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How Does Change in Land Use Impact the Water Chemistry Parameters in the Streams of Oswego County, NY?

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sponsored and co-authored by Suann Yang, PhD

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Abstract

Land use within a watershed is closely tied to stream water chemistry. Anthropogenic chemical inputs eventually make their way into streams, affecting fluvial ecosystems. Sources of these anthropogenic inputs change over time, especially when rural landscapes become increasingly urbanized. We studied the relationship between land use and stream water chemistry for Oswego County, New York, because riparian zones in this county have shifted to residential from agricultural and forested land uses. We extracted data from the New York State Department of Conservation (DEC) Department of Water (DOW) Monitoring Portal. Results show that residential land use contributes higher carbon, nitrogen, and phosphorus to streams in Oswego County, New York. However, the data collected for sites in Oswego County are sparse, and thus our results may be misleading. We will conclude with recommendations to Oswego County for a sampling strategy that better encompasses the major waterways of the county.

Land use has an impact on water quality, with each distinct type of land use (e.g. agriculture, forest, residential, and commercial) impacting the watershed in its own unique way. Land use changes occur constantly and can have various impacts on the surrounding environment including a change in water quality, watershed function, quality of wildlife habitat, and human health (Environmental Protection Agency [EPA], 2022). Land use management is especially important in the outcome of water quality for nearby streams because urbanization increases impervious surfaces, which allows for an increase in runoff to enter the water, degrading the water quality. Degradation of water quality is harmful to aquatic and fluvial ecosystems because increased runoff leads to the formation of harmful algae blooms, and increased suspended solids increase turbidity and harm aquatic wildlife (Giri & Qiu, 2016).

Monitoring these changes in land use is important, especially since the impact on the environment is so great.

Some of the chemicals present in waterways may be a result of runoff from nearby terrestrial sources and have the potential to flow downstream and affect a large area. Water quality monitoring is especially important in regard to chemical parameters because of the large number of chemicals used in everyday life that are usually drained into fluvial ecosystems (Myers, n.d.). The abundance of each of these chemicals is important to monitor because if there is too much or too little of each parameter, the trophic state of the ecosystem may be impacted (Allan et al., 2021).

Some of the most important nutrients to stream ecosystems are nitrogen, phosphorus, and carbon (EPA, n.d.). Nitrogen and phosphorus are typically limiting nutrients in aquatic ecosystems, and carbon is the primary food source (EPA, n.d.). Nitrogen is required for the production of amino acids and proteins. Phosphorus is commonly the limiting factor in aquatic ecosystems; it is necessary for cell division and is present in very small quantities. Nitrogen and phosphorus are both essential for fluvial ecosystems, however, too much may cause eutrophication which can be harmful to the ecosystem (Shen et al., 2020). Carbon is required in aquatic ecosystems in order to provide a food source to low level consumers, however, it is associated with high runoff levels within a fluvial ecosystem (Volk et al., 2002). It is important to focus on these specific chemical parameters because of the influence they have on the water.

New York State's Department of Environmental Conservation (NYS DEC) has been monitoring stream water chemistry since 1972. The historical trends suggest that total Kjeldahl nitrogen and total phosphorus have the most impact on stream water quality in New York State because high concentrations could be detrimental to the fluvial ecosystem (Smith et al., 2018). However, the impact of specific land use types on stream water quality is not well characterized for Oswego County. In this report, we analyzed relationships between the land use surrounding waterways and nitrogen, phosphorus, and dissolved organic carbon, with the goal of providing a starting point for understanding the water quality trends for Oswego County.

Methods

Data was obtained from the NYS DEC Division of Water (DOW) Monitoring Portal. We filtered the data by county and downloaded two separate CSV files that included the chemistry parameters and land use data for only Oswego County. Because land use type for most of the sites was missing from this data source, we classified the dominant land use at the sites by using the coordinates for each sampling site to locate the sites in Google Earth Pro. We zoomed in so that our screen was about 3 square kilometers (eye elevation approximately 3000 ft). This allowed us to accurately assess the land uses at all sites. If multiple land uses were present, whichever land use took up the largest area was determined to be the dominant land use. We used Google Earth Pro's historical imagery feature to determine the land uses at various sampling dates.

