Impacts of drainage systems on phosphorus dynamics and crop productivity in the Red River Valley, southern Manitoba

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1.Background and introduction

Agricultural practices, aimed at optimizing crop production, have been identified as primary non-point sources of phosphorus to aquatic ecosystems. Agricultural runoff, characterized by the discharge of nutrients, pesticides and sediment, poses a substantial threat to the ecological balance of surface water bodies worldwide (Liu et al., 2021).

It was believed that surface runoff was the main pathway for phosphorus leaving agricultural fields, due to its capacity to carry phosphorus-rich sediment, while sub-surface phosphorus transport was considered minimal, owing to sorption mechanisms (Mcdowell et al., 2001). However, it has now been recognized that tile drainage also plays a significant role in phosphorus export, especially in soils with preferential flow pathways and drainage systems (Fisher, 2015).

Phosphorus export from agriculture fields in the Northern Great Plains is contributing to harmful algal blooms and eutrophication of freshwater lakes, such as Lake Winnipeg. Therefore, Edge-of-field runoff monitoring is a crucial method for collecting water quality information, which can then be related to various factors like climate, soil and field management practices.

2. Objectives

The objective of this on-farm study was to assess the effects of tile and surface drainage on (1) the fate of phosphorus in farmland under agricultural crop production, and (2) crop yields.

3. Materials and methods

3.1 Study area:

The research is an on-farm study in the Red River Valley, Manitoba.

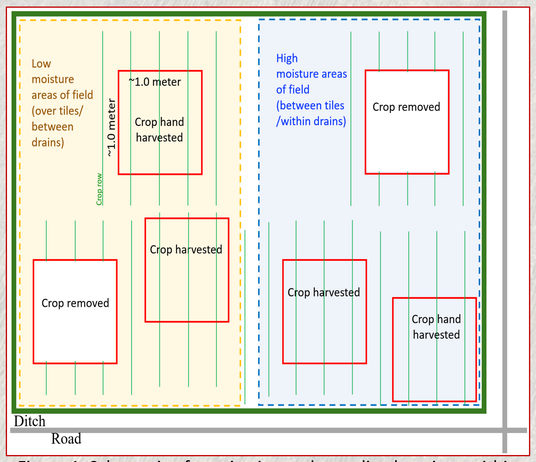

Figure 1. Schematic of monitoring and sampling locations within low moisture and high moisture areas

3.2. Laboratory analyses: Phosphorus concentrations

Soil particulate phosphorus concentration (mg kg^{-1}) and total phosphorus concentration (mg kg^{-1}) in grain and residue was measured by wet oxidation method using sulfuric acid-hydrogen peroxide digestion. Furthermore, water samples were analyzed at two edge-of-field locations (surface drains discharging into the ditch) and at a culvert draining the field ditch into the provincial ditch.

4. Results and discussion

4.1. Phosphorus variation in soil

Surface drainage can facilitate sediment movement by runoff with the lower total phosphorus at surficial layers. Tile drainage at 15-30-cm depth had the lower total phosphorus, which may suggest either uptake by plants or leaching into the subsurface during drawdown or drainage.

Tile drainage proved to be a better practice to maintain or retain the amount of water extractable phosphorus, reducing the potential for its loss through runoff.

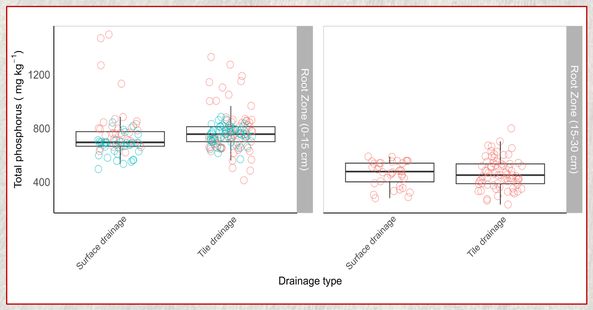

Figure 2. Total phosphorus concentration changes in soil samples across different drainage type (2022-2023).

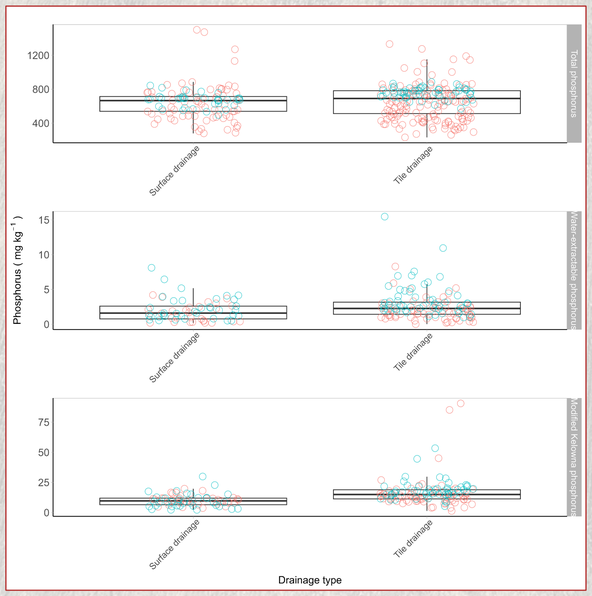

Figure 3. Variation of phosphorus forms in soil samples across different drainage type (2022-2023).

4.2. Crop yield variation

Total phosphorus was relatively higher in grain and plant residue samples on tile drainage compared to surface drainage in 2022 and 2023. However, total phosphorus was higher in grain samples on surface drainage in 2022. Yield variation was not agronomically significant between drainage types.

