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Optimizing soil nutrient management: Agricultural Policy/Environmental extender (APEX) model simulation for field scale phosphorous loss reduction in Virginia

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Abstract.

Managing soil nutrients is crucial for enhancing crop productivity and meeting consumptions demands while minimizing environmental impacts. Sustainable agriculture relies on well-planned soil nutrient management strategies. Phosphorous (P) stands out among the 16 essential soil nutrients, particularly in Virginia, where natural P levels are typically low. Adequate amount of P is necessary for the early root formation and plant growth. However, excess amount of P in the soil leads to increase the eutrophication of the waterbodies. The case of hypoxia in Chesapeake Bay and the Gulf of Mexico is evidence of excess nutrient use among agricultural producers. While previous research has primarily focused on watershed level studies, current investigation aims to simulate the impacts of various management practices (including fertilization, tillage, and conservational methods) specifically on P loss at field level in Virginia. Moreover, previous studies only focused on technological based analysis and development, without working closely with farmers and understanding their perspectives about modeling tools. The objectives of this study include modeling the baseline phosphorous losses for the year 2023 and then predicting the advantages of adopting new practices for individual fields in Virginia. This study aims to use monetary incentives provided to a small group of farmers for reducing P in their field. To achieve the goal, we are combining multispectral drone imagery and Digital Elevation model (DEM) along with field data such as soil information, geolocation data, daily weather data (precipitation, minimum and maximum temperature) and surveys collected from the maize and soybean farmers regarding their specific fertilizer and manure application practices in Virginia. We utilized

Agricultural Policy/ Environmental Extender (APEX) model version 1501 specifically ArcAPEX to simulate phosphorous loss using the aforementioned datasets. The preliminary result of the present study of four Virginia field of area ≤1.8 hectares shows that the total mineral P loss for year 2023 is 0.56, 0.62, 0.38 and 0.93 kg/ha respectively and total organic P loss is 0.94, 1.04, 0.64 and 1.6 kg/ha respectively. Overall, this study helps in creating a platform for farmers informed decision making process relating to P management in soil in Virginia and tests whether performance-based mechanisms can work for protecting ecosystem services.

Keywords.
Phosphorous, Agricultural Policy/ Environmental extender, soil nutrient management

Introduction

Soil nutrient plays an important role in enhancing crop productivity and meeting consumptions demands while minimizing environmental impacts. Phosphorous (P) is one of the 16 essential nutrients needed by crops for proper growth and development (Holtan et al., 1988) and limit the plant growth in many soils. P stands out among all the essential nutrients in Virginia as here soil are naturally low in P Content and therefore require supplemental P to maximize the yield (Mullins, 2000). However, excess amount of P in the soil leads to increase the eutrophication of the waterbodies that threatened the aquatic life (Reid et al., 2018). Agricultural runoff is one of the dominant sources of P loading to the impacted surface/fresh water. While previous studies focus on the watershed level loss and technological based analysis and development, present study focuses working closely with farmers and simulates the impacts of various management practices (including fertilization, tillage, and conservational methods) specifically on P loss at field level in Virginia using a field scale hydrological model called Agricultural Policy/ Environmental Extender (APEX) model. The specific objectives of this study include

Objectives

- To model the current conditions and associated Phosphorous losses for 2023.
- Test a performance-based payment for ecosystem services with farmers in Virginia

Study area

The study was (Figure:1) conducted in 4 fields (≤1.8 hectares) located in Fredericksburg, Virginia, USA. The major crops grown in these fields are corn and soybeans. This region of Virginia has regional climate with mild winters, warm and humid summer. It has an average temperature of 56 °F and an average annual precipitation of 40 inches and snowfall of 12 inches.

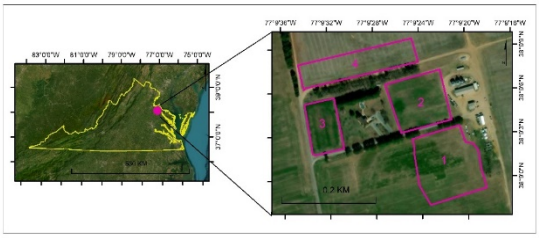

Figure 1:Study Area

Data used and Methodology

The ArcAPEX user interface for APEX version 1501 was used in the present study for deriving Phosphorous loss from the field of Virginia. The primary input to the model includes elevation, land use and soil maps, weather data and management practices. The Digital elevation model (DEM) data was used at 1 m resolution downloaded from United States Geological Survey (USGS). The land use map at 1m resolution was derived from DJI Mavic 3M multispectral drone for the year 2023. The Soil was obtained from the Soil survey Geographic database (SSURGO) (NRCS, 2010). Weather data which include maximum and minimum temperature and Precipitation were downloaded from the year 1990-2023 from National Centers for Environmental research, National Oceanic and Atmospheric Administration (NOAA) and all the management practices information from the farmer.

