Environmental Functions of Alluvial Soils in Coal Mining Regions of Eastern Pennsylvania

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Introduction

Coal is known to contain elevated concentrations of both lead (Pb) and arsenic (As) (Belkin 2007). Exposure to these metals can cause negative health effects including: nervous system, brain, and kidney damage (NRDC 2007). Alluvial landscapes in eastern Pennsylvania have been shown to contain high concentrations of anthracite coal-contaminated legacy sediments derived from upland erosion since European settlement of the region (Stinchcomb et al. 2013). Coal materials are deposited in alluvial landscapes of the North Branch Susquehanna River (NBSR) during flood events because woody riparian vegetation slows floodwater velocity and these landscapes flood more frequently due to relatively low elevation compared to the surrounding river banks (**Fig. 1**). Trapping and retention of coal materials from the river system during flood events provides a major water quality improvement function to downstream waterways, such as the Chesapeake Bay.

To date, little research has been done on the ecosystem services provided by alluvial landscapes, such as river islands and tributary deltas, in coal mining regions. Thus, the goals of this research were to **(1)** quantify the amount of coal contained in the alluvial soils of the NBSR, **(2)** understand the role of coal overwash in trace metal contamination, and **(3)** evaluate the potential for acid sulfate drainage from reworked coal alluvium.

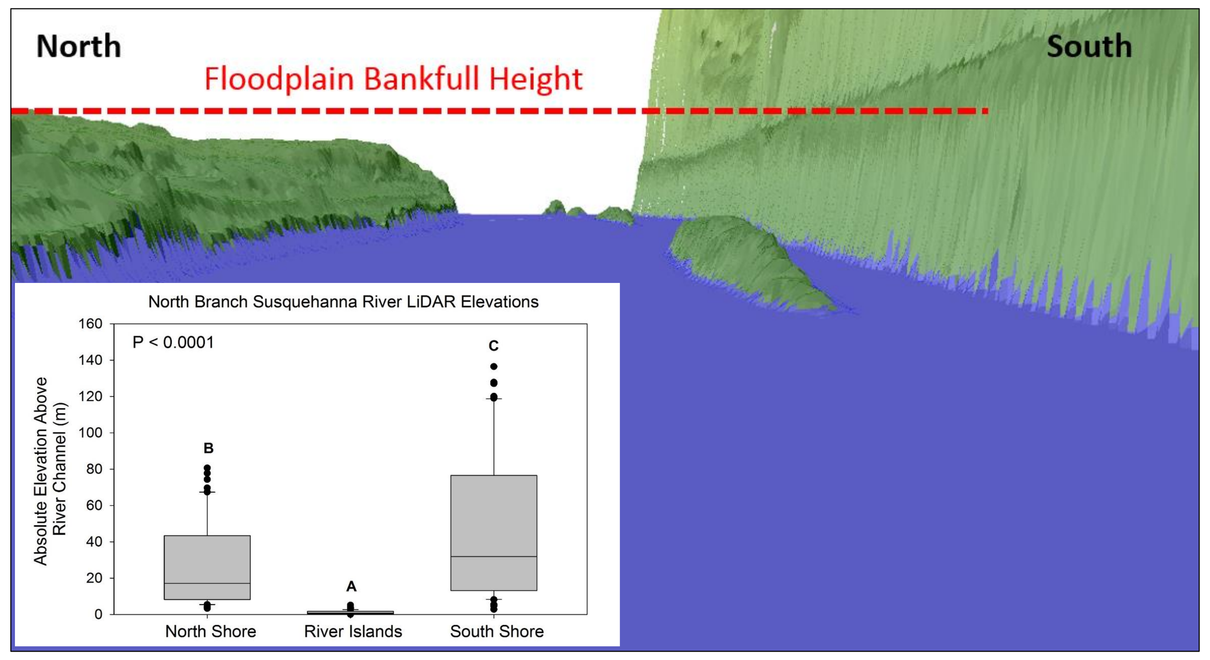

Fig. 1: 3-D representation of typical river islands in the Susquehanna channel. Image created using LIDAR elevation data (10x exaggeration). Box plot of average elevations among NBSR islands and contiguous shores (n = 50). Means with different letters are significantly different (one-way ANOVA and Tukey's HSD tests).

