Sources, sinks, and transport of nutrients across a mixed-use watershed in Ohio

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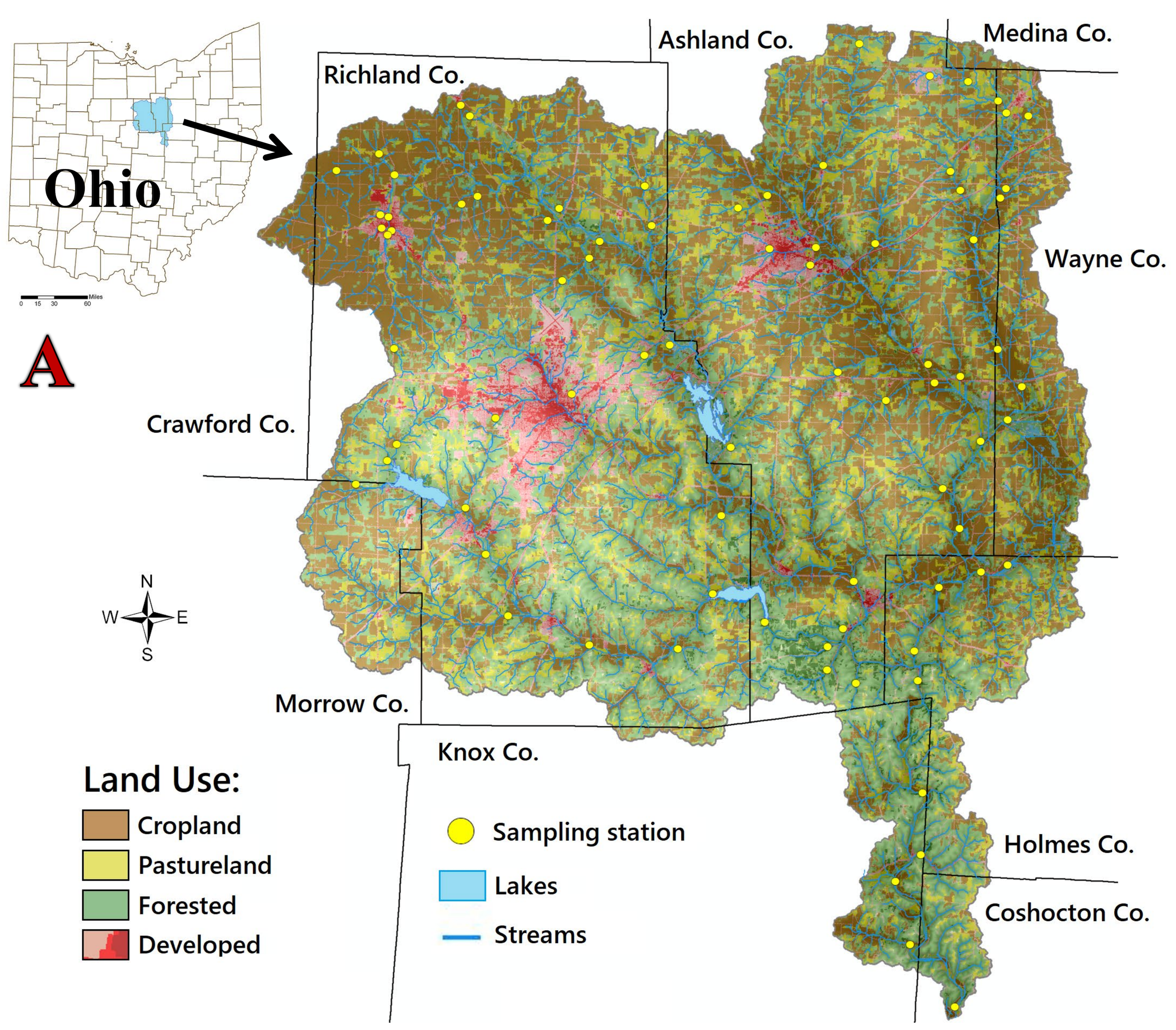
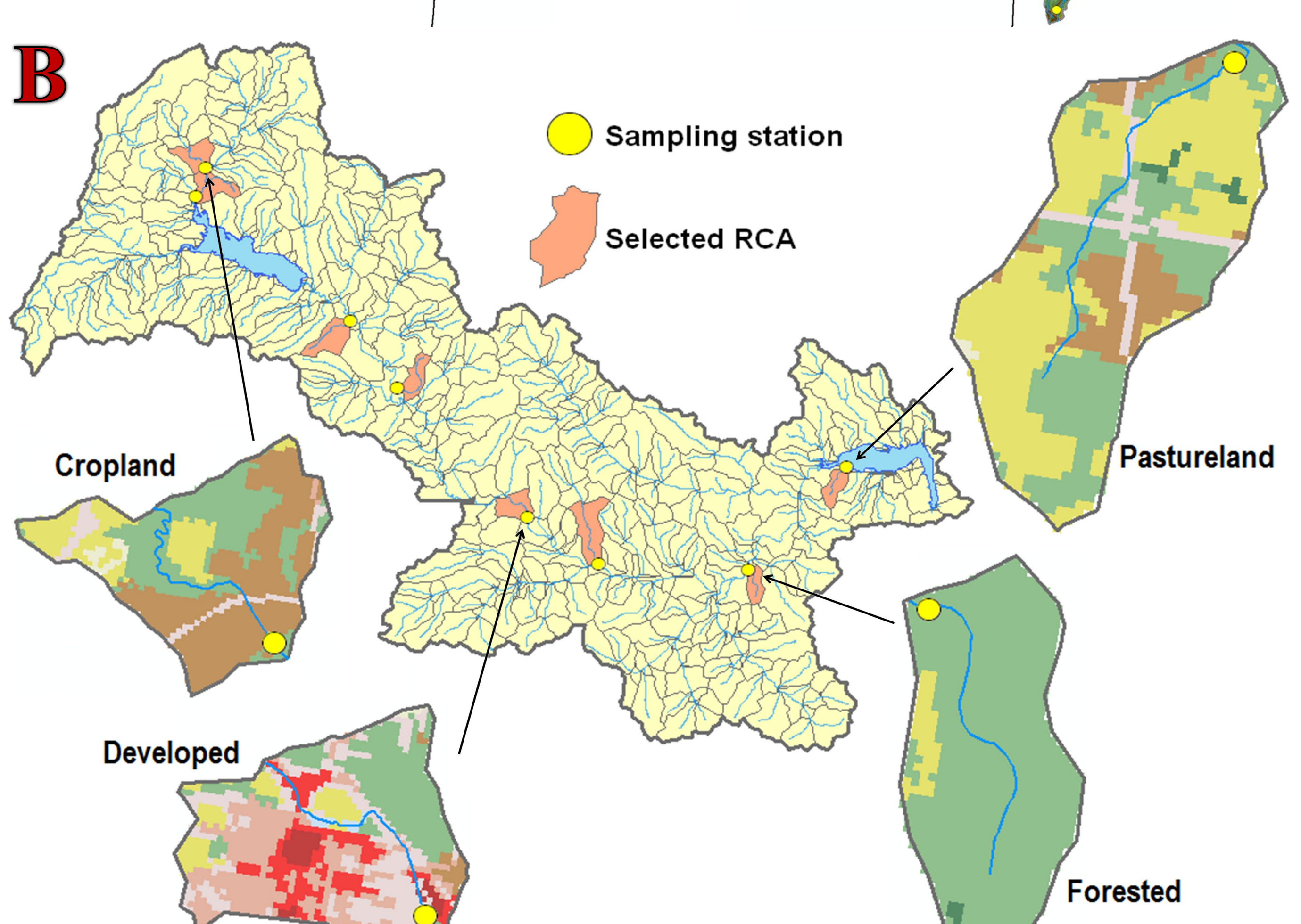
Introduction

