USING DRONES IN A THREATENED ARCHAEOLOGICAL LANDSCAPE

RAPID SURVEY, SALVAGE, AND MAPPING OF THE MAYA SITE OF SATURDAY CREEK, BELIZE

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Unmanned Aerial Vehicles (UAVs), otherwise known as drones, offer a relatively inexpensive method for rapidly surveying and mapping archaeological sites in open areas with minimal vegetation and are particularly useful for salvage situations where sites are under threat of destruction. Drones are becoming increasingly common in archaeology because they offer a powerful and effective method for revealing surface and subsurface features of archaeological sites (e.g., Casana et al. 2014; Smith et al. 2014; Wernke et al. 2014). UAVs offer an efficient means of collecting extremely high-resolution imagery in open areas with broad aerial coverage, such as cleared pasture and agricultural fields. In optimal conditions, drones can produce aerial mapping and 3D landscape modeling with centimeter accuracy. In the case of Saturday Creek, an ancient Maya site in Belize (Central America), photogrammetry with UAVs offered an optimal aerial technique for mapping large portions of the site (Figure 1). While the site core is located in bush, the majority of the Saturday Creek hinterland settlement is located in open fields that were mechanically cleared of jungle vegetation between 10 and 25 years ago. Over the years, most of the stone—the remnants of once intact ancient Maya architecture—have been systematically removed by Mennonite farmers to avoid damage to their plows. The repeated plowing and removal of stone has shaved off more and more of the mounds each year, making it difficult to discern them on the ground, especially in the case of the smaller mounds (Lucero et al. 2004). Salvaging what we can of Saturday Creek before further destruction occurs is a primary goal of the Belize River East Archaeology (BREA) Project and was one of the reasons for using UAVs to photogrammetrically map the settlement in the open agricultural fields.

Mapping the Site of Saturday Creek with Drones

The drone mapping at Saturday Creek was aimed at documenting the hinterland settlement before further damage to the mounds occurs. When Willis and Walker arrived at Saturday Creek in January 2014, the hinterland settlement had just been plowed, but not yet planted, creating optimal visibility. The fresh plowing churned up artifacts, and numerous scatters of material culture were readily visible on the surface. Because there was little to no vegetation cover, even the lowest mounds were visible and subtle archaeological features were detectable with photogrammetric survey. In less than two days, Willis and Walker flew four drones across an area of Saturday Creek measuring roughly 7 km^2. They used two different kinds of drones, a multi-rotor UAV called a MikroKopter Hexakopter and an ardupilot fixed-wing drone called a Swinglet CAM. These ready-to-deploy, lightweight UAVs have onboard systems that include a digital camera, a GPS, and a radio receiver, which is controlled by a ground-based computer via a 2.4GHz radio modem for data transfer. A total of 14 missions were flown with the Swinglet CAMs and another eight flights were flown with the multi-rotor UAVs. A total area of approximately 620 ha (1,530 acres) was mapped in approximately eight hours of fieldwork and yielded about 2,500 high-resolution photographic images.

For high-resolution mapping, the goal is to generate a very dense Digital Terrain Model (DTM), which produces an aerial photo-mosaic and recreates the topography of the region. This is accomplished through a digital process called photogrammetry that extracts 3D data from a series of overlapping images using commercial photo-merging software. To link the series of aerial images of Saturday Creek, a series of Ground Control Points (GCPs) were placed on the ground at