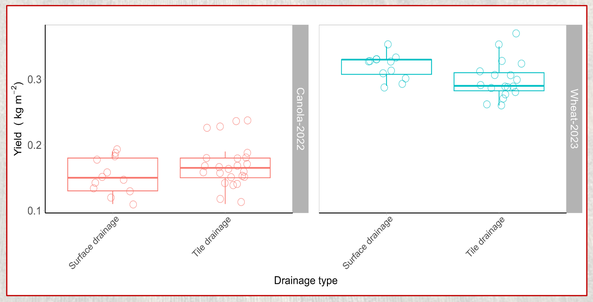

Figure 4. Yield variation for different crops across drainage type (2022-2023).

4.3. Phosphorus and sediment loads in runoff

The high-intensity event, May, 2024, stands out as the most severe, which is characterized by marked increases in water discharge, which in turn derived the transport of sediment and nutrients across the landscape. Water discharge was not prominent in June and July, peaking at around 2 and 7.5 L s^{-1}, respectively. In contrast, water discharge in May reached approximately 40 L s^{-1}. This discharge pattern aligns closely with the peaks in nutrient and sediment loads, suggesting that high-flow conditions play a central role in mobilizing both sediment and nutrients.

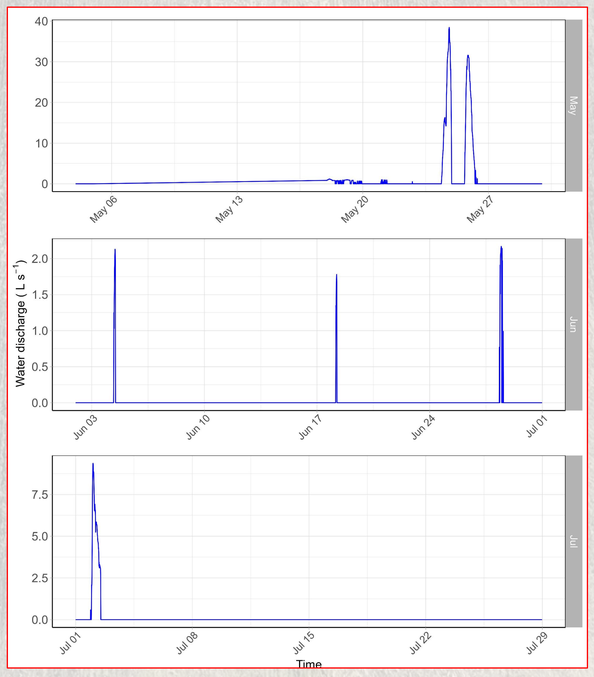

Figure 5. Water discharge at one station located within the local ditch over the growing season in 2024 (May, June and July)

The hydrological connectivity between rainfall, runoff, and nutrient transport is evident, as water flow acts as the primary driver of nutrient and sediment export in the system during this event. Sediment load reaches a peak, surpassing 12,000 mg s^{-1} before sharp decline. The transport of sediment during high-flow events facilitates the movement of phosphorus, which highlights the role of water erosion in nutrient movement when the soil is not protected by plants. In addition, the peak patterns of total phosphorus and total dissolved phosphorus loads, suggest rapid and short-term phosphorus loading into the water column.

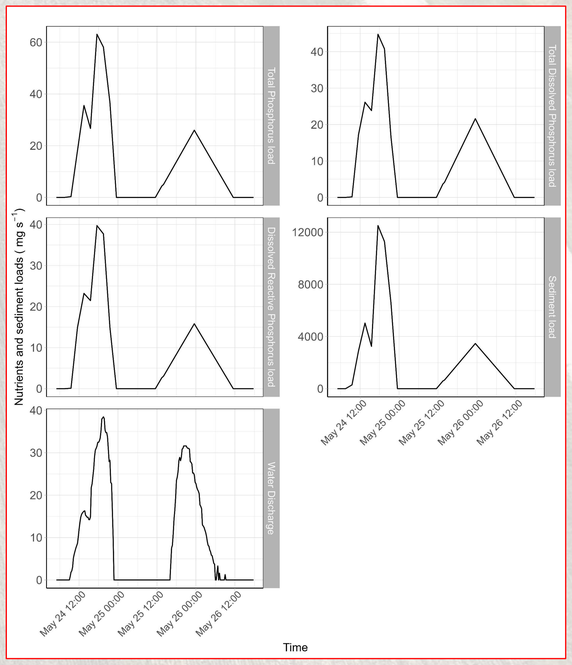

Figure 6. Variations in nutrient and sediment loads, and discharge at a station located within the local ditch during an erosive rainfall event in May, 2024.

5. Conclusion

This study may suggest either phosphorus uptake by plants or leaching into the subsurface during drawdown may be facilitated by the tile drainage system, it might not agronomically improve crops yield. Furthermore, the results showed that much of the transported phosphorus is in a dissolved form, posing an immediate risk to downstream ecosystems.

6. References

Fisher, M., 2015. Subsoil Phosphorus Loss: A complex problem with no easy solutions. CSA News, 60(2), pp.4-9.

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Mcdowell, R.W., Sharpley, A.N., Condron, L.M., Haygarth, P.M., Brookes, P.C., 2001. Processes controlling soil phosphorus release to runoff and implications for agricultural management. Nutr. Cycl. Agroecosystems 59, 269–284.