Study Area

The study area for this research was the NBSR in the Ridge and Valley province of eastern Pennsylvania (**Fig. 2**). The study included 4 river islands and 4 alluvial deltas. All study areas are subject to flooding from the main river channel and the deltas also receive floodwaters from tributary streams.

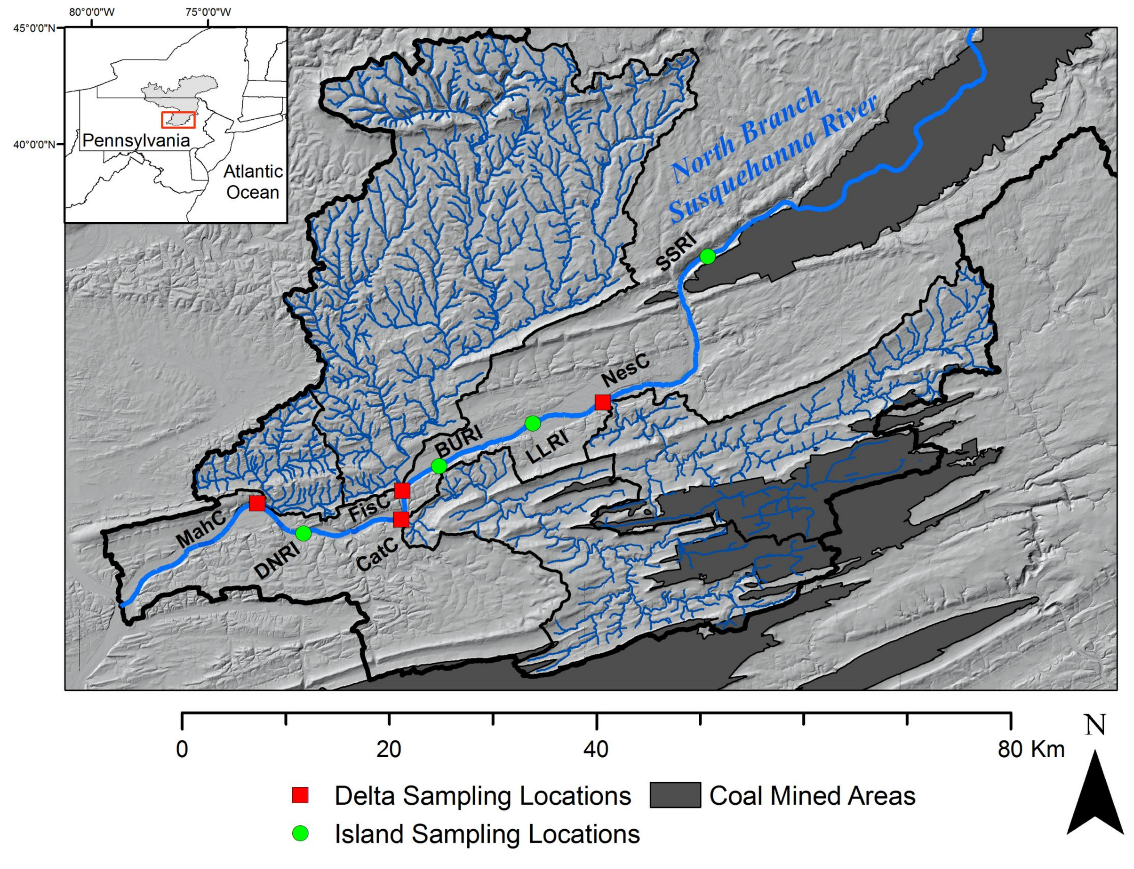

Fig. 2: Overview map of study sites in the NBSR basin.