Results and Discussion

Phosphorous loss at field scale in Virginia was simulated from the year 2000 to 2023. The average annual organic P loss, mineral P loss and P loss in runoff varies from the year 2000 to 2023 in each field. The preliminary result of the present study of four Virginia field of area ≤1.8 hectares shows that the total mineral P loss for year 2023 is 0.56, 0.62, 0.38 and 0.93 kg/ha respectively and total organic P loss is 0.94, 1.04, 0.64 and 1.6 kg/ha respectively. We found that mineral P loss is more as compared to organic P loss. The average annual P loss is shown in figure 2.

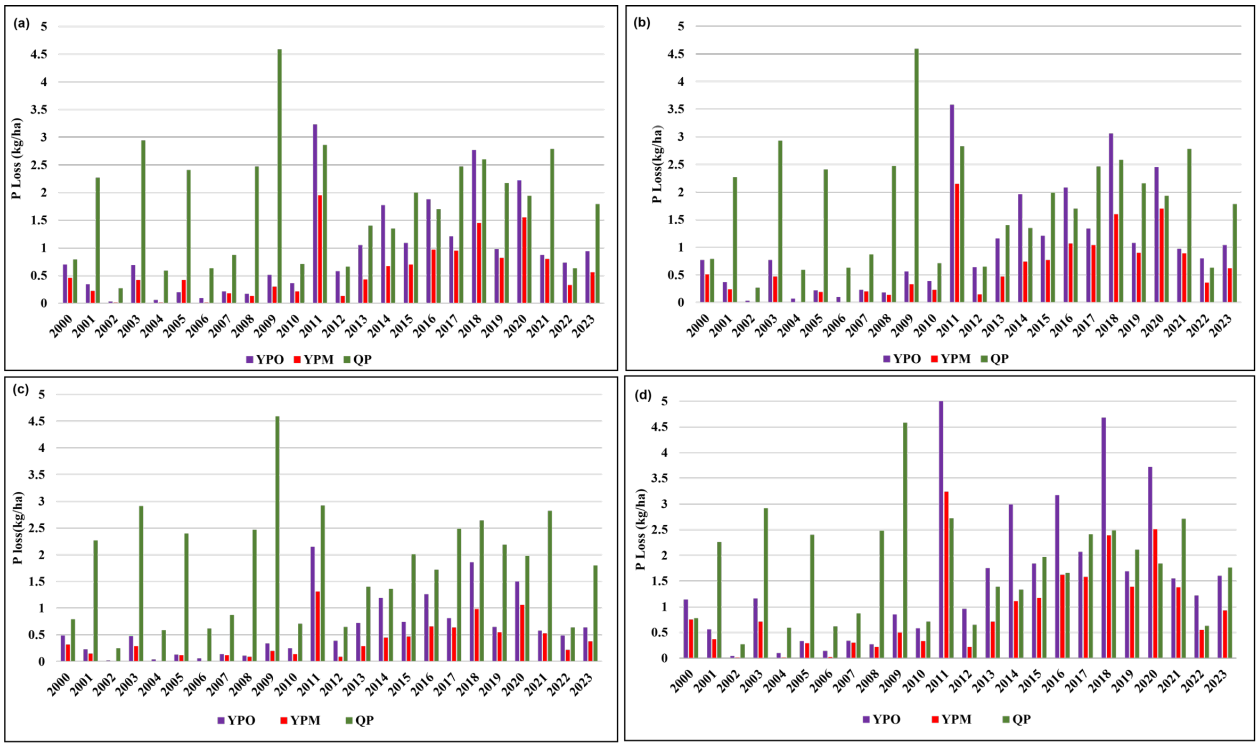

Figure 2: Average annual organic phosphorous (YPO) loss, mineral Phosphorous (YPM) loss and Phosphorous loss in runoff (QP) (2000-2023) (a) field 1 (b) field 2 (c) field 3 (d) field 4

Conclusion

This study helps in creating a platform for farmers informed decision making process relating to P management in soil in Virginia and tests whether performance-based mechanisms can work for protecting ecosystem services.

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