In many ecosystems on land and sea, the supply of nutrients is a key factor controlling the nature and diversity of plant life, the population dynamics of both grazing animals and their predators, and vital ecological processes such as plant productivity and the cycling of carbon and soil minerals. Over the last century, runoff from farms and cities, along with land cover and land use changes, have drastically altered the mass balance of nutrients in aquatic systems, affecting both their ecological functioning and the living communities they support. Here we present the results of a multi-year nutrient assessment of streams and lakes from the Mohican River Watershed, in North-Central Ohio, which drains to the Ohio River and into the Gulf of Mexico.

Study Sites

A total of 64 streams and 8 lakes/reservoirs have been sampled periodically since the summer of 2008 (Fig. A). A GIS-based landscape model was used to examine the relationships between streams and their catchments. Land use data from NLCD was used to select representative reach-catchment units in one of four categories: forested, developed, cropland, and pasture (Fig. B).





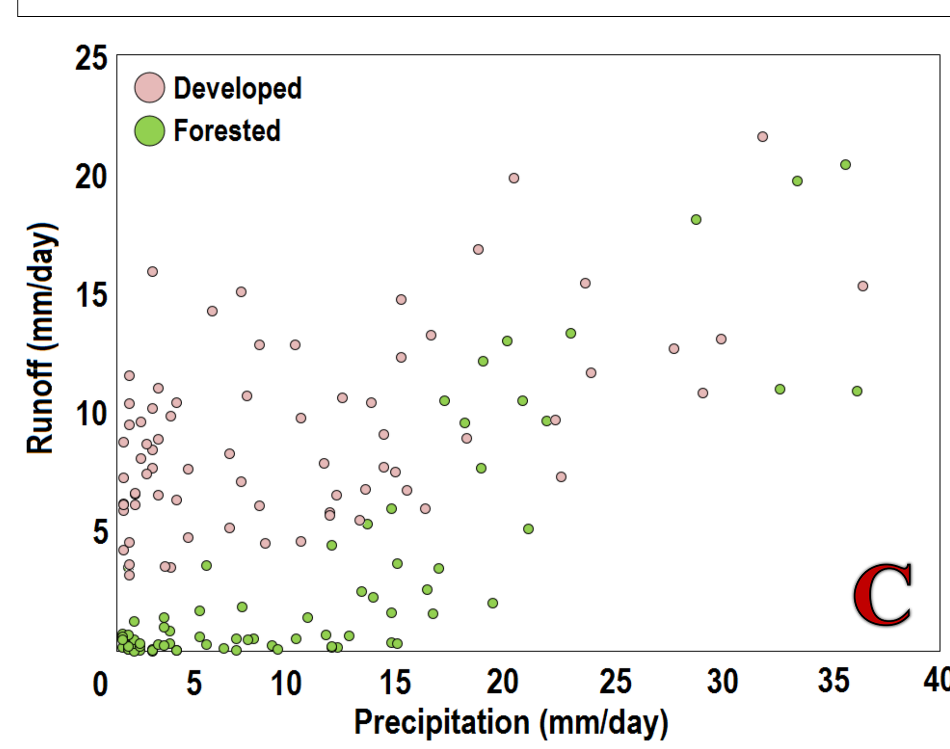
Precipitation data from the NCDC Climate Data Online website and stream flow data collected by our team and provided by the USGS NWIS gauges in our study streams were used to estimate runoff generation and responses to precipitation events.

