Optimal Management of Legacy Phosphorus under Limited Information

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Introduction and Motivation

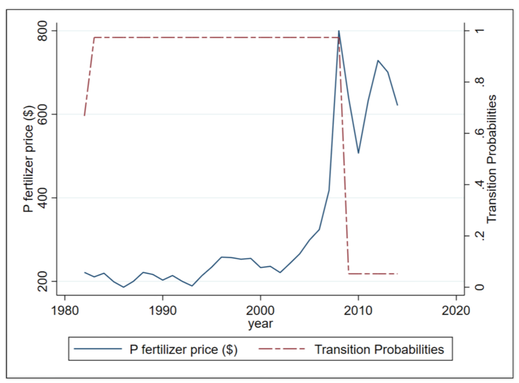
- Over-consumption of synthetic **phosphorus (P)** fertilizers in agriculture causes environmental harm such as nutrient loss and water pollution.
- A portion of phosphorus accumulates in soil and is known as '**Legacy P**'.
- This Legacy P may partially substitute for synthetic P fertilizers, reducing environmental damage and promoting sustainability.
- **We analyze farmers' optimal P fertilizer application under economic (fertilizer price and risk preference) and physical uncertainty (Legacy P bioavailability and P use efficiency), which can be mitigated by using partially observable information.**

Methods

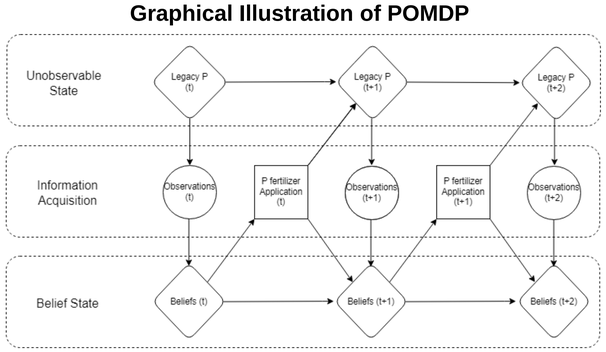
- We utilize Iho and Laukkanen's (2012) crop yield function and Legacy P dynamic system, where P's impact on crop yield depends on fertilizer application rates and Legacy P presence.
- **Markov Switching Dynamic Regressive Model** is utilized in this study, based on P fertilizer price data to identify two price states (moderate and high), with transition probabilities determined through regression.
- **Partially Observable Markov Decision Process** (POMDP) is applied to model the uncertainty associated with Legacy P bioavailability, considering both the state of the Markov Process and the information acquisition by farmers through P fertilizer application and soil sampling.

P fertilizer Price and State Transition Probability (1960-2014)

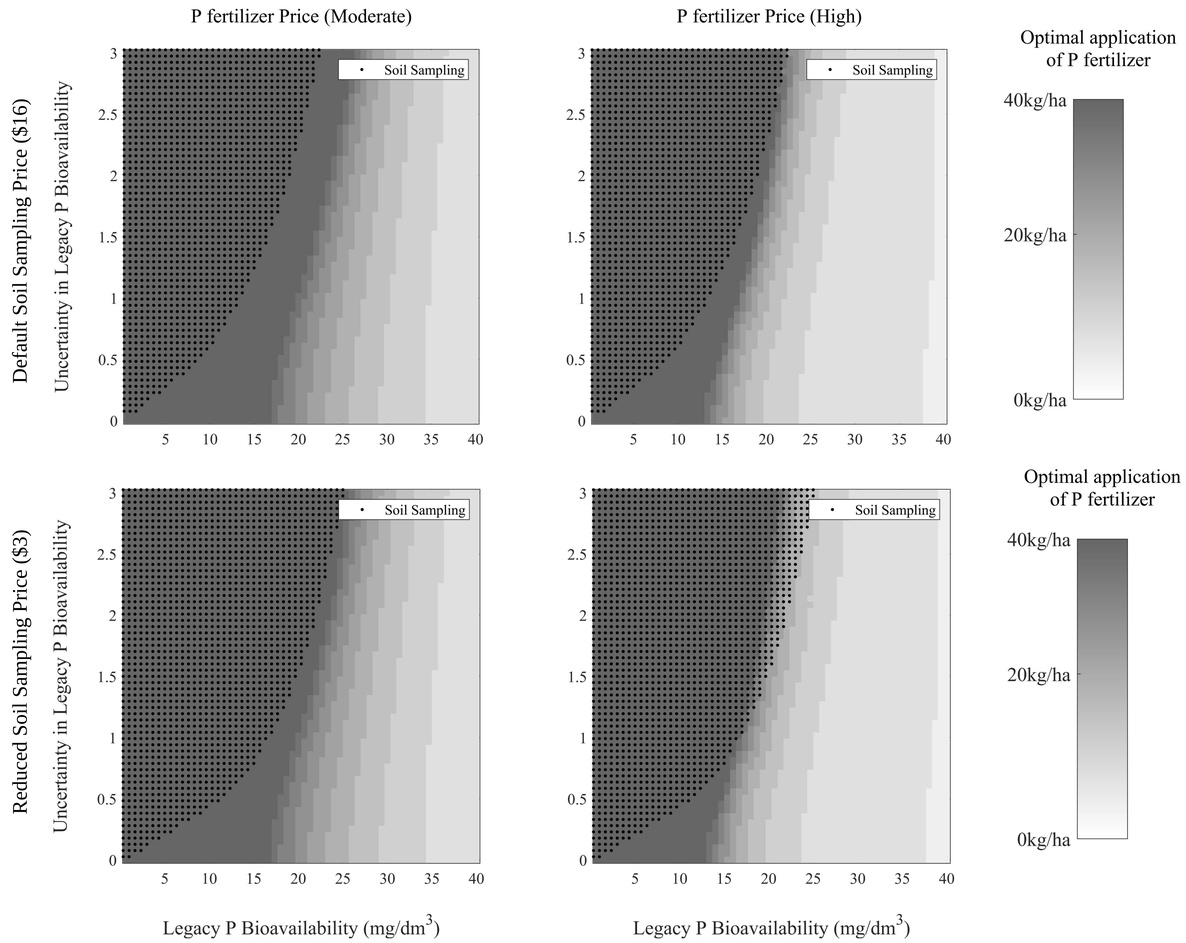
(Super-phosphate 44-46% Phosphate, $ per material short ton)



Graphical Illustration of POMDP



Results: Optimal Application of P Fertilizer and Soil Sampling



Conclusions

- **Increasing the uncertainty in Legacy P bioavailability can lead farmers to adopt more P fertilizer as a precautionary measure to ensure that crops have sufficient access to P.**
- **Farmers adopt soil sampling to better understand Legacy P bioavailability and make informed decisions on fertilizer application rates when faced with low legacy P availability and high uncertainty.**
- **Farmers become more sensitive to soil sampling prices as uncertainty in Legacy P bioavailability increases.**

Policy Implications

- Our model will be enhanced to incorporate an eutrophication damage, which will enable computation of optimal fertilizer inputs and soil sampling from "**resource manager (social planner)**" perspective, which will ultimately facilitate the design of policies promoting socially optimal application of fertilizers and use of legacy P stocks.