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Nutrient Concentrations in Big Creek Correlate to Regional Watershed Land Use

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In the Ozark Mountain karst region, nutrient concentrations in streams of the Buffalo, Upper Illinois and Upper White River watersheds increase as the percent of land in pasture and urban use increases. Averaged over the last three years, nutrient concentrations in Big Creek above and below the C&H Farm are similar to concentrations found in other watersheds where there is a similar amount of pasture and urban land use.

Background

Land use within watersheds influences the quantity and quality of water draining from a watershed. As land disturbance increases and use intensifies, there is a general increase in stormwater runoff and nutrient inputs that leads to a greater potential for nutrient discharge to receiving waters. For instance, with urban growth, more impervious surfaces increase the flashiness of runoff, stream flows and wastewater treatment discharge. Also, as areas of agricultural production grow, more fertilizer is applied to achieve optimum production. Thus, as the percent of a watershed drainage area in pasture, row crop or urban use increases, there is a general increase in nutrient concentrations in storm and base flows.

In this fact sheet, we show the effect of land use on nitrogen (N) and phosphorus (P) concentrations in streams of the Ozark Highlands and Boston Mountains, northwest Arkansas, by combining previously published data for the Upper Illinois River Watershed (Haggard et al., 2010), Upper White River Watershed (Giovannetti et al., 2013) and ongoing monitoring in the Buffalo River Watershed. The location of these watersheds is shown in Figure 1. The relationships between stream nutrient concentrations and land use for the region are used to determine if a permitted concentrated animal feeding operation (CAFO) in Big Creek Watershed, a sub-watershed of the Buffalo River Watershed, has affected stream water quality. Land use in these watersheds is given in Table 1.

Nitrate-N, total N, dissolved P and total P concentrations have been measured over varying periods during base flow at the outlet of sub-watersheds in the Big Creek (two sites, 2014 to 2017), Buffalo (20 sites, 1985 to 2017), Upper Illinois (29 sites, 2009) and Upper White River Watersheds (20 sites, 2005 to 2006) (Figure 1).

Data from Big Creek were paired with discharge available from a gaging station just downstream from the swine CAFO, where the USGS developed the rating curve; discharge information was only available from May 2014 through December 2017. The data were then used to look at changes in flow-adjusted nutrient concentrations[A] in Big Creek (White et al., 2004).

[A]Concentration is defined as the mass of a substance (M), such as a nutrient, over the volume of water (V) in which it is contained, or C = M/V. "**Flow-adjusted nutrient concentrations**" – when looking at how concentrations change over time in streams, we have to consider how concentrations might also change with stream flow (volume of water) and not just change in mass; nutrient concentrations often have some type of relation to flow, maybe increasing or even decreasing as stream flow increases. We have to flow-adjust concentrations so we can remove the variability in concentrations that flow might cause to see how things are changing over time.

