Summer 2019 Field Report: New machine-learning computer program to find and study caves, karst, and climate in the Guatemalan tropical forest of the Maya Lowlands

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Fieldwork Introduction and Objectives

The main objective of my summer 2019 fieldwork was to ground-truth the results of a LiDAR-based machine-learning computer program that I designed to identify potential cave entrances. The secondary fieldwork objective was to collect a stalagmite climate record, if an appropriate one was identified. I was able to comprehensively address the first objective, which has already helped me to move my dissertation forward significantly. Since we did not find a stalagmite during this field season, I was not able to address the second objective. My field season was a great success, despite an unexpected change of location immediately before the start of the season. Three days before my field season was scheduled to start I received notice that our permit to work in Guatemala was severely delayed due to the upcoming presidential election. It became readily obvious that if I waited for the permit to come through I might find myself unable to do fieldwork at all this summer. Therefore, my advisor helped me to quickly get permission for my technical caver Mike and me to work at the Programme for Belize Biosphere Reserve (PfB) in northwestern Belize and stay at an archaeological field camp inside of the Reserve. Since the fieldwork that I had planned was based on ground-truthing the output of a computer program, I was able to run the already-written computer program over the LiDAR imagery for PfB and quickly generate a map of predicted cave entrance locations for my new study site.

The program to find cave entrances enables the efficient identification of caves in hard-to-access areas located under dense tropical forest canopy. In summer of 2018 my colleagues and I spent a full week hiking for 8+ hours each day to reach locations where we thought there might be caves, based on manual study of topography. While we did find a couple of caves, most locations that we explored were not caves. This method of cave identification required a huge expenditure of time and energy. My program greatly minimized this expenditure, taking us directly to a number of caves and cave-like features.

Fieldwork Detail

My cave entrance-finding program, which I will hence refer to as 'The Program,' identified about 50 potential cave entrances within the approximately 250,000-acre PfB (Figure 1). These individual points were concentrated in four main areas within which the density of potential cave entrances was highest. Once I arrived at PfB, I determined which of these areas of high density I would be able to access based on distance from road and possibility of using already-cut access trails. I didn't have a vehicle for the first two days that I was at PfB due to my very recent decision to come and work in Belize. For that reason, on my first day at PfB (6/5) I accompanied an archaeologist that was working at a site near one of my potential cave entrance points (though the point was not located in one of my high-density clusters). The archaeologist's site had to be accessed using a kayak to cross a river (the Rio Bravo). Once she had crossed the river Mike and I used the kayak to attempt to access the cave point, but it turned out to be too far to go by kayak. After this first day of failed ground-truthing, we had much more success and positive results!

On my second day at PfB (6/6) I accompanied a committee member of mine (Duncan Cook, Australian Catholic University) with whom I hope to collaborate on some speleothem work to ground-truth a cave entrance point located near his destination that day. The point identified by The Program turned out to be a 30-foot-high x 60-foot-long bedrock cliff that contained several fairly large voids (1.5 ft-long) that terminated too shallowly to be called caves. After that second day, Mike and I had our own transportation and a couple of field assistants to help us machete to points. Over the next few days (6/7-6/10) we ground-verified about 8 cave points, of which 7 were cave-like features. This included 2 rock shelters, 3 of which appeared to be chultuns (underground storage containers constructed by the ancient Maya, usually carved into an existing space in the rock), and 2 voids or holes in rock faces that were large enough to contain bats but too shallow to be considered true caves.

On 6/11 we found our first true cave (Figure 2), right where one of my Program points predicted. This cave was located in a ravine at the base of a 7-foot-tall rock face. The entrance was 9 feet long x 2 feet and 5 inches wide. The cave extended for about 30 feet, 17 feet of which I was able to explore. After that the cave narrowed such that I couldn't reach the end of the passage, but I was able to measure the total distance using a laser distance measurer (a disto). The cave did not contain any decoration of any kind (such as stalagmites or stalactites). We ground-truthed several other points that day and found what looked to be a collapsed cave. Rubble was blocking the entrance so we were unable to more fully explore. During the next day's ground-truthing (6/12) we found a fairly large rock shelter (30 feet long x 20 feet high) and a steeply incised dry stream bed that contained a series of about five small, 3-meter-deep voids at the base of where the vertical side of the bed intersected the bottom of the bed. On 6/13, with two days of fieldwork left, I planned to hike out to the most difficult-to-access point identified by The Program. This point was located about 2 miles from the road, in a steep area that stair-stepped up the escarpment. After three hours of difficult macheting and hiking, we came through a dense area of forest and found the most impressive cave-like feature identified during the field season: a 200-foot-long x 100-foot-wide x 160-foot-deep collapsed cave complex (a type of sinkhole; Figure 3). The feature was composed of two adjoining sinkholes, connected in the center by a giant arch with a land bridge above it (this was part of the ancient cave roof that had not yet collapsed). At the bottom of the sinkhole, which was sheer cliffs on all sides, there appeared to be an entrance to a cave passage. We found this feature at the end of the day, and spent that evening assessing how to best safely explore it on our last day of fieldwork. That evening, Mike and I trained on our rope rappelling and ascending system, going up and down a tree in field camp.

