# Changes in Soil Phosphorus Over Fifteen Years in Taylor Slough, Everglades National Park

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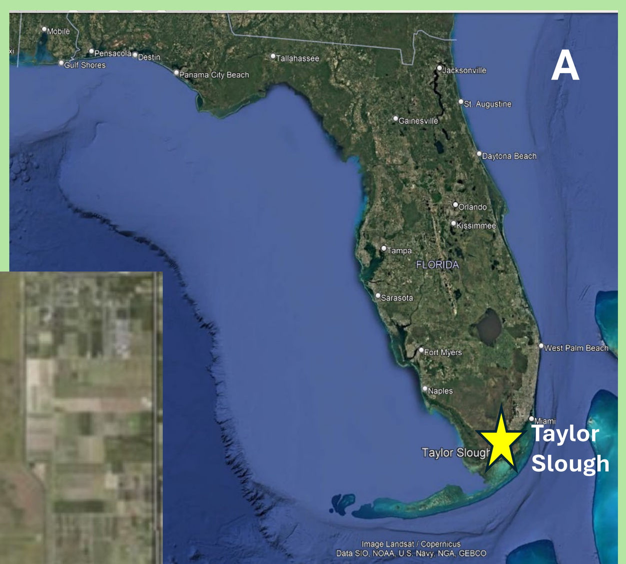
**Abstract:** Everglades National Park (ENP) in Florida, USA has been experiencing threats of increasing eutrophication from runoff from upstream agricultural and urban areas. The Everglades is naturally an oligotrophic and therefore low-phosphorus (P) system, and consequently, increasing P enrichment is threatening local vegetative communities and altering native food web dynamics. Changes in hydrology upstream of the study site have occurred within the past several years that may have led to downstream changes in hydroperiod as well as soil TP. In order to look at long-term changes over time, soil collection and analysis have been conducted at a series of transects in the Taylor Slough area of ENP in 2012, 2018, and 2023. The most recent analysis from October 2023 has yielded some surprising results with average soil total phosphorus concentrations shifting from no significant differences from 2012-2018 to decreasing by 22% from 2012 to 2023. At first glance, this appears to be a positive shift in eutrophication reduction. However, the inorganic fraction of soil phosphorus has increased significantly by 33% from 2012 and no significant differences were found between 2012-2018. This indicates a loss of organic phosphorus that has accompanied a loss of organic matter of 5% since 2012 and 13% since 2018. Therefore, it becomes apparent that when sampling an area for changes in P due to eutrophication, total P might not be enough to understand the total picture of P cycling within a system for making future management and restoration decisions.

