Spatial Heterogeneity of Buried Soils and Post-Settlement Legacy Sediments in the Christina River Basin

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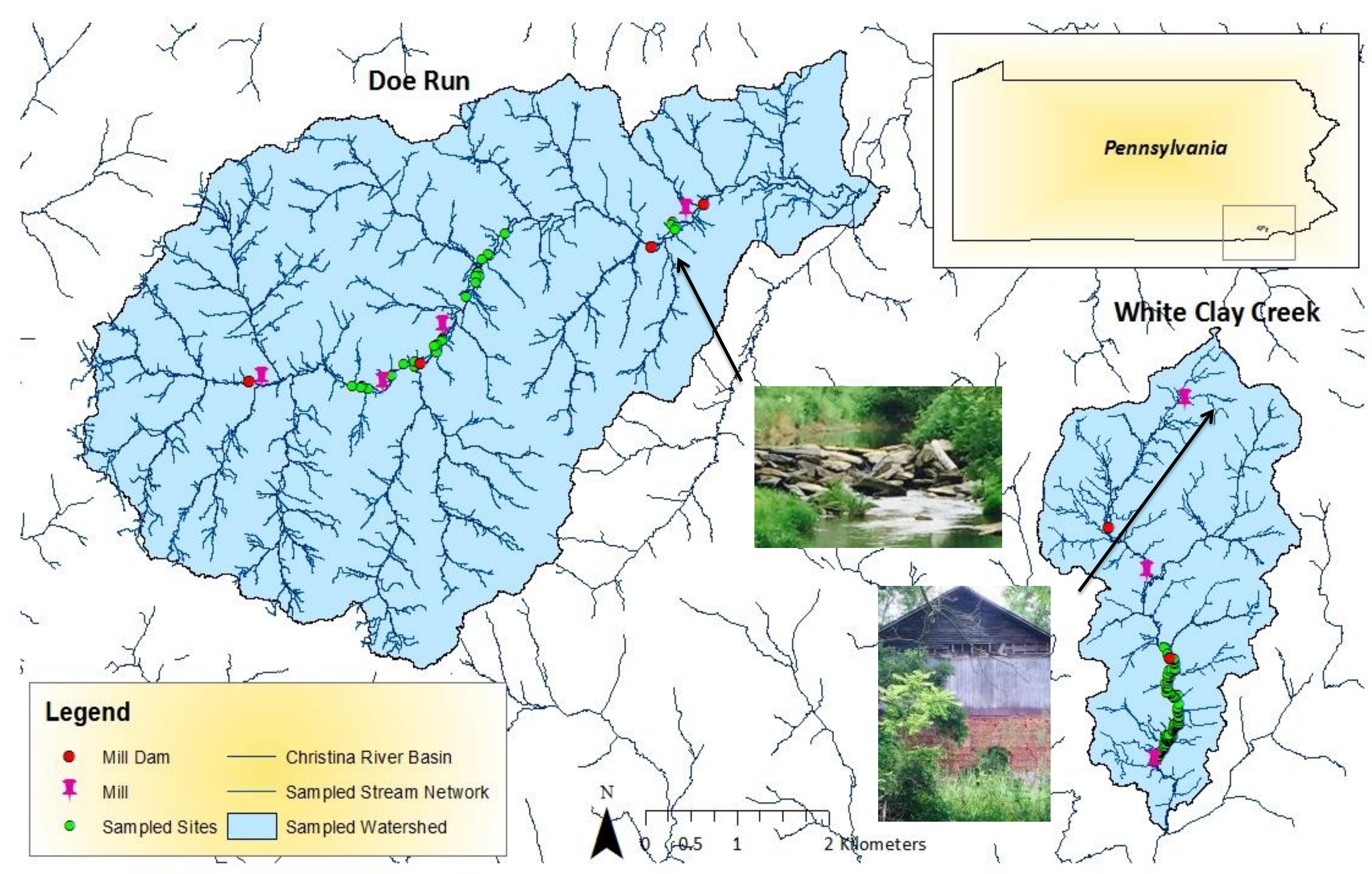
Introduction

Floodplains in the mid-Atlantic Piedmont of the United States are characterized by large post-settlement alluvium deposits originating from colonial-era deforestation and ongoing hillslope land disturbance. Furthering land use impacts, water-powered milling from the late 17th to early 20th century was historically intensive in the region, aiding in the floodplain storage of alluvium deposits behind mill dams. These deposits, referred to as legacy sediments, overlay a comparatively organic-rich, pre-disturbance, buried floodplain soil interpreted as grass-dominated wetlands (Walter and Merritts 2008). Some debate has emerged regarding the ubiquity of both the interpreted pre-disturbance wetlands, their nature, and the thickness of legacy sediments in modern floodplains (Montgomery 2008, Bain et al. 2008).

