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Poster Session: "Undergraduate Geoscience Research Highlights"

Origin of stream bed sediments in northwest New Jersey: Factors of land use and source determined by trace element analysis

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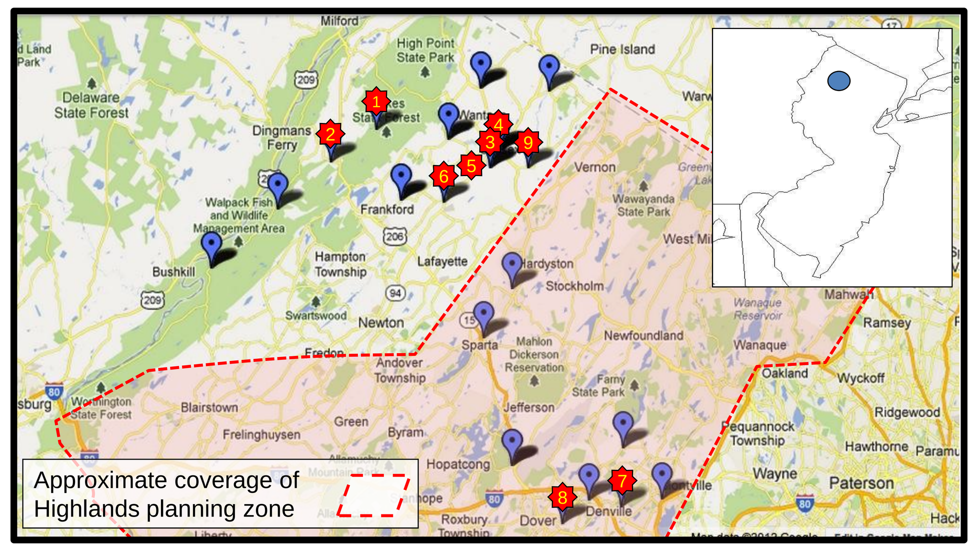
Introduction

The works of Gellis et al. (2009) and Devereux et al. (2010) demonstrated the applicability of trace elements to fingerprint the source of stream sediments in the Chesapeake/Susquehanna watershed. Sediment sources could be attributed to various land uses/land covers, important in assessing the impacts of agriculture, deforestation or reforestation, and urbanization on erosion and sedimentation of rivers and wetlands.

Northwest New Jersey has similar concerns for its water resources, given the land use tensions of growing urbanization as well as the need to conserve natural resources and open space. We attempt a similar study here, as part of the larger NSF REU-sponsored project at Montclair State University and NJ School of Conservation, "Multidisciplinary environmental science research on forest lakes in Northwest New Jersey." The eventual goal is to assess the origin of stream sediments in a cross-section of streams in the Highlands Region and Delaware Valley, by means of field-based fluvial geomorphic surveys, and sampling and laboratory analysis of stream sediments as well as contributing soils from upland areas in the watersheds.

The results presented here illustrate an initial analysis of stream bed sediments only. *What trace elements are best related to stream stability measures? Can trace elements indicate proximal sources of sediment, such as stream banks and reworked channel sediments?*

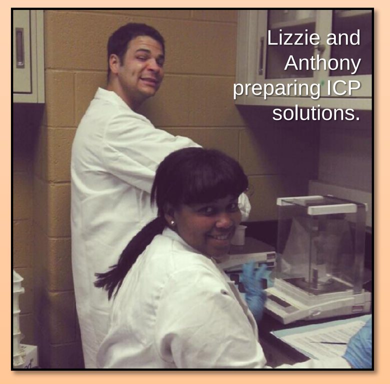
Fig. 1. Locations studied during the REU project. Red-starred locations are subject of this presentation: 1-2 Flat Brook (mostly forested), 3-6 Papakating Brook (agriculture, some urban and forest), 7-8 Rockaway River (mostly urban), and 9 Wallkill (forested and agriculture).