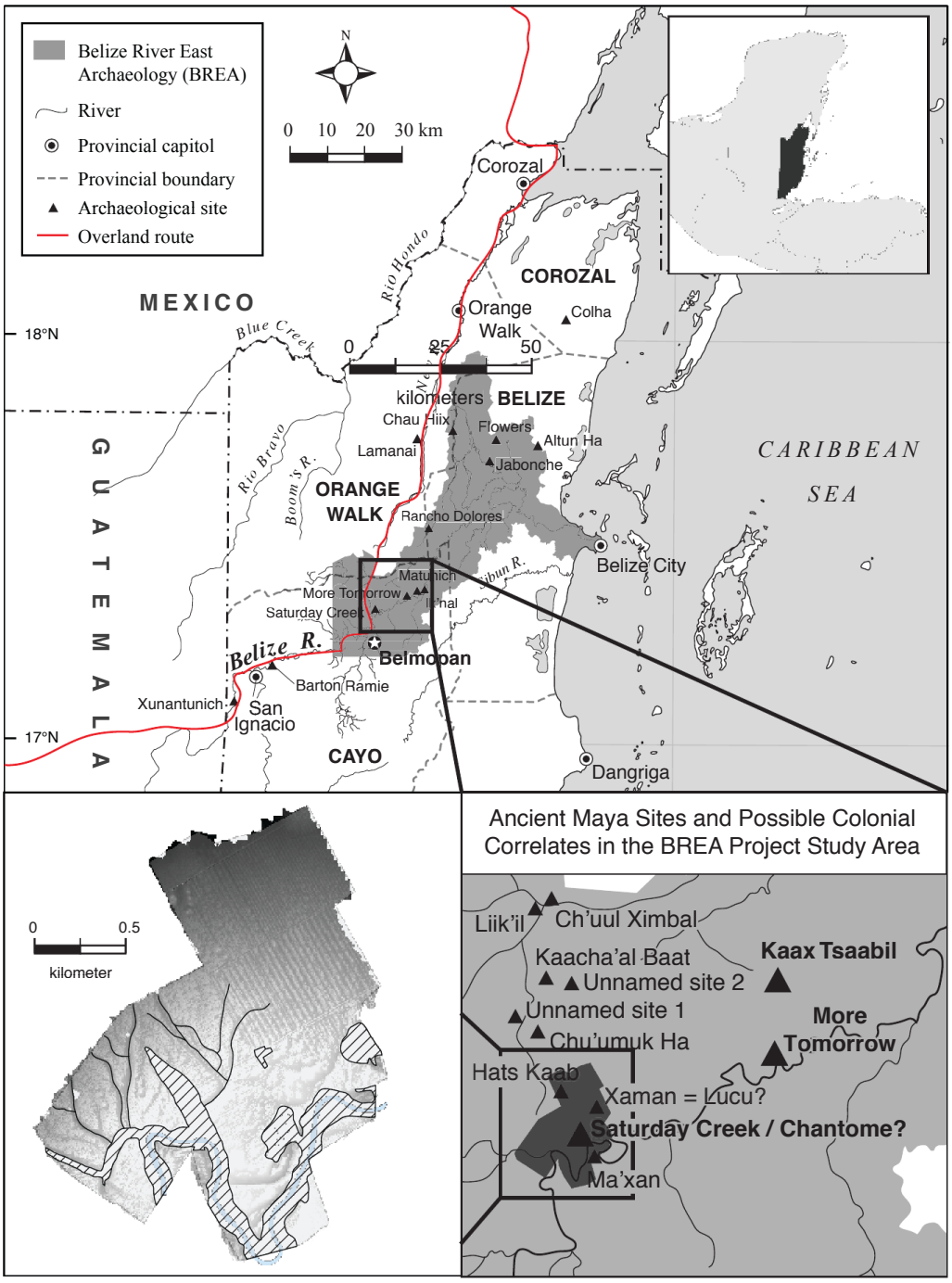

Figure 1. The BREA Project study area, shown in gray (above) with two inset maps (below) demarcating the drone survey area (map prepared by M. Brouwer Burg).