Today, there is concern about the contributions that legacy sediments may make to sediment and nutrient pollutions of modern streams.

This study, in the broadest sense, aims to **1) characterize the spatial variation, or lack there-of, in legacy sediment thicknesses across floodplain landscape, and 2) determine the variability of the thickness and nature of the buried pre-settlement organic soil.** There is particular interest in the **spatial relations between colonial mill dams and legacy alluvium deposits**. We hypothesized that 1) thicknesses of legacy sediment deposits would vary depending on proximity to historic mill dam locations, and that 2) buried organic soil layers would also vary in thickness and composition, reflecting a heterogeneous pre-settlement floodplain landscape.

Study Area



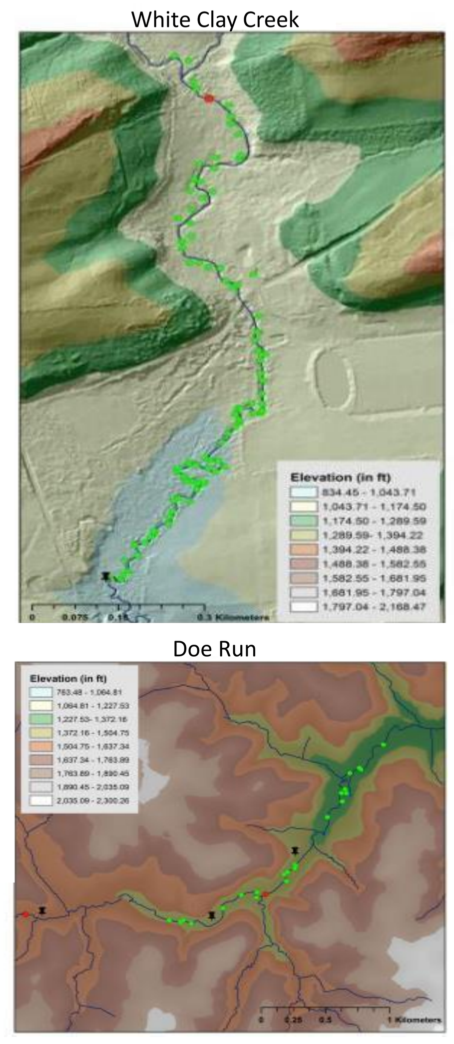


Figure 1 (above): Watersheds of White Clay Creek and Doe Run study reaches located in Chester County, Pennsylvania. White Clay Creek is an 18.5 mile-long designated Wild and Scenic tributary of the Christina River. Doe Run meets White Clay Creek in the Christina River, which serves as a tributary to the Delaware River.

Figure 2 (right): Topographic maps of White Clay Creek and Doe Run floodplains.

Methodology

- 248 samples were collected from exposed banks along White Clay Creek and Doe Run.
- Samples were tested for organic content, grain size, and elemental analysis.
- Measurements of sediment thickness were taken for each sampled layer.
- Historical maps from 1883 were used to identify mill and dam locations.