Because of insufficient sampling, statistical tests were not possible for comparing Kjeldahl nitrogen, orthophosphate, and dissolved organic carbon across dominant land use of sample sites. Comparisons were made graphically with the *ggplot2* package (Wickham, 2016) in the R Programming Environment (R Core Team, 2022).

Results

The results of our qualitative analysis show that sites classified as residential tended to have the highest impacts. Nitrogen content was highest at residential sites, followed by forested sites, and then commercial and agricultural sites (Figure 1).

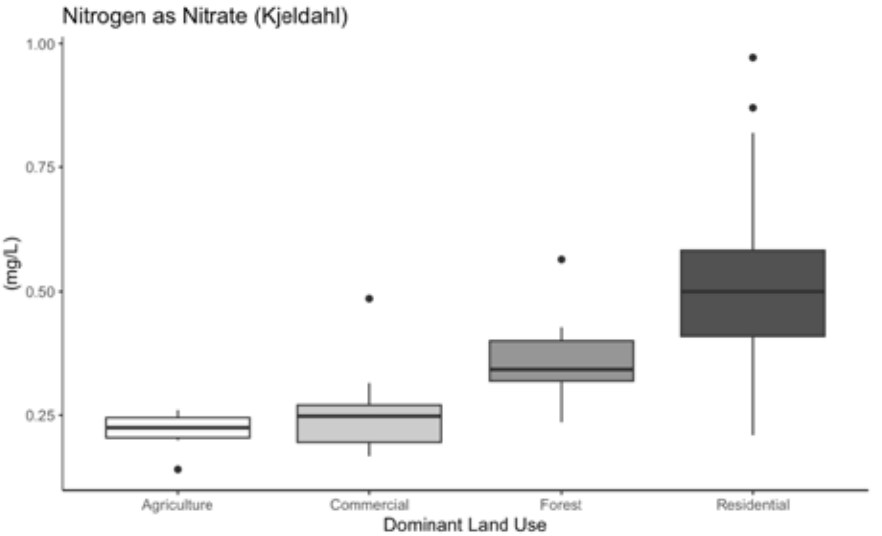

Figure 1: Nitrogen content measured as Nitrate (Kjeldahl) based on land use type.

Similarly, phosphorus was highest for residential sites. The other three land use categories appear to be identical, near zero (Figure 2).

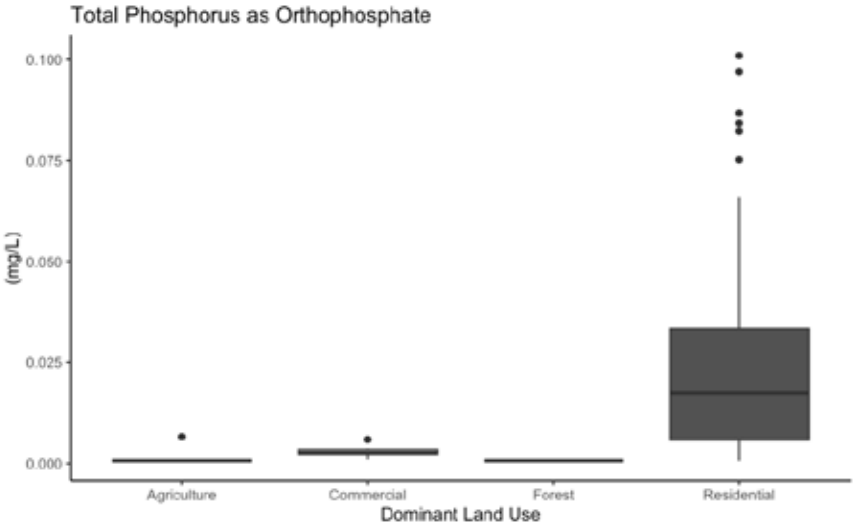

Figure 2: Total Phosphorus as Orthophosphate based on land use type.

In contrast, carbon was highest for forested sites and residential sites. Agricultural sites may have a higher carbon content than commercial sites do (Figure 3).