## Introduction and Methods:



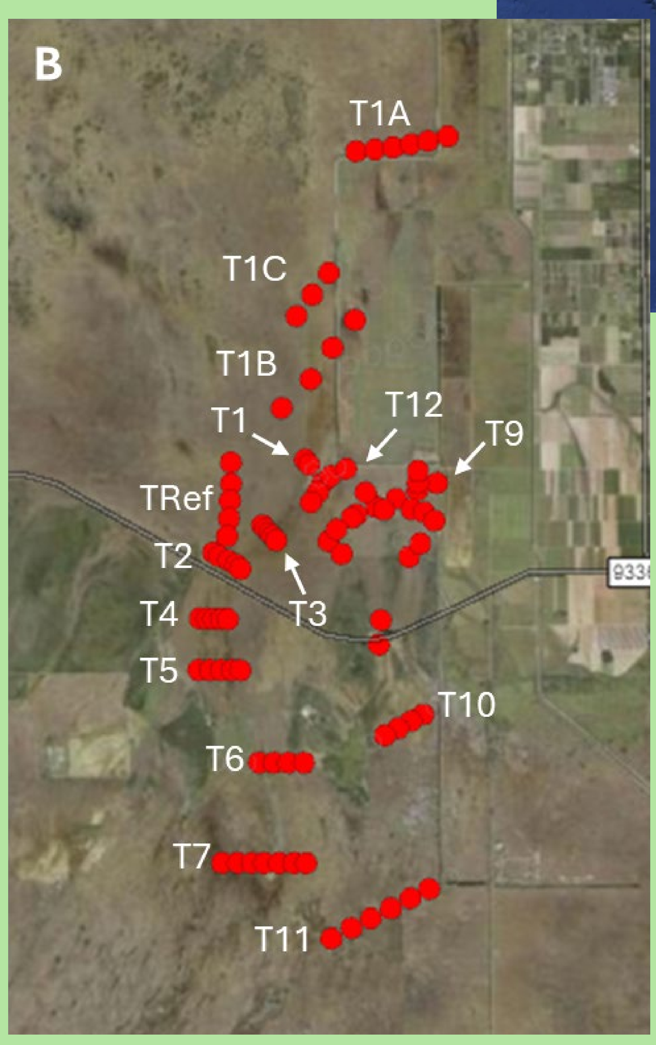




**Figure 1:** A) Star resembles sampling location of Taylor Slough in the Everglades National Park in south Florida. B) Map of sites sampled in Taylor Slough in 2012, 2018, and 2023. T1A, T1B, T1C, and TRef were only sampled in 2018 and 2023.

Excess P from agricultural production, water management, and urban development can have consequences on the biogeochemical cycling of nutrients in soils of the Everglades (Gaiser et al. 2006; Noe et al. 2007). The addition of excess P in an oligotrophic system can halt microbially mediated processes and alter soil formation through increases storage of phosphorus in organic soils and vegetative community shifts (Reddy et al. 2011, Gaiser et al. 2006; Noe et al. 2007). The primary objective of this project was to evaluate soil P after restoration efforts with the hypothesis that soil P will maintain enriched conditions regardless of restoration efforts, because of long-term P storage within the organic soils (Reddy et al. 2011). In order to monitor the inputs of phosphorus into the soil over time, soil cores have been collected at transects (Figure 1) across Taylor Slough in 2012, 2018, and 2023. A helicopter is used to access each site and collected triplicate 10 cm cores with a polycarbonate hand core. Once brought back to the airport, two of the 10 cm triplicate cores are extruded into a bag and one is sectioned into 0-2, 2-4, 4-6, and 6-10 cm sections. These cores are then brought back to lab on ice for bulk density, organic matter, total carbon (TC), total nitrogen (TN), total phosphorus (TP), and total inorganic phosphorus (TPi) analysis. The results were analyzed in R.



**Figure 2:** A) Field core collection from a helicopter. B) Cores collected from one transect brought back for extrusion and analysis.

