Examining phosphorus contributions from alluvial soils – a comparison of three Vermont, U.S.A. River corridors

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Abstract
The distribution of soils in the floodplain environment is highly complex. The often extreme spatial variability of alluvial soils, in both the vertical and lateral dimensions, creates challenges to adequately capture the range in P values found in the riverine environment. It is important to take samples from a wide range of geographic locations and soil series. Lack of data on phosphorus levels in floodplain soils impede research efforts aimed at reducing the rate of P delivery to Lake Champlain, Vermont, U.S.A. Once estimates for sediment loading rates have been derived, it is crucial to know the P values of the eroded material. Results from soil sampling projects in 2007 and 2008 along the Rock River, Rugg Brook / Mill River and Lewis Creek corridors have greatly expanded the soil database. Profile characterization gives a wealth of chemical and physical data for 28 sites. Preliminary results highlight some important differences between the three study areas. Levels of soluble P, which approximate concentrations of P in the soil solution, the mobile fraction, were higher in the Rock River samples. Across all sites, percent carbon and silt content tend to be correlated with higher P values.

Key Words
Phosphorus, sediment pollution, Lake Champlain, benchmark soils, soil series.

Introduction
Lake Champlain, located in the northeast of the U.S., suffers declining water quality with every year. Target levels for phosphorus inputs to the lake have been set by the two bordering states of Vermont and New York, as well as, the bordering province of Quebec, Canada. Water monitoring efforts reveal that many portions of the lake continue to exceed the Total Maximum Daily Load (TMDL) for phosphorus (LCBP 2008). Eroding soils from stream banks may be one of the largest sources of sediment and phosphorus pollution entering Vermont's surface water (DeWolfe *et al.* 2004). Much effort has been expended on water monitoring, yet few systematic studies have focused on the relationship between soil-landscape variability and background or native levels of P in soil (Ross *et al.* 2008). The intent of this study is to perform a variety of P soil tests in addition to the full range of chemical and physical data from the Natural Resources Conservation Service (NRCS) - Soil Survey Laboratory, to characterize the pedons sampled along three river corridors. The data generated will provide more accurate quantification of P levels in soils from eroding river banks. Moreover, this study will provide insights as to how well alluvial soil map-unit descriptions and generalized data for soil series reflect the actual soil characteristics found at specific sites.

Methods
A total of 28 sites have been sampled to a depth of over 120 cm, in most cases. Three river corridors which are spread out geographically across northern Vermont were studied (Figure 1). The majority of samples are from so-called "benchmark soils" which are distributed widely throughout numerous physiographic regions of the northeastern United States. Efforts were made to take samples in areas that were in close proximity to sloughing banks. Many Vermont streams and rivers are incising downward into the streambed, resulting in floodplains that no longer receive sediment when the river is at flood stage (Figure 5). The increased velocity of floodwaters, trapped in the channel, further exacerbates the problem of eroding river banks; thus there are extensive areas from which to take samples. The goal was to find areas that have been largely unmanaged, without fertilizer inputs, in order to gain an understanding of background P levels in relatively unaltered soils. The riparian corridor sampling project has been a joint undertaking of the University of Vermont and USDA-NRCS. Parallel efforts to develop a bank stability / toe erosion model by the USDA Agricultural Research Service, in collaboration with the Vermont Department of Environmental Conservation, will also benefit from the expanding database of P levels in alluvial soils that is being developed from this study. Pedon characterization studies previously conducted over the past decades by NRCS in Vermont did not include data for phosphorus. The Agricultural Testing Laboratory at the University of Vermont has done

Figure 1. Three Vermont River Corridors along which soil pedon samples were taken.

extensive testing of the top 30 cm of the soil for farm field samples but the samples lack precise spatial data. It is important to see how P levels vary in the soil profile with depth, as bank erosion removes material far below the soil surface. Samples of all horizons from each soil pit were analyzed separately. The laboratory techniques employed by the USDA Soil Survey Laboratory are fully described in the Soil Survey Methods Manual (Burt 2004). Soil layers that were over 25 cm in thickness were split into separate samples. This allowed investigation of chemical differences within a seemly homogenous horizon, at least to visual and tactile observation. Each river corridor makes a transition from a surrounding landscape of glacial till deposits in the headwaters, to a predominance of lacustrine silts and clays, originating from glacial lake and marine sediments from past glacial episodes, near the mouth of each river. The alluvial veneer overlies a variety of parent material (Table 1). Sampling was targeted to encompass areas both within and outside the maximal extent of glacial lakes and seawater incursions from earlier geologic epochs.

Table 1. Taxonomic Classifications of the subset of sites that are "Benchmark" Soils.