Methods

Alluvial soils were described from islands (n = 4, 3.0-13 ha size) and major tributary deltas (n = 4, 3.0-17 ha size) within the NBSR. Soils were fully described and sampled in the field to at least 100 cm using standard procedures (pits, auger borings) and samples were collected by horizon (Schoenberger et al. 2012). A total of 12 soils were sampled within the study sites in the summers of 2015 and 2016.

Collected soil samples were placed in a cooler and returned to the laboratory for analysis. Samples were oven dried at 60 °C and sieved through a 2 mm mesh to remove coarse mineral and organic fragments. A portion of the samples were used for soil texture analyses using the hydrometer method. Additional subsamples were washed using a 63 µm sieve to remove the clay and silt fractions and examined under a Meiji MX9200 microscope at 100x magnification. A total of 200 sand-sized grains were counted to quantify the proportion of each sample that was contaminated with anthracite coal.

Subsamples of the sieved materials were also homogenized using mortar and pestle and analyzed using X-ray Fluorescence (XRF, Niton XL3t GOLDD) for total elemental analysis. Alluvial soil trace metal concentrations were also compared to background levels in regional soils (Vosnakis et al. 2009; Ciolkosz et al. 1998).

An aerobic incubation pH experiment was conducted in the laboratory (Soil Survey Staff 2014) to evaluate the acid sulfate potential of alluvium in the region. Samples from the BURI site were used because the upper two horizons represent modern agricultural/urban alluvium while the lower four horizons were interpreted to be highly contaminated with anthracite coal. This allowed for comparison between older and more modern alluvial deposits.