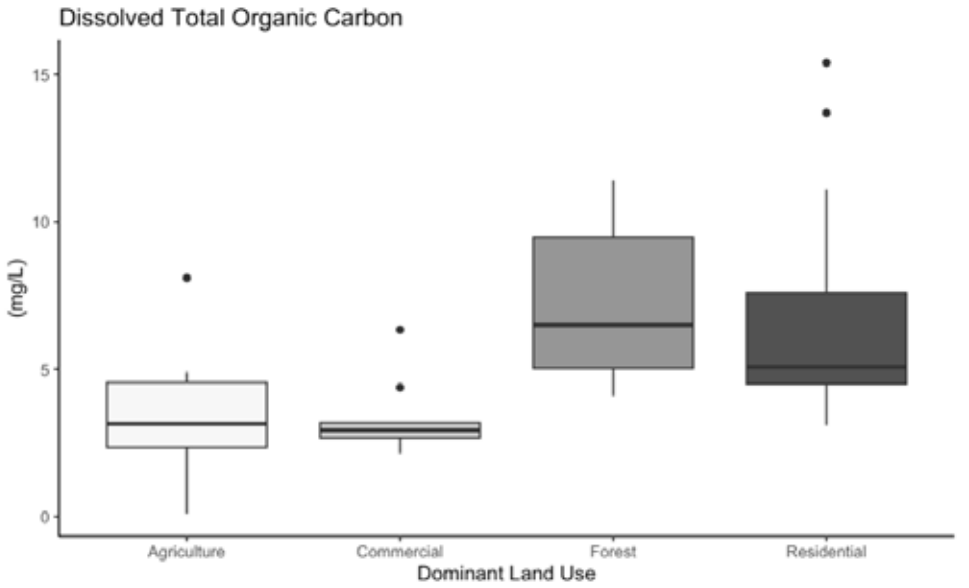

Figure 3: Total Dissolved Carbon based on land use type.

Discussion

Residential land use appears to have the highest negative impact on stream water quality. Previous studies show that urbanization increases the amount of impervious surfaces that result in higher amounts of runoff and pollution in the water (Smith et al., 2018). Typically, areas downstream from heavily human-impacted areas have a lower water quality because of point source and nonpoint source pollution sources present in urban areas. Studies that analyze the spatial relations between water chemistry and land use emphasize the importance of understanding the functionality of the ecosystem within a watershed to utilize the most sustainable practices and to prevent pollution from entering the water in the future (Wang, 2001).

Although our results show higher values of nitrogen and phosphorus in the stream near residential land use, that does not mean that these values are high enough for concern. Typically, small amounts of these chemicals are necessary for the functionality of the ecosystem (Giri & Qiu, 2016). Because these nutrients are cycled rapidly through ecosystems, and concentrations can vary vastly across ecosystems, the NYS DEC uses a narrative-based assessment of these values instead of a numeric standard (in contrast to pollutants such as heavy metals). This standard is "None in amounts that result in the growths of algae, weeds and slimes that will impair the waters for their best usages" (NYS DEC, n.d.). We were not able to assess whether or not the levels of nitrogen, phosphorus and dissolved organic carbon did lead to excess growth. This is again due to the lack of data available to us. To fully assess the level of these

nutrients using the narrative standard that the DEC uses, there would need to be data collected containing biomass quantities. This data collection can be done through direct sample collection or through estimation (Madsen, 1993).

Our ability to compare the impacts of land use types on carbon, nitrogen and phosphorus was limited by sampling history in Oswego County, which illustrates the importance of consistent water monitoring. Land use data collected from the NYS DEC was limited for Oswego County; there were not enough values to adequately complete a full historic analysis without collecting our own data manually using Google Earth. Overall, the land use historical analysis was difficult to accomplish; however, based on the results of this study, the patterns of land use in Oswego County is an important factor for the water quality of the surrounding watersheds. Moving forward, we recommend sampling from sites more evenly across different land uses, and more regularly.

Overall, it is important to pay attention to how human activities impact stream water quality because of how easily disturbed a fluvial ecosystem is. Stream water quality monitoring with standardized sampling techniques allow for comparisons within and between water conservation districts (Smith et al., 2018). A more systematic sampling scheme for Oswego County will permit a more complete analysis of land use impacts in the future, and help identify conservation priorities for these stream ecosystems.

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