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► **To cite this version:**

Adrian Chase, Diane Chase, Arlen Chase. Ethics, New Colonialism, and Lidar Data: A Decade of Lidar in Maya Archaeology. *Journal of Computer Applications in Archaeology*, 2020, 3 (1), pp.51-62. 10.5334/jcaa.43 . hal-02567666

**HAL Id: hal-02567666**

**<https://hal.science/hal-02567666>**

Submitted on 7 May 2020

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## POSITION PAPER

# Ethics, New Colonialism, and Lidar Data: A Decade of Lidar in Maya Archaeology

Adrian S. Z. Chase\*, Diane Chase† and Arlen Chase‡

Maya archaeology has witnessed a paradigm shift in interpretations of the past with regards to the structure and organization of ancient societies as a result of the introduction of lidar to the field a decade ago. Lidar provided control of spatial parameters in a way that had not been previously possible. But, the introduction of this technology has also involved researchers in a series of broader ethical debates. While archaeology has always provided huge data sets for processing, the digital lidar files are even larger and also need appropriate long-term storage and management considerations. It is here that there are differences of opinion worldwide on how to treat lidar data as scientific and open yet national and protected datasets. Some countries do not want fully public access to these files because of the potential danger posed to the looting of their heritage and security or military concerns. Yet, to a large extent, technology is overtaking some of the debate over accessibility, especially as newer satellite technology will surely alter the perceived physical boundaries and challenge the sovereignty of modern nation-states. However, how lidar is used and accessed in the future has become a cross-national issue that is worthy of being addressed in greater detail.

**Keywords:** Lidar; Ethics; New Colonialism; Sovereignty; Looting; Mesoamerican Archaeology

## 1. Introduction

Lidar has had a revolutionary effect on archaeology. After a decade of use in Belize, it has transformed our understanding of ancient Maya settlement and has profoundly affected archaeological interpretations of the past. In Mesoamerica, the technology is now recognized as an important tool for identifying and interpreting past settlements. Yet, the introduction of lidar to the research repertoire has also raised a host of ethical issues that must be resolved.

The introduction of broad-scale lidar to Maya archaeology over a decade ago has resulted in a paradigm shift in the field (Chase et al. 2012), leading researchers to examine models of ancient complexity reflected in more broadly sampled landscapes (e.g., Canuto et al. 2018; Chase 2017; Chase and Chase 2016a). Lidar constituted a major advance in Mesoamerican settlement studies by demonstrating the extent of ancient occupation, land use, and terraforming, as well as offering clues to settlement boundaries (e.g., D. Chase and A. Chase 2017; Chase et al. 2014a, 2014b). Lidar has permitted a much broader view of sites, landscapes, and land use by revealing new public architecture, extensive settlement, roads, and the

remnants of large agricultural systems (e.g., A. Chase et al. 2010, 2011; D. Chase et al. 2011; Canuto et al. 2018; Reese-Taylor et al. 2016; Ringle et al. 2017). New analyses and techniques are also permitting more sophisticated research questions to be addressed through the use of lidar, such as those regarding the control of water flow, the design of ancient space, and the identification of inequality (e.g., Chase 2016b, 2017; Chase and Weishampel 2016). And, while lidar ground-truthing has been called for by some researchers (e.g., Ford and Horn 2018), others are realizing that, rather than on-the-ground checks, what is needed is more extensive archaeological excavation to determine the dating and function of identified features (e.g., A. Chase and D. Chase 2017; Inomata et al. 2018, 2020). The ability to undertake large-scale spatial analysis with lidar has increased archaeological foci from site cores to entire regional systems (e.g., Chase et al. 2012, 2014b). As researchers have the tools to examine new questions relative to the use of ancient landscapes (e.g., Chase and Chase 2016b), older paradigms that saw the Maya as simple chiefdoms practicing slash-and-burn agriculture (e.g., Webster 1998) are being put to rest.

While lidar has served as a catalyst for reframing research questions in Mesoamerican archaeology, in the Maya area, it has also raised a host of ethical questions that are not fully resolved. Some of these ethical questions may be exclusive to Mesoamerican archaeology, but others are framed by the wider use of broad scale lidar throughout other parts of the world (e.g., Evans et al. 2013; Stott et

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al. 2018). The ethical issues concerning the archaeological use of lidar data have thus far seen only preliminary consideration in the published literature of Mesoamerica (e.g., A. Chase and D. Chase 2017: 464; Chase et al. 2011: 397; Chase et al. 2016: 226–227; Fernandez-Diaz et al. 2018) and require a more robust discussion in hopes of guiding future work in archaeological lidar (see papers in this Special Collection).

## 2. Background

After two decades of use, lidar data in archaeology provides a new frontier for ethical discourse. Because of the relatively recent adoption of lidar in archaeological areas like Mesoamerica, ethical issues remain that do not constitute stark contrasts of right and wrong or of good versus evil. Potential questions arise because of different contexts, practices, assumptions, and goals. These lead to complex problems for the field framed by the interests of various stakeholders, as outlined below, each of which has some claim to the issues at hand. This debate also moves between current standards of archaeological ethics and goals to remake the field in efforts to be both more scientific through open science (see Marwick et al. 2017) while at the same time continuing to decolonize archaeological practice.