Sampling & Analysis

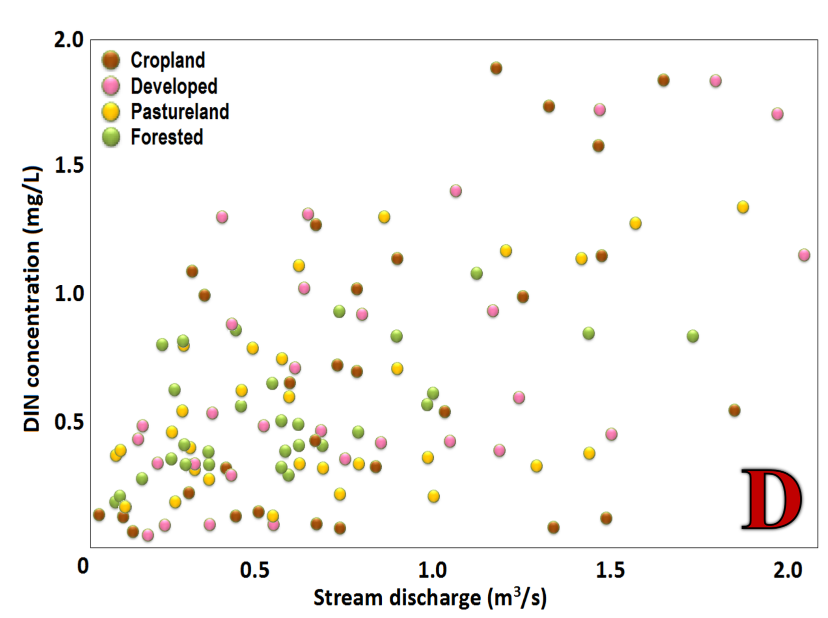
Stream-water samples were filtered in the field and kept in a cooler until arrival at the lab were they were kept frozen until analysis. Nutrient concentrations (inorganic fractions such as NO_2; NO_3; NH_4; PO_4; as well as TN and TP) were measured and used for calculation of nutrient fluxes within the watershed. Sampling was undertaken during both baseflow and stormflow conditions in order to evaluate the effects of precipitation on nutrient transport. Rainwater samples were also analyzed in order to assess nutrient contribution from atmospheric deposition. Additional measurements in the field included air and water temperature, pH, TDS, dissolved oxygen, and stream flow. Our aim was to investigate mixed land use headwater catchments for (1) the amount of water leaving the reach-catchment units during periods of stormflow compared with baseflow between storms; (2) the amounts of nutrients transported in each condition; and (3) the relationship between nutrient transport and the land use of the reach-catchment units.

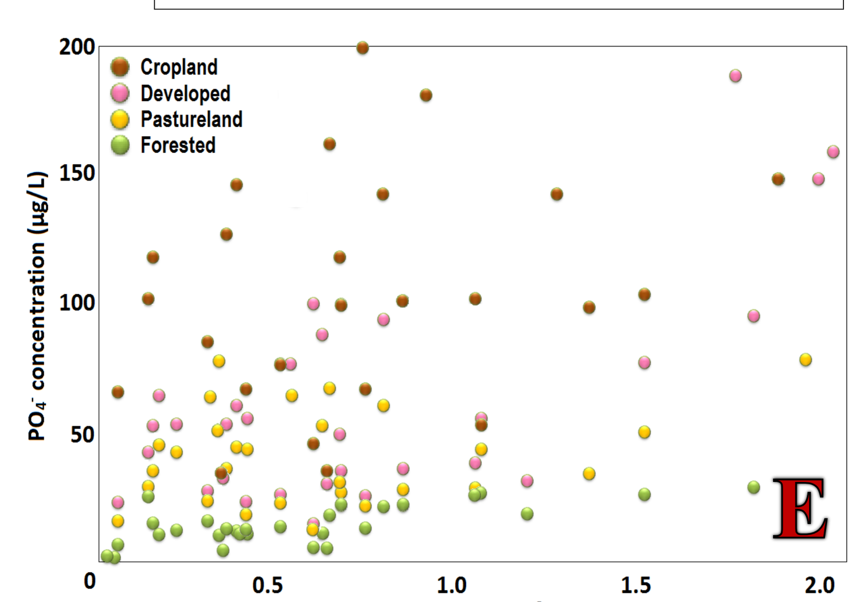
Results & Discussion

Hydrological conditions during the study period exhibited marked seasonality, with usually dry winter seasons (total ppt ranging from 20.96 cm to 28.50 cm) and wet spring seasons (total ppt ranging from 22.25 cm to 46.76 cm). Runoff generation in response to precipitation events is faster in streams draining developed catchments compared to forested streams (Fig. C). Nevertheless, our data indicates that only about 25% of precipitation inputs were translated into quick flow. This suggests that for the majority of precipitation events, only a small portion of the reach-catchment area contributes to streamflow, and that hydrologic connectivity in the watershed may be limited. Future work will investigate this assumption, but previous studies have shown that both the storage conditions just prior to a precipitation event – and the total event input as indicated by the maximum storage achieved during the event – are important predictors of potential runoff response. They have also shown that the largest and/or terminal storage element will dominate the runoff response to any precipitation event.



