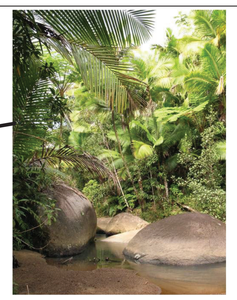
National CZO Program | CRITICAL ZONE OBSERVATORIES
studying the zone where rock meets life
funded by NSF

Luquillo Critical Zone Observatory

Penn University of Pennsylvania

How do "Critical Zone Processes" Vary with Bedrock Lithology?



Granodiorite Bedrock (Icacos USGS)

Hornfels Peaks

Volcaniclastic Bedrock (Bisley USFS)

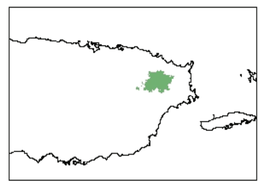
Coastal Plain Alluvium

Meteorologic Stations Stream Gages

General LCZO information available at www.sas.upenn.edu/lczo
Data available at www.sas.upenn.edu/lczodata
Real time Hydrologic data available from the USGS waterdata.usgs.gov/pr/nwis/rt

LCZO research is based around 7 broad hypotheses that address the following science questions:
How does saprolite advance vary with regolith thickness and landscape position?
How are soil carbon, surface redox, and plant nutrient cycling coupled and decoupled from lithology, landscape position, and climate?
How does lithology influence sediment supply and the residence time and routing of water and solutes across the landscapes?
How do the morphology, biogeochemistry, and vegetation of riparian zones vary with lithology, climate, and basin size?
How does basin lithology influence depositional environments and stratigraphic resolution of the coastal and fluvial sediments?

LCZO Sampling and Monitoring Sites



Soil Survey: 227 Quantitative pits; Analysis of collected material will focus on answering the following questions. What effect do parent materials have on soil texture, moisture holding capacity, nutrient pools and nutrient cycling. The study will also investigate the effect parent materials have on forest communities such as their species composition, biomass, productivity and the cycling of N and P.
Deep Wells: Three deep wells drilled to 37, 27 and 28 meters to investigate the depth of fracturing (depth of the critical zone), depth of weathering and investigate the character of bedrock-weather interface in volcaniclastics. Monthly water sampling will also be conducted for chemistry, recharge rates and response. Correlations between groundwater and climatic variations will be investigated.

Instrumentation and Data Sets

Instrumentation: Over 8 stream gages, 3 walk up canopy towers, 4 meteorological stations, three deep observation wells, lysimeters nests, an extensive GIS system and numerous long term vegetation plots are available.

Signature Data Sets: Because the Luquillo Mountains have been a research center on tropical forests for over a century, many long term environmental data sets exist. For references and online access see the LCZO data page (https://www.sas.upenn.edu/lczodata), the Luquillo LTER (http://luq.lternet.edu/) and the USGS -WEBB (http://water.usgs.gov/webb/) pages. Signature data sets include:

Hydrology: Hourly and daily measurement of radiation, air pressure, temperature, relative humidity, precipitation, wind speed, wind direction exist for 4 metrological stations. The world's longest known record of weekly rainfall and throughfall and associated chemistry is maintained at the site and available. In addition to the eight stream gages that are maintained by the USGS and the LCZO maintains and publishes discharge records for three stream gages in the Bisley Watershed.

Geochemistry and Biogeochemistry: The LCZO is developing a extensive data set of Luquillo soils and bedrock geochemistry. The basic chemistry of weekly rainfall, throughfall, and stream flow is also maintained and available from the LCZO and Luquillo LTER web pages.

Spatial Data Sets: A 10 m DEM and associated spatial data sets are also available for the upper Luquillo Mountains. LiDAR based spatial data sets are being developed.

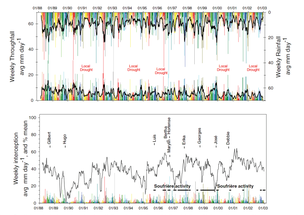


Figure 2 Meteorological events, volcanic activity and weekly throughfall, rainfall, and interception as weekly mean mm per day. Black line represents running average. Bar colors represent January in grey, February in yellow, March in dark yellow, April in orange, May in red, June in dark grey, July in light green, August in dark green, September in light blue, October in dark blue, November in cyan and December in olive.

