Soil and sediment nutrient dynamics under variable climate conditions in a Mississippi agricultural watershed

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Introduction

Alluvial floodplains can be hotbeds for nutrient fluxes due to naturally high nutrient content of soils and sediments, potential nutrient additions and disturbances from agricultural activities, and periodic flooding that may occur in these areas (Reavis and Haggard, 2016; Scott et al., 2014). Wetting and drying of soils and sediments can alter redox properties, microbial content, and induce nutrient transformations that have been shown to lead to releases of phosphate and ammonium (Kinsman-Costello et al., 2016). Temperature and kinetics play important roles in regulating these nutrient fluxes (Bai et al., 2017).

The Mississippi Alluvial Plain, USA, is a region that experiences highly variable climate and hydroperiod fluctuations. Over-bank flooding from regional rivers and back-flooding from the Mississippi River often inundate soils and sediments throughout the year (Berkowitz et al., 2019). In addition, it is common for soils to experience cycles of drying and saturation or inundation. Based on our studies, soils located in the agriculturally rich Mississippi Alluvial Plain have medium to high phosphorus content without frequent fertilization. In this study we explore the effects of temperature, habitat, and length of inundation on nutrient fluxes from soils and sediments from Beasley Lake Watershed, a highly studied agricultural area in the Mississippi Alluvial Plain. As many areas of this region experience recurring inundation, these results may help to understand the timing and potential extent of nutrient fluxes caused by extreme events.

Methods

Soils/sediments were collected from two locations within five different land-uses(cropland, Conservation Reserve Program land (CRP; i.e. reclaimed agricultural land), forest/riparian wetland, sediment retention pond, and drainage ditches) within the watershed (Figure 1). Soil sample locations were selected to include one location per land-use that typically experiences ephemeral standing water, such as topographic depressions within the cropland, CRP, and forested areas. All sediment sample locations in the ditches and sediment retention ponds included ephemeral or perennial standing water. The top 0-5 cm was collected from 15-20 locations within a 2 m^2 area and homogenized.

After homogenizing samples, large pieces of organic matter were removed, and a sub-sample was analyzed for moisture content. The samples were dried, ground, and sieved for consistency to 2 mm. Samples were analyzed for total carbon (C) and nitrogen (N) via CNS organic elemental analyzer. Samples were extracted using the EPA 5050b method for total concentrations of aluminum, iron, manganese, calcium and phosphorus. Mehlich-3 extractions were used to measure the concentrations of iron, manganese, calcium, phosphorus, potassium, magnesium, copper, and zinc. Both extractants were analyzed with an ICP-MS. Soil texture analysis was conducted using the pipette method.

To simulate flooding, 10 g of dried soil/sediment was placed into an 8 oz acid-washed glass mason jar with 40mL of deionized water. Lids were placed lightly on top of jars, but not sealed to allow air flow. Five replicates from each were incubated at 5, 15, 25 and 30°C to represent different seasonal temperatures throughout the year. Water was sampled from sacrificial samples at 4, 8, 12, 24 and 48 h to evaluate the kinetic properties of nutrient fluxes. Water samples were frozen and analyzed with a spectrophotometer to determine dissolved nutrient concentrations.