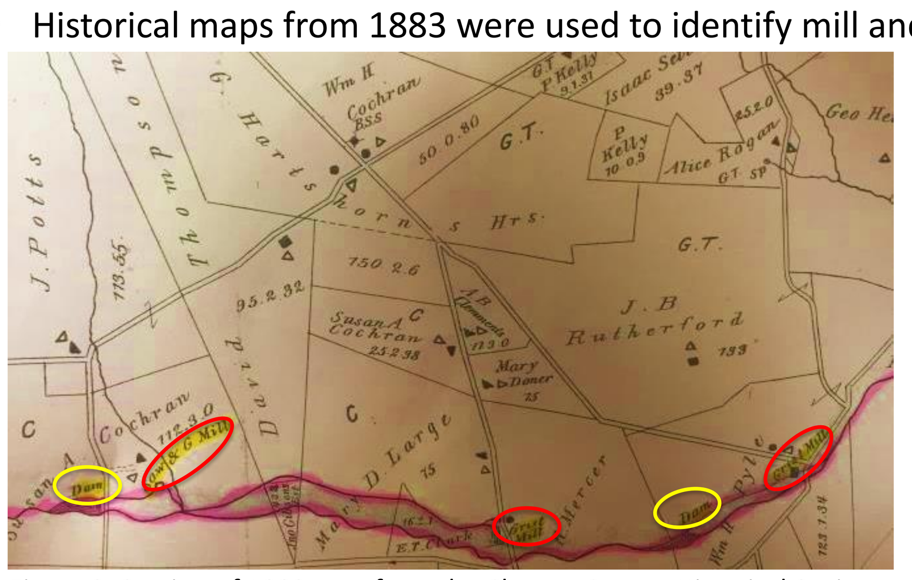


Figure 3: Section of 1883 map from the Chester County Historical Society of Newlin Twp. indicating the location of dams and mills along the study section of Doe Run .

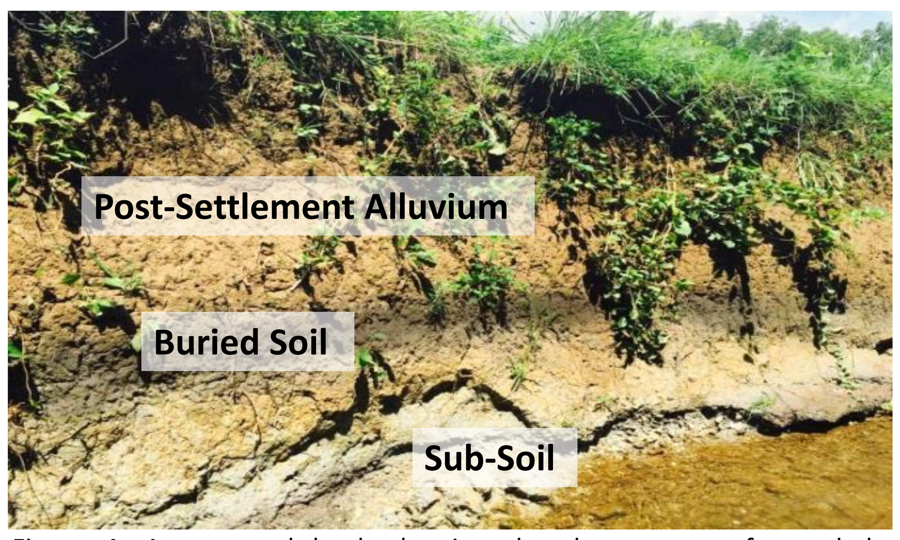


Figure 4: An exposed bank showing the three types of sampled sediment layers, post-settlement alluvium, organic buried soil, and sub-soil.

Results

	Sediment Thickness (cm)				Organic Content (%)			
	Mean	**Standard Dev.**	**Min.**	**Max.**	**Mean**	**Standard Dev.**	**Min.**	**Max.**
WCC BS	35.5	15.2	13	78	5.2%	0.07	1.7%	1.6%
WCC PSA	70.5	24.2	24	161	4.4%	0.015	9.9%	8.8%
DR BS	24.3	12.7	13	55	3.1%	0.016	1.0%	5.6%
DR PSA	86.2	30.0	28	145	3.7%	0.014	1.2%	3.4%

Figure 5: Statistical description of samples processed for % organic content, which was calculated via loss on ignition. Sample thickness was measured in field. Layers analyzed include the post-settlement alluvium(PSA) and buried soil (BS) for White Clay Creek (WCC) and Doe Run (DR).