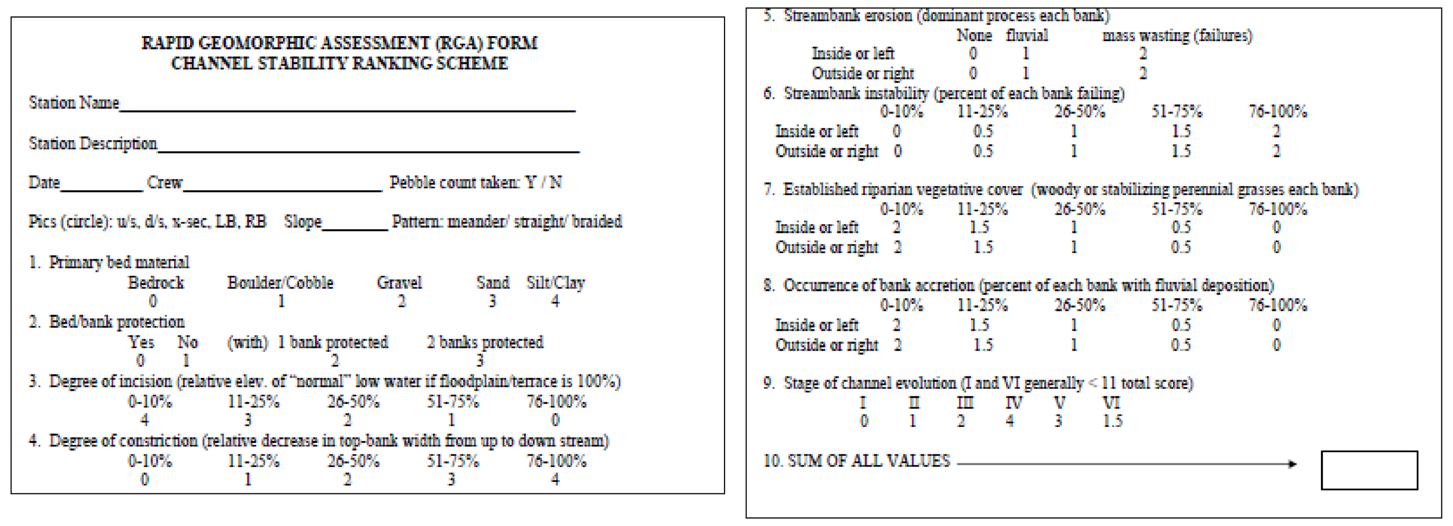
Methods

1. Field locations involved a selection of forested, agricultural, and urban settings. REU team members used the Rapid Geomorphic Assessment (RGA, figure 2), observing stream channel, bank, and floodplain criteria (Kline et al. 2009), to assess channel stability. Stream assessment Samples were obtained from locations along the Flat Brook, Wallkill, and Rockaway River watersheds (see figure 1). Core samples of sediments and soils employed a PVC pipe tool, and sectioning the core into 2-3cm increments into storage bags in the field.
2. Samples were oven dried, then pulverized to a fine powder using a metal rock mortar and pestle and a Model 8500-115 Shatter Box and placed in storage bottles.
3. Approximately 0.1g of fine powder is combined with 0.4g of LiBo flux and fused in a muffle furnace at 1050° C. The molten bead is dropped into a 7% HNO3 solution and dissolved to a 500x dilution factor. The 500x solution is then diluted with 2% HNO3 for a 10,000x dilution suitable for ICP-MS.
4. Sample trace element analysis was conducted by the use of inductively coupled plasma mass spectrometry (ICP-MS) on a Thermo X-Series quadrapole inductively coupled plasma mass spectrometer, housed in the Dept. of Earth & Environmental Studies, Montclair State University. Along with the project samples, 7 USGS rock standards (W-2, G-2, BIR-1, DNC-1, GSP-2, QLO-1, SCO-1) and 4 blanks were used for instrument calibration. A drift solution was measured every sixth sample to correct for variations in ICP-OES instrument sensitivity during each run. Trace element data presented here are the average of 3 replicate runs (Table 1). ICP-MS instrument precision for trace elements is ± 1-6.5%, and accuracy is ± 5% but generally below ± 2%. Samples were analyzed for W, V, Cr, Co, Ni, Ga, Rb, Sr, Y, Zr, Nb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Pb, Th, and U.

REU team sampling sediment and recording stream channel data.



Lizzie and Anthony preparing ICP solutions.