## Results and Discussion:

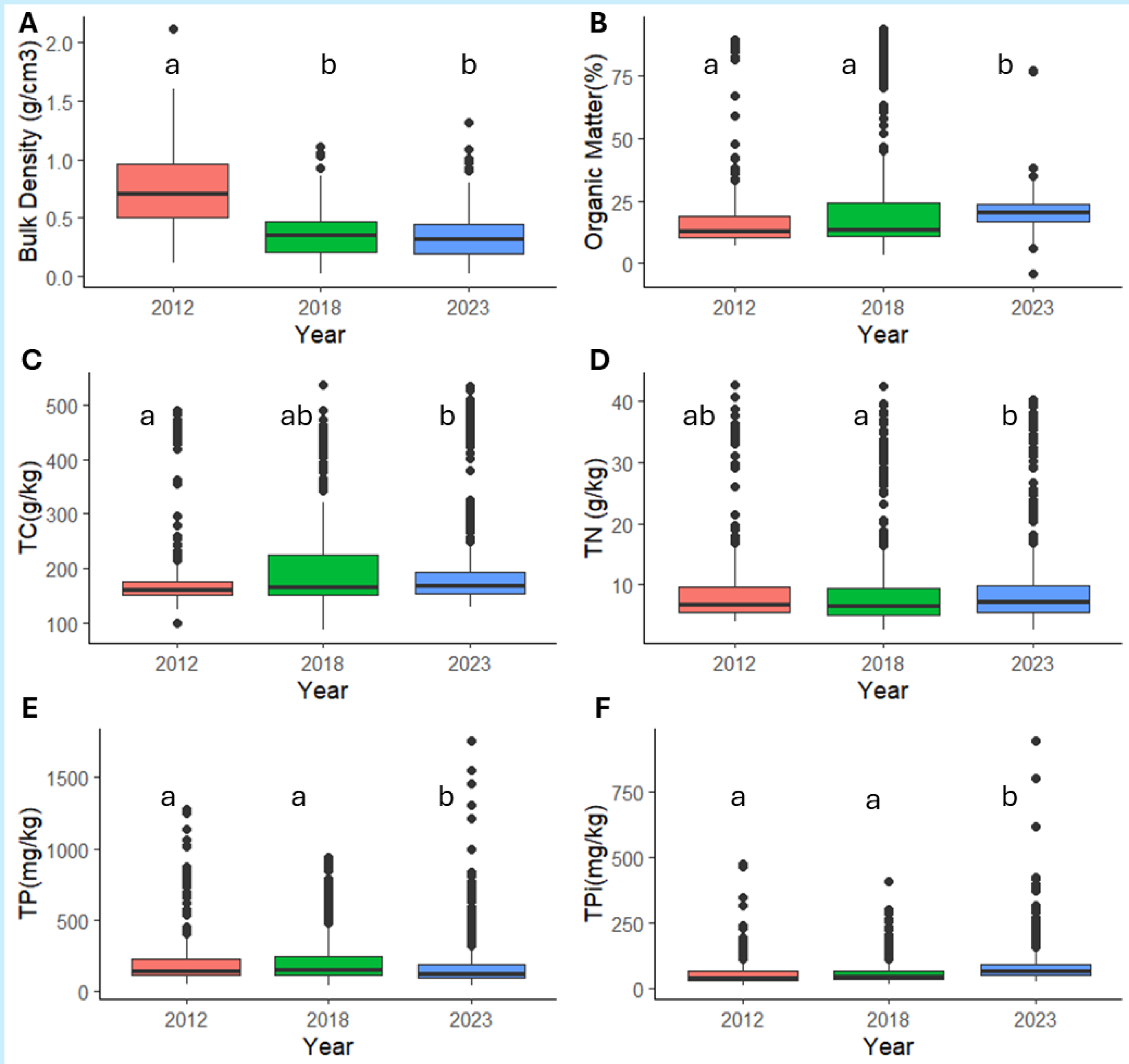



**Figure 3:** Boxplots displaying the differences in mean and range for A) bulk density, B) organic matter, C) total carbon, D) total nitrogen, E) total phosphorus, and F) total inorganic phosphorus in soil samples collected from 2012 (pink),2018 (green), and 2023 (blue). The letter above each plot show where significant differences were found between years of each analyte, as determined by Kruskal-Wallis and Wilcoxon Rank Sum tests.

| Analyte | 2012 vs 2018 | 2012 vs 2023 | 2018 vs 2023 |
|---|---|---|---|
| BD | < 2.2 x $10^{-16}$ | < 2.2 x $10^{-16}$ | 0.084 |
| LOI | 0.1 | < 2.2 x $10^{-16}$ | < 2.2 x $10^{-16}$ |
| TC | 0.086 | **0.015** | 0.852 |
| TN | 0.091 | 0.347 | **0.012** |
| TP | 0.99 | 5 x $10^{-5}$ | 1 x $10^{-5}$ |
| TPi | 0.18 | < 2 x $10^{-16}$ | <2 x $10^{-16}$ |
| TPo | 0.31 | < 2 x $10^{-16}$ | < 2 x $10^{-16}$ |