The next day (6/14), we hiked out to the sinkhole on the path that we had cut the day before. After training our Belizean field assistants on our backup haul system in the event that something went wrong, Mike (who has a skillset that makes him highly qualified for this type of work, including membership on a cave accident rescue team) attempted to rappel into the sinkhole. It took him three separate attempts to find an area of the sinkhole that was stable enough for him to safely rappel down. He got to the bottom of the sinkhole which turned out to be quite steep and loose. He was able to get near to the possible cave entrance and take some photos, but loose rocks prevented him from getting close enough to get a really good look. It appears that it could be a collapsed cave entrance, but more work and vertical rope gear are required to further investigate. We safely wrapped up that day's fieldwork and caught our flights home.

Conclusion and Next Steps

The Conference of Latin American Geography PhD Field Study Award helped make this work possible, and the remainder of my dissertation will be built upon this work. The ground-truthing that I completed this summer confirms that my machine-learning cave entrance identification methodology works. It also made it clear to me that integrating the LiDAR point cloud into my model will help to make it more accurate and will help to decrease identification of some cave-like features like rock shelters. Though I did not find any stalagmite climate records, and therefore did not install any Hobo temperature monitoring devices, I will continue this portion of the project at two different sites in Guatemala next year, collaborating with Duncan Cook on this portion of the project. Based on the success of ground-truthing my computer program, my dissertation work has grown to include developing similar methods for the identification of Maya mounds, architecture, and wetland fields. This makes my work relevant to an even broader audience across diverse fields. The machine-learning methods that I am developing will be geographically transferable and have the potential to be of service outside of academia across a range of uses such as natural hazard identification (faults, sinkholes, landslides), forest inventory mapping, and planning and development work.

Budget Detail

CLAG funds were used to pay the wage for two additional local field assistants for three days at $20 per person, per day, for a total of $120. Funds were used to pay for food and board for two nights in Belize City on our way to and from field camp, for a total of $130 (2 nights at $55 per night + 10 for food). Funds were also used to buy necessary field equipment: geologic compass ($68), laser distance measurer ($50), rock pick ($30), four caving headlamps ($50 each for a total of $200), folding shovel ($25), 40mx9mm static rope for rappelling ($150), rappelling device ($105), ascender and pulley ($122), and refurbished Dell Toughbook Field Computer ($500) necessary for updating and verifying machine-learning maps daily.

