Introduction and Hypothesis

Nitrogen pollution is a major environmental issue for aquatic ecosystems. Farmers use nitrogen-based fertilizers to boost crop productivity. However, when they run off into other lakes and ponds, they provide too many nutrients to algae, causing their populations to grow out of control and leading to eutrophication and potentially wrecking the entire ecosystem. Wetlands, both natural and engineered, have the power to filter out these harmful excess nutrients biologically, preventing them from loading ponds. The wetlands use processes such as nitrification and denitrification to convert nitrogen into less destructive forms. Cheng et al. (2020), Wang et al. (2016), and Bertassello et al. (2025) all provide evidence supporting my hypothesis that nitrogen levels in water will decrease after passing through a wetland system, because wetland plants, soils, and microbial communities naturally facilitate nitrogen removal.

Literature Review

Studies find that wetlands reduce nitrogen levels in many different natural areas. Instead of relying solely on basic setups, underground wetlands use plants like Iris pseudacorus to help break down nitrogen, boosting cleanup far beyond what non-wetlands can do (Wang et al., 2016). Across Europe, wetlands remove over a million tons of nitrogen each year; their reach and connectivity play a significant role in trapping pollutants (Bertassello et al., 2025). On top of that, model work by Cheng et al. (2020) shows that even small patches of wetland added to agricultural zones or areas with dirty runoff can make U.S. river basins twice as effective at removing nitrates. All this adds up: teamwork between plants and microbes, smart water routes, and focused wetland restoration and construction efforts turn wetlands into strong filters against nitrogen pollution.

Data Description

The data for this project come from Wang et al. (2016), who studied the effectiveness of constructed wetlands in removing nitrogen from water. Their dataset, which I used for my analysis, includes measurements of total nitrogen and chemical oxygen demand from water samples collected before entering the constructed wetlands and after passing through them, but I am focusing only on total nitrogen. These nitrogen levels were measured using standard water-testing methods that rely on color changes to determine concentrations. The study included repeated measurements across several wetland units to help reduce the impact of random variation and makes the results more reliable. Samples were collected over multiple time periods so the researchers could see how nitrogen levels changed under different conditions, including colder weather. It was essential to ensure that the flow rate and setup of the wetland units remained consistent throughout the study. This allows us to focus on the difference between “before” and “after” nitrogen levels without worrying that outside factors caused the changes. As a whole, the dataset’s structure makes it well suited for evaluating how effectively a wetland system filters nitrogen from water.

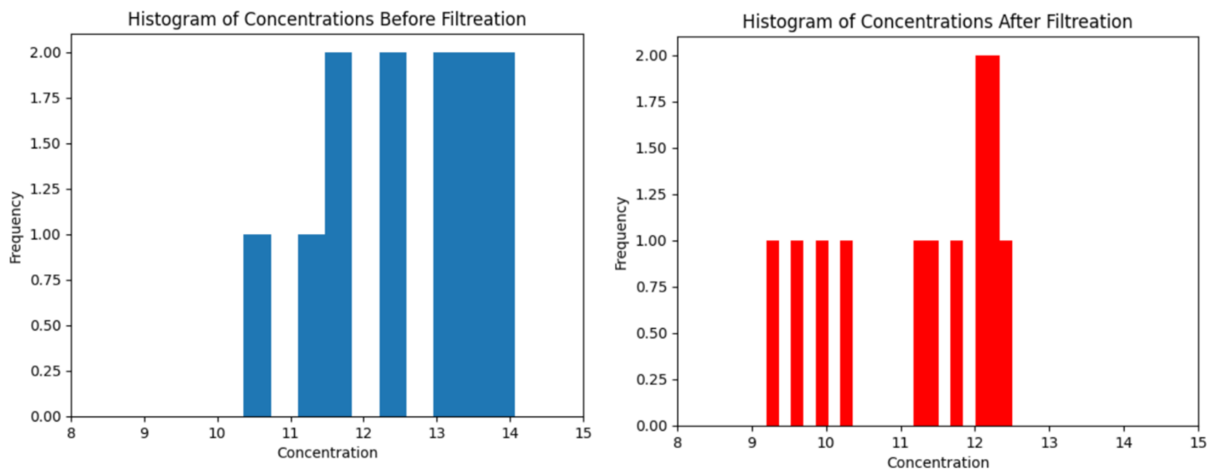

Figure 1: Side-by-side histograms comparing total nitrogen in water before and after the water has been filtered through a wetland

Result A Correlation

To evaluate whether nitrogen levels decreased after the water passed through the wetland system, I compared Total Nitrogen (TN) concentrations measured before filtration with those measured after filtration. The correlation analysis showed that the two variables were highly correlated. The Pearson correlation was 0.91 and the Spearman correlation was 0.92, both with extremely low p-values, indicating a consistent, statistically significant pattern. This strong positive relationship suggests that samples with higher initial nitrogen levels still tended to have higher nitrogen levels after treatment. Even so, the absolute TN values decreased from the “before” to the “after” measurements, which matches the expected effect of the wetland. Together, these results show that while initial nitrogen levels strongly influenced final concentrations, the wetland system still reduced nitrogen levels, supporting the hypothesis that nitrogen levels decrease after filtration.