**Table 1:** Wilcoxon- Rank Sum results comparisons between 2012, 2018, and 2023 sampling events for each analyte..

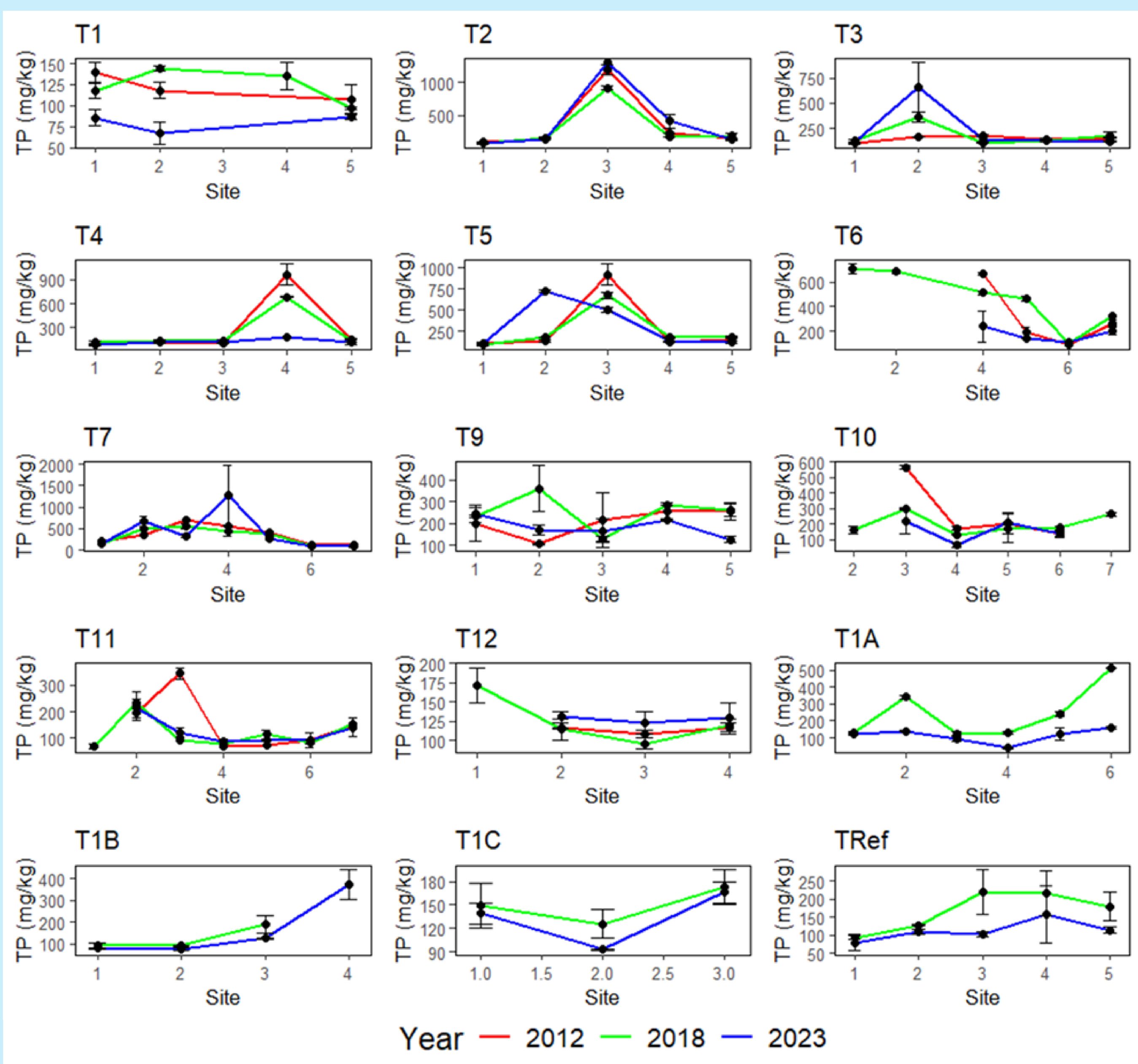



**Figure 4:** Total phosphorus average and error bars (1 SD from the mean) for 2012 (red), 2018 (green), and 2023 (blue) across sites for transects 1-12, 1A, 1B, 1C, and Ref. Transects 1A, 1B, 1C, and Ref were only created and sampled in 2018 and 2023.

**Table 2:** Mean and one standard deviation (in parentheses) for each analyte measured in soil from each sampling year. Most prominent changes are in the decrease in average total phosphorus (blue box), increase in average total inorganic phosphorus (red box), and the calculated decrease in total organic phosphorus (orange box).

| Analyte | 2012 | 2018 | 2023 |
|---|---|---|---|
| BD | 0.73 (0.34) | 0.35 (0.19) | 0.34 (0.19) |
| LOI | 21.45(22) | 23.03(23) | 20.40(6.5) |
| TC | 193.65 (92) | 203.60 (85) | 197.52 (83) |
| TN | 10.11 (8.9) | 9.78 (8.6) | 10.10 (7.9) |
| TP | 234.85 (228) | 222.15 (183) | 192.41 (206) |
| TPi | 61.13 (61) | 58.98 (48) | 91.11 (91) |
| TPo | 173.73 (185) | 163.17 (149) | 101.30 (135) |

