Pollyanna Lind – SRA Report September 15, 2013

**Geomorphology and sediment dynamics of a tropical montane river**
**-- Rio Pacuare, Costa Rica**

Short Article

Tropical rivers support richly diverse ecosystems and the growing socioeconomic demands of expanding populations. Anthropogenic growth coupled with climate change will inevitably strain the valuable resources that these rivers provide including freshwater, rapid hydro-electricity development, ecology, and agriculture.[1,2] And yet the physical processes (geomorphology and hydrology) of tropical rivers remain greatly understudied, especially when considering the multitudes dependent on them, and the varied habitats that they provide. Most recently, scientists identified stream flow and transport of sediments as critical components for addressing adaptation and mitigation of tropical systems for anthropogenic and climate change impacts.[3] In humid mountain tropical systems, the hydraulic and geomorphic processes are complex and rapid.[4,5] Climate patterns in these regions create both low-flow periods and intense precipitation events that result in large magnitude flows.[6] Preliminary findings from this research indicate that high flows capable of mobilizing large volumes of sediment including boulder-size grains can occur multiple times in a year.

This research quantifies *for the first time* the physical (geomorphic) processes of a dynamic tropical mountain river. A unique combination of field research and remote sensing are applied to define complex channel and floodplain characteristics. This project maps and characterizes sediment sources and estimates transport rates to create reach-scale sediment budgets. Hydraulic and sediment transport models will quantify sediment flux to characterize system sensitivity to projected climate change and impoundment (dam) scenarios. As the first research of this types, this project provides a broad view of sediment dynamics and channel geomorphology. Beyond expanding the science of tropical river geomorphology, the results of this work ideally will aid in the sustainable development, management, and conservation of tropical rivers by offering fundamental information to scientists and resource managers about how these systems work.

This research is being conducted on the Rio Pacuare, located in Costa Rica's Talamanca Mountains in Central America. Like many other rivers of the Talamanca Mountains, the Rio

[1] Vörösmarty, C.J., Green, P., Salisbury, J. and Lammers, R.B., 2000. Global Water Resources: Vulnerability from Climate Change and Population Growth. Science, 289(5477): 284-288.

[2] Kaygusuz, K., 2004. Hydropower and the world's energy future. Energy Sources, 26(3): 215–224.

[3] Wohl, E., Barros, A., Brunsell, N., Chappell, N.A., Coe, M., Giambelluca, T., Goldsmith, S., Harmon, R., Hendrickx, J.M.H., Juvik, J., McDonnel, J. and Ogden, F., 2012. The hydrology of the humid tropics. *Nature*, 2: 655– 662.

[4] Wohl, E., 2005. Downstream hydraulic geometry along a tropical mountain river. In V.P. Singh (Ed.), *The Rio Chagres, Panama*. Water Science and Technology Library. Springer Netherlands, pp 169–188.

[5] Restrepo, J.D., Lopez, S.A. and Restrepo, J.C., 2009. The effects of geomorphic controls on sediment yield in the Andean rivers of Colombia. *Latin American Journal of Sedimentology and Basin Analysis*, 16(2): 79.

[6] Restrepo, J.D., Kjerfve, B., Hermelin, M. and Restrepo, J.C., 2006. Factors controlling sediment yields in a major South American drainage basin: the Magdalena River, Colombia. *Journal of Hydrology*, 316: 213–232.

Pacuare was considered for hydroelectric development in the past and will likely be reconsidered for development in the future. At play here are indigenous-rights, eco-tourism, and the combination of local and international development politics. The Rio Pacuare was also selected as the study area because it is free flowing, relatively accessible, and is defined by a variety of physical characteristics common in Central American mountain rivers.[7]

As a SYLFF SRA fellow I was able to complete extensive field work on the Rio Pacuare from November 2012 through April 2013. This allowed for both wet season (Nov-January) and dry season (Feb-April) data collection. I have extensive field work experience but the dynamic nature of tropical region climate patterns and rivers made this project a more challenging than most. For example, a single rain event could make access to or evacuation from a site hazardous due to quickly rising water levels or road washout. None-the-less, multiple types of surveys were successfully completed. Surveys included digital photogrammetry (Structure from Motion – SFM) to create high-resolution 3-D models for capturing grain mobilization and site characteristics; channel flow velocity, sediment size distribution and composition, channel slope, and channel cross section topography, and; field checking of mapped sediment sources (active floodplains, bars, tributary alluvial fans, and visible hillslope or landslide colluvium). Upon returning from the field, data processing and analysis began immediately. This is the first time that SFM techniques have been used for this purpose and the resulting models from the 2012-13 field season are excellent.

Preliminary findings confirm that tropical mountain rivers are geomorphically connected systems predicted to be sensitive to changes in discharge regimes. Irregularly dispersed sediment inputs (tributary, landslide, floodplain, channelbed) result in gluts and pulses of downstream sediment fluxes. Grain size distribution tends to be related to channel slope and width rather than common down-stream fining patterns. Qualitative analysis indicates that impoundment (dam construction) and climate change (altered precipitation regimes) have the potential to alter local and system-wide geomorphic processes. The scale of those alterations will be estimated through the use of computer modeling.

The complexity and size of this project requires an additional season of data collection before results are finalized. The coming year's data will then be processed with last year's data for use in hydraulic and sediment transport computer models. The models will quantify volume of sediments transported annually, confirm the rates of connectivity occurring in the system, and estimate the impacts of climate change and dam construction scenarios on the Rio Pacuare.

Thanks to the SYLFF SRA fellowship this project developed into a substantial study. As a result, funding from the Geological Society of America and the National Science Foundation have been awarded to complete the research in 2013-2014. Presentation of the preliminary findings from 2012-2013 were presented at the International Association of Geomorphologists conference in Paris, France – August, 2013. There is still work to do to complete this dissertation research but it would have never gotten this far or developed so successfully with SYLFF.

[7] Marshall, J.S., 2007. Geomorphology and physiographic provinces in Central America: geology, resources, hazards (Vol. 1). Bundschuh, Jochen and Alvarado, eds. Taylor & Francis Group plc, UK.

Research site on the Rio Pacuare – February 2013


Structure from Motion (SFM) 3D model of site surface – Rio Pacuare