Informing the regulation of sediment in streams: determining natural rates of sediment generation in economically important landscapes

Societies are dependent on access to abundant, clean water. Sediment, a non-point source pollutant, has been identified as a major cause of impairment in United States water bodies (USEPA, 2000; Chao et al., 2007). Sediment affects water quality both physically and chemically. High turbidity increases reflected heat, decreasing water temperature (Ryan, 1991). Filtration and chemical treatment for sediment removal increase water treatment costs (Holmes, 1988). Material adsorbed to sediment can desorb and trigger chemical changes in streams (Pintilie et al., 2007); for example, heavy minerals, bacteria, and organic matter can reach water bodies adhered to sediment and change water chemistry; sediment-associated organic matter can lower dissolved oxygen levels (Bilotta and Brazier, 2008).

Sediment is sourced from erosion at both the watershed scale and from channel banks (Trimble, 1997). There are several pathways by which sediment reaches streams: overland flow, channel and bank erosion, and mass wasting (Randhir and Hawes, 2009). Although erosion rates (and thus rates of sediment supply to watersheds) are related to natural factors, such as geology and climate, accelerated erosion is often triggered by human activities (Douglas, 1969; Ouyang et al., 2010). Deforestation, development, agriculture, and the increase of impervious surfaces in watersheds can significantly increase erosion and sediment loading to streams and rivers (Foley et al., 2005; Marshall and Shortle, 2005).

Methods for quantifying erosion (and sediment generation) have evolved from measuring the volume of sediment deposited in standing water and normalizing by area draining to the sampling point (Judson, 1968), to the measurement of suspended solids carried by a stream (Judson and Ritter, 1968), to isotopic methods such as the use of cosmogenic nuclides (Bierman and Nichols, 2004). During the 1990s, cosmogenic isotopes emerged as the premier method to estimate long-term or background erosion rates from sediment (Bierman, 1994'; Bierman and Steig, 1996; Brown et al., 1995; Granger et al., 1996). Cosmogenic isotopes are formed when rocks and sediment are exposed to cosmic rays (Lal and Peters, 1967). As a result of this interaction, isotopes, such as ^{10}Be, accumulate in rock and soil. Production of these isotopes decreases exponentially with depth and is in general inconsequential below 2 meters depth in rocks (Lal and Peters, 1967). Because of this, ^{10}Be is a good indicator of the near-surface residence time of materials - hence, the rate at which earth surface is eroding. Cosmogenic nuclides provide a robust method to quantify erosion rates, because they integrate enough time to average out extreme events on centennial time scales. These isotopes have the potential to provide long-term data that can help place human influences on the landscape and its processes in context (Bierman and Nichols, 2004; von Blackenburg, 2005).

^{10}Be has been widely used as a proxy of long term erosion rates. However, as Portenga and Bierman (2011) showed, there are still areas where no cosmogenic nuclide analysis has been done (Figure 1) and thus long-term, background rates of erosion and sediment generation are poorly, if at all, constrained.

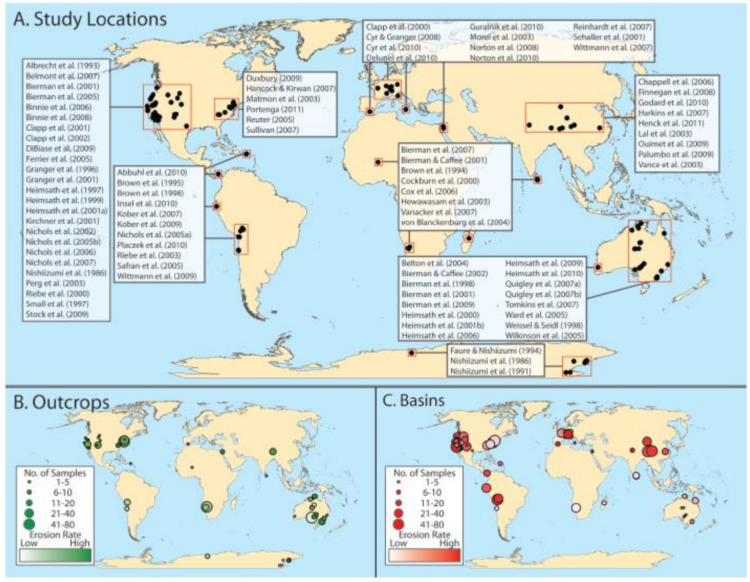

Figure 1: Geographical distribution of cosmogenic ^{10}Be erosion rate date, from Portenga and Bierman, 2011. (A) Location of studies compiled in the paper, (B) distribution of outcrop samples and (C) drainage basin samples.