Series name	U.S. Soil Taxonomy Reference	Number of sites
Winooski	Coarse-silty, mixed, active, mesic Fluvaquentic Dystrudepts	3
Hadley	Coarse-silty, mixed, superactive, nonacid, mesic Typic Udifluvents	7
Limerick	Coarse-silty, mixed, active, nonacid, mesic Fluvaquentic Endoaquepts	8
Buxton	Fine, illitic, frigid Aquic Dystric Eutrudepts	2
Vergennes	Very-fine, mixed, active, mesic Glossaquic Hapludalfs	2

Results

Alluvial soils do not conform to the standard ABC model of profile development (Riecken and Poetsch 1960). Constant input of new sediment confounds the sequence of: A horizons accumulating organic matter, chemical tansformations in the B horizons and the original parent material being transformed by the soil development processes. An A horizon can easliy be destroyed or buried. B horizons may never develop. A diagnostic test for alluvial material is the uneven distribution of carbon throughout the soil profile. The frequently chaotic sequence of horizons in an alluvial soil profile, complicates sampling protocols. Decreasing P levels with increasing depth, normally found in soil profiles is not often observed in alluvial soils (Figure 2).

The Rock River has the worst water quality of any tributary of Lake Champlain (Figure 4). A comparison of soluble P levels among all three river corridors, shows the Rock River samples to have a higher proportion of measurable readings (Figure 3). The water soluble phosphorus is the fraction extracted by distilled water in laboratory tests. It represents an attempt to approximate the P concentration in the soil solution, i.e. the mobile P (Burt 2004). The highest reading in the Rock River samples is from an A horizon that had high organic matter content. While, the highest reading of all the samples was from a Cd horizon of lacustrine origin. Samples from Lewis Creek had few readings that registered above trace amounts, except in the clay soils dominated portion of the corridor.

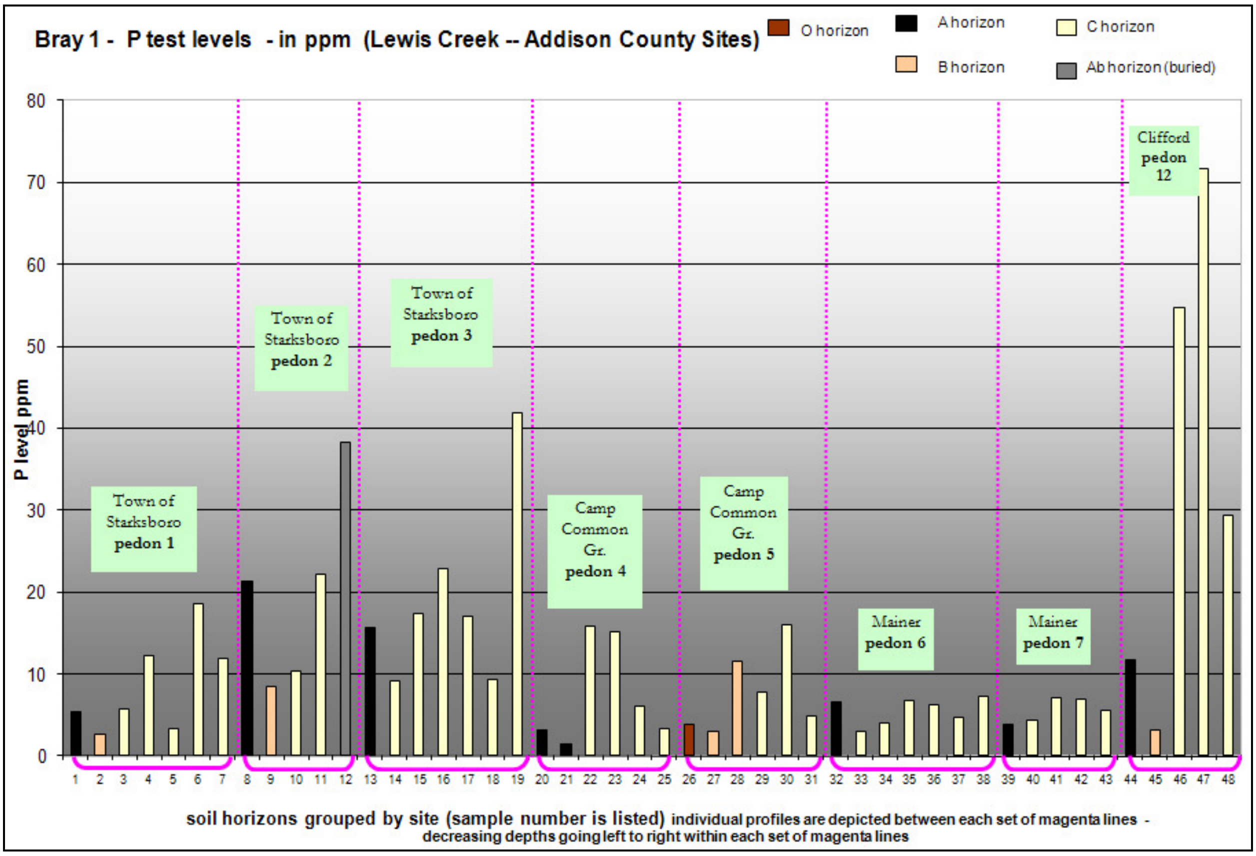

Figure 2. Comparison of P levels using the Bray 1 test between horizons and pedons along Lewis Creek.