Figures

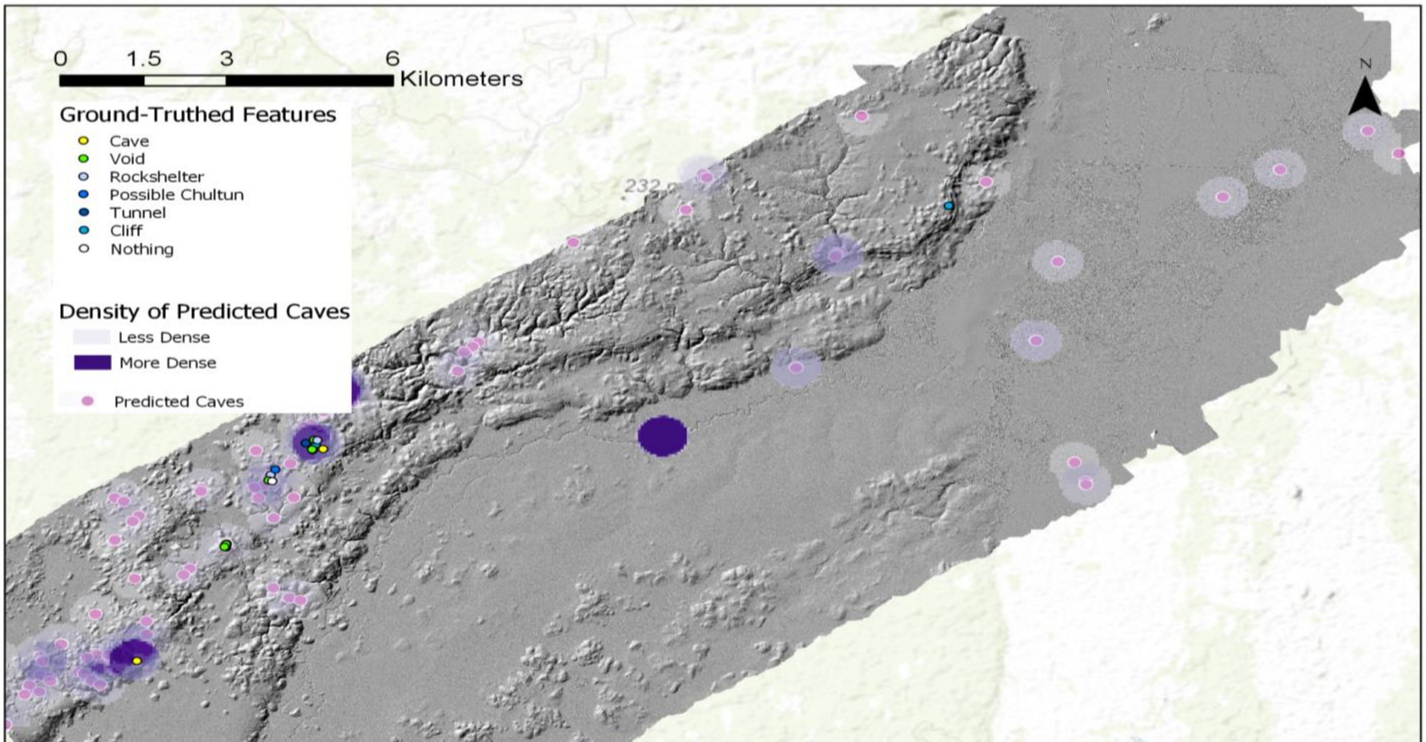

Figure 1: PfB cave location map, clustered by cave point density. Pink points represent predicted cave entrances; darker purple areas represent areas of high predicted cave density.

Figure 2: The first cave we found. The entrance is to the left of the person standing at the back of the photo. That's me in the front of the photo.

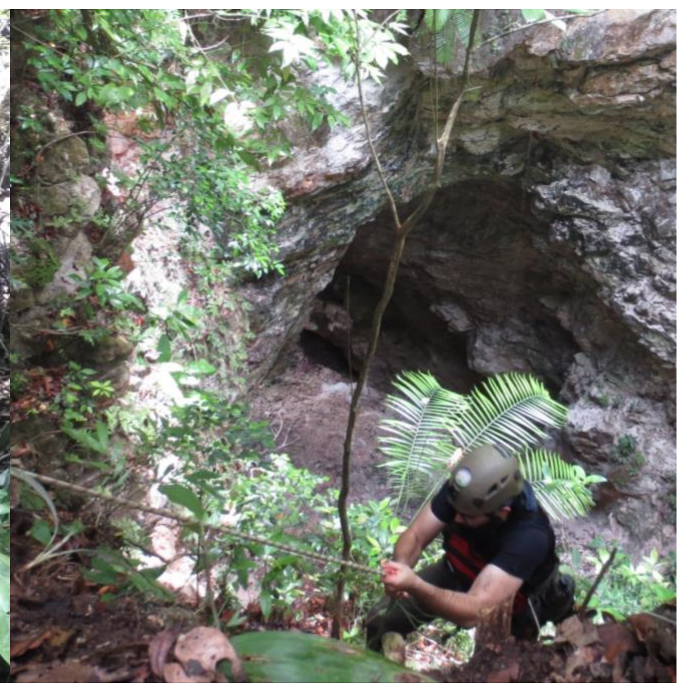

Figure 3: Mike rappels into the giant sinkhole that we found on our second-to-last day in the field.