Leila Donn
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Modern and Paleo Floodplain Mapping of a Neotropical Watershed in the Belize-Guatemala Transboundary Area: Improving resilience in an area that regularly floods

Abstract: For my master's thesis, I am looking at the long-term influence of humans on the geomorphology and flooding frequency of the Belize River Valley in western Belize. For this class, I am using LiDAR imagery and ground-truthed flood deposit locations determined from summer 2017 sampling, combined with ArcGIS's hydrologic modeling tools, to create a series of flood potential maps. To accomplish this, I will begin by mapping the modern river system and watershed, as well as the paleo river system as it would have existed during the height of regional Maya civilization from 3000 to 1000BP. I will then use these data to build flood potential maps with the Height Above Nearest Drainage method. These maps will offer insight into both paleo and modern landscape formation through sediment aggradation and/or erosion, and will be spatially and geomorphically connected to a range of Maya sites. Overlaying these data will help differentiate between human versus natural drivers of floods through the relationship between presence of landesque capital (such as agricultural fields), known flood sediment, and mapped probability of inundation. These data from the three-mile reach will provide the basis for a larger area study of river valley formation and flooding potential throughout the Belize River Valley, including San Ignacio, the second-largest city in Belize. Combining these data will also help to create a more targeted sample plan for the next round of sampling, focusing on areas with excellent, long-term flood records.

Update:

I am creating a recurrence interval for an approximately 3-mile reach of the Mopan River in the Belize River Valley (Figure 1). I am interested in looking at several different sizes of floods, and am still refining what these will be; at present, I am thinking perhaps of looking at the 10-year flood, the 50-year flood, the 100-year flood, and the 500-year flood. I will also attempt to replicate this process for the paleofloodplain, which would have been located approximately four meters below the elevation of the modern floodplain. This project will service as the first step in creating a method of flood potential mapping that will be based on a combination of approximately 4,000 years of ground-truthed flood sediment deposits, LiDAR imagery, and GIS mapping. I'll eventually want to apply this method to a much larger area in the Belize River Valley.

First, it's important to note that there is very limited and inaccurate gauging data for my research area. The Belizean government at some point maintained several gauging stations across the country, but does not appear to have measurements available past the 1990s. Trigg et al. (2016) checked the reliability of some of this data against a Regional Flood Frequency Analysis (RFFA) model created by Smith et al. (2014). They found that the data that does exist for the Mopan River is too high and therefore is unreliable. Therefore, I need to create my flood maps in an area where reach discharge and channel geometry does not exist. I am working to develop a method, but there are still many areas that I need to clarify and develop a better understanding of.

The first thing that will need to happen is the establishment of a delineated stream network that I have confidence in. Currently Hydrosheds offers a delineated stream network for the whole of Belize, mapped by Jan C. Meerman with Belize Tropical Forest Studies located in the capital of Belize - Belmopan. I am not sure how reliable this dataset is, though, because parts of this dataset clearly do not line up exactly with streams shown on my LIDAR, and are even several meters offset. I don't know if this is data I should try to work with, or if I should delineate the streams, catchment, and watershed myself using the steps defined in class as part of our DEM watershed delineation exercise. For the three-mile reach, another option would be just to delineate the stream network by hand since it's such a small area. But I'm not sure how that would work with determining catchments and watersheds, and this wouldn't be a replicable procedure for my eventual goal of creating a series of flood maps for a large area within the Belize River Valley.

The next thing that I would need to do, I think, is determine the channel hydraulic characteristics. First, I'll determine channel width. Charim et al. (2016) did this by using Google Earth to measure the stream width at several points and then related that to upstream accumulating area that flows into each point where width was measured. I could do this part in Arc, though, using my LiDAR dataset. I could determine the upstream flow accumulating at each of these points from the attribute table if this is a value that is calculated, or potentially by hand. From there, Charim et al. fit a spline model to the data that allows the river width to be estimated at any point based on this relationship. This assigns widths to all channel cells within the model. From there, I need to estimate river depth. I may do this by using the RFFA created by Smith et al. (2014), based on their estimate of bankfull discharge, using Manning's equation. Smith et al.'s RFFA enables the estimation of return period discharges anywhere in the world based only on Köppen–Geiger climate classification, upstream area, and annual rainfall.

Then, I need to connect the relative elevation of each land surface cell above the stream reach to the stream cell into which it would flow. This is essentially the process of creating my own COMID to relate stream cells to land surface cells that drain into them. The land surface cells immediately adjacent to the stream will be set to height values of zero, and then the height above this zero will be calculated for all of the higher land surface cells. This elevation value will represent the stage above bankfull at which the given land surface cell would flood. Last, I will calculate what magnitude flood it would take to flood each of the land surface cells above the reach (using the bankfull discharge value from the RFFA and the elevations calculation in the last step). From here I could create a series of flood potential maps for the flood recurrences of my choosing.

Once I've worked through this process, I want to do the same thing for the paleofloodplain. This is even trickier, because I have to begin by mapping the paleofloodplain. This would need to be done by hand, I think, and will be much more accurate once I incorporate ground-truthed flood sediments into it. Currently, what I am able to do is, using the highly accurate LiDAR dataset I have, take my best guess of where I see paleochannels and map where I think the river used to flow. I would probably use the same catchments and watershed from my modern maps, at this point. And then I would measure width of any visible paleochannels to the best of my ability and estimate river depth using the same method as specified above. From this point I would continue with my flood mapping as detailed above.

I am making progress on figuring out how I am going to create my flood maps, but I still have some things to work out. Another member of my lab group suggested going a different direction with flood mapping. He suggested that instead of using estimates of river depth and bankfull discharge from an RFFA, to instead use the terraces adjacent to the river as flooding thresholds. This might be something to look into more, but currently I'm focusing on this method that I've seen other people use in the included papers.

Smith, A. Sampson, C., Bates, P. 2014. "Regional Flood Frequency Analysis at the Global Scale." *Water Resources Research* 51: 539-553.

Trigg, M., Smith, A., and Sampson, C. 2016. "CHaRIM Project (www.charim.net) Belize National Flood Hazard Mapping Methodology and Validation Report (FINAL VERSION)." *Carribean Handbook on Risk Information Management*

Figure 1: Map of three-mile reach of the Mopan River, including points where sediment samples were collected in summer 2017. Also shows archaeological sites located along reach.