Heartsill-Scalley, T.; Scatena,F.N.; Estrada,C.; McDowell,W.H.;Lugo,A.E. 2007. Disturbance and long-term patterns of rainfall and throughfall nutrient fluxes in a subtropical wet forest in Puerto Rico. Journal of Hydrology 333, :472- 485.

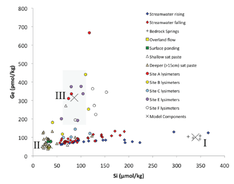


Figure 7. Ge versus Si concentrations for stormflow stream water, groundwater, soil pore waters (lysimeter) for sites A–F, saturation paste experiments, and surface water samples. Shaded box shows the error envelope used in the model to define the composition of component III. Error estimates for components I and II are similar to the size of the identifying symbols (see Table 6).

Kurtz, A. C., F. Lugolobi, and G. Salvucci (2011), Germanium-silicon as a flow path tracer: Application to the Rio Icacos watershed, Water Resour. Res., 47, W06516, doi:10.1029/2010WR009853.

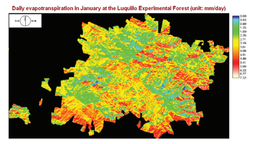


Figure 5a Derived daily average aET in January (unit: mm/day).

Wu, Wei; Hall, Charles A.S.; Scatena, Frederick N.; Quackenbush, Lindi J. 2006. Spatial modelling of evapotranspiration in the Luquillo experimental forest of Puerto Rico using remotely-sensed data.. Journal of Hydrology 328, 733- 752.

Table 4. Evaporation Components for Selected Tropical and Warm Temperate Forests

Location and Source[a]	Type[b]	P	ET	E_t	E_s	E_s/E_t
Queensland, Australia, 1	1	4035	1420	1010	420	2.40
Puerto Rico, 2	1	3685	2420	1790	630	2.84
Puerto Rico, 3	1	3480	2180	1365	815	1.67
Fiji, 4	1	2015	1740	365	1375	0.27
Fiji, 5	1	2015	1540	355	1185	0.30
Sapiang, East Malaysia, 6	2	3945	1835	870	965	0.90
Jamaica, 7	2	3745	2000	710	1290	0.55
French Guyana, 8	2	3725	1440	560	880	0.64
West Java, Indonesia, 9	2	2850	1480	595	885	0.67
Peninsular Malaysia, 10	2	2775	1555	640	915	0.70
Eastern Brazil, 11	2	1819	1365	220	1145	0.19
Western Amazonia, Peru, 12	3	3065	1535	470	1065	0.44
Guyana, 13	3	2480	1485	345	1135	0.30
Central Amazonia, Brazil, 14	3	2390	1225	245	980	0.25
Sapchut, East Malaysia, 15	3	2370	1440	290	1150	0.25
Tai, Ivory Coast, 16	3	1995	1415	265	1150	0.23
South Island, New Zealand, 17	4	2610	1100	650	350	1.86
Pipkinnen, Wales, United Kingdom, 18	4	2035	865	530	335	1.58

Evaporation values (mm yr^{-1}) are rounded off to the nearest 5.
[a]Sources: 1, *Gilmour* [1975]; 2, this study (1990); 3, this study, 1997; 4, *Waterloo et al.* [1999], 6-year-old pines; 5, *Waterloo et al.* [1999], 15-year-old pines; 6, *Malmer* [1993]; 7, *Richardson* [1982]; 8, *Roche* [1982]; 9, *Calder et al.* [1986]; 10, *Abdul Rahim et al.* [1995]; 11, *Holscher et al.* [1997]; 12, *Ellenberg et al.* [1994] and R. A. Vertrees, personal communication, 1998; 13, *Jetten* [1994]; 14, *Shuttleworth* [1988] and *Lloyd and Marques-Filho* [1988]; 15, *Kuraji and Paul* [1994]; 16, *Collinet et al.* [1984] and *Hufen et al.* [1990]; 17, *Pearce and Rowe* [1979] and *Rowe* [1979]; and 18, *Calder* [1990].
[b]Type codes: 1, Coastal and island sites, outer tropics; 2, continental edge, equatorial; 3, continental, equatorial; and 4, coastal sites, temperate latitude.