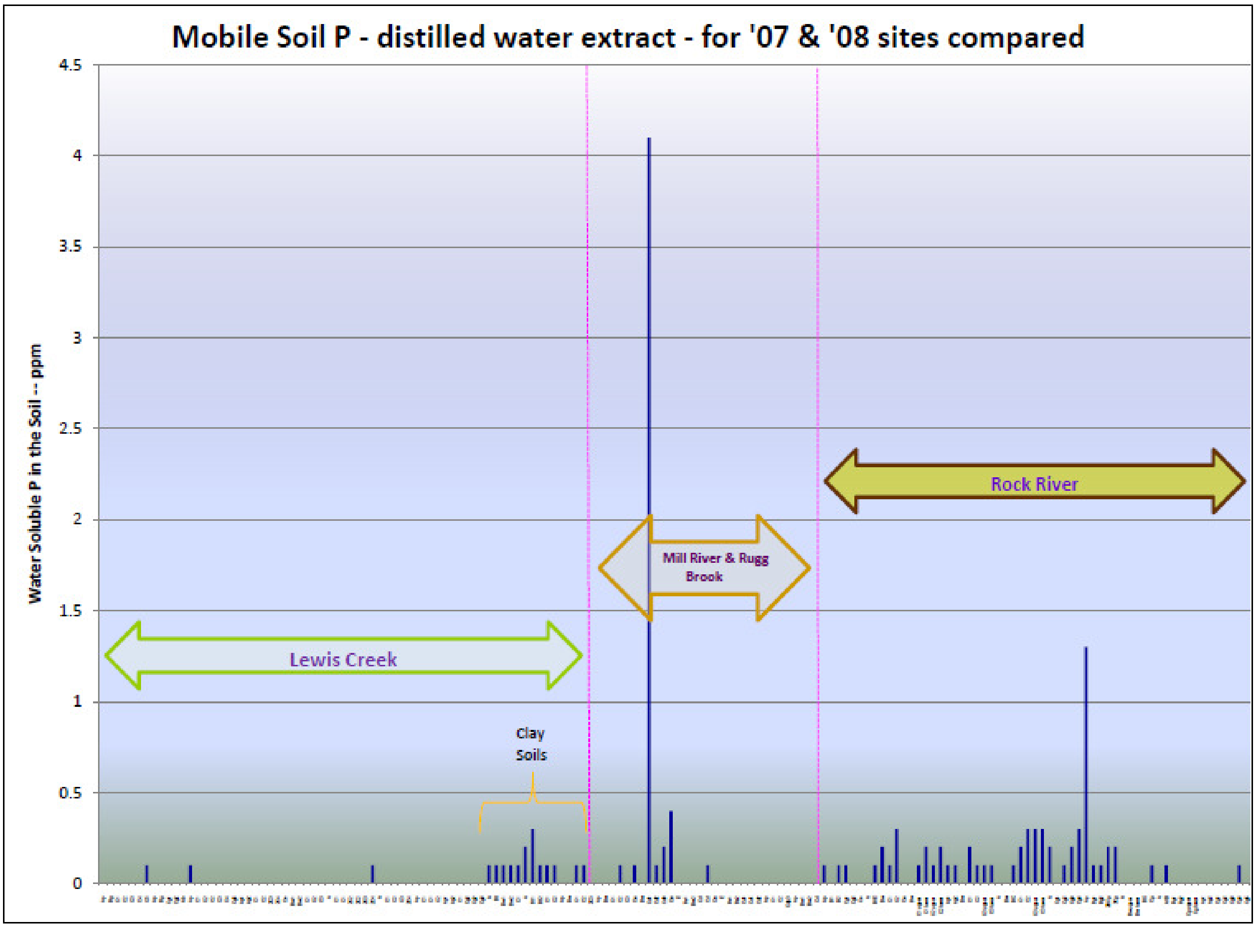

Figure 3. Comparison of soluble P levels between all horizons and pedons – along Lewis Creek, Rugg Brook/Mill River and the Rock River.

Figure 4. Near the mouth of the Rock River – evidencing severe water quality issues.

Figure 5. Bank erosion along Rugg Brook – within the past 5 years the streambed has incised 2.5 meters.

Comparisons of soil P levels with soil properties measured in the laboratory and in the field will reveal relationships and the factors that are most influential, as more data become available. P tests have largely been focused on agronomic production; less is known about which test or combination of tests best quantify "algal-available P" - as soil particles move from land to become suspended in water.

Conclusion

Preliminary results indicate differences of P levels and dominant soil textures among the three river corridors. The high variability of soil P levels among horizons in the individual site profiles and among different profiles within the same soil series, reinforces the need to develop a database that encompasses the full range of values that might be encountered. Additionally, the soil series as currently delineated on soil maps for these riparian areas often greatly oversimplifies the actual complex pattern of soils. Due to severe geomorphologic processes, data from field samples in alluvial landscapes often fall outside the limits listed in the range of characteristics for soil series in the NRCS Official Series Description (Drohan *et al.* 2003). Continued characterization studies will provide site specific data and that will allow a more comprehensive evaluation of how floodplain soils are mapped. Rather than using a single soil series, it may be more realistic to use soil complexes, consisting of several soil series in one map-unit.

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