My PhD will determine background erosion rates in areas of the United States and Brazil that are important for economical and environmental reasons (the agricultural midwestern US, the Pacific Northwest where salmon fisheries are important, and the Atlantic Highlands of Brazil where both forestry and agriculture are economically critical). I will integrate GIS and cosmogenic nuclide analysis to determine background rates of sediment generation and relate these rates to landscape metrics such as slope, elevation, and vegetation communities. Knowledge of background or natural sediment generation rates is key for responsible environmental management, in particular when determining Total Maximum Daily Loads (TMDLs). These loads, a regulatory goal, must be set so that they are consistent with sediment loads supplied by natural systems before human intervention and land development. For prediction of sediment loads in unsampled watersheds, it is important to know how geographical factors such as topography, climate and rock type correlate with sediment generation rates. I will use one summer each for field work (sample collection) in the US and Brazil. Work in Brazil will be facilitated by my advisor's existing collaborations with hydrologists at the Federal University of Rio Di Janeiro. The Brazil portion of my research will provide the cross-cultural experiences I need to become a competent scientist with a global view of the environment. According to Nerad and Cerny (2002), the next generation of researchers are expected not only to acquire traditional academic research competencies and professional skills but also multi-cultural competencies in order to work and function in a world of international teams in a global setting.

The midwestern United States, where agriculture is an important economic activity (Paggi et al., 2011), is one of the regions where little cosmogenic nuclide analysis of background sediment generation rates has been done; yet, there are clear indications that agricultural activity has impacted water quality by increasing nutrient and sediment loading (Tong and Chen, 2002). Quantification of background sediment generation rates in this region is critical because these rates represent the amount of sediment that the landscape produces naturally and which streams can transport without altering system function.

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A third gap in ^{10}Be-derived sediment generation rates is the heavily settled and productive Atlantic highlands of Brazil, a developing nation. Here, intensive agriculture and forestry threaten the environment, economy, and stream health. The Atlantic highlands are intensively farmed, and the site of significant forestry activity but the areas relies on clean water for the tourism economy, in particular, the beaches to which rivers discharge. Fieldwork and a semester residency in Brazil brings the opportunity to learn another culture, language, and to consider the impact of agricultural activity on food security issues.

Geographical Information Systems (GIS) are helpful tools for environmental assessment, because they provide a means to display geographic data and explore the spatial distribution of an environmental phenomenon and identify impacted areas. GIS makes it easy to quantify landscape-level variables (i.e.: elevation, slope, watershed area), extract information from digital images (flow direction, watershed delineation, among others), and perform spatial analysis over large areas. I will integrate GIS with field work and clean room laboratory work to quantify erosion rates and relate them to physiography. Interpretations of my results will take into account economic factors such as tourism, salmon fishing and export, and agriculture.

My work, providing cosmogenic-derived erosion rates for environmentally sensitive and economically important areas will be a significant contribution to Environmental science; specifically, my work will provide the data needed to set regulatory thresholds for sediment delivery from disturbed systems Portenga and Bierman (2011) concluded that erosion rates, and thus sediment generation rates, can be predicted more accurately at regional rather than global scales – thus the need for more fieldwork and isotopic analysis. Publication of my data will benefit several disciplines including water quality research, land use practice decisions, and natural resources management. My research will shed some light on the interactions between environment, society, and economy from a sediment generation perspective.

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Sosa-Gonzalez, Veronica

U.S. Citizen

EPA-F2012-STAR-E3: Safe and Sustainable Water Resources: Water Quality--Hydrogeology and Surface Water (E3)

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Informing the regulation of sediment in streams: determining natural rates of sediment generation in economically important landscapes

Doctoral, June 2015

Watershed science

Entering Doctoral Student (ED)

Personal Statement

With only one percent of the world's water available for human consumption, its sustainable use is a priority. Natural resources management is evolving from a science-based discipline to a cross-disciplinary realm integrating economics, science and the study of human-dominated landscapes. It's this new dimension of resources management that inspires me. I would like to use my scientific knowledge to reduce the gap between science and real world application by working with communities and giving them the tools to manage resources locally, for a positive regional outcome.

Community managed resources became important to me early in my undergraduate years. It began during my time at a community center back home where I tutored children in math and science. My community was affected by unequal economic development and its effects, when a stream was altered to build luxurious residences. It was then that I became aware of my desire to get involved in environmental education and communities. I explored my leadership by organizing and conducting activities for different educational levels and target populations (kids, teenagers, and adults).

Other experiences in science education have required leadership skills, which allowed me to polish my own. As an intern for the Vermont EPSCoR Streams Project in 2009, I led field sessions that highlighted the use and importance of a GPS and the usefulness of GIS in water quality research for high school students. This past summer I mentored two undergraduate students for the Streams Project. My involvement ranged from project design and sampling to data analysis and poster preparation. I was also an assistant faculty member for the Governor's Institute of Vermont: Environmental Science and Technology, a week-long residential learning program for highly motivated high school students. I guided field work sessions, laboratory sessions, and global environmental issues discussions. Even though grabbing the students' attention and involving them posed a challenge at the beginning, the experience was invaluable. I proved to myself that my ability to promote science education is one of my biggest assets. Leadership is a useful skill, but it does not stand on its own, it is best employed with collaborative efforts.