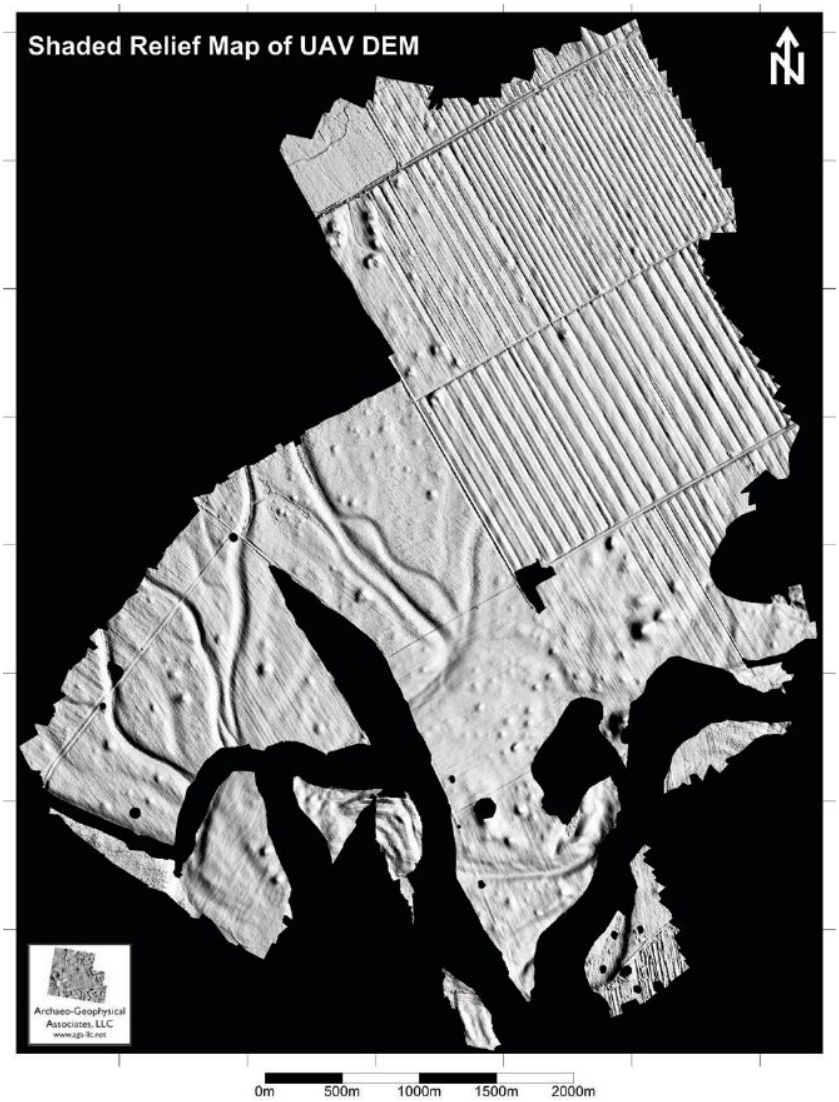

Figure 2. DEM with virtual illumination highlighting mound presences (created by M. Willis).

several geo-referenced locations in the open fields prior to the UAV flights. Under optimal conditions, the precise location of the imagery can be established to within ± 10 cm. The software uses the estimated camera positions of all the tiled images to derive a 3D polygonal mesh of the ground surface, producing a digital elevation model (or DEM). Using Global Information Systems (GIS) software, a hypsographic map was created with 5-cm contours as well as a slope model.

Results

At Saturday Creek, the low house mounds in the hinterlands are difficult to discern on the ground due to repeated plowing over the years and removal of stone from the mounds. After analyzing the 3D data, an unprecedented number of archaeological features were identified in the open fields. Most of these appear to be small earthen mounds that are low to the ground, which we interpret as the remains of