Grain Size Analysis

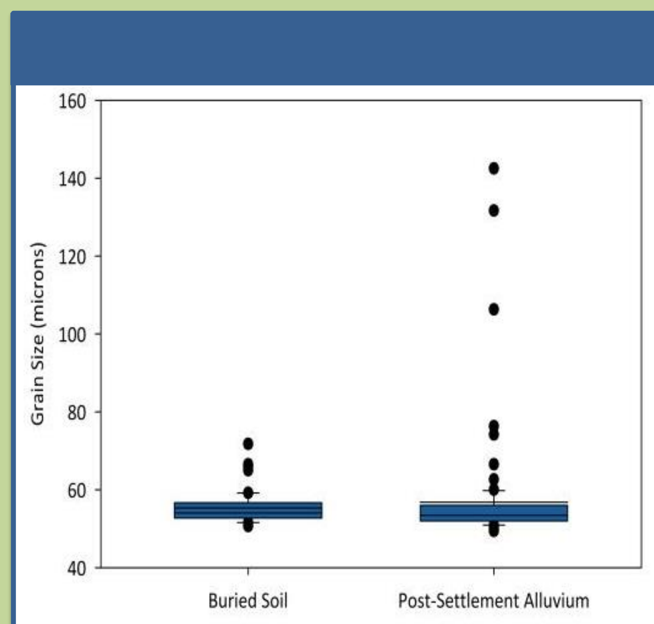


Figure 6: Comparison of D_{10} values for WCC buried soil and post-settlement sediment layers. No statistically significant difference was found.

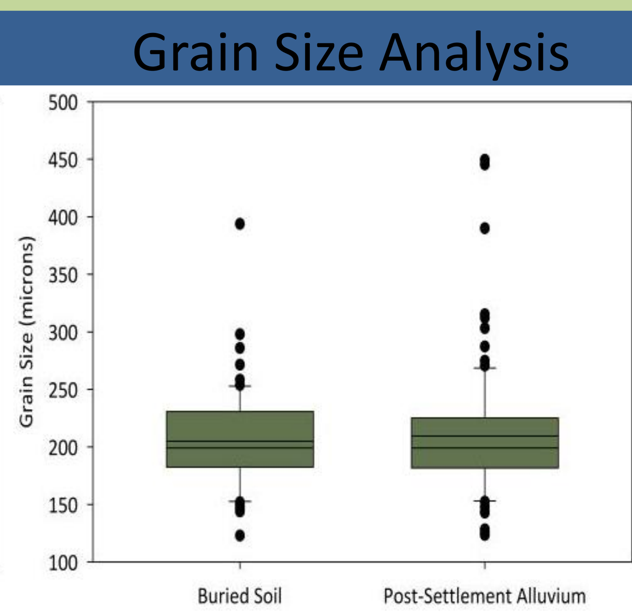


Figure 7: Comparison of D_{50} values for WCC buried soil and post-settlement sediment layers. No statistically significant difference was found .

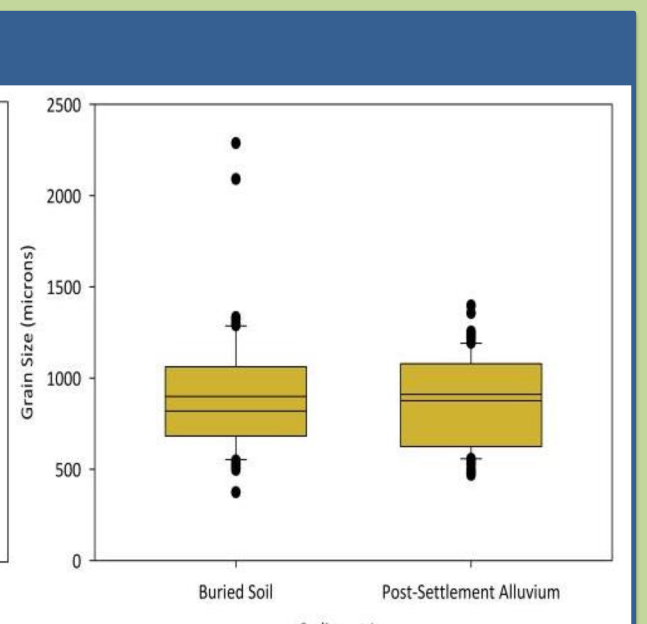


Figure 8: Comparison of D_{90} values for WCC buried soil and post-settlement sediment layers. No statistically significant difference was found.