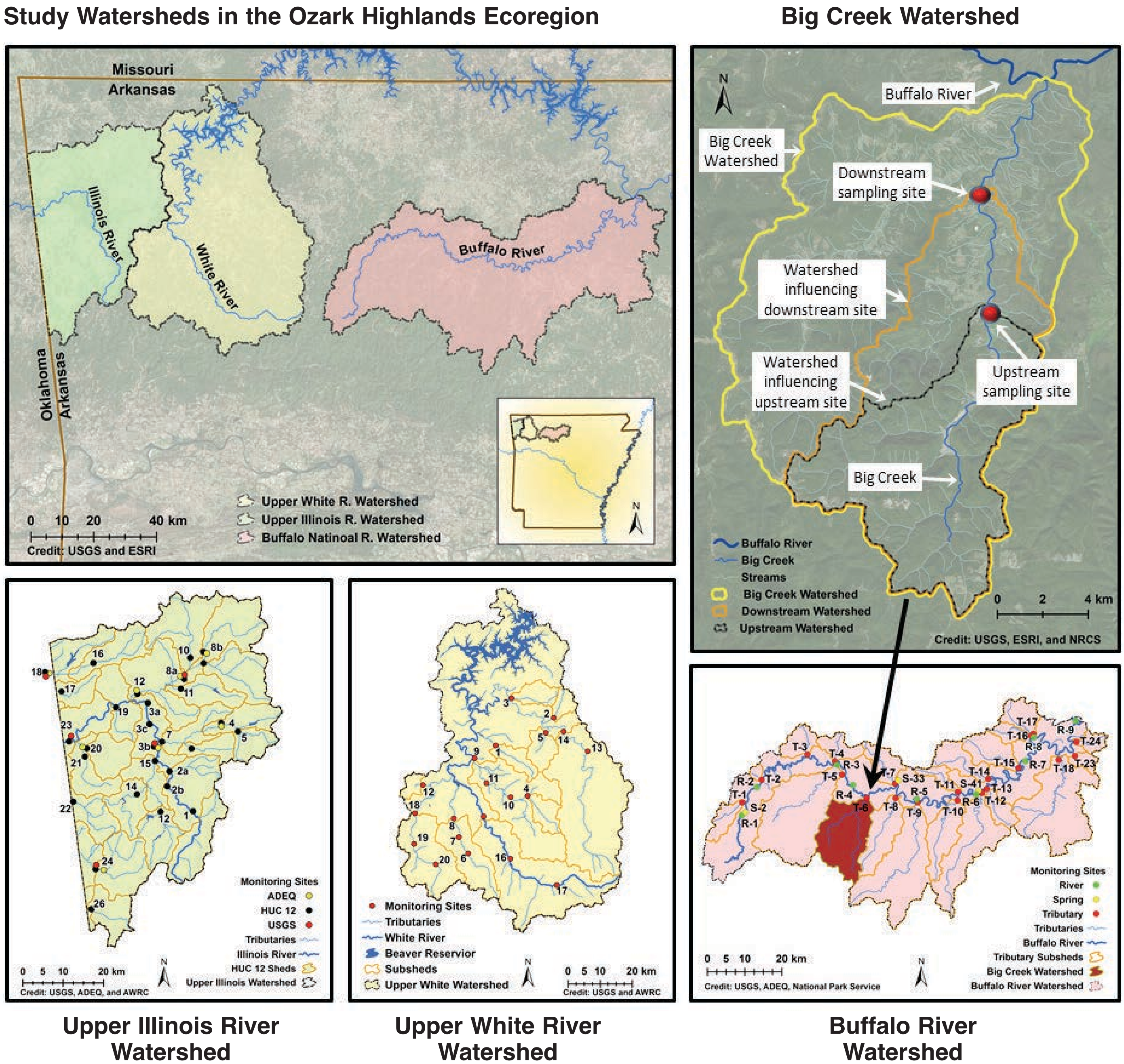

Figure 1. Location of the Big Creek, Buffalo River, Upper Illinois River and Upper White River watersheds in the Boston Mountains and Ozark Highlands ecoregion. *Information from U.S. Geological Survey (USGS), Environmental Systems Research Institute (ESRI) and National Aeronautics and Space Administration (NASA).*

Table 1. Percent of forest, pasture and urban land use in the Big Creek, Buffalo River, Upper Illinois and Upper White River watersheds.

Watershed	Forest	Pasture	Urban
	- - - - - - - - - - - - - - - - - - - -	%	- -
Big Creek*			
Upstream	89.5	8.0	2.6
Downstream	79.5	17.0	3.5
Buffalo River	52 - 99	0 - 25	0 - 1
Upper White River	34 - 90	7 - 55	0 - 44
Upper Illinois River	2 - 70	27 - 69	3 - 61

*Up and downstream of CAFO operation and fields permitted to receive manure.

Putting Stream Nutrient Concentrations Into Context at Big Creek

Geometric mean concentrations[B] of stream P and N are related to the percent of watershed drainage area in pasture and urban land use for the Buffalo, Upper Illinois and Upper White River watersheds (R^2 of 0.56 to 0.81 where the number of observations is 71; Figure 2)[C]. The dashed lines on Figure 2 represent the upper and lower thresholds concentrations, where there is a 95 percent confidence that a stream draining a watershed with a specific percent pasture and urban land use will have a P and N concentration within those thresholds.