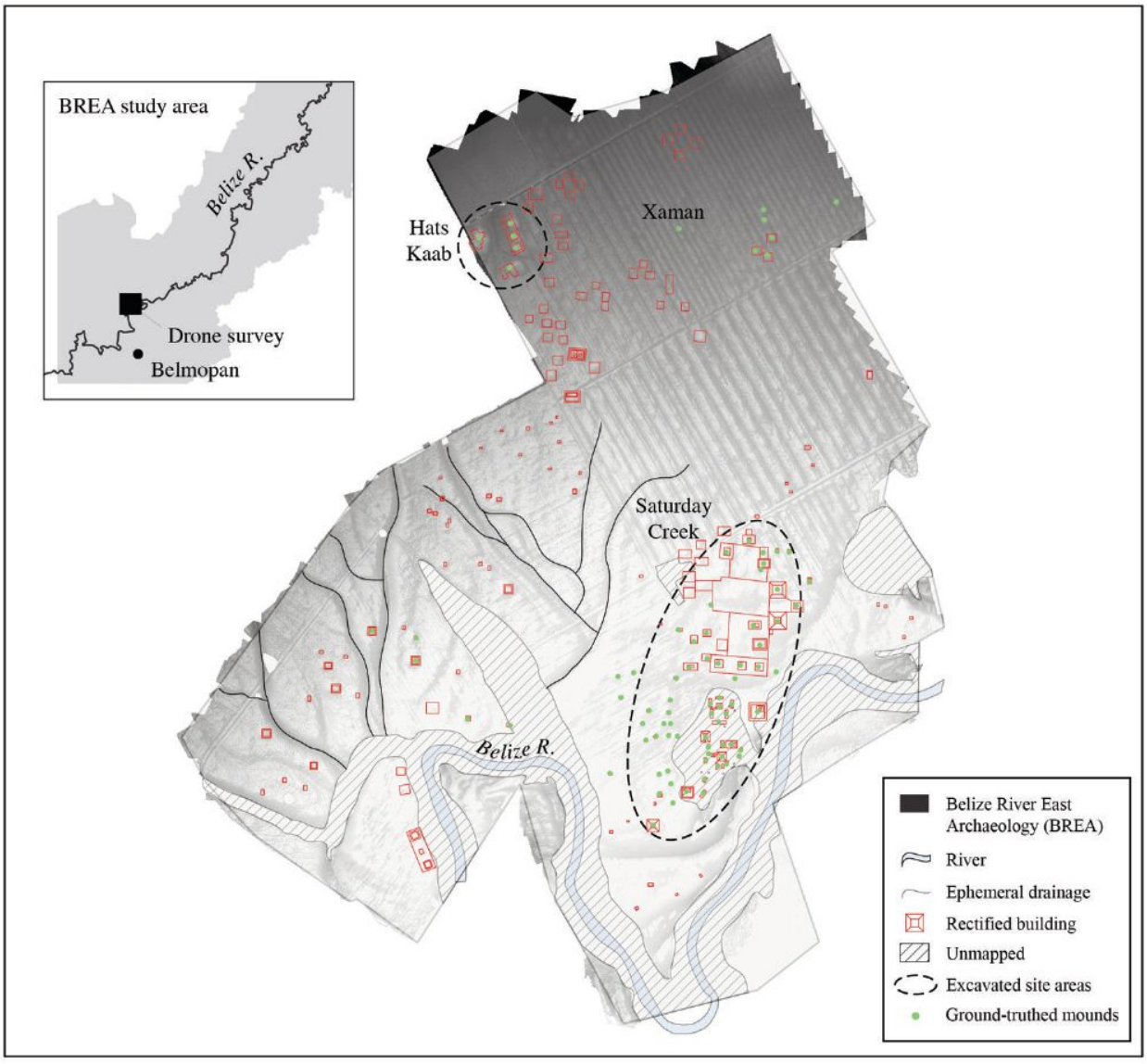

Figure 3. Rectified map of Saturday Creek site core and hinterland settlement (created by M. Brouwer Burg).

ancient Maya platform structures. These mound features become more obvious in the GIS when a virtual light source is used to illuminate the model from highly oblique angles (Figure 2).

The densest settlement appears to be to the north of the site core in the vicinity of Hats Kaab. This large complex resembles an ancient Maya E-Group architectural configuration. It contains a triangular arrangement of structures that may have served to commemorate astronomical events, among other functions (Brouwer Burg et al. 2015; Runggaldier et al. 2013). Although most of the hinterland settlement consists of small to medium sized mounds, the Hats Kaab complex represents one of the more substantial plaza groups in the

hinterland area, located about a kilometer to the north of the Saturday Creek site core. The Hats Kaab group was cleared of forest about 10 years ago and, according to locals, the mounds were bulldozed substantially. During the summer of 2011, the Hats Kaab complex that covers an area roughly 380 m x 350 m was mapped with a Nikon TDS by the BREA survey team (see contributions in Harrison-Buck 2011). This involved the collection of around 1,000 data points with the Total Station, which took about two days (roughly 14 hours) to map. In January 2014, Walker and Willis were able to map this same area in about three minutes using drones. Both produced comparable contour maps of the mounds. The map created with the TDS has the advantage of the archaeologist's trained "eye," catching precisely what is there and in some cases recording small details that are not picked up in the photogrammetric map. The map produced by the TDS is also "cleaner" than the photogrammetric image, omitting certain things, like plow marks, that the unmanned drones do not filter out. However, the expedience of the UAVs is unparalleled. In less than two days (the total time it took to map Hats Kaab with the Total Station), Willis and Walker were able to cover an area over 50 times the size of Hats Kaab and expediently map an archaeological landscape that consists of a dense and expansive regional settlement. The results of this study leave little doubt that in high-risk situations, such as Saturday Creek, where destruction of the archaeology is occurring at a rapid pace and time is of the essence, drones offer a fast and effective solution, providing detailed maps of a site in a fraction of the time it takes to map with a Total Station. We produced a preliminary rectified map of the drone survey based on a combination of the aerial imagery, elevation data from the DEM, and ground-truthing (Figure 3). The green dots on the map show the mounds that have been verified to be archaeological in nature via pedestrian survey. These locations contained evidence of mounded architecture, and surface inspection also revealed associated artifact and/or daub scatters on nearly every mound feature. A cursory inspection of the diagnostic ceramic material found on the surface indicates that many of these structures were continuously occupied from Preclassic to Postclassic times (ca. 500 B.C.–A.D. 1200).