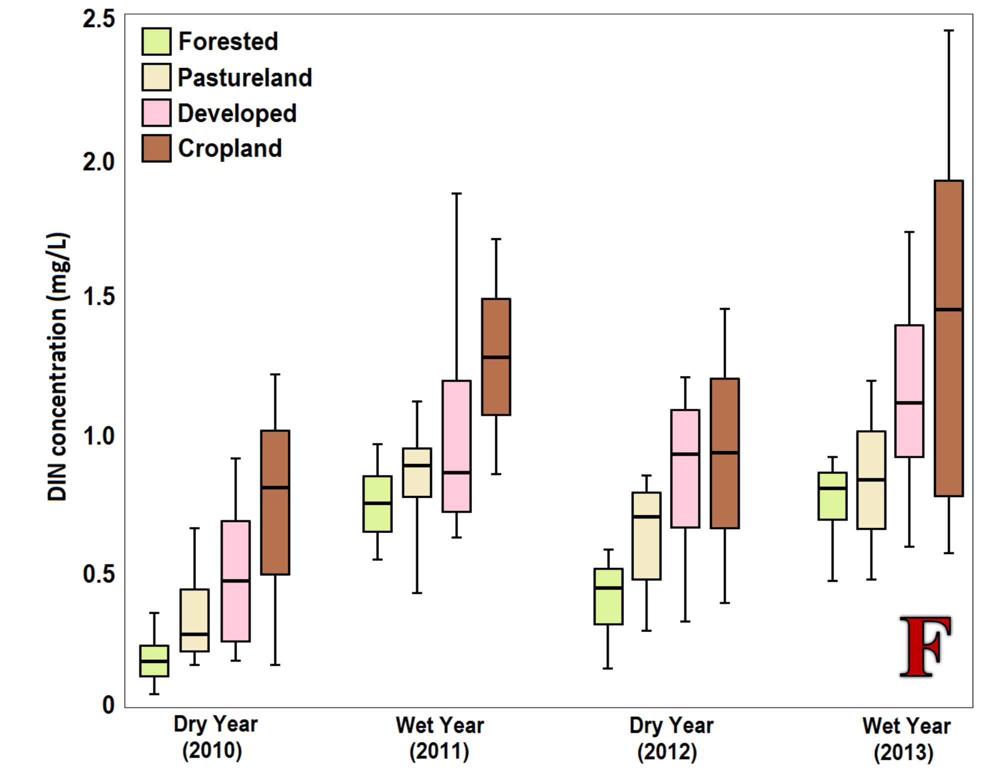
Hydrological factors, along with the land use of the reach-catchment area, have a strong influence on nutrient fluxes, as indicated in Figs. D and E). There is a significant, positive correlation between runoff and nutrient concentrations (R^2 values are: 0.40 for streams draining developed landscapes, 0.34 for forested streams, 0.30 for cropland, and 0.28 for pastureland).