Sediment Thickness

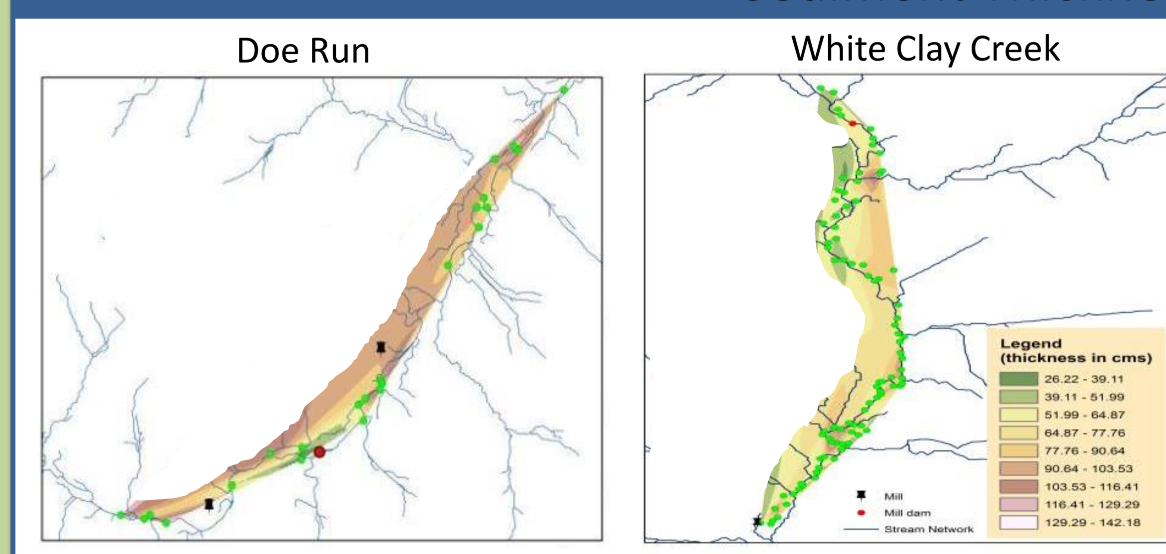


Figure 9-10 (left to right): Isoline of post-settlement alluvium concentration showing the thickness of sediment layers for studied reaches in Doe Run and White Clay Creek.

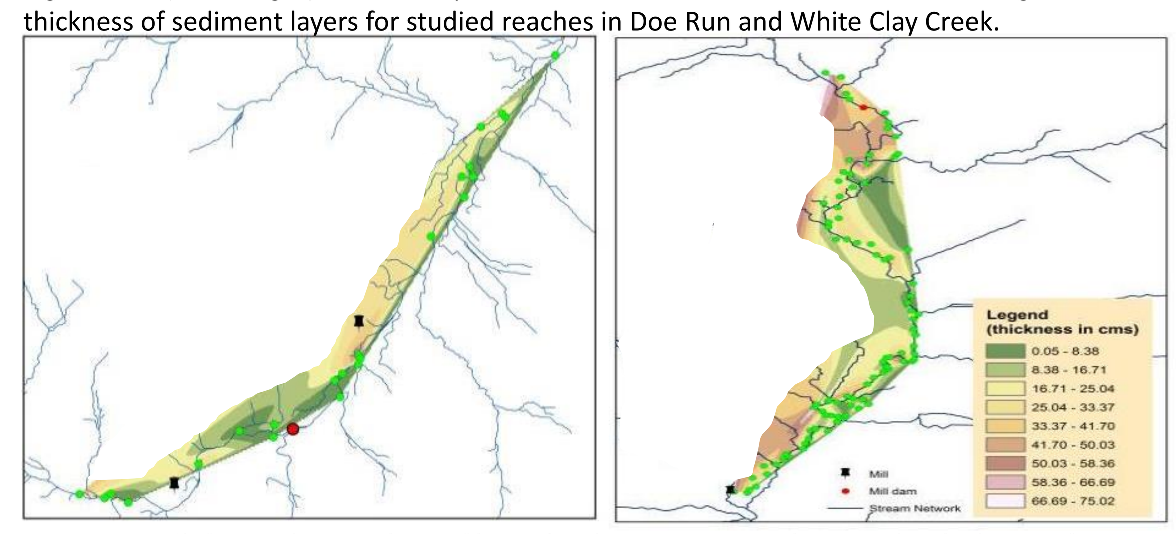


Figure 11-12 (left to right): Isoline of buried soil concentration showing the thickness of sediment layers for studied reaches in Doe Run and White Clay Creek.