Team work was an everyday tool for field, laboratory and office work, when I was interning with the USGS. I collaborated on several projects during the internship, but my focus was on a project studying land use changes and their influences on river flow in Puerto Rico. Working as part of the Cosmogenic Nuclide Laboratory and Geomorphology Research Group, while attaining my Master degree, provided another opportunity to solidify my capabilities as a teammate. Communication, organization and shared allocation of tasks are common practice in the group, to guarantee quality research and data. Experiences that strengthen my collaborative potential also improved my communication skills. Training incoming researchers in the Cosmogenic Nuclide Laboratory facilities, assisting at the Governor's Institute, mentoring undergraduates, and serving as a Teacher's Assistant for an undergraduate level laboratory provided opportunities to transfer knowledge in assertive ways.

Each of these experiences contributed in part to my decision to conduct research in water resource management and get involved in community-managed natural resources. My Master's program at UVM gives me a holistic perspective on resource management and the tools I need to connect the dots and discover ways to use my acquired skills. Communication skills, leadership, knowledge transfer potential, passion, laboratory work skills and discipline, combined to provide me the skill set for engaging in rigorous scientific research, and taking part in the creation of sustainable solutions for environmental problems. These sustainable solutions will only come from cross-disciplinary research and the community's involvement in applying solutions and decision making processes.

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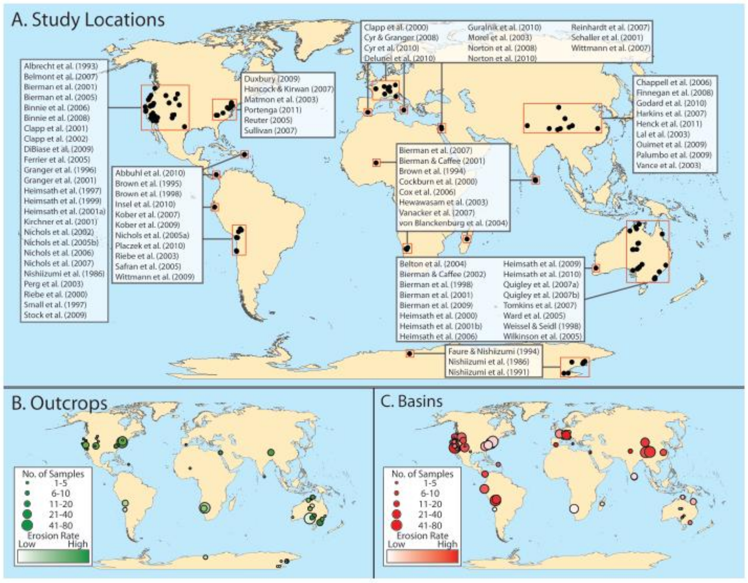

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Background information

Education

- University of Vermont, Burlington, VT
  2010-Present
  M.S. in Natural Resources
  Advisor: Paul Bierman

- Universidad de Puerto Rico, San Juan, PR
  2005-2010
  B.S. in Environmental Sciences
  Cum Laude
  Advisors: Jorge R. Ortiz-Zayas and José A. Molinelli

Experience

- Teaching Assistantship
  University of Vermont, Burlington, VT
  Fall 2011-Spring 2012
  Leading laboratory and field sessions, facilitating water and soil samples analysis, grading laboratory reports and oral presentations

- Research Assistanship
  University of Vermont, Burlington, VT
  Fall 2010-Summer 2011
  Quartz extraction and purification, ^{10}Be extraction from quartz, sample preparation for Accelerator Mass Spectrometry analysis

- Streams Project mentoring
  Vermont EPSCoR, Burlington, VT
  May 2011-August 2011
  Advise undergrad students, help in their project and sampling design, help in field work and sampling, Guide them on their poster preparation and presentation

- Governor's Institute of Vermont
  Burlington, VT
  June 19-25, 2011
  Leading field and laboratory work sessions, organizing and leading global environmental issues discussions

- Intern
  March-July 2010 USGS, Guaynabo, PR

Water quality sampling, updating water quality database, digitizing maps using ArcGIS

- Intern
  May-August 2009 VT EPSCoR Streams Project, Burlington, VT
  Research on water quality trends using ArcGIS, conducting field sessions for high school students, guiding educational sessions for high school students using ArcGIS

- Tutor (Biology, Chemistry and Physics), Universidad del Este, Carolina, PR
  January-May 2009
  Guiding study sessions, developing study guides and preparation tests

- Exchange Student
  Spring 2008 Universidad Autónoma de Madrid, Madrid, Spain
  Courses: Statistics, Basic GIS, Environmental Systems, and Social Geography

Presentations

- Geological Society of America National Meeting
  October 8-12^{th,} 2011 - Minneapolis, MN
  Determining long-term erosion rates in Panama- using ^{10}Be
- VT EPSCoR Streams Project Symposium
  April 19th, 2010 – Burlington, VT
  A GIS-based analysis of the impacts of landscape-level variables on water quality