Discussion

The results of the photogrammetric mapping with UAVs reveal startling new data on the settlement density around Saturday Creek. We can now say that Saturday Creek was a large city center with a densely settled supporting population. We believe it served as a central node on the landscape and continued to be densely populated through time because of its location at an important crossroads. The Spanish accounts suggest that the overland route extended south from the Chetumal Bay in Mexico to the head waters of the New River in Belize, known as Ram Goat Creek, and then continued overland through swamp and pine savannah until it reached a partially submerged "natural bridge" of stone that the Spanish used to cross Labouring Creek (Jones 1989:138, 312, [n.35]; see also Scholes and Thompson 1977:45). From there, the route was said to head south overland to an arrival point on the Belize River named "literally, 'the hamlet where Chantome had been'" (Jones 1989:287–288), suggesting that this site was no longer occupied when the Spanish arrived. We believe that Chantome is the ancient name for the Saturday Creek site (see contributions in Harrison-Buck 2011, 2013, 2015).

Over the past several BREA field seasons, we have attempted to further define the location of the north-south overland route and the associated Contact-period settlement. We conducted a least-cost path analysis in GIS, isolating the most efficient route for movement across the landscape (Brouwer-Burg et al. 2014). We carried out a series of pedestrian survey transects and identified a string of Maya settlement that runs roughly north-south in a linear path between Labouring Creek and the Saturday Creek site (Harrison-Buck 2015). In addition, we carried out a series of test excavations in the Saturday Creek site core and have found evidence of Spanish artifacts in the context of Maya ritual cache deposits, lending support to the identification of this site as Chantome (Harrison-Buck 2015). Finally, although further testing is needed, the results of the drone survey present evidence of particularly dense settlement to the north of the Saturday Creek site core in an area we refer to as Xaman, which we believe may represent the town of Lucu.

Concluding Thoughts

In the tropics, archaeological sites like Saturday Creek that have been subject to modern farming practices for years are thought to have little to no archaeological value because of the highly destructive nature of the bulldozing and repeated plowing. In the Maya Lowlands, these sites are often ignored by archaeologists in favor of sites covered in forest. Yet, despite the impacts of industrialized agriculture at Saturday Creek, surface collection and excavation of the E-Group has demonstrated that a large amount of archaeological data still exists even in the midst of this highly effaced earthen architecture (Brouwer Burg et al. 2015; Runggaldier et al. 2013). Moreover, the UAV aerial imagery shows the existence of numerous preserved earthen mounds that, in many cases, are almost imperceptible when standing on the ground. The drone results from Saturday Creek—a site that has endured

repeated plowing for as many as 25 years—demonstrates that these damaged archaeological landscapes are worth salvaging and can yield valuable data.

As a mapping tool in archaeology, drones are more commonly used in naturally open areas with exposed ground, such as barren deserts or xeric shrublands (Casana et al. 2014; Smith et al. 2014). Although few have considered using drone technology for mapping in the tropics, numerous archaeological sites are bulldozed and cleared of bush every year as a result of industrialized agriculture. Our study of Saturday Creek attests that UAV technology is particularly useful for providing detailed 3D maps of dispersed settlements across large expanses of open fields, which would be time-consuming and arduous to map with a TDS. Moreover, the Saturday Creek drone data produced a Digital Terrain Model (DTM) that contained over 100 million individual elevation points, which is comparable to the resolution collected by LiDAR systems, but took a fraction of the cost and time. Photogrammetric mapping with UAVs offers an inexpensive and expedient method for salvaging important site information before it is further damaged or erased all together.

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