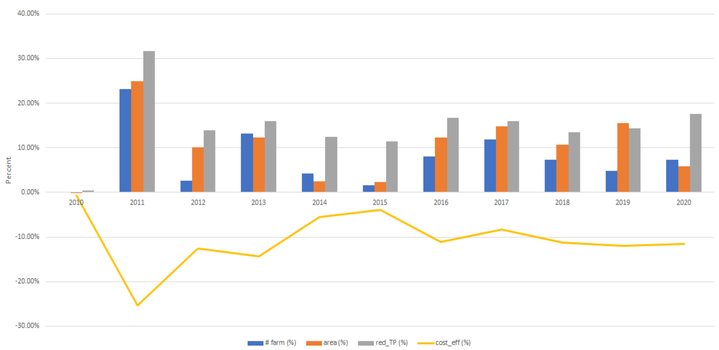

Figure 3. Results from ABM. Cost-Eff is PfP cost-efficiency measured as cost to reduce 1lb TP, compared to pay-for-practice. All % values represent difference between PfP and pay-for-practice (Y-axis). Negative percent means PfP is more efficient meaning the cost to reduce 1lb of TP is lower than pay-for-practice.

- By introducing PfP to increase the use of BMPs, we observe, on average:
  - About a 10% increase in cost-efficiency compared to pay-for-practice to reduce 1lb TP/ac
  - Increases in the number of participating farmers and in BMP area (about 7% and 10%, respectively)
  - About a 15% increase in TP reduction

Future work

- Study the impact of transaction costs
  - A new program could involve high transaction costs for agricultural producers
  - Investigating network effects (e.g., BMP advice from neighbors) could offset those transaction costs
- Examine different types of farmers and their willingness to adopt new technology
- Expand to the Upper East Fork Watershed where there is more agricultural land use