Results

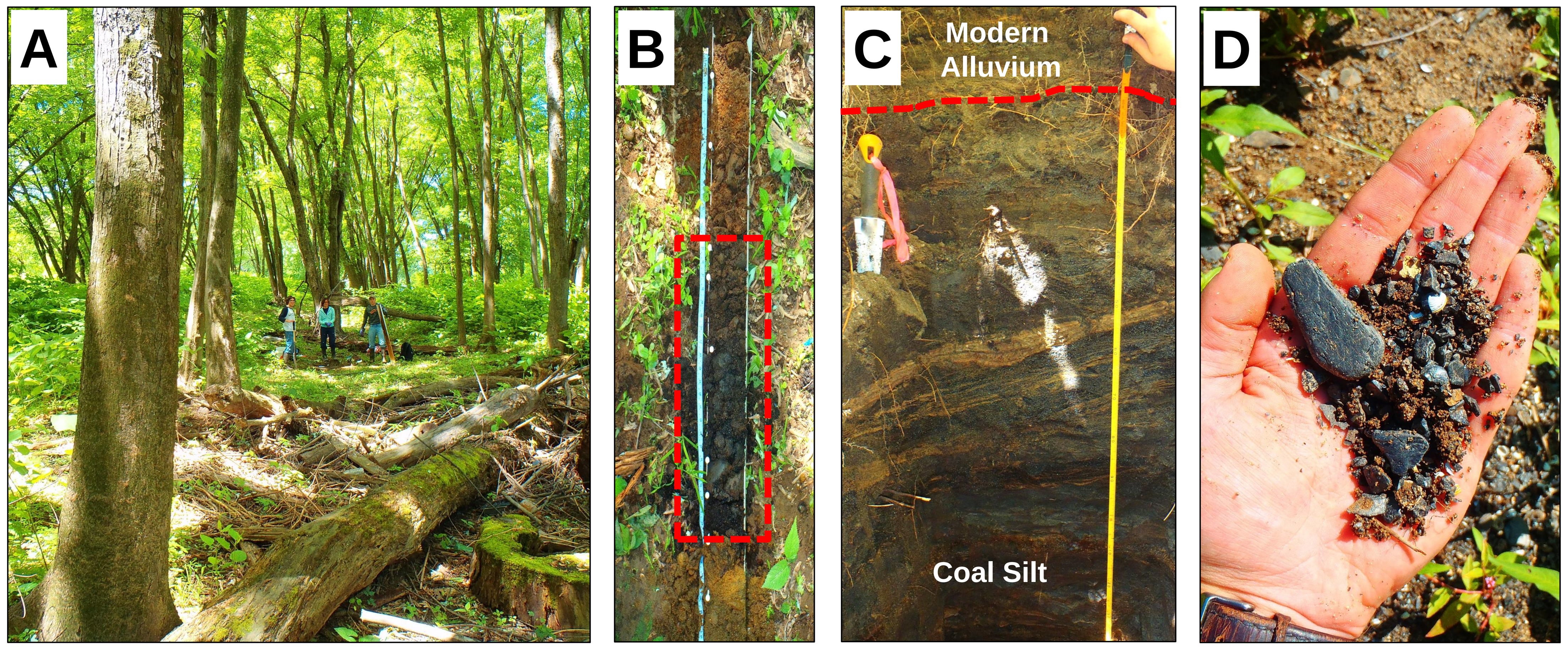

Fig. 3: Representative field photos, **A:** typical alluvial landscape of the NBSR dominated by silver maple (*Acer saccharinum*) trees, **B:** soil auger boring showing coal contamination at depth (dashed box), **C:** hand-dug soil pit showing extent of buried coal deposits (>1.20 m thickness), **D:** reworked surficial coal deposits are common in high-energy landscapes of the NBSR.

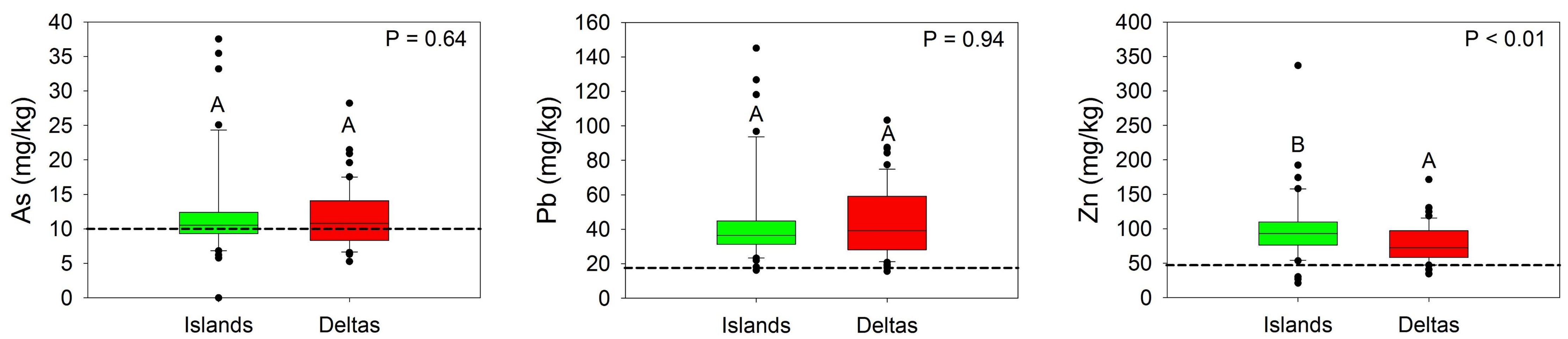

Fig. 4: Mean concentrations of As, Pb, and Zn found in alluvial soil horizons of islands (n = 40) vs. deltas (n = 54). Means with different capital letters are significantly different according to Student's T-Tests. Dashed lines represents regional soil background levels of each metal derived from Ciolkosz et al. 1998 and Vosnakis et al. 2009.