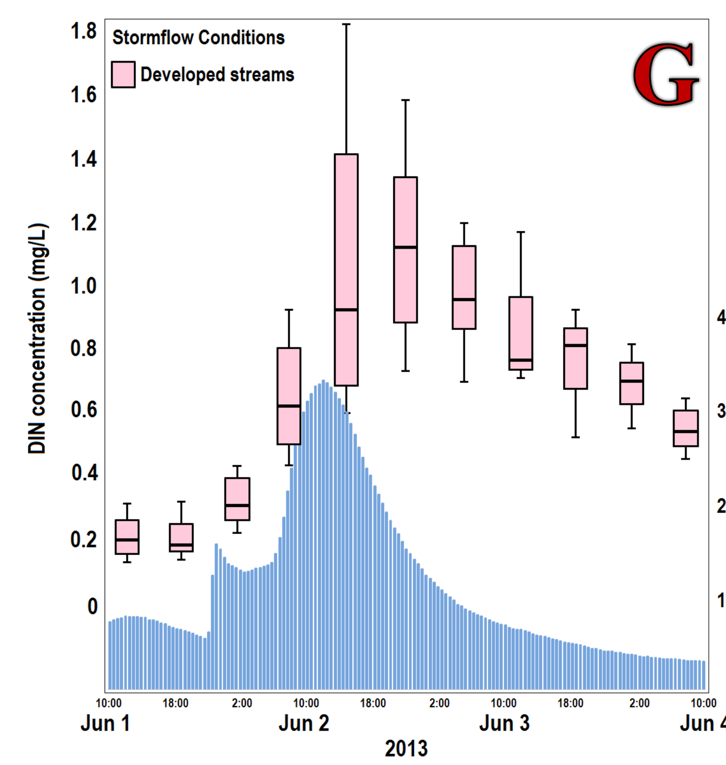


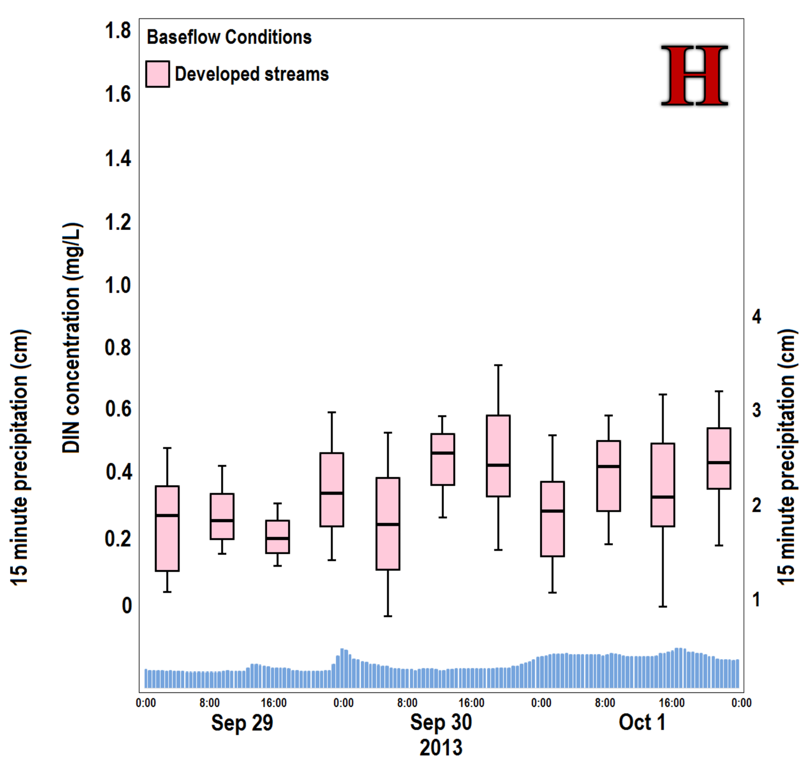
Results & Discussion (cont…)

This short-term hydrological variability is compounded by the effects of long-term geomorphic and climatic changes. Although our long-term dataset showed no significant increasing or decreasing trends in nutrient concentrations at the studied streams, there were significant inter-annual and seasonal variations on both DIN ($p = 0.02$) and PO_4 concentrations ($p < 0.01$), and an increase of over 15% in nutrient export was observed during wetter years (Fig. F).



In addition, there is a marked shift between local and external controls on biogeochemical processes under baseflow and stormflow conditions. During stormflow, nutrient input is primarily hydrologically controlled (Fig. G). During baseflow (Fig. H), biological processes dominate both the production and removal of nutrient ions from the stream.





Seasonal transport coincided with water flow and was greatest during the months of April to June and least during the winter months (December to February). Although it needs further exploration, a preliminary analysis of the organic fractions of N and P suggests that export of these constituents is also higher during spring months.

Year-to-year fluctuations of nutrient transport values were smaller with the baseflow chemical movement than with the stormflow. We estimate that only about 20 to 30% of the annual nutrient export from these headwater streams takes place during baseflow. These amounts are smaller for streams draining developed landscapes and higher for streams draining forested catchments. In general, less N and P were moved out of the watershed than were received during precipitation events, suggesting that these streams were sinks for N and P. Once again, there are significant differences based on the dominant land use. Streams draining agricultural lands export a higher fraction of the N and P received during precipitation events than the other land uses.

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