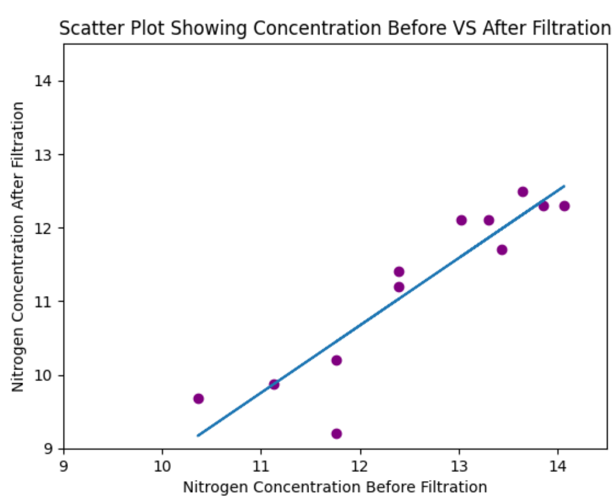

Figure 2: Scatter plot of nitrogen concentration before vs after filtration

Results B

Principal Component Analysis (PCA) is a method for simplifying large datasets by identifying major patterns, particularly when many variables are measured simultaneously. I attempted to use PCA to compare nitrogen levels before and after the wetland, color-coding the points as “TN Before” (blue) and “TN After” (red). However, PCA does not work well for my dataset because I have only one variable (total nitrogen) measured twice per sample, and the points blend into a purple, nonsensical plot. With so little information, PCA cannot create a meaningful comparison. Since PCA isn’t the right tool for this type of paired data, I decided to use a paired t-test, which directly compares the before and after nitrogen values. The t-test showed a significant drop in nitrogen after filtration ($t = 9.01$, $p = 1.09 \times 10^{-6}$), supporting my hypothesis that the wetland system reduces nitrogen levels.

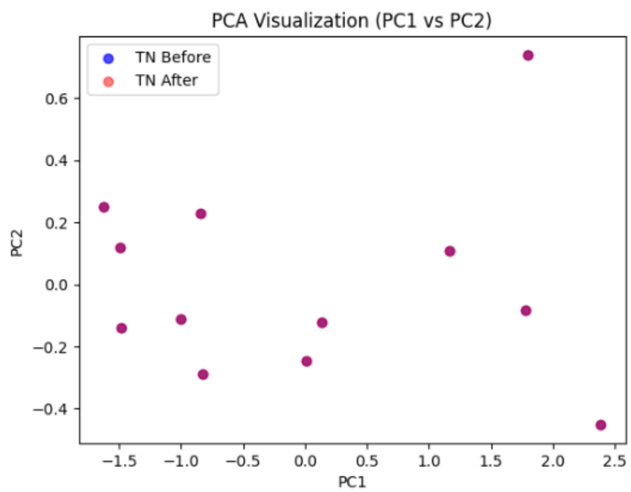

Figure 3: PCA plot comparing nitrogen concentrations before and after filtration

Conclusion (What I Learned)

From this project, I learned how to evaluate environmental data using several analytical tools, including correlation analysis, PCA, and statistical testing. My hypothesis that nitrogen levels would decrease after passing through a wetland system was strongly supported. The paired t-test showed a significant drop in total nitrogen ($p \approx 1.09 \times 10^{-6}$), indicating that this decrease did not happen by chance. Although PCA was not useful for my dataset, the t-test demonstrated that the wetland acted as an effective natural filter. From a broader perspective, these results support the idea that constructed wetlands can play an important role in reducing nutrient pollution and improving water quality. This aligns with larger environmental trends showing that nature-based solutions can be both effective and sustainable.

Limitations and Future Study

A primary limitation of this study is that the dataset included only nitrogen concentrations and COD, without other environmental factors such as flow rate or rainfall that might also affect nitrogen removal. Because of this, we can’t certainly state that the wetland itself caused the change, or if other natural conditions played a role. In future work, I would include more variables and a larger sample size to better understand what drives nitrogen reduction and how consistently the wetland performs under different conditions.

Bibliography

Bertassello, L.E., Basu, N.B., Maes, J. et al. The important role of wetland conservation and restoration in nitrogen removal across European river basins. Nat Water 3, 867–880 (2025). https://doi.org/10.1038/s44221-025-00465-0

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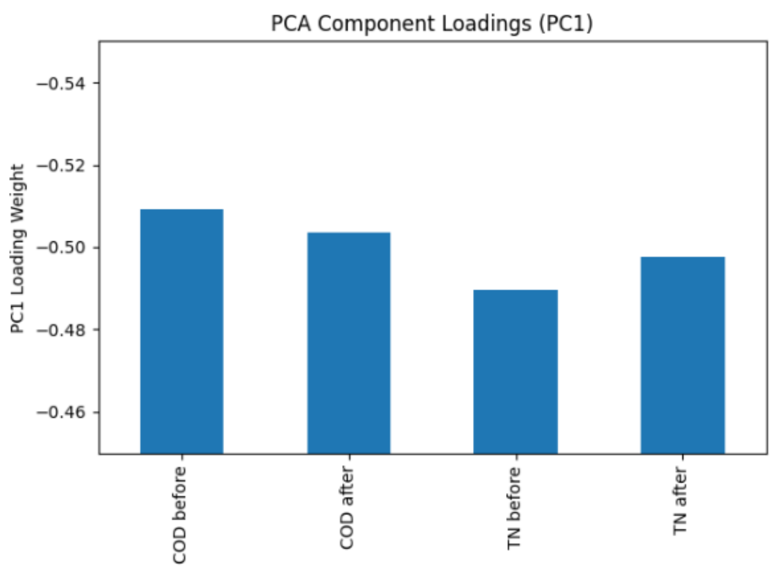
Supplementary Information



https://github.com/jacobross-30/Ross_Jake_ENV3040_Project