The relationship between land use and stream nutrient concentrations is not a model that can be used to predict concentration. Given the large variability observed in these relationships, they simply show trends between two variables, land use and stream nutrient concentrations. Continued monitoring of stream concentrations in Big Creek will continue to more reliably define trends.

As the percent pasture and urban land (i.e., land use intensity) increases, so does stream P and N concentrations (see Figure 2). The general increase in nutrient concentrations is consistent with the fact that fertilizer (as mineral and manure sources) is routinely applied to pastures to maintain forage production, as well as deposition of nutrients by grazing cattle.

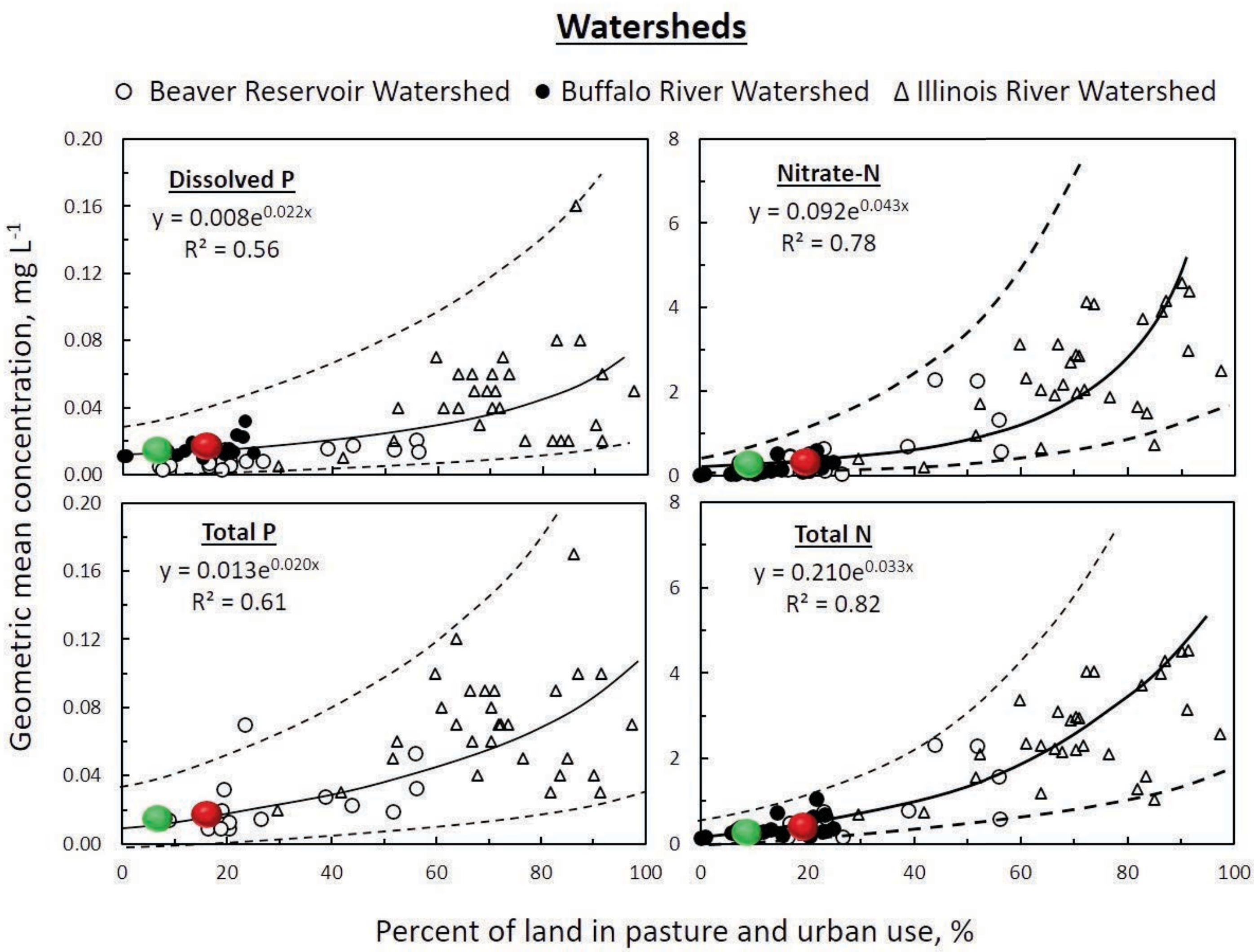

Figure 2. Relationship between land use and the geometric mean N and P concentrations (mg L^{-1}) in the Buffalo, Upper Illinois and Upper White River watersheds. Dashed lines represent the 95 percent confidence intervals for the estimated mean (solid line). Green points are geometric mean concentrations measured upstream of the CAFO on Big Creek and red points are geometric mean concentrations measured downstream of the CAFO on Big Creek.

[B]"**Geometric means**" – There are many ways to calculate the central or typical value of a data set, like the average or median. With water quality data, the geometric mean is often used because it minimizes the influence of really low or high values on the average.

[C]"**R^2**" is the **coefficient of determination** – the proportion of variance in the dependent variable (i.e., vertical axis) that is predictable from the independent variable (i.e., horizontal axis). The closer to 1 the value is, means less variability and the better the relationship between the two variables is.