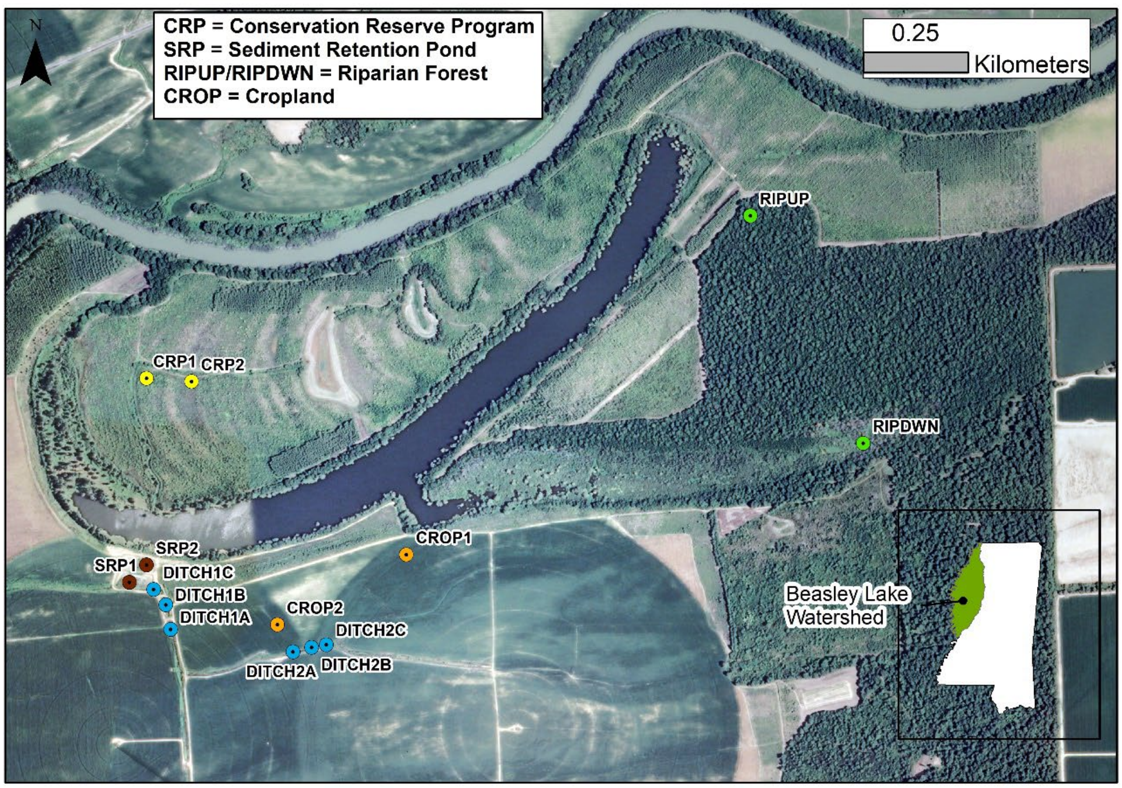

Figure 1. Locations of soil and sediment samples taken from Beasley Lake Watershed

Results

Soil and Sediment Properties

As the soils and sediment came from very different habitats, there was fairly high variability in many of the properties. Percent carbon (%C) varied from around 1% in cropland to over 5% in the flooded forest area (RipDown). Percent nitrogen (%N) varied similarly to carbon with the same pattern across sites: the lowest %N was in cropland sites ($<0.1\%$) and the highest was in the forested areas (0.39%). Percent carbon was able to explain 97% of the variance in %N; therefore, these two components seem tightly coupled across the soils/sediments sampled. Total phosphorus (TP) was similar across cropland, CRP, ditch and SRP locations, but was significantly higher in the forest. Total phosphorus concentrations were highly correlated with percent clay in the samples ($r^2=0.72$). Mehlich-3 extracted phosphorus, was significantly lower in the cropland and CRP sites at higher elevations, and higher in the ditch sites.

Nutrient fluxes

Nutrient flux patterns were quite complex and more statistical analysis is ongoing; however, several emerging patterns were observed. With respect to phosphate fluxes, samples from CRP, riparian forest and cropland had similar patterns; the peak phosphate flux occurred at 24 h across most temperature treatments (Figure 2.). There was not a clear relationship between temperature and peak fluxes, as was expected. Ammonia releases peaked between 8 and 12 h after inundation and then dropped drastically by 24 h. Peaks were highest in the 25 and 35°C treatments (Figure 2). Nitrate patterns were more divergent, but peak releases were generally measured around 24 h and were typically higher for the lower temperature treatments (5 and 15°C). Flux results from two different habitats are provided for illustrative purposes (Figure 2).