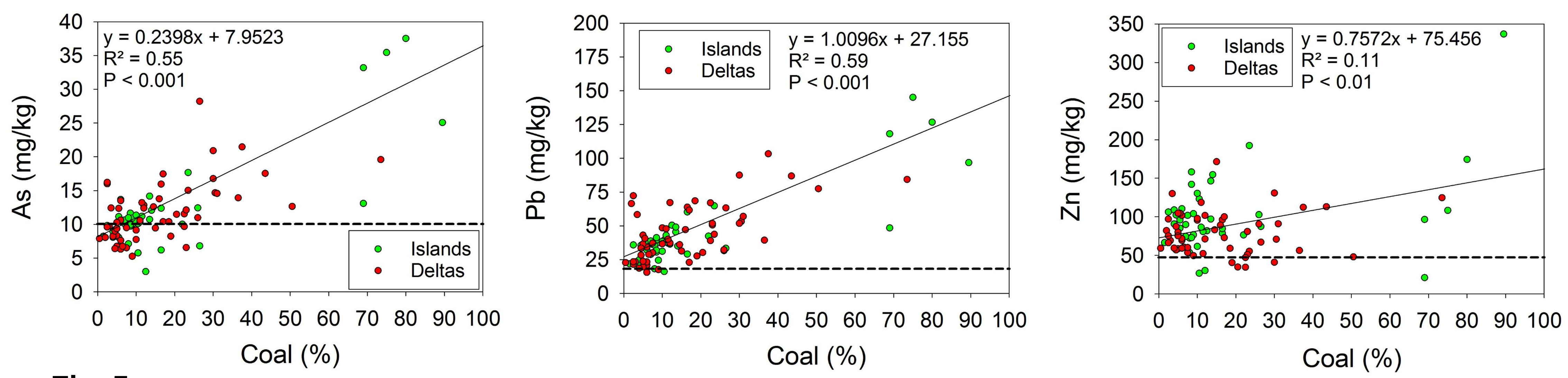

Fig. 5: Significant linear relationships between coal contamination (% coal in sand fraction) and concentrations of As, Pb, and Zn found in alluvial soil horizons. Dashed lines represents regional soil background levels of each metal derived from Ciolkosz et al. 1998 and Vosnakis et al. 2009.

Results (Cont.)

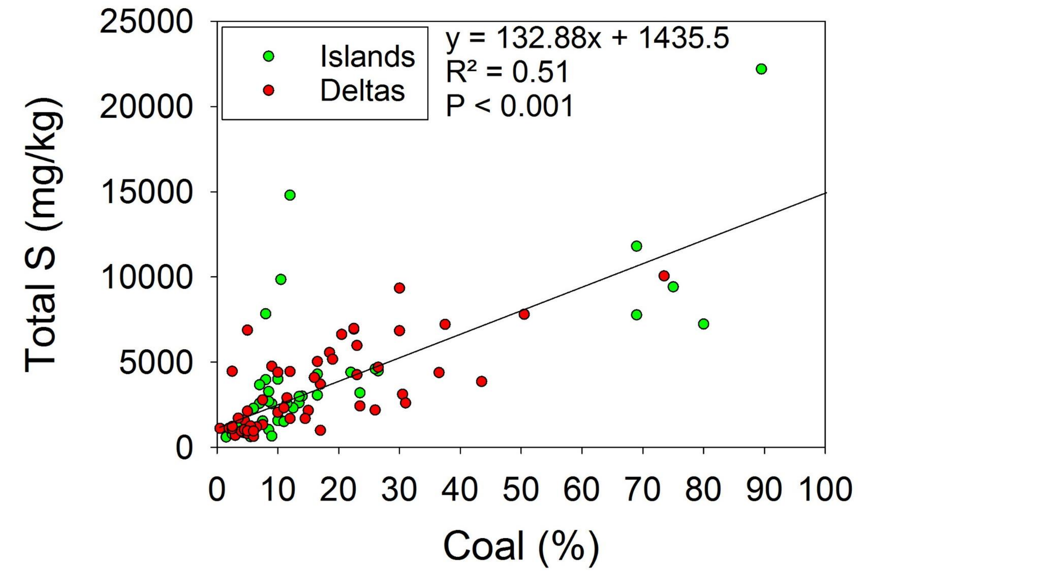

Fig. 6: Significant positive relationship between alluvium coal contamination and total sulfur concentration.