RAPID GEOMORPHIC ASSESSMENT (RGA) FORM
CHANNEL STABILITY RANKING SCHEME

Station Name________

Station Description________

Date________ Crew________ Pebble count taken: Y / N

Pics (circle): u/s, d/s, x-sec, LB, RB Slope________ Pattern: meander/ straight/ braided

1. Primary bed material

Bedrock	Boulder/Cobble	Gravel	Sand	Silt/Clay
0	1	2	3	4

2. Bed/bank protection

Yes	No	(with) 1 bank protected	2 banks protected
0	1	2	3

3. Degree of incision (relative elev. of "normal" low water if floodplain/terrace is 100%)

0-10%	11-25%	26-50%	51-75%	76-100%
4	3	2	1	0

4. Degree of constriction (relative decrease in top-bank width from up to down stream)

0-10%	11-25%	26-50%	51-75%	76-100%
0	1	2	3	4

5. Streambank erosion (dominant process each bank)

	None	fluvial	mass wasting (failures)
Inside or left	0	1	2
Outside or right	0	1	2

6. Streambank instability (percent of each bank failing)

	0-10%	11-25%	26-50%	51-75%	76-100%
Inside or left	0	0.5	1	1.5	2
Outside or right	0	0.5	1	1.5	2

7. Established riparian vegetative cover (woody or stabilizing perennial grasses each bank)

	0-10%	11-25%	26-50%	51-75%	76-100%
Inside or left	2	1.5	1	0.5	0
Outside or right	2	1.5	1	0.5	0

8. Occurrence of bank accretion (percent of each bank with fluvial deposition)

	0-10%	11-25%	26-50%	51-75%	76-100%
Inside or left	2	1.5	1	0.5	0
Outside or right	2	1.5	1	0.5	0

9. Stage of channel evolution (I and VI generally < 11 total score)

I	II	III	IV	V	VI
0	1	2	4	3	1.5

10. SUM OF ALL VALUES →

Fig. 2. The field-based Rapid Geomorphic Assessment (RGA) survey (Kline at al. 2009).

Abstract

Streams in northern New Jersey span a broad range of environments and land covers, including urban, agriculture, wetlands, and forest. Stream sediments receive input from these environments, and indicate pulses or stages of land use change, or stability. In this project, we use trace elements, including rare earth elements, to fingerprint sediment sources and differentiate between land use as well as immediate sources of sediment, such as stream banks, floodplains, uplands, or urban inputs.

Samples of stream bed, stream bank, floodplain sediments, and urban and upland soils were obtained from eight locations in the Flat Brook, Rockaway River, and Wallkill River watersheds in Sussex and Morris counties in New Jersey. Samples were prepared for trace element analysis with inductively coupled plasma mass spectrometry (ICPMS). Element content was compared to land use, sediment source, and a stream stability index (the Rapid Geomorphic Assessment, RGA). Several elements (V, Cr, Ni, Sr, Pb) were statistically significant at distinguishing between land use. Zr and W were able to distinguish sediment source (i.e. floodplain, bank, upland, etc.) with statistical confidence. Related to stream and bank stability, the RGA showed significant positive correlation with Cr and Co content (increasing Cr and Co with increasing instability), indicating these elements as good proxy indicators for bank erosion. Ongoing studies of element ratios, combined with Cs-136 and Pb-210 activity levels by gamma detector, will further refine the sediment characterization, with an eventual goal of approximating a sediment budget across different land uses and identifying hot spots that deliver disproportionately high amounts of sediment.