In the Big Creek watershed, the percent of land influenced by human activities (i.e., pasture plus urban) doubles from ~10 percent to ~20 percent in the drainage area upstream and downstream of the CAFO. In Big Creek itself, upstream of the swine production CAFO, the geometric mean concentrations of dissolved P, total P, nitrate-N and total N during base flow were 0.009, 0.030, 0.10 and 0.20 mg L^{-1}, respectively, between September 2013 and December 2017. Directly downstream of the CAFO, the geometric mean concentrations in Big Creek during base flow over the same period were 0.011, 0.030, 0.25 and 0.37 mg L^{-1}, respectively.

Geometric mean nutrient concentrations in Big Creek above and below the swine production CAFO and its current potential sphere of influence from slurry applications are similar to or lower than concentrations measured in rivers draining other sub-watersheds in the Upper Illinois and Upper White River watersheds with similar proportions of agricultural land use. (See Figure 2.)

Have Nutrient Concentrations Changed in the Short Term at Big Creek?

Long-term (e.g., decadal scale) water quality data are needed to reliably assess how stream nutrient concentrations have changed in response to watershed management and climate variations (Hirsch et al., 2015). The literature shows that stream nutrient concentrations can change relatively quickly in response to effluent management (e.g., Haggard, 2010; Scott et al., 2011), but seeing a response (i.e., decrease or increase in concentrations) from landscape management can take decades or more (Green et al., 2015; Sharpley et al., 2013). A myriad of factors may influence observed nutrient concentrations in streams, including discharge, biological processes and climactic conditions (i.e., drought and floods), and dominant transport pathways. Thus, we need to use caution when interpreting trends in water quality over databases that only cover a limited timeframe. Flow-adjusted concentrations showed no