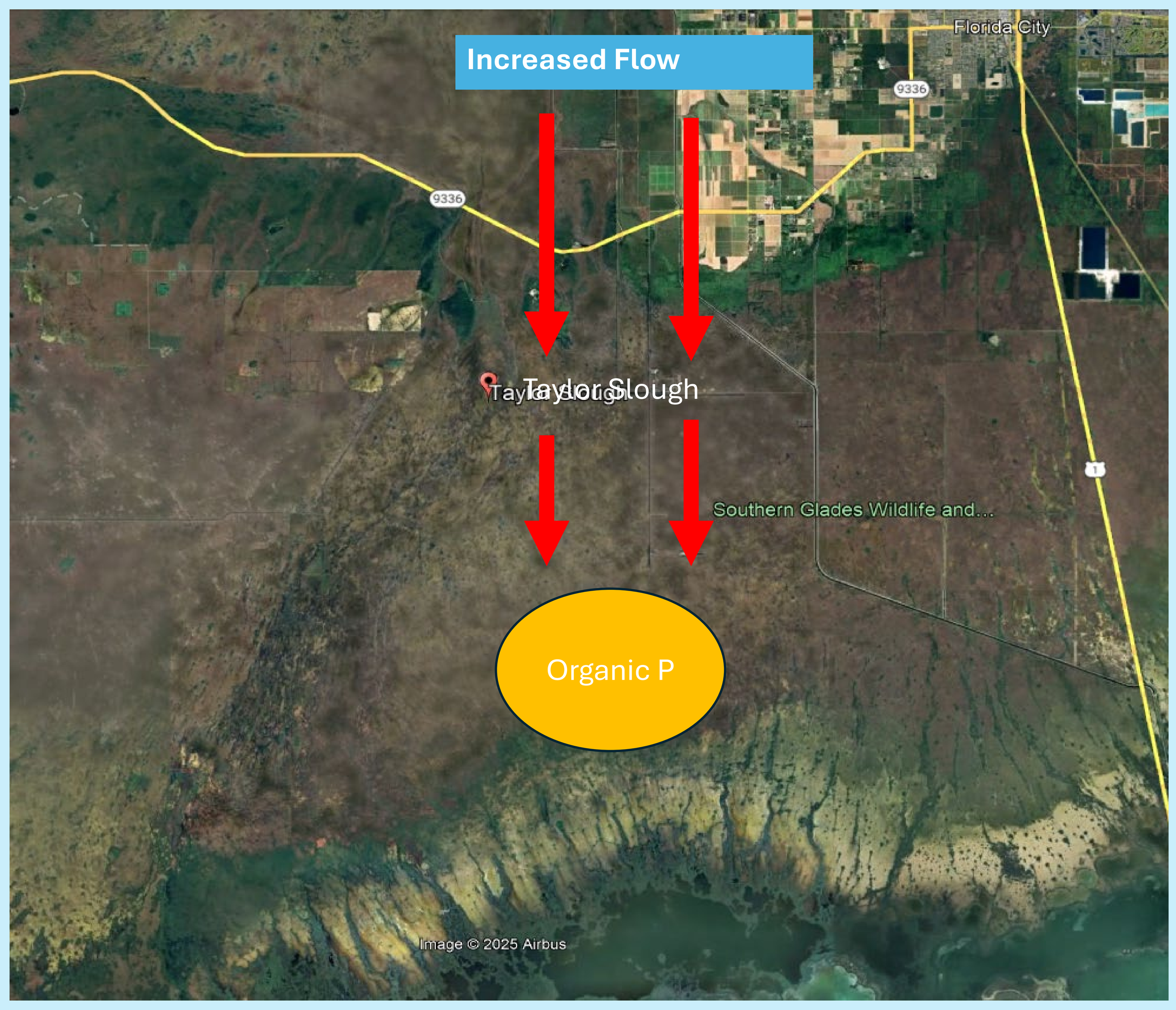



**Figure 5:** Although the reason for loss of organic P to Taylor Slough has not yet been confirmed, it is theorized that increased flow of water through Taylor Slough has led to movement of organic matter (and organic phosphorus) downstream that has led to a decrease in TP and TPo in soils in Taylor Slough. Although the decrease in total phosphorus seems beneficial to Taylor Slough specifically, the downward movement of phosphorus might be putting the far southern Everglades at greater risk of vegetative shifts and invasive species intrusion.