Results

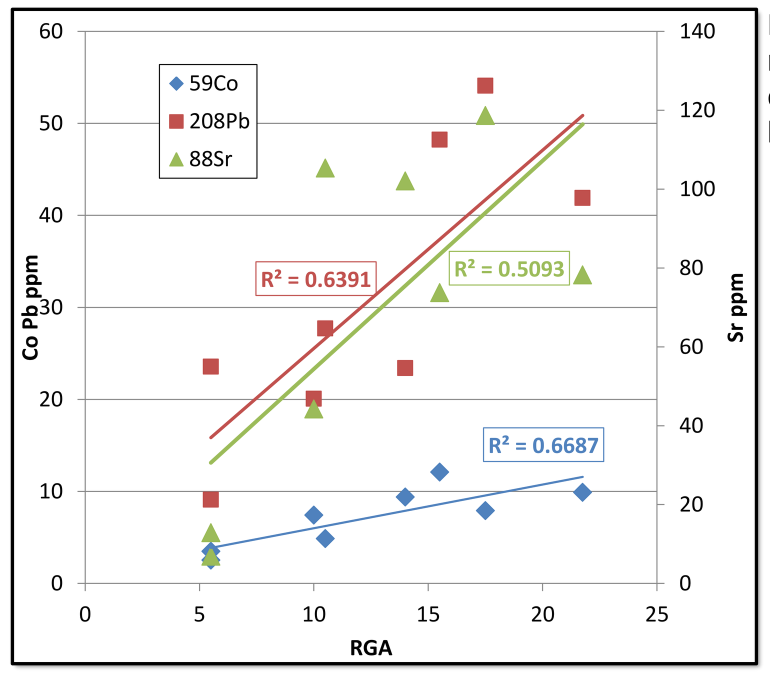


Fig. 3. Cobalt, Lead, and Strontium are examples of trace elements exhibiting a linear relationship with the RGA value: as RGA increases (increasing instability), trace element content increases. These elements are more mobile when bank erosion is higher. Trend lines with respective correlations are shown.

Fig. 4. Gallium, Rubidium, Yttrium, and Niobium are examples of trace elements exhibiting a complex nonlinear relationship with the RGA value. Trace element content peaks at middle RGA values, and decreases at the RGA extremes, a relationship that approximates a polynomial function (curves shown for Rb and Y, with respective correlation). Reasons for this relationship are unknown, but may have to do with particle size of the sediment, such as clay content.

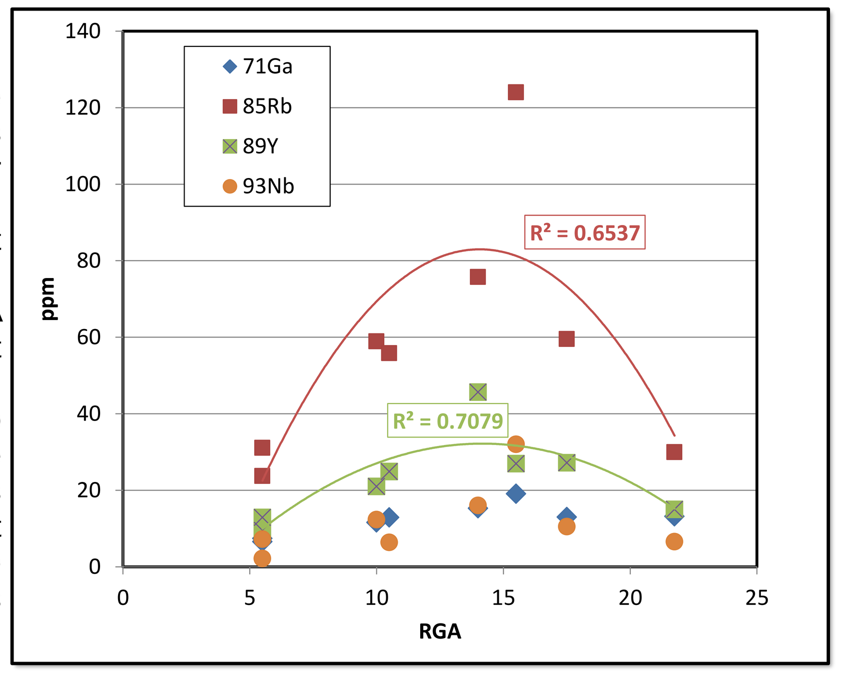
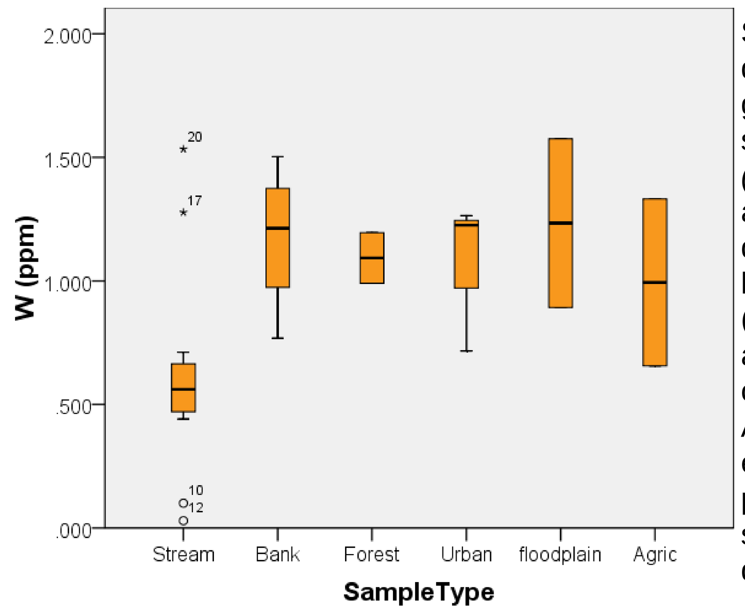
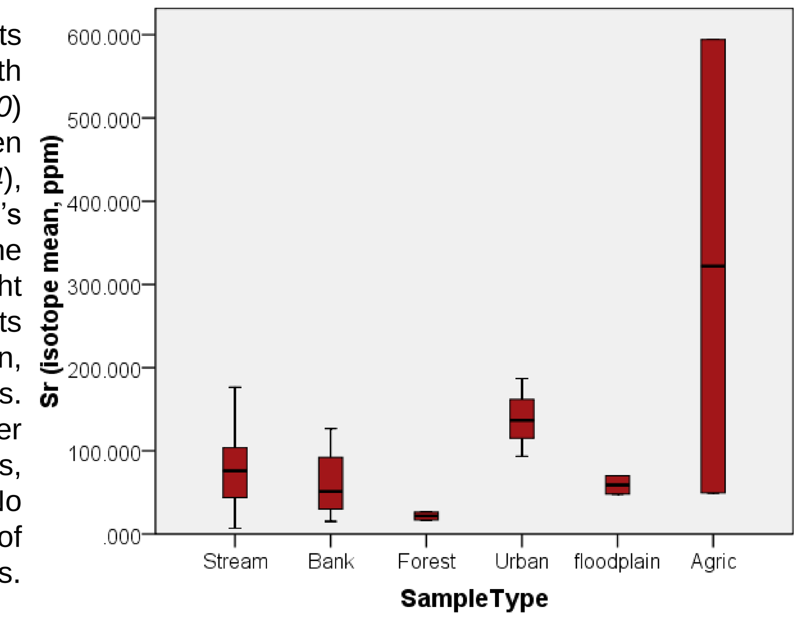