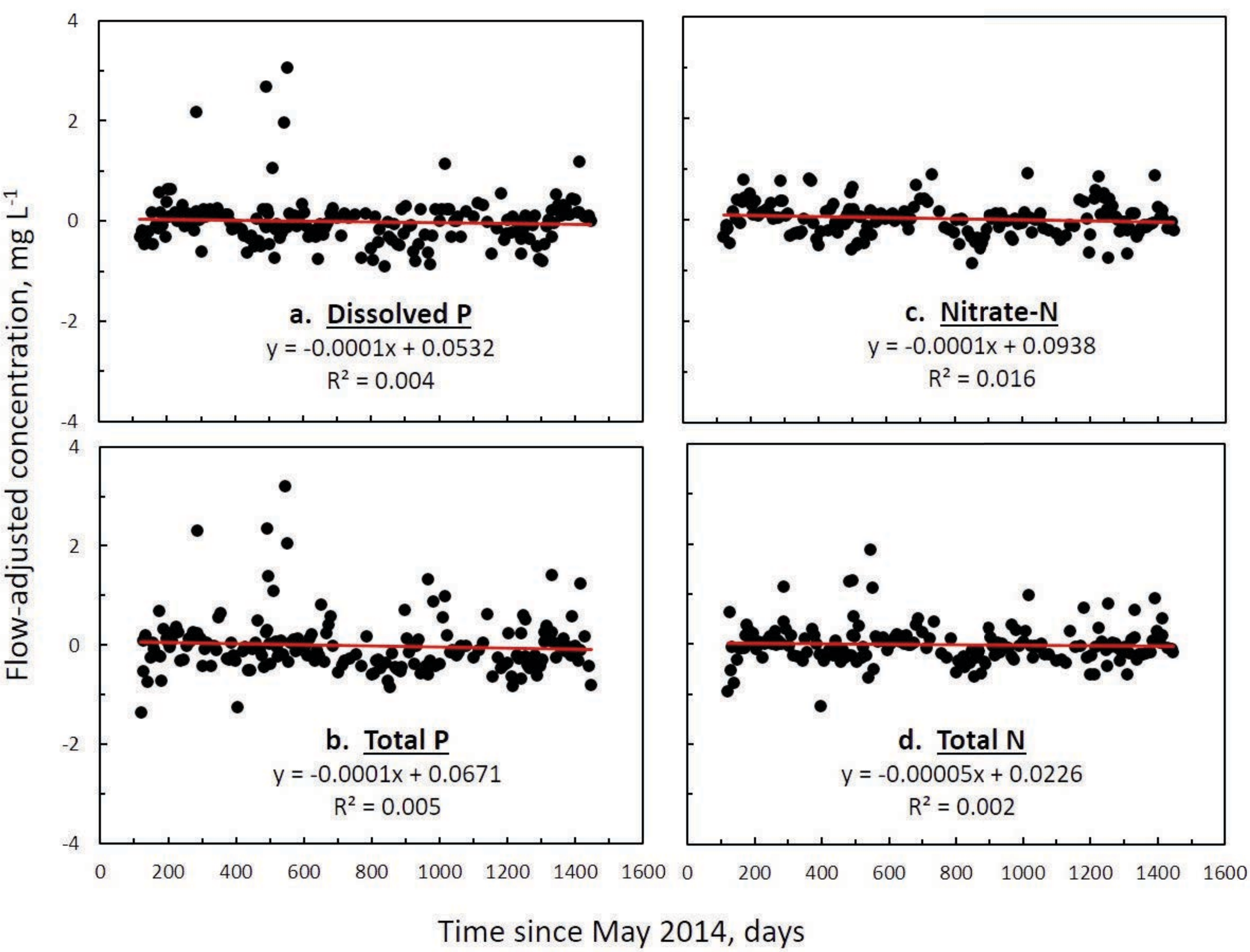

Figure 3. Change in flow-adjusted concentration of (a) dissolved P, (b) total P, (c) nitrate-N and (d) total N over time since May 2014, when monitoring in Big Creek started.

statistically significant increasing or decreasing trends in dissolved P, total P, nitrate-N and total N (R2 <0.016); where number of observations is 182) over the current monitoring period (Figure 3).

Summary

Nutrient concentrations at Big Creek upstream and downstream of the swine CAFO, and indeed most tributaries of the Buffalo River, are low relative to other watersheds in this ecoregion (Figure 2). This provides a starting point to build a framework to evaluate changes in nutrient concentrations of streams as a function of land use and management.

The evaluation of flow-adjusted concentrations over time showed that nutrients in Big Creek were not increasing over the short duration of monitoring for which concentration and discharge data were available (May 2014 through April 2017). At this point in time, it is evident that nutrient concentrations in Big Creek have not increased at the monitored site. However, flow and nutrient concentration data over a longer period are needed to reliably quantify water quality trends and characterize sources, and monitoring needs to continue for at least a decade to evaluate how discharge, season and time influence nutrient fluxes.

Stream nutrient concentration-land use relationships are not a predictive tool. However, use of these relationships provides a method to determine if nutrient concentrations in a given watershed are similar to observed nutrient concentration-land use gradients in other watersheds of the Ozark Highlands and Boston Mountains. Over time, tracking these relationships provides a mechanism to note and evaluate changes in nutrient concentrations.

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