The primary issues pertaining to lidar rest on the nature of the continuum from archaeological stewardship to public domain datasets. Lidar data itself remains costly, and not every project or researcher can easily afford to collect such data. Data collection has been funded by an assortment of private and public entities, with permissions granted from multiple state or government agencies. The different governmental and academic participants in lidar data collection, curation, and use each possess goals that mostly overlap on issues of data accessibility and site protection. Some sovereign nations or agencies, in efforts to protect sites or for other reasons of security, wish to restrict access to these datasets to interested scholars and credentialed researchers (e.g., Belize; see Chase et al. 2016, Chase et al. 2014a). This has led efforts to establish precedents and avenues for opening data access to other researchers couched in methods acceptable to local governments.

While there is a clear benefit to data-sharing in archaeology, archaeological permitting authorities may lack the desire to make lidar data completely available for reasons of national security or site protection, thus potentially giving rise to tensions concerning the desires of some (e.g., the National Science Foundation in the USA) for open science in archaeology, i.e. in its purist form, complete open accessibility of lidar and other archaeological data (discussions in Cohen et al., in press; Fernandez-Diaz and Cohen, in press). Handled poorly, this can lead to tensions and potentially new forms of colonialism. We contend that an appropriate balance can be achieved. While the scale of impact arguably may be different – with one difference likely being the source of funds – the concern might be paralleled with concerns that are sometimes expressed relative to foreign nationals working on classified projects in hard science labs. When scholars push cultural practices for digital openness onto countries that are unwilling,

without seeing appropriate consideration or accommodation of national concerns, that act itself can perpetuate colonialist research attitudes and increase, rather than lessen, divides. While foreign archaeologists can and do provide their input to local institutes of archaeology, ethical responsibilities require deferring to national sovereignty and authorities when working in other countries. Each country shows a unique idiom of archaeological practice and no single standard has yet emerged, even if we can generally agree on ethical practices between multiple sets of guidelines (see, for example, those of the Society for American Archaeology, World Archaeological Congress, or European Association of Archaeologists). Thus, open communication and discussion of these issues are essential.

A secondary issue rests with the desires of other stakeholders. While researchers, funding agencies, and lidar specialists handle data collection and distribution, other potential uses exist (see Cohen et al., in press). Government departments and militaries could easily use this data for hydrological studies, resource management, military planning, or a host of other purposes. In addition, private industry can also make use of these datasets (e.g., flood insurance planning or logging). In a more local sense, nearby communities provide a separate stakeholder group with distinct goals and interests. Tour guides and others involved in the tourism industry indirectly benefit from the findings of lidar data through press releases and the dissemination of findings and the effects on increasing tourism to the sites mentioned. The general public benefits from the findings of lidar research through news outlets, tour guides, books, and public outreach. News and entertainment organizations benefit through their business models by creating television specials and news articles for public consumption. Finally, looters and pillagers of the archaeological past also form a significant part of the conversation about lidar data. While researchers can use the datasets to identify looting, public datasets can also be used by looters to provide clear maps of good spots in which to excavate. It should be noted that studying looting and other illicit activities is difficult because of the nature of those activities (which often take place in offseasons, at night, or in remote locations). However, history has shown that not all looting occurs at the individual level and that a potentially greater danger to site preservation is the use of lidar data by organized groups that undertake looting. The efforts and organization that can sometimes be expended are evident in the Maya area; potential examples include the chain-sawing and surreptitious removal of monuments from Maya cities (see Tremain and Yates, 2019) as well as the systematic excavation of tombs at sites like Rio Azul, Guatemala (Adams 1986). There are also certainly other groups that can draw a benefit from or be impacted in some way from lidar analysis, each with differing desires, capabilities, and benefits gained from direct or indirect access to lidar data.

The primary issues in considering these groups and their potential interests can be exposed through reviewing existing archaeological ethical guidelines. In the case of the Society for American Archaeology (SAA), relevant

considerations with regards to data management and preservation rest on these following principles: stewardship of the archaeological record (#1), intellectual property of scholarship (#5), and long-term record keeping (#7). The unconditional preservation of the past emerges as an archaeological imperative, along with the preservation and sharing of data resulting from research. In addition, the guidelines on accountability to the public (#2) and guarding against the commercialization of the archaeological record (#3) impact this discussion. These two guidelines establish a firm desire to make findings as available as possible while also protecting the archaeological record from commercial exploitation. The role of archaeologists as stewards of sites, disseminators of knowledge, and bulwarks against profiteering from the past is clearly established in the SAA and other archaeological guidelines.