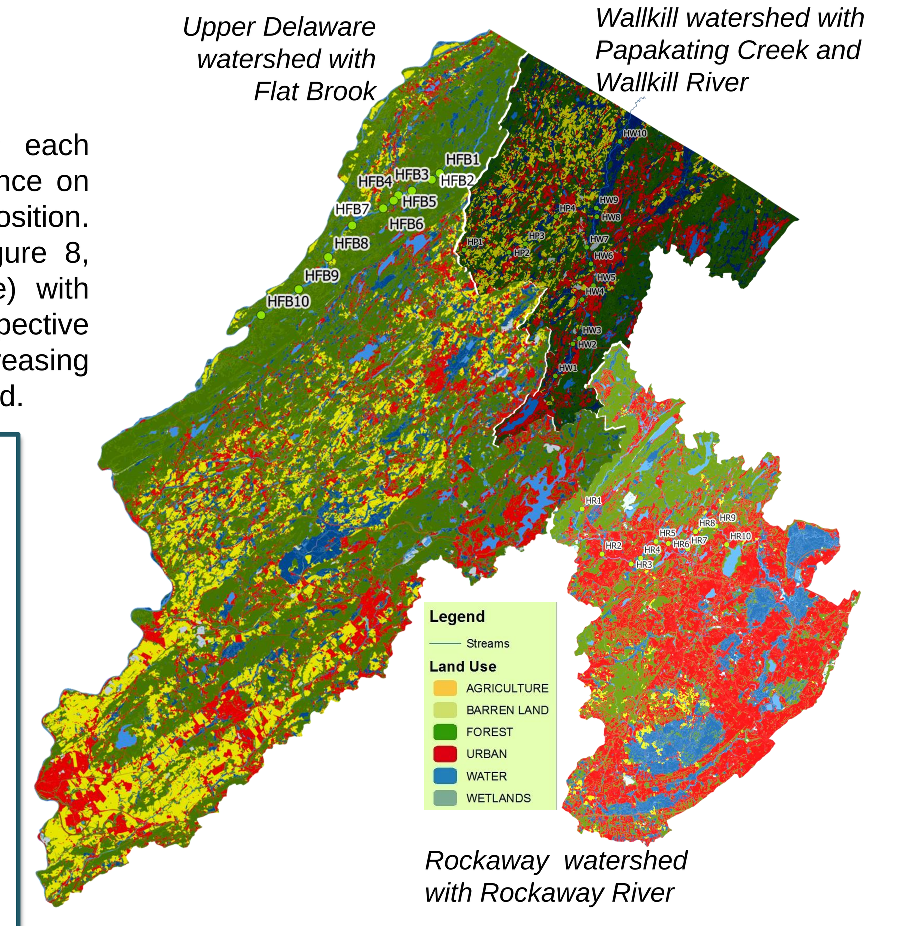
Fig. 5 Examples of stream quality as measured by RGA. Wallkill (left), north of Sussex, has vegetated but moderately unstable banks (RGA=14). Flat Brook (right), at NJSOC, is heavily forested and bouldery, with very stable banks (RGA=5.5).