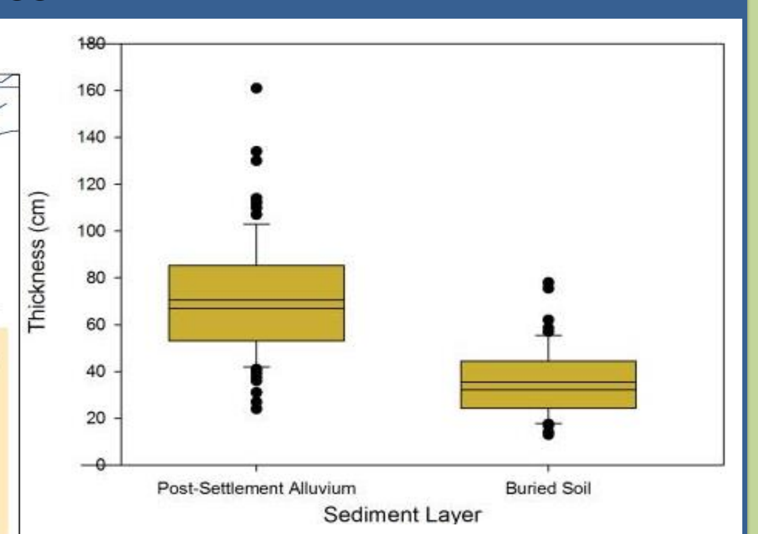
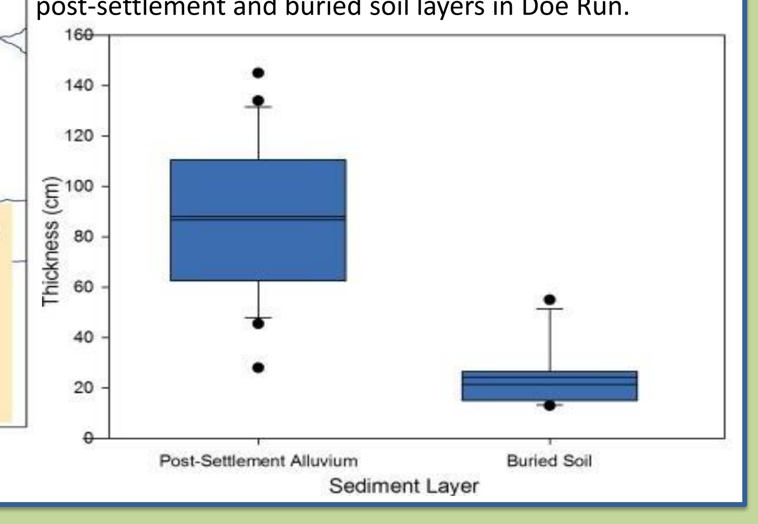


Figure 13 (above): Comparison between the thickness of post-settlement and buried soil layers in White Clay Creek.

Figure 14 (below): Comparison between the thickness of post-settlement and buried soil layers in Doe Run.



Organic Content

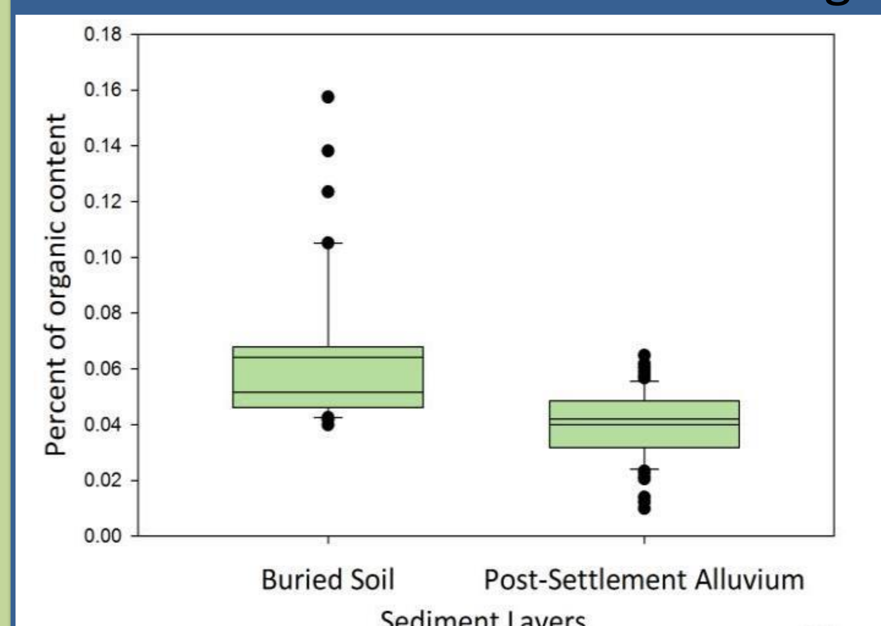


Figure 15: Comparison of % organic material between adjusted post-settlement and buried soil layers of White Clay Creek. Difference between the layer's loss on ignition is statistically significant (P=<0.001).