Based on recent discussions that have occurred among the archaeological lidar community (e.g., the December 2018 Paris Dialogue on Archaeological Lidar), it seems that a split among lidar scholars rests in the degree of accessibility that is accorded existing lidar data. Americanists were generally more concerned with the prevention of looting and respecting each nation's sovereign rights to govern lidar data recorded within their territory, while Europeanists were generally more concerned with facilitating open science and ensuring reproducibility through the creation of international standards on lidar data collection, research, and use. Both sets of perspectives remain valid and both sides respect the opinions of the other. Yet, this creates an ethical conundrum that cannot easily be resolved. The following consideration of data management, data accessibility, and stakeholders' roles pertaining to lidar provides a context for framing the conversation and hopefully helps in decreasing any divide between lidar researchers.

### 3. Data Management

Collecting lidar datasets creates huge digital files with all the issues inherent to 3D data in archaeology (see Opitz and Herrmann 2018; Richards-Rissetto 2017; Richards-Rissetto and Schwerin 2017; Richards-Rissetto and Landau 2019), in addition to the issues of long-term storage and accessibility that files of this size entail (see Kansa et al. 2014; Kansa et al. 2019). Currently, there are three acceptable means of securing these datasets. First, the data can be curated on a management platform like tDAR, OpenTopography, or other repositories such as Zenodo (Fernandez-Diaz et al. 2014, McManamon et al. 2017, <https://about.zenodo.org/policies/>). These organizations specify goals to ensure the long-term storage and accessibility of these datasets, but each has their unique weaknesses (e.g. costs and file-sizes for tDAR, public domain requirements for OpenTopography, and lack of multi-generational storage or future usability guarantee for more than twenty years for Zenodo). Second, the data can be stored by government agencies which often handle similar types of large datasets. Third, universities, research institutes, or libraries can bear the brunt of data storage, as they often have in the past. Finally, and unacceptably,

the data could just be stored on researcher's hard drives and local computer systems leading to a single accident that erases everything. Needless to say, regardless of how openly accessible the dataset is, safeguarding and expending all efforts in attempting to guarantee data operability and long-term storage is imperative.

In terms of data management platforms, tDAR has high costs for storing large data files, although that cost has gone down over time. Currently, one gigabyte of data costs \$500 USD. In some cases, this can make the storage of lidar data as or more expensive than the initial collection of that data. In terms of benefits, tDAR ensures that files are maintained in the most modern file format, allows for protected access of files, and has long-term file security provided through an arrangement with the Arizona State University library. OpenTopography has the benefit of providing free storage but stipulates that the datasets stored must be in the public domain. Public domain means that no one owns the data; instead, it belongs to everyone all at once and may be used for any purpose, including commercial uses. This can create a separate ethical issue. Making the lidar accessible with some form of public domain status or creative commons license might be more amenable to archaeological funding agencies but likely not to local and foreign governments.

It is important to note that the issue of openness is not limited to lidar data. There are similar debates regarding the appropriateness of treating all archaeological collections as public domain. This too remains an open question for archaeologists to resolve (Nicholas 2014; Brown and Nicholas 2012). Thus, the public domain question has a much larger scope, with the discussion being amplified in the context of data like lidar that is already digital. In any case, the type and degree of openness needs to be decided among the primary stakeholders: researchers, government agencies, funding providers, and communities. Our recommendation is that, if the data are made public, then they should have a creative commons license instead of *carte blanche* public domain status. Some creative commons licenses can prevent commercialized use of the dataset and the potential ethical issues that arise from that status; however, this should be well thought out first and may entail many unintended legal consequences rendering it a poor choice (see Hagedorn et al. 2011).

One question at hand, however, is who or whether anyone should be able to profit or materially benefit from archaeological lidar data (*sensu* Kansa 2016; Wells et al. 2015)? And, who benefits from open access? Lidar flights are not free. They are often funded by public or private granting agencies but also sometimes by private donors. The current system provides operating revenue to cover costs of some of the agencies that collect lidar data (i.e. NCALM) as well as to software developers of data processing and analysis tools (i.e. LAsTools). Both of these groups have expressed interest in making lidar datasets open access, but both of them would also profit from increased interest in lidar use and collection – a possible conflict of interest. Would NCALM fly free lidar flights in order to make the resulting data open access? Or, would LAsTools provide their full program for free? Neither of these are

fair questions. Modern social norms expect people to be paid for their efforts and for the costs to obtain lidar and to develop software. Yet, when both groups advocate for public access of archaeological lidar, they also advocate for advancement of their own interests. While there is a difference between for-profit and non-profit entities, material benefit should be considered by archaeologists who must decide how comfortable they are with commoditizing the process of archaeological inquiry (Kansa 2016; Wells et al. 2015). Regardless of one's stance on data acquisition, profit-making, and archaeological research, the goals of scientific inquiry and open science suggest that archaeologists and other scholars should push for more open source and freely available software (e.g. GRASS GIS, QGIS, or SAGA GIS for geographic information system software; R or SciPy for statistics software; and GRASS's LiDAR toolset, FUSION, CloudCompare, or custom code with PDAL – libLAS has been depreciