

## CASE STUDY

# Whose Data Is It Anyway? Lessons in Data Management and Sharing from Resurrecting and Repurposing Lidar Data for Archaeology Research in Honduras

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As a response to Hurricane Mitch and the resulting widespread loss of life and destruction of Honduran infrastructure in 1998, the United States Geological Survey (USGS) conducted the first wide-area airborne lidar topographic mapping project in Central America. The survey was executed by the Bureau of Economic Geology at the University of Texas at Austin (BEG) in 2000, and it was intended to cover 240 square kilometers distributed among 15 flood-prone communities throughout Honduras. The original data processing produced basic digital elevation models at 1.5-meter grid spacing which were used as inputs for hydrological modeling. The USGS published the results in a series of technical reports in 2002. The authors became interested in this dataset in 2013 while searching for geospatial data that would provide additional context and comparative references for an archaeological lidar project conducted in 2012 in the Honduran Mosquitia. After multiple requests to representatives from the USGS and BEG, we found various types of processed data in personal and institutional archives, culminating in the identification of 8-mm magnetic tapes that contained the original point clouds. Point clouds for the 15 communities plus a test area centered on the Maya site of Copán were recovered from the tapes (16 areas totaling 700 km<sup>2</sup>). These point clouds have been reprocessed by the authors using contemporary software and methods into higher resolution and fidelity products. Within these new products, we have identified and mapped multiple archaeological sites in proximity to modern cities, many of which are not part of the official Honduran site registry. Besides improving our understanding of ancient Honduras, our experiences dealing with issues of data management and access, ethics, and international collaboration have been informative. This paper summarizes our experiences in the hope that they will contribute to the discussion and development of best practices for handling geospatial datasets of archaeological value.

**Keywords:** lidar; archaeology; data access; legacy data; cultural patrimony; Honduras

## 1. Introduction

The application of airborne mapping lidar, also known as airborne laser scanning (ALS), for archaeological prospection was recognized in European settings in the early 2000s (Barnes 2003; Bewley, Crutchley & Shell 2005; Shell & Roughley 2004), but it was not until 2009 that the technique saw its first archaeological applications in densely vegetated tropical regions such as in Central America and Southeast Asia (Chase et al. 2011; Evans et al. 2013; Fisher et al. 2016). Over the past ten years, archaeological projects have been based on dedicated ALS collections (Canuto et al. 2018; Chase et al. 2011; Chase et al. 2016; Evans et al. 2013), while a few projects have used data that were collected for other purposes or even open

data made accessible by government entities (Golden et al. 2016; Johnson & Ouimet 2014). The importance and impact of reusing open data have been broadly recognized (Molloy, 2011), in particular the reuse of open ALS data and analysis tools for the geosciences (Krishnan et al., 2011). However, the reutilization and accessibility of open archaeological ALS data in the Americas remains elusive. There is an expectation that digital archaeological data will be stored and reused in perpetuity (Bevan 2015; Huggett 2018; Kansa & Kansa 2018; McCoy, 2017), but there remain hurdles for ALS datasets ranging from laws and regulations regarding geospatial and archaeological resources to academic politics.

The authors have worked on multiple archaeological lidar projects in Latin America that have a range of requirements for data management and access (Fernandez-Diaz et al. 2018; Fernandez-Diaz et al. 2014b; Fisher et al. 2017; Fisher et al., 2016). While conducting research for a project in the Honduran Mosquitia, we came across a legacy lidar dataset collected in 16 different areas of Honduras

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early in 2000 (see **Figure 1**). These data were collected by the U.S. Geological Survey (USGS) as a form of international assistance in response to the devastation caused by Hurricane Mitch in late 1998 (Gutierrez et al. 2001; Mastin, 2002). Over four years, the authors tracked down the dataset in its various forms in the hopes of locating the original point clouds. Since this dataset (hereafter referred to as the **2k-Hn-Lidar** project or dataset) was collected by the USGS and funded by U.S. taxpayer money through the U.S. Agency for International Development (USAID), and because the USGS has a history of making their data accessible to the public (Kriesberg et al., 2017), we were able to contact the USGS and request access to these data. Access to the original point clouds enabled the authors to reprocess the dataset using current software, including applying algorithms that enhanced the applicability of the lidar data for archaeological purposes.

In this paper, we use the 2k-Hn-Lidar dataset as a case study for how we might reuse and repurpose ALS data for archaeological studies, including but not limited to tracking rates of site degradation, cultural heritage management, and settlement pattern analyses. While a few archaeological projects have used data collected for other purposes (Golden et al. 2016; Johnson & Ouimet 2014), the work presented here is different because: 1) the data were already 17 years old when we accessed them in 2017

and they were collected with the first generation of commercial-off-the-shelf (COTS) sensors, and the data had to be located, resurrected, and reprocessed; 2) these data represent a random sample of a large area of Honduras, including diverse regions for which there has been limited systematic archaeological work; 3) they represent a snapshot in time from which we can trace whether archaeological settlements have been destroyed or modified by environmental and infrastructural changes.

Through this extended process, we asked and were asked variations of the same basic question: *Who owns these data and how can they be accessed?* As such, we have been able to reflect on the implications of the many different answers to these questions. We present our experience with the 2k-Hn-Lidar data as a case study to offer insights into issues related to data management, ownership, dissemination, and international collaboration. We first provide an overview of the dataset, and of our efforts to locate and resurrect the point cloud. We then briefly summarize the archaeological potential of the dataset and how it can enhance our understanding of Honduran archaeology. Our discussion includes the lessons that we have learned from this case study as they relate to data management, data ownership, and the communication and protection of archaeological information that is visible in digital geospatial datasets. We conclude with a few



**Figure 1:** Map showing the location of the 15 primary mapping target areas of the 2k-Hn-Lidar plus the small test area centered on the Maya site of Copán.

points emphasizing the relevance and challenges of working with legacy geospatial data, and with archaeological lidar in particular.

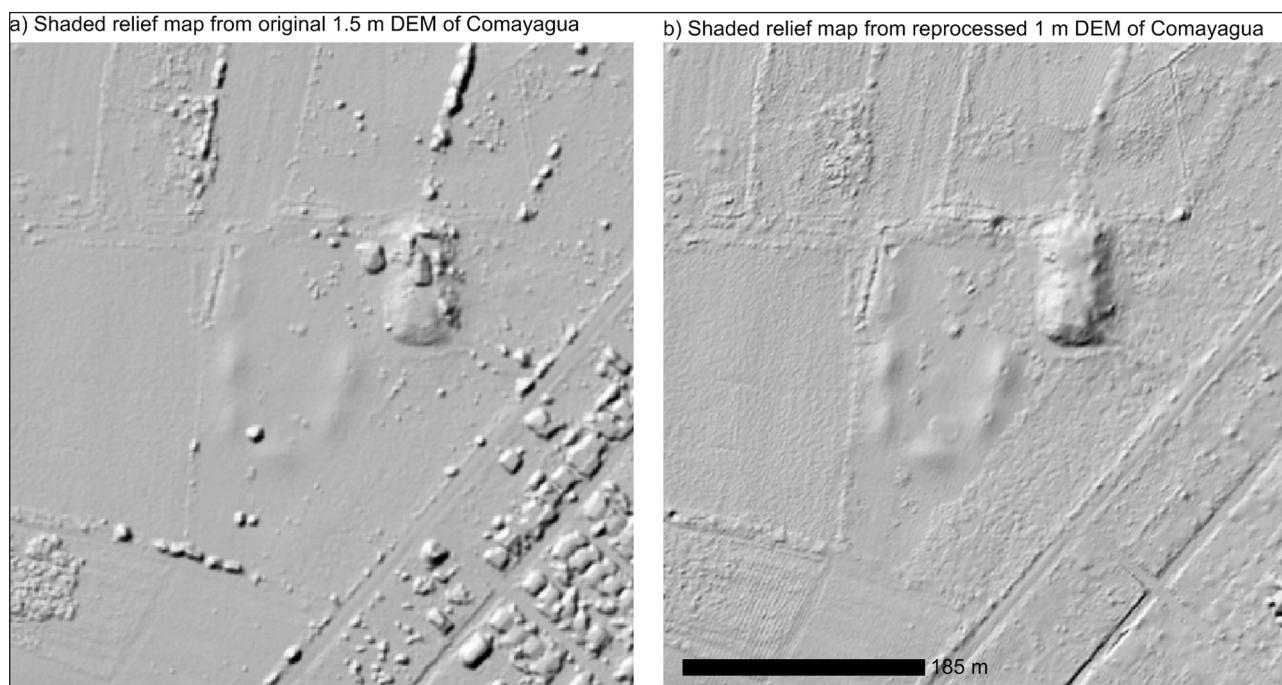
## 2. Materials and Methods

We first became aware of the 2k-Hn-Lidar in early 2013, while we were conducting background research on remote sensing data in Honduras. After initial internet searches, we contacted the USGS in September 2013 to request information regarding the whereabouts of the dataset and the possibility of accessing it for our archaeological purposes. In October 2013, 2k-HN-Lidar project lead scientist Dr. Mark C. Mastin provided us with rasters that the USGS had labeled as bare earth (BE) products. These BE rasters were in .e00 format, an old ArcGIS format, which gave us our first taste of the data conversions that would be necessary to resurrect this dataset. The BE .e00 rasters have a grid spacing (resolution) of 1.5 m and are a digital representation of the natural terrain and the built environment (see **Figure 2**). The vegetation information was mostly removed using tools and algorithms that were available in 2000. In November 2013, we accessed another set of rasters designated by the USGS as “all points” (AP) that were generated by interpolating the elevations of the returns. Unfortunately, there were no point clouds.

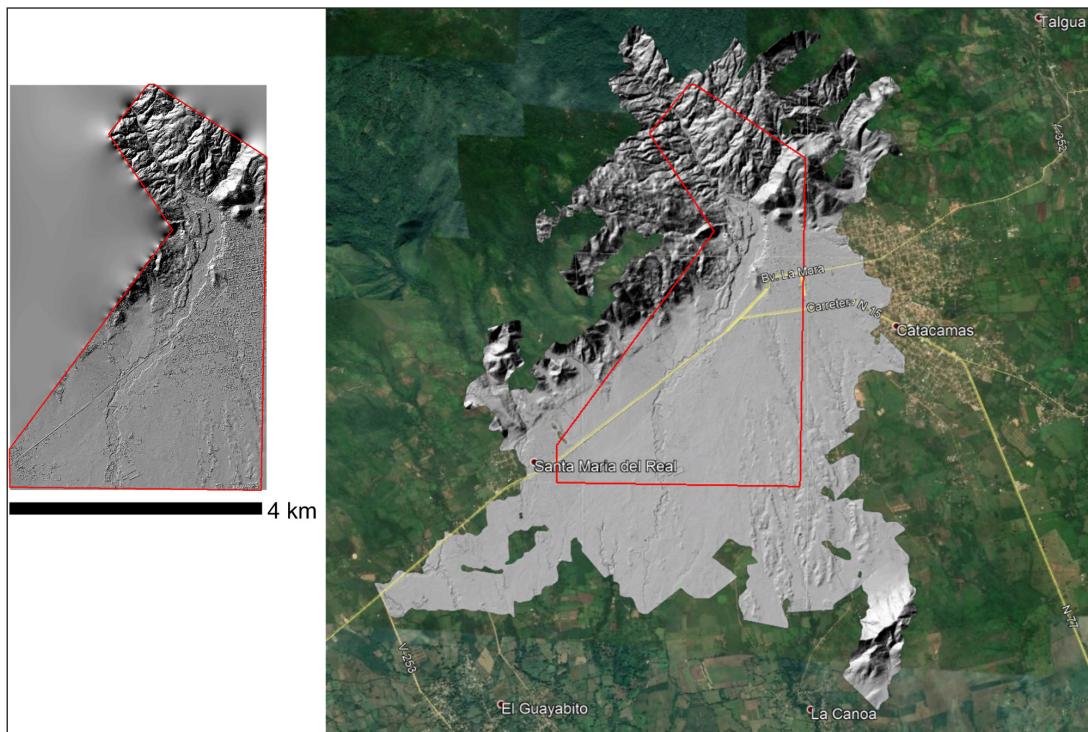
We were able to generate shaded relief maps using the hillshade tool in ArcGIS from the original USGS rasters, but our ability to identify archaeological sites was limited by the raster’s low fidelity and resolution, due in part to the rudimentary algorithms and tools originally used to “filter” the vegetation and interpolate the data. We also realized that the rasters were cropped to narrow areas of interest relevant to the development of risk maps for flooding. In our experience, we knew that the point cloud

would cover a greater extent than we could see represented in the rasters (see **Figure 3**). In March 2017, we contacted Dr. Jason Stoker at the USGS and asked him to inquire directly with the Bureau of Economic Geology (BEG), the institution behind the data collection in 2000, as to whether the original point clouds remained in the BEG archives.

On March 22, 2017, Rebecca Smyth and John Andrews of BEG confirmed that they had been able to locate some data that had been backed up on a server by Roberto Gutierrez, a retired researcher who had served as one of the project principals in 2000. This archive included only small sections of the point cloud, and at this point the concern was that the original point clouds had not been stored on any server or hard drive due to limited digital storage space in 2000 (R. Smyth and J. Andrews, personal communication 2018). This response was disappointing, but it also led one of the authors to remember that in the late 1990s and early 2000s, large amounts of data were backed up via magnetic tapes rather than on hard drives. The magnetic tapes were a cheaper storage solution, but they were slow to read and write, and they were not used for real-time data access (Bhushan, 2018). Initially, we received a negative response about the possibility of magnetic tapes. A few days later, John Andrews informed us that someone from BEG knew of a storage facility where 8 mm magnetic tapes (see **Figure 4**) were stored, and that backup copies from the 2000 project made in October 2001 could be located. Finding the tapes was encouraging, but recovering data from the tapes was not guaranteed, since magnetic media degenerates over time and due to environmental conditions, and because the hardware for reading them is old and unreliable. During April and May 2017, Dallas Dunlap of BEG



**Figure 2:** Shaded relief maps of a Mesoamerican site in the Comayagua valley of Honduras derived from **a)** the original 1.5 m grid spacing “all points” (AP) DEM including terrain and buildings, **b)** the reprocessed 1 m grid spacing DEM.



**Figure 3:** Shaded relief maps illustrating the coverage of the original and the reprocessed DEM for Catacamas, Olancho.



**Figure 4:** Photo of 8 mm magnetic tape cartridges, similar to the ones used to store the original 2000 lidar point clouds.

undertook the tedious process of reading the data from the magnetic tapes and transferring them to hard drive storage. We received ASCII text files containing the point clouds on May 23, and July 6, 2017.

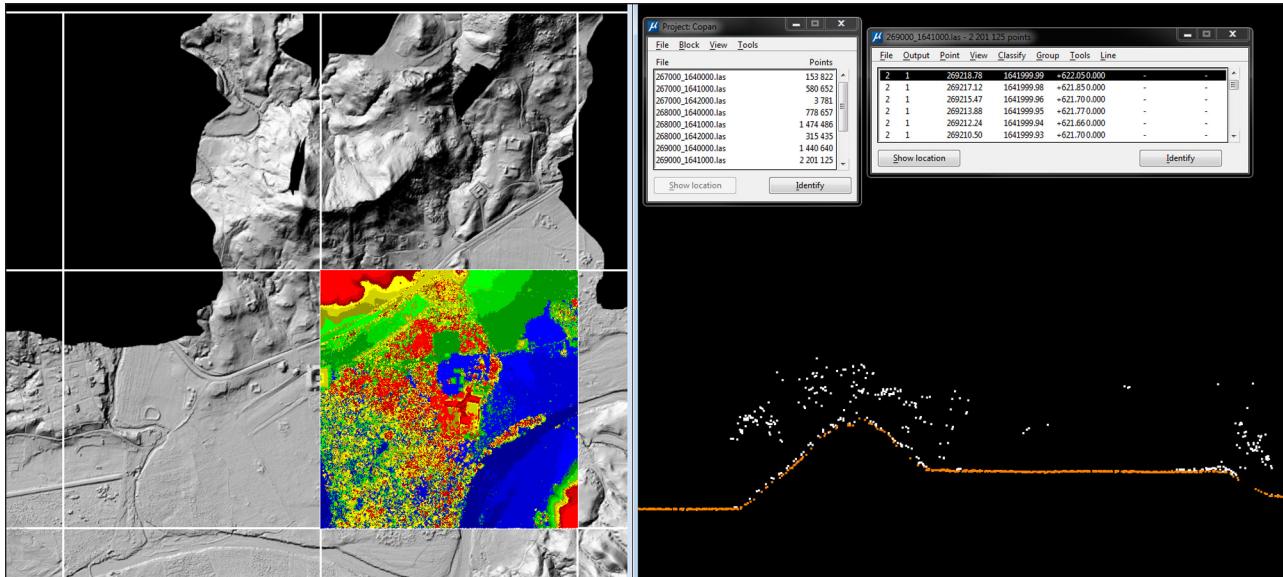
The ASCII point cloud files were in a nine-column format used by Optech for their early ALS systems that were able to record first and last lidar returns. The nine columns consist of a time stamp for each outgoing laser pulse and three coordinates (X,Y,Z) plus one intensity value (I) for the first and last returns. In the event that the sensor detected only a single return per pulse, identical values for the XYZI were reported for both the first and last return. While this point cloud format can be read by current software such as Terrasolid TerraScan, we were interested in updating the point cloud to the LAS 1.2 format which is a current and universally accepted point cloud format (ASPRS, 2005). The data were thus reprocessed with current techniques and procedures followed by the National Center for Airborne Laser Mapping (NCALM) as described by Fernandez-Diaz et al. (2014a). For this purpose, we developed Matlab code to read the nine-column format, separate the lidar returns into flight strips based on the return's time stamps, and assign a return type tag (first and last). Once the point clouds were separated into flight strips and supplemented with the return information, these were loaded onto Terrasolid's TerraScan software in 1 km × 1 km project tiles (see **Figure 5**), and stored as LAS 1.2 files.

The LAS tiles were then classified into ground, modern building, and un-classified (vegetation) returns using Terrasolid algorithms. From the classified tiles, we generated first return (DSM) and ground return (DEM) raster files at 1 m spacing using the Kriging interpolation routine in Golden Software Surfer (and scripter). Hereafter we use the acronym DEM as per American usage to refer to the bare-earth model which corresponds to DTM in European usage as described by Fernandez-Diaz et al. (2014a). Also using Surfer, we generated standard shaded

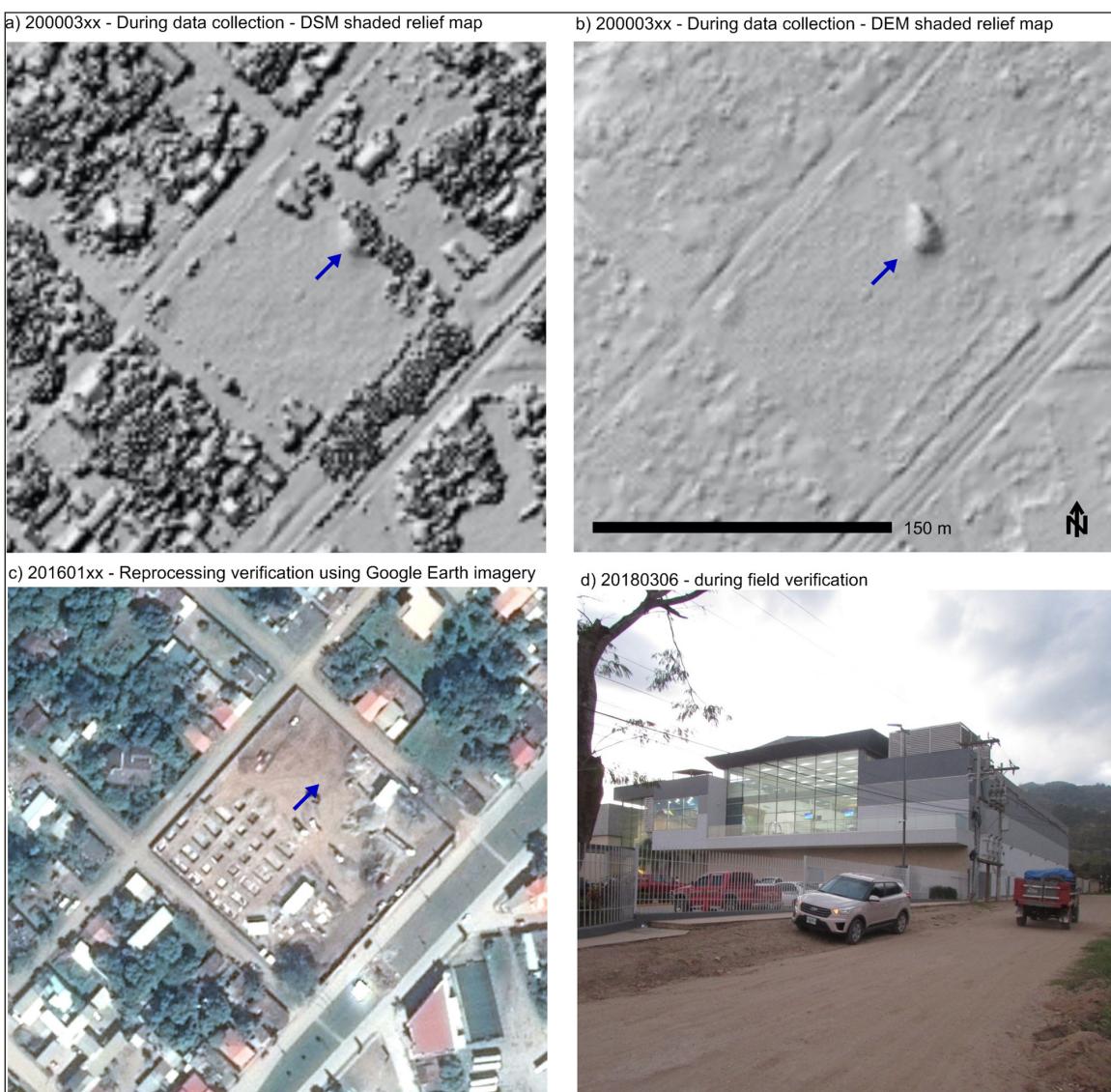
relief maps (315° azimuth and 45° elevation illumination) for both the DEM and DSM rasters, which we have exported as Google Earth KMZ overlays. Having the DEM and DSM shaded relief maps as Google Earth files allowed us to analyze the 2k-Hn-Lidar within the context of current and historical satellite imagery, which enabled us to understand how changes in agriculture and urbanization have impacted the archaeological record (see **Figures 6** and **7**). We have conducted limited ground validation of some sites, and plan to conduct a thorough ground validation and registry of additional identifiable sites. **Table 1** summarizes the lidar data details for the 15 flood-prone regions targeted by the original survey in 2000, plus the Maya site of Copán.

### 3. Archaeological Insights

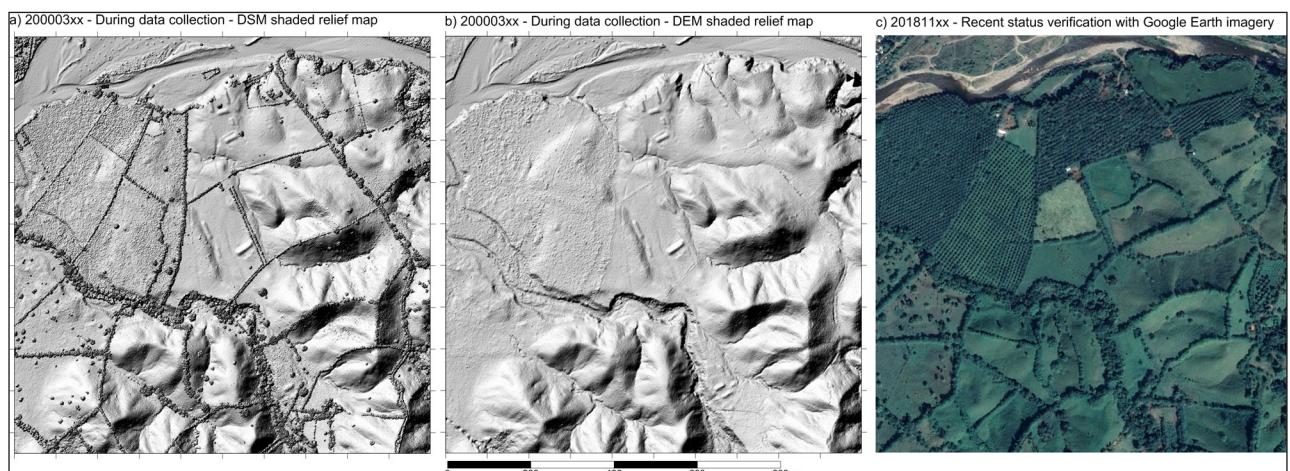
Archaeological sites are visible in many of the 16 locations within the 2k-Hn-Lidar, including the first lidar data from the Maya site of Copán (see also Gutierrez et al., 2001) (**Figure 5**). As listed in **Table 1**, the 2k-Hn-Lidar includes modern settlements in valleys known for Mesoamerican influence such as the Sula Valley (El Progreso, Choloma, La Lima) and the Comayagua Valley, as well as a small area centered around the core of Copán. Of special interest to us was the coverage in regions such as the Aguán Valley and the Olancho Valley, for which there is limited information about prehistoric settlements including for the briefly studied Talgua caves and village site in Olancho (Begley 1999; Cruz-Castillo 2010; Dixon et al. 1998; Stone 1941). In all but three of the coverage areas, we were able to identify obvious or potential archaeological sites. Due to urban development, we were not able to identify sites in Tegucigalpa, or within the coverage corresponding to Nacoame or Siguatepeque. We will expand on the archaeological data and implications of the identification and ground validation of these sites in a different publication; however, in order to provide some archaeological context for the potential of legacy lidar data, we include



**Figure 5:** Screen capture of Terrasolid's TerraScan running over MicroStation and displaying lidar raster and point cloud products collected around the Maya site of Copán.



**Figure 6:** Multi-temporal geospatial datasets to illustrate cultural patrimony degradation through time in Catacamas, Olancho. Shaded relief maps of the **a)** DSM and **b)** DEM at the time of the lidar collection in 2000. Blue arrows mark the remains of a potential archaeological mound typical of the northeastern Honduras cultural region. **c)** By January 2016, the mound had been completely destroyed for modern construction. **d)** During field verification in March 2018, we found that a shopping mall had been built over the archaeological site.



**Figure 7:** The evolution of a large archaeological site in the Aguán Valley just south of the city of Tocoa. Shaded relief maps of the **a)** DSM and **b)** DEM at the time of the lidar collection in 2000. In early 2000 there was little vegetation over the site and half of the northern plaza was eroded by the river over an unknown time period. **c)** Today, a large section of the archaeological site has been converted into a palm oil plantation.

**Table 1:** Data reprocessing details for each of the 16 surveyed areas of the 2k-Hn-Lidar.

#	Survey area	# Laser pulses	# Returns	Planned area [km <sup>2</sup> ]	Reprocessed area [km <sup>2</sup> ]
1	Catacamas	40,250,525	44,469,824	8.4	44.50
2	Choloma	27,608,138	30,207,845	7.2	28.68
3	Choluteca All	98,494,411	99,095,313	37.1	99.03
4	Comayagua	51,554,910	53,395,425	20.9	57.28
5	El Progreso	51,415,302	54,059,220	14.7	52.67
6	Juticalpa	28,370,848	30,622,081	6.4	31.93
7	La Ceiba	36,270,655	37,010,294	10.9	36.42
8	La Lima	78,252,820	81,154,391	33.6	75.02
9	Nacaome	41,141,456	44,458,600	10.4	46.59
10	Olanchito	20,732,891	22,279,919	5.2	20.09
11	SantaRosaAguan	17,922,243	17,777,556	6.4	15.89
12	Siguatepeque	38,999,796	43,149,562	12.1	43.82
13	Sonaguera	15,702,309	16,432,410	4.9	16.26
14	Tegucigalpa	90,494,544	96,585,944	54.2	103.37
15	Tocoa	23,621,189	25,795,109	7.4	22.27
16	Copán	9,135,323	9,135,323	—	6.49
	Total	669,967,360	705,628,816	240	700

here figures for sites that have been previously documented (**Figure 5**), that have been lost to development (**Figures 3 and 6**), or that are somewhat protected on private or government land (**Figures 2 and 7**).

One particularly prominent set of archaeological features is near the modern city of Tocoa in northeastern Honduras (**Figure 7**). Situated within the inland Aguán Valley, this modern city is in a broad river valley with vegetation that ranges from tropical rain forest to pine and oak. Previous archaeological work by W. Duncan Strong (1934) and Doris Stone (1941) showed that ancient sites in the region cluster along rivers and tributaries, including the Chiapas Farm sites, which included burials, jadeite artifacts, and pottery that helped define the Early Selín period (300–600 CE) (Cuddy 2007; Healy 1993). Near Tocoa, architecture to the south of the city consists of three or four plaza groups on a hill immediately south of the Tocoa River. At least 10 mounds are visible in the 2k-Hn-Lidar data over an area of approximately 19.9 hectares. The location of these sites on raised ground above a flood plain may have been for protection from flooding or other safety hazards in the lowlands. It is possible that this site represents the archaeological mounds at “Toloa” that were described by Herbert Spinden (1924). He observed that the mounds were constructed of water-worn stones which may have once formed the base of adobe walls, and that the largest mound was accessible by two flights of slab stairs. There are also similarities in form and orientation between the Tocoa mounds and those documented at the Marañones Upper Group along the Río Plátano (Begley 1999). Overall, the Tocoa architecture follows the pattern that is typical, in terms of size and orientation, of monumental architecture in

eastern Honduras located at least 100 km inland (e.g., at Marañones and the site of Las Crucitas (Lara-Pinto & Hasemann 1991)). This distance from the coasts could indicate intra-regional trade along river systems and tributaries (e.g. Cuddy 2007).

These preliminary insights, drawn from our reuse and repurposing of the 2k-Hn-Lidar dataset, clearly illustrate the archaeological potential of legacy lidar data. Archaeologists could conceivably use such datasets to address questions about settlement pattern distribution, assist in the management of cultural heritage in areas subject to urban development, and evaluate the scale of cultural heritage destruction. It is also worth pointing out the potential of such datasets for contributing to the prehistory of non-Maya Central America, a region that is understudied within the context of Americanist archaeology. Existing research in Central America often focuses on the Maya, and it is important to enhance archaeological understanding of adjacent cultural patterns in the region (Begley 1999; Cuddy 2007; Joyce 2015; Schortman & Urban 2011). In recent years, landscapes within Central America and Honduras have been at particular risk of devastation from natural and/or anthropogenic threats such as flooding, deforestation, and political turmoil (McSweeney et al. 2014). Additionally, much archaeological material from the region remains in museum or private collections that may be unknown to researchers or difficult to access (Jones 1992). These reasons, combined with the difficulty of accessing certain parts of Honduras, mean that systematic archaeological research from remote sensing data is critical for documenting the cultural heritage of the region. Other regions of the world face similar problems, which suggests that legacy lidar datasets have enormous

potential for contributing to our global understanding of the human past.

#### 4. Reflections and Lessons

In this section, we reflect on the case study presented above and highlight a few important lessons that we have learned as we identified, processed, and tried to improve accessibility to a legacy lidar dataset. We have discussed ethical issues surrounding archaeological lidar data previously (Fernandez-Diaz et al. 2018), and other questions related to best practices and ethics are explored by Cohen et al. (in press). We hope that this will further encourage archaeological and non-archaeological lidar acquisitions to more carefully consider database management, data accessibility, and digital cultural patrimony during research design, throughout the life cycle of research programs, and also beyond.

##### 4.1. Data Management

Our experience with the 2k-Hn-Lidar highlights the ways in which geospatial datasets are intrinsically multipurpose, and underscores their potential to support applications that might be difficult or even impossible to anticipate. The 2k-Hn-Lidar were originally collected to develop flood risk maps at an early stage in the evolution of airborne mapping lidar technology. In hindsight, it is quite remarkable that the first airborne lidar survey of a Mesoamerican site was used to test and develop ground/vegetation classification algorithms for non-archaeological purposes. The data and results of these scans over Copán were not shared widely with members of the archaeological and engineering research communities (Gutierrez et al. 2001), and consequently it took nearly a decade after the 2k-Hn-Lidar collection, and the development of a new generation of lidar sensor and processing algorithms, to fully realize the potential of archaeological lidar in highly vegetated areas of Mesoamerica (Chase et al. 2011). It is also interesting that this first lidar survey of Central American archaeological settlements does not focus on the Maya region, but rather records a larger number of widespread settlements and sites created by ancient people living outside the Maya zone, in Honduras. As we noted above, this area has long been neglected in Central American archaeology and more recently in wide area ( $>100 \text{ km}^2$ ) lidar acquisitions (apart from data discussed in Fernandez-Diaz et al. 2018; Fisher et al. 2016). This means that legacy ALS datasets have the potential to not only be repurposed for different disciplines, but also for different research goals within the field of archaeology (Huggett 2018; Wylie 2016).

We recognize that it is impossible to anticipate all potential uses for ALS data and future processing or analytical developments, and yet our experience with the 2k-Hn-Lidar demonstrates that data should at least be preserved in their raw and/or primary forms for future studies. Reuse and repurposing of ALS datasets are possible with raw data forms obtained from the navigation and lidar sensors. Importantly, however, these data are rarely reprocessed except by data providers who have access to ALS proprietary software. Primary or intermediate products such as the sensor trajectory and the geolocated and calibrated point clouds have the most value for reprocessing.

In our case study, access to the primary data product in the form of the point cloud enabled us to reprocess the dataset specifically for archaeological prospection. Current and future ALS projects should thus make sure to store raw and primary data forms to better facilitate future reuse and repurposing of geospatial information.

This case study also showed that stored data must be migrated and updated into new media and formats as they become available (Richards-Rissetto & von Schwerin 2017). The 2k-Hn-Lidar dataset is so old that the point cloud, which contains the richest level of geospatial information and hence the largest storage requirements, was stored on magnetic tapes. We were fortunate that hardware and software to read the tape data were available, but also that the storage lifetime of the magnetic media had not expired. In addition, while a large portion of the original point clouds were recovered from the tapes, we could not recover point clouds for smaller test areas. In some cases, these data represent the only archaeological record of sites or structures that since 2000 have been destroyed by agriculture or development. We strongly recommend the constant upgrading and preservation of geospatial datasets. Though the costs and procedures involved in upgrade and storage management are high, archaeologists and other scientists who collect and store ALS data must build these costs into new research programs well before data acquisition.

##### 4.2. Data Ownership and Access

This case study also brings up critical questions regarding data ownership and access. Who owns or controls ALS data? Who can access them and how should they do it? Despite calls for open access geospatial data (e.g., Huggett 2014; Opitz & Herrmann 2018), these questions do not have straightforward answers. As with any other commodity, one might contend that whoever pays for data collection is the entity that owns and controls the data access. However, we argue that geospatial information is a distinctly different category of commodity because of its multipurpose nature, and because the uses or applications that can be derived from it are practically limitless. Potential users and applications can range from for-profit entities that can employ the data for financial gain to individuals working towards the protection of natural or cultural resources. Moreover, in addition to the traditional financial ownership paradigm, we argue for the concept of moral ownership. At its core, this means that the people or institutions that hold a special interest in or ownership of the land, resources, and elements captured in the geospatial data, should also be able to access the datasets. Such moral ownership may not be possible in all countries, but the concept at least considers the role of multiple stakeholders, including descendant communities and current landowners. In addition to digital ownership, copyright regulations can restrict the access and utilization of data from the actual owners of the cultural and historical patrimony, a process that represents a form of digital colonialism (Beck 2018; Thompson 2017).

Unlike ALS collection in the research or academic sectors, there are international legal frameworks for the use of remote sensing techniques for surveillance and

mapping by state actors of third countries. For example, the 1986 United Nations “Principles relating to remote sensing of the Earth from outer space” and the 1992 Open Skies Treaty are relevant to our discussion. The former provides a non-binding framework and guidelines on the application of remote sensing from space across borders for the benefit and interest of all countries. It confirms the unrestricted right to perform remote sensing activities without prior consent or notification from/to the country being observed. In return, the observed country can access the data on a non-discriminatory and reasonable cost basis (UN 2008). The Open Skies Treaty is an agreement between 34 state parties – including the U.S., Canada, all European countries, Russia, and many of the countries that were part of the Soviet Union – for conducting military surveillance from airborne platforms. Under this treaty, the observed country must receive a copy of all data collected from the flight and all other signatory states have the option of purchasing a copy from the observing state (Arms Control Association 2019). These frameworks demonstrate the critical implications of remote sensing activities to the sovereignty and national security of states, and also exemplify the concept of moral ownership of geospatial data by recognizing the rights of the observed state to copies of the data collected over their territory. Importantly, however, these examples only apply to state actors and data access, rather than to cultural heritage and data ownership concepts.

In the case study discussed here, the 2k-Hn-Lidar dataset was collected under the direction of the USGS and funded by USAID. Even before 2000, the USGS was making data they had collected with U.S. public funds accessible to the research community, and more broadly to the public. As such, the 2k-Hn-Lidar data are public goods owned by the U.S. and its citizens. Yet, these valuable data were collected over a third sovereign country. Arguably, the citizens and government of Honduras are also “moral” owners of the digital elevation data and can thus establish guidelines regarding dataset access. Since digital elevation data does not become archaeological until it is processed and interpreted, it is worth pointing out the potential distinction between the digital and archaeological data: moral owners of the digital data may be different from the creators of archaeological materials (see related discussions in Gibbon (2005), Lobo, Talbot & Morris (2016), and Lydon (2008)). For example, moral owners of both the digital elevation data and the archaeological information could include stakeholders such as the Honduran Institute of Anthropology and History and descendant communities of the people who created the material culture documented in the lidar data. Other moral owners of the digital elevation data may be entities with interests in Central American environmental and economic changes such as natural resource management professionals, urban planners, and geological hazard mitigation specialists.

The USGS recognizes moral ownership. For example, in the early 2000s, copies of the 2k-Hn-Lidar were delivered to different Honduran institutions including the Honduran cartographic institute (Instituto Geográfico Nacional) and a private university (UNITEC). It is unknown what happened to these shared data.

This sharing was based on precedent: in Honduras and many other Latin American countries, there was a program that allowed these countries to develop their topographic maps at scales as large as 1:50,000 through funding, equipment, and assistance from the U.S. Between 1946 and 1989, the U.S. Defense Mapping Agency (DMA) participated in an international collaboration project known as the Inter-American Geodetic Survey (IAGS). The IAGS functioned via bi-lateral agreements between the U.S. and the individual countries. The standard agreement established that the U.S. would assist in or conduct basic geodetic survey and collect aerial photography as a basis for creating the topographic maps. The U.S. would provide copies of all materials to the host country. Furthermore, it was agreed that the U.S. would not share the geospatial data with any third country, including other members of IAGS (Granicher 1972; IGS 1961; NGA 2018).