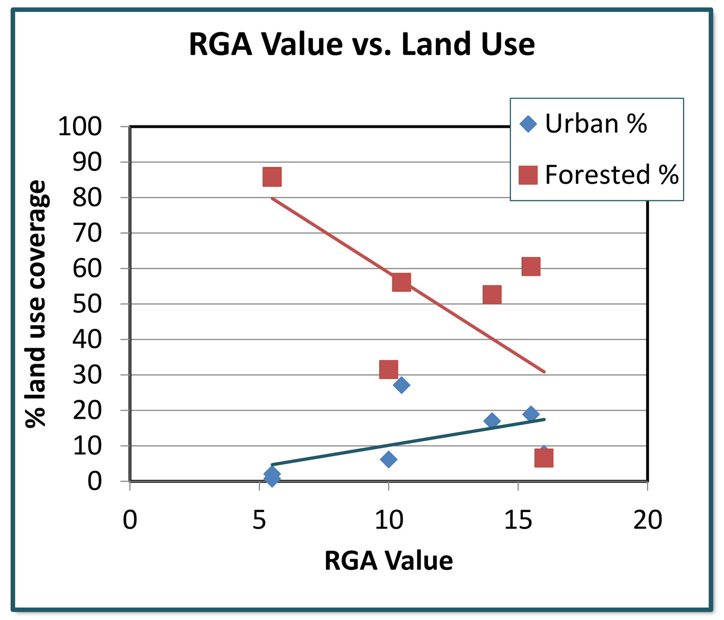


Several of the trace elements differentiated sediment source with good (*p<0.05*) to marginal (*p<0.10*) statistical significance: Tungsten (*p=0.052*), Strontium (*p=0.024*), and Cobalt (*p=0.090*). Tungsten's distribution is shown to the left(Figure 6a), and Sr on the right (Figure 6b). Stream bed sediments are distinctly lower in tungsten, compared to other sources. Agricultural soils, and to a lesser extent urban sediments, preferentially contribute Sr. No single trace element is capable of distinguishing all sediment sources.