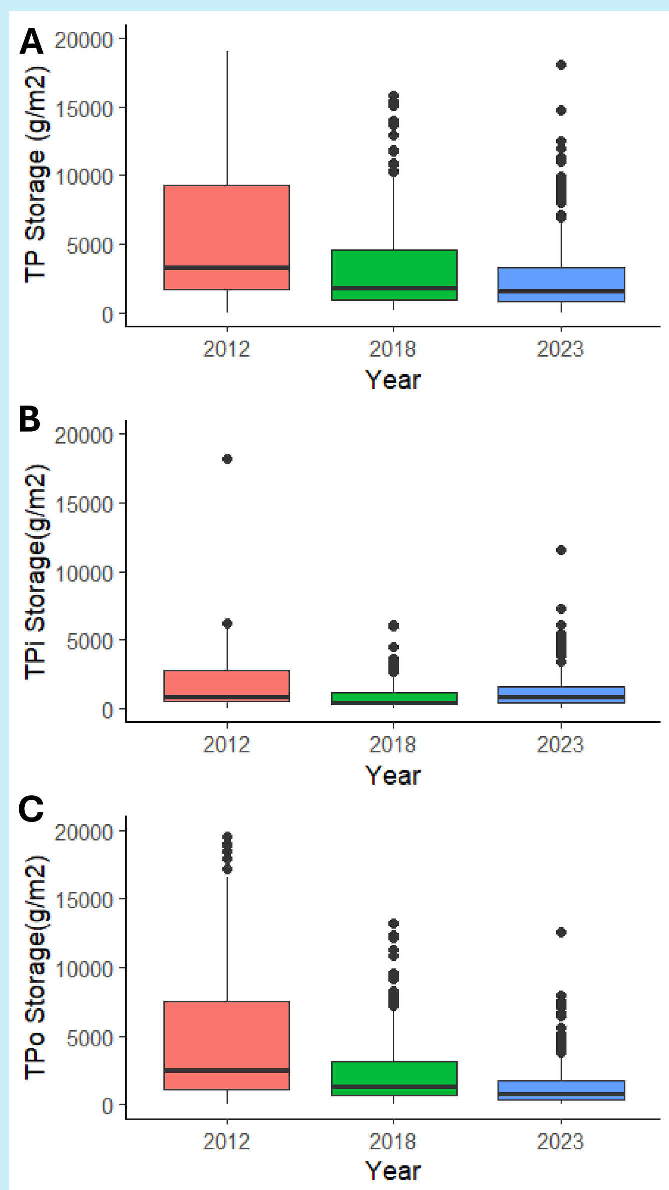



**Figure 6:** Boxplots of calculated values for soil storage of A) total phosphorus (g/m$^2$ ), total inorganic phosphorus (g/m$^2$ ), and total organic phosphorus (g/m$^2$; calculated from TPi – TP = TPo). Total phosphorus and noticeably total organic phosphorus storage are much less in 2023 than in 2012 or 2018. This information appears to be further proof that organic phosphorus is being removed from Taylor Slough and likely being moved downstream into the southern Everglades,

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**References:** Gaiser, E. E., Childers, D. L., Jones, R. D., Richards, J. H., Scinto, L. J., & Trexler, J. C. (2006). Gaiser, E.E., et al. Periphyton responses to eutrophication in the Florida Everglades: Cross-system patterns of structural and compositional change. Limnol. Oceanogr., 51(1, part 2), 2006, 617–630. *Limnol. Oceanogr*, *51*(1), 617–630. https://doi.org/10.4319/lo.2006.51.1_part_2.0617; Noe, G.B., Childers, D.L. Phosphorus budgets in Everglades wetland ecosystems: the effects of hydrology and nutrient enrichment. *Wetlands Ecol Manage* **15**, 189–205 (2007). https://doi.org/10.1007/s11273-006-9023-5; Reddy, K. R., DeBusk, W. F., DeLaune, R. D., & Koch, M. S. (1993). Long-Term Nutrient Accumulation Rates in the Everglades. Soil Science Society of America Journal, 57(4), 1147–1155. https://doi.org/10.2136/SSSAJ1993.03615995005700040044X