IAGS work in Honduras started in 1947 with the establishment of basic geodesy networks followed shortly thereafter by aerial photography collected by the U.S. Air Force. The 1:50,000 scale maps were produced between 1961 to 1987; originally, their release was strictly controlled by the Honduran military (International Cartographic Association 1991). Recognizing the utility of these maps for a variety of purposes, the government then made them available to the public by the end of the 1990s. While the U.S. has fairly clear policies on open access to data funded by U.S. taxpayers, in our dealings with different Honduran governmental agencies, it is evident that Honduras does not, and that accessing and using the 2k-Hn-Lidar presents a formidable challenge not only to the government but to anyone interesting in working with the dataset. Like early restrictions on the release of topographic maps, with their high resolution, ALS data are critical to national security and may be restricted in terms of public dissemination and use. This adds complications to principles of academic freedom regarding research and publication that investigators throughout the world value (Euben 2002; Karran 2007).

This case study allows us to consider ownership and access issues related to the improvement and generation of derivative products from open access data. We have benefitted from having access to the original 2k-HN-Lidar, and we want other researchers to have access to our modernized and improved dataset. This is not only to comply with the guidelines of reproducible research, but also because we believe in the democratization of geospatial data and applications (see discussions in Bevan 2015; McCoy 2017; Opitz & Herrmann 2018). In addition, because of the technical, ecological, cultural, and historical importance of this dataset, we have even considered the possibility of making it open to the public. This comes with the challenge of obtaining approval from agencies in both the U.S. and Honduras, which will take more time and which will likely continue to inform and shape our opinions regarding data ownership and access. While there is no doubt in our minds that making the dataset open access can bring multiple scientific and societal benefits, it is important to note that open access comes with the risk of damage or loss of cultural and natural patrimony that we cannot

anticipate (see, for example, discussions in Huggett 2014; Richardson 2018; Ur 2006).

#### 4.3. Protection of Cultural Patrimony

As we began our research into the Honduran Mosquitia and remote sensing data in the country, we had no idea what kinds of data we would identify. Once we started recognizing archaeological sites and structures in the updated 2k-Hn-Lidar dataset, we faced the challenge of how to communicate these findings to the proper authorities. The Honduran law regarding the protection of cultural patrimony (Decreto Legislativo 220–97) does establish in Article 19 that any person that by accident or during the execution of a construction project comes across an archaeological site or artifact ("antiquity" is the literal translation from the Spanish) should report it immediately to the Honduran Institute for Anthropology and History. While the wording of the article is vague and does not specify cultural heritage in geospatial data, the intent behind it seems clear and can be extended to ALS data. In addition, in Honduras, researchers must register, establish collaborative frameworks, and obtain project specific permits from the government. Most of these regulatory procedures were established when remote sensing was not an integral part of an archaeological project and certainly before most forms of open access geospatial data existed. As demonstrated with this case study, anyone can come across a geospatial dataset with archaeological data without visiting a study area. While most ethical researchers work within a given country's laws and institutions, the potential of looting or destruction of cultural patrimony due to ignorance or poor intentions is a matter of great concern to authorities, and is a factor that limits the possibility of open access archaeological geospatial datasets. On the other hand, this case study also shows that many sites that were visible in 2000 have been partially or completely destroyed by urban and agricultural development. Providing broad access to geospatial datasets may not necessarily slow or stop the rate of loss of cultural heritage, but such access would at least provide a record or baseline of what existed in the past and some benefit to authorities.

### 5. Conclusions

In this paper, we have provided a detailed overview of our efforts to recover and analyze data from the first successful, wide-area, topographic lidar survey in Central America that mapped several Mesoamerican sites and sites from other cultural groups in 2000. Throughout our efforts to resurrect and reprocess a legacy dataset, we learned that it had documented a large collection of archaeological sites from both Maya and non-Maya regions across a random sample of Honduras. In addition, this process has served as a valuable example on issues related to geospatial data management, ownership, and access for archaeological studies. The case study presented is just one of many examples that illustrates the importance and challenge of long-term digital cultural preservation and continued improvement and utilization. Our experiences inform the argument that funding entities and principal users of geospatial data collections should recognize moral ownership

of stakeholders beyond local governments. Developing guidelines that ensure fair data access to such moral owners is imperative to avoid repeating the errors from the past in its modern form in what has been called "digital colonialism."

While there exist international legal frameworks which provide some reference regarding data access for state actors working across borders, these do not always apply to researchers, institutions, or individuals conducting archaeological research in foreign territories. In addition, codes of ethics about data management in archaeology — such as the guidelines put out by the Society for American Archaeology or the World Archaeological Congress — have limited to no mention of digital heritage (though see Santana Quintero et al. 2019 for discussion of digital heritage ethics and conservation professionals). The efforts undertaken with this special issue to propel the development of best practices for the use of ALS data by local or foreign researchers for archaeological studies is an important but limited first step. We argue that there is a need for the establishment of broader international principles, perhaps under the framework of the United Nations Educational, Scientific and Cultural Organization (UNESCO), that will recognize the importance of geospatial data for cultural heritage investigation and preservation, at the same time as it provides guidelines for equitable access to such data. This case study also illustrates the importance of historical geospatial data for cultural and natural resource inventory and for monitoring in places like Honduras where climatic, political, economic, and social conditions not only threaten the valuable heritage resources, but also make the execution of traditional archaeological projects difficult.

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### Competing Interests

The authors have no competing interests to declare.

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