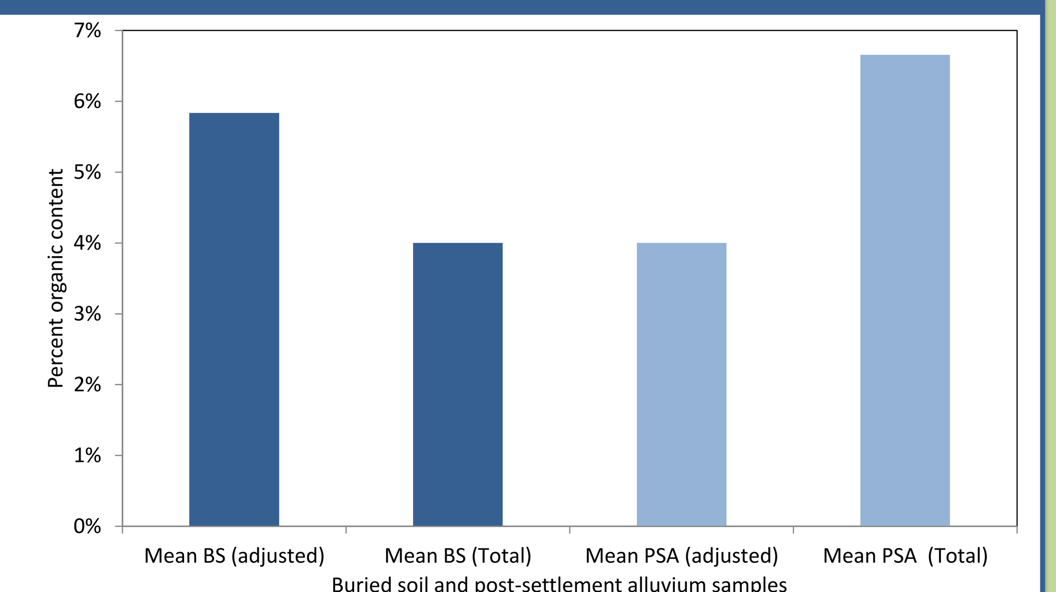


Figure 16: White Clay Creek % organic material including all outlier samples that do not fit the defined post-settlement alluvium (PSA) or buried soil (BS) characterization. Samples are grouped by PSA with high organic content and BS with low organic content. Difference of % organic material between Doe Run and White Clay Creek buried soil is statistically significant (P=<0.001).

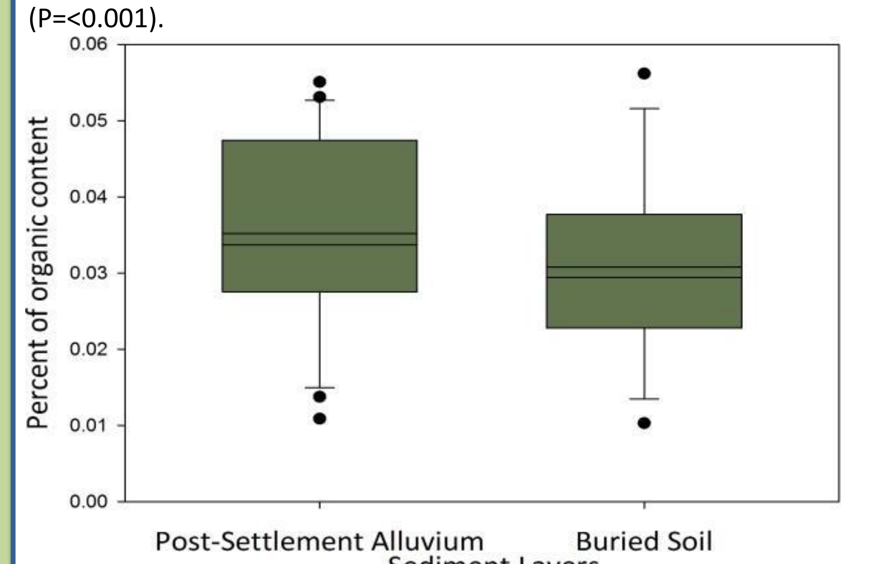


Figure 17: Comparison of % organic material between post-settlement and buried soil layers of Doe Run. Difference between the layer's loss on ignition is not statistically significant.