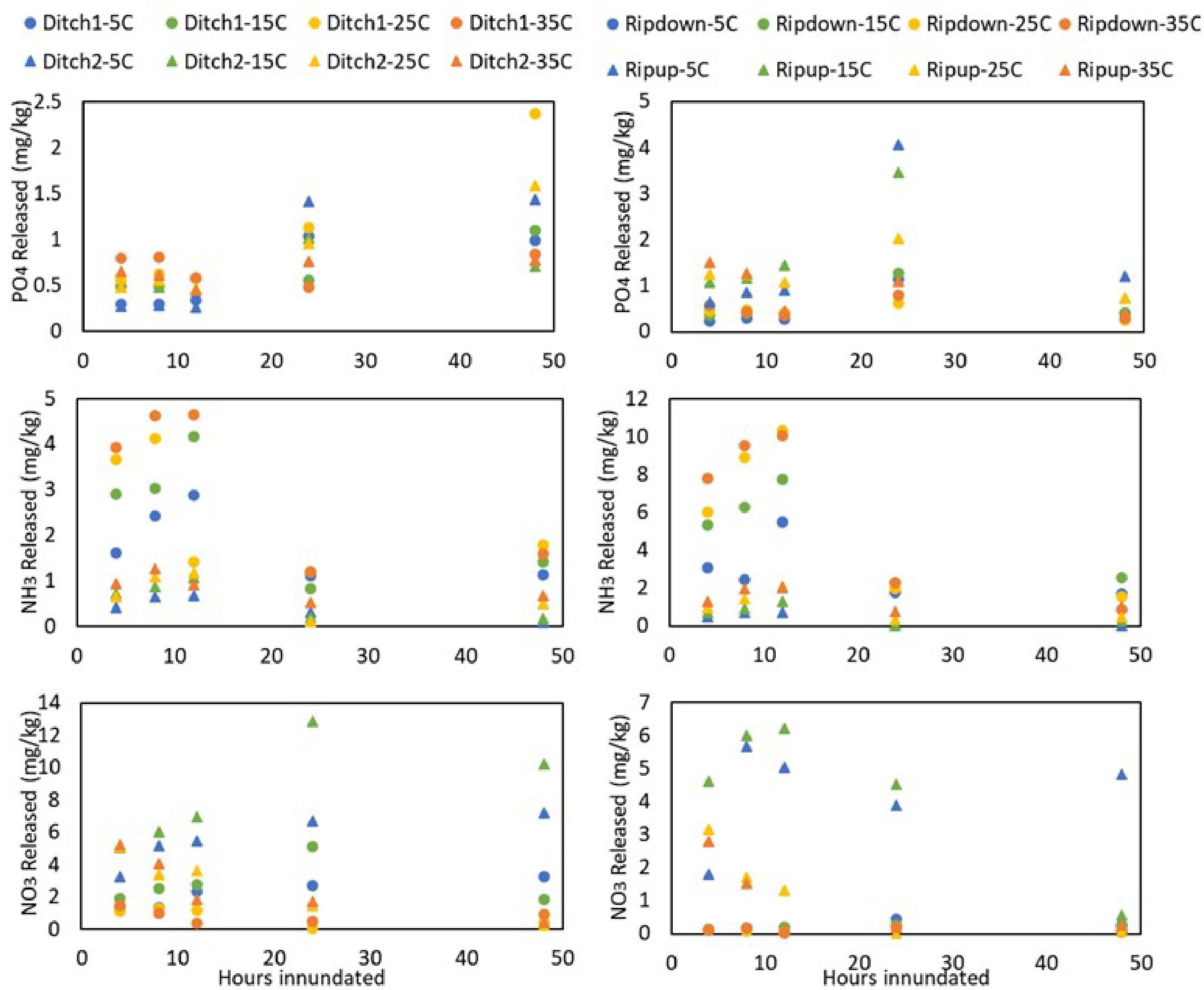

Figure 2. Phosphate (PO4), ammonia (NH3) and nitrate (NO3) fluxes for ditch and forest habitats.

Conclusions

Drying and re-wetting of soil and sediments alters biogeochemistry and can cause nutrient transformations. Our experimental results show that inundating dried soils can cause rapid releases of ammonia, nitrate and phosphate. Understanding nutrient fluxes under flooded conditions is important for estimating potential pulses of dissolved nutrients after flooding event and relating those to ecological consequences. Further work needs to be done to understand the causal factors related to nutrient fluxes from different habitats.

References

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