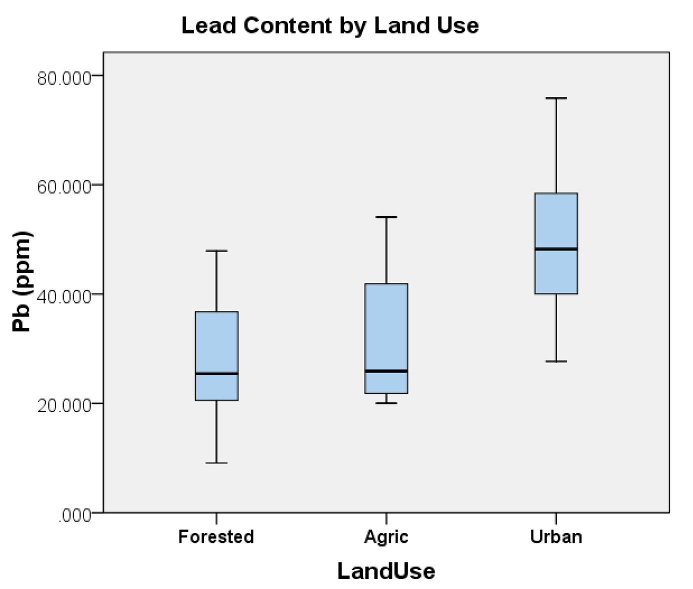


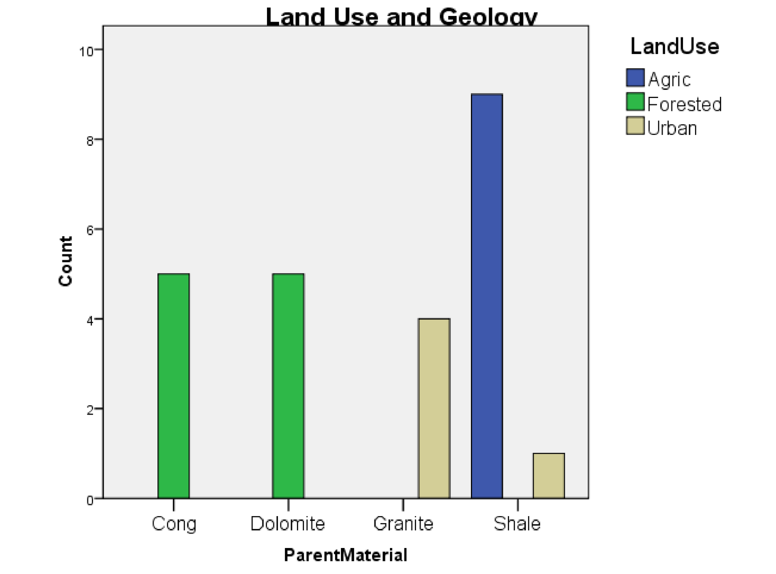
The predominant land use or land cover in each drainage basin (figure 7, right) had some influence on both stream quality and the trace element composition. RGA was shown to correlate to land use (Figure 8, below). RGA value increases (more unstable) with increasing urban land coverage in the respective watershed. RGA value decreases with increasing forested land coverage in the respective watershed.





Land use class is differentiated by tungsten (ANOVA *p=0.044*) and lead (ANOVA *p*=0.022). The boxplot of lead is shown here (Figure 9 below left), indicating elevated lead in urban areas. There is a field data bias, however. An accidental outcome of the data gathering strategy showed a covariance of land use with geology. Urban areas were sampled only in granitic or shale bedrock areas; conglomerate and dolomite dominated in forested watersheds (figure 10, below right).





Discussion and Conclusions

- Trace elements respond differently to within-channel erosion potential. Several elements, notably Cobalt, Lead, and Strontium, indicated a good correlation to the RGA stability assessment (fig. 3). In other words, an increase in these elements in indicative of increased within-channel and/or bank erosion. Other elements, such as Gallium, Rubidium, Yttrium, and Niobium, indicate a more complex relationship with stream stability (fig. 4). Both very stable (low RGA) and very unstable (high RGA) conditions seem to limit the abundance of these trace elements, while middle values of stability have higher trace element content. It is clear that a better understanding of the trace element and sediment budget is needed, a topic of ongoing research. There is already indication that the RGA is well correlated to land use, such as coverage of forested and urban land in the watersheds.
- Sediment sources are important, and some trace elements reveal the origin of the sediment (within the channel, in the banks or floodplain, from upland forested or agricultural areas, or urban sources). No single element is able to differentiate all sediment sources, and a combination of elements would be necessary to discern all sediment sources.
- Our preliminary chemical analysis indicates that some trace elements are also related to land use, relating to the sediment source. Chromium, for instance, is statistically significant in determining a difference between forested, agricultural, and urban influences. These relationships will be explored further as additional samples are analyzed. Currently, the existing samples co-vary land use with local geology, a confounding issue.
- We hope to gain a better understanding of the trace element flux and budget such that it relates to erosion and sediment transport and storage. Samples are being processed for Pb-210 and Cs-136 activity levels that will serve to differentiate recent versus older sediments.

Acknowledgments

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