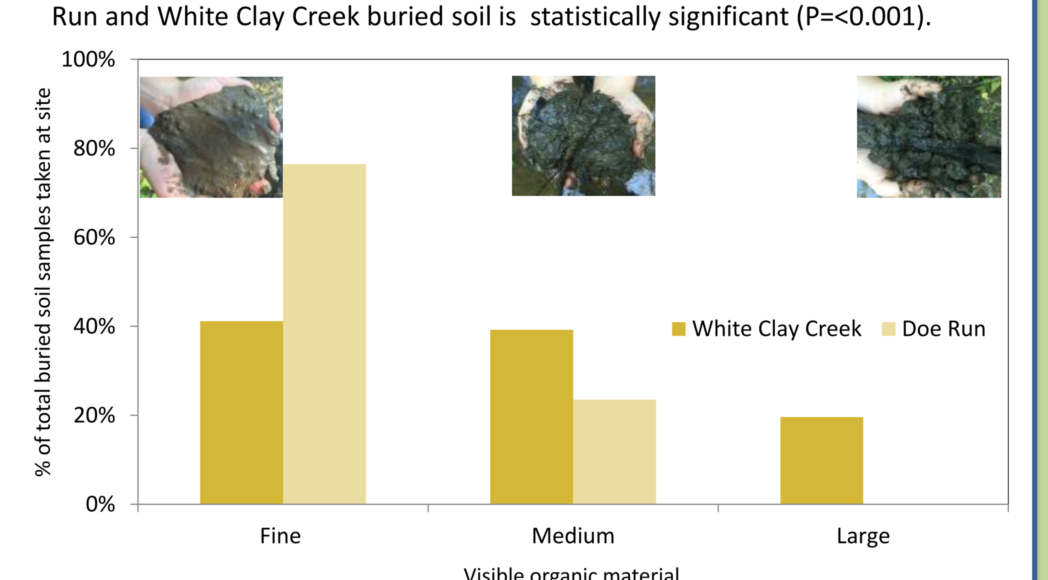


Figure 18: Visible organic material within buried soil samples subdivided by fine particulate organics, small woody debris and leaf liter, or large woody debris.

Discussion

Results from this study suggest that a wide variance exists in the spatial characteristics of post-settlement alluvium and buried soil floodplains along mid-Atlantic Piedmont streams. Variation exists between the thickness and composition of buried organic soil and post-settlement layers, reflecting a heterogeneous pre-settlement floodplain landscape. Variation further exists in post-settlement deposition thickness above mill dam locations, a divergent observation from the described sediment impoundments by Walter and Merritts (2008).

Although it has been previously suggested by Walter and Merritts (2008) that pre-settlement floodplain conditions resembled a scrub-vegetated wetland meadow across the Piedmont Valley, large woody debris and leaf liter contained in buried soil layers of the sampled streams suggests that the landscape was far more heterogeneous and included large forested reaches along the floodplains. Small-scale regional observations, thus, cannot necessarily be generalized to a wider setting without examining the nature of damming and mill use that took place. Historical maps of Chester County from 1883 and LIDAR imagery show that local streams were diverted through a mill race, an alternative to the stacked dam method observed in Lancaster County (Walter and Merritts 2008).

The large extent of post-settlement alluvium deposited along floodplains constitutes a reexamination of natural channel formation. The morphologies and functions of pre-settlement streams are substantially different from those of modern streams, requiring the spatial heterogeneity between streams to be carefully accounted for in stream restoration efforts. A pristine stream thus becomes an unlikely template for restoration because the drivers of stream dynamics have all changed (Wilcock 2008). Contemporary alterations of river sediment constitute a legacy for the future (Wohl 2015).

Moving forward, an elemental analysis will be done in order to:

- Examine carbon content and the potential of pre-settlement floodplains as a carbon sink.
- Use of floodplains for carbon sequestration
- Analyze presence of pollutants such as nitrogen and phosphorus in post-settlement alluvium layer, which are carried downstream

References and Acknowledgements

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