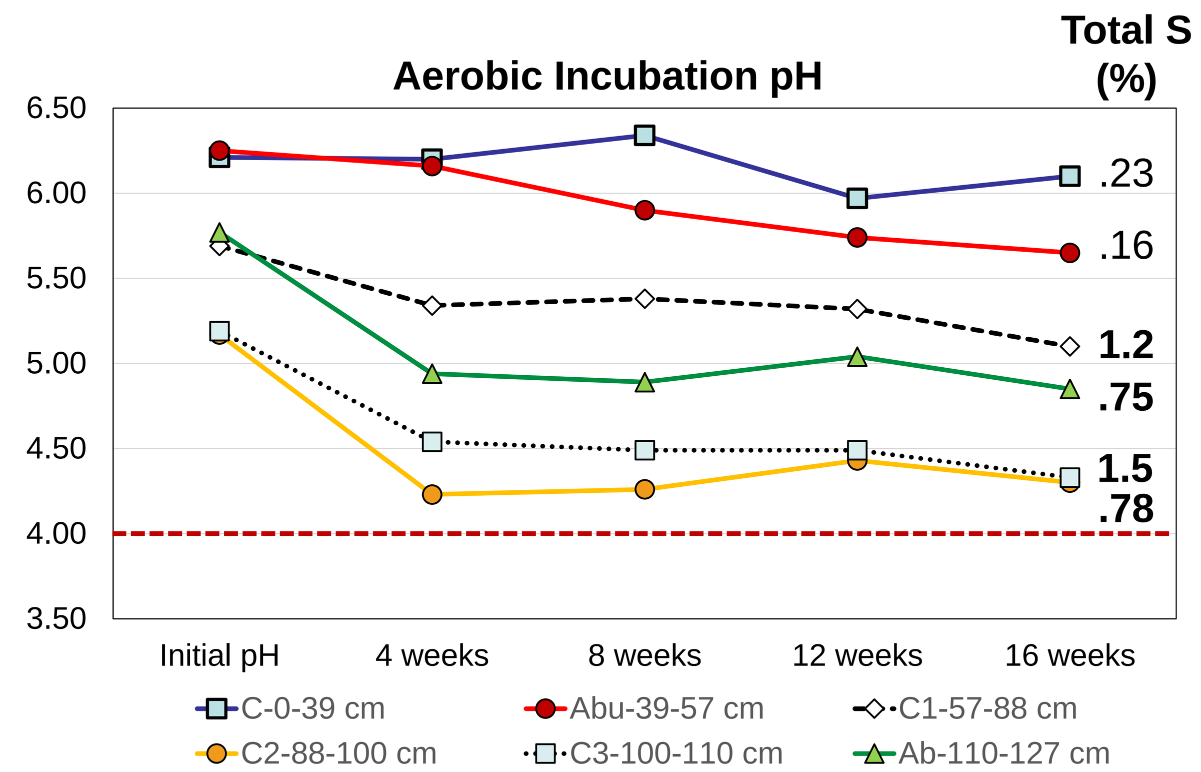

Fig. 7: Incubation pH experiment for BURI soil horizons. Deep horizons that were most contaminated with coal dropped in pH over 16 weeks, but not below the 4.00 pH threshold for true sulfidic materials.

Discussion

Anthracite coal grains were <u>ubiquitous</u> in all alluvial landscapes of the NBSR, accounting from between 1.0-89.5% of the sand fraction, regardless of depth and landscape (**Fig. 3**). This suggests all floodplain areas continue to trap and retain contaminated sediments from floodwaters.

Metal concentrations between islands and deltas were only different with regard to Zn (**Fig. 4**). However, As and Pb levels were most significantly correlated with coal present, suggesting coal deposition is related to these metals (**Fig. 5**).

Total S concentrations were very high in alluvial soils containing significant coal overwash (**Fig. 6**). Initial incubation pH experiments suggest the materials are not sulfidic (**Fig. 7**) and that much of the total S is likely not pyrite or in a reduced form. Because of the age of these deposits (>100 years) sulfides may have already oxidized since initial deposition on the floodplain. Further incubation pH experiments are ongoing.

On-Going Work

- Calculation of metal <u>pools</u> and extrapolation to the total Susquehanna basin (>2400 ha land potentially impacted)

Acknowledgements

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