Schellekens, J., L. A. Bruijnzeel, F. N. Scatena, N. J. Bink, and F. Holwerda (2000), Evaporation from a tropical rain forest, Luquillo Experimental Forest, eastern Puerto Rico, Water Resour. Res., 36(8), 2183–2196, doi:10.1029/2000WR900074.

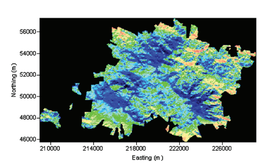


Figure 23 The ratio of aET to rainfall over the whole LEF.

Wu, Wei; Hall, Charles A.S.; Scatena, Frederick N.; Quackenbush, Lindi J. 2006. Spatial modelling of evapotranspiration in the Luquillo experimental forest of Puerto Rico using remotely-sensed data.. Journal of Hydrology 328, 733- 752.

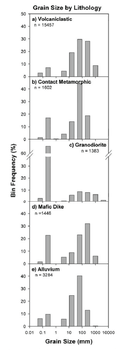


Figure 5. Grain size histograms for all measured clasts at all locations, grouped by lithology. Bins are logarithmically distributed at 2ϕ intervals.

Pike, Andrew S.; Scatena, F.N.; Wohl, Ellen E. 2010. Lithological and fluvial controls on the geomorphology of tropical montane stream channels in Puerto Rico. Earth Surface Processes and Landforms. DOI: 10.1002/esp.1978.

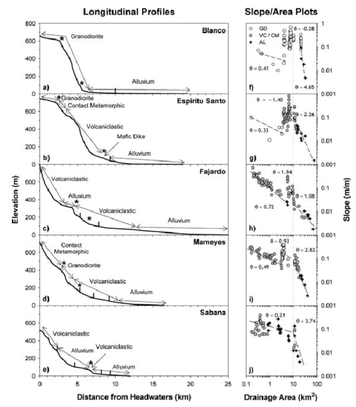


Figure 2. Longitudinal profiles of the main stem of each river highlighting the relationship between local profile shape and lithology (a–e). Mapped faults (vertical bars) are indicated. Slope–area plots (f–j), using points spaced every 10 m in elevation along the main stem, are shown to indicate changes in the concavity index (θ). Points are plotted according to the underlying lithology (white circle = granodiorite, grey circle = volcaniclastics and contact metamorphics, black cross = alluvium). The break where drainage area exceeds 10 km^2 is indicated by the dashed line. Concavity values are derived from best-fit lines based on the lithology in headwater reaches, and for points where $DA > 10$ km^2. Black asterisks in the longitudinal profile plots indicate changes in the slope-area relationships.

Pike, Andrew S.; Scatena, F.N.; Wohl, Ellen E. 2010. Lithological and fluvial controls on the geomorphology of tropical montane stream channels in Puerto Rico. Earth Surface Processes and Landforms. DOI: 10.1002/esp.1978.

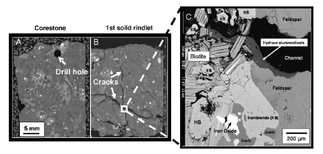


Fig. 3. Backscattered electron maps (BSEM) of thin sections of Rio Blanco quartz diorite. The top edge of the thin section in (A) is the edge of a corestone adjacent to the rindlet zone. No secondary porosity is evident in the corestone (sample drill hole is evident). The thin section in (B) entirely spans the first cohesive weathered rindlet layer above the corestone and is cross-cut by micro-cracks. (C) A BSEM image of a microcrack formed in the rindlet shown in (B). A hydrous aluminosilicate phase is only observed lining channels. Iron oxides have formed near hornblende and biotite crystals.

Fletcher, R.C., Buss, H.L., Brantley, S.L., 2006.Aspheroidal weathering model coupling porewater chemistry to soil thicknesses during steady-state denudation. Earth Planet. Sci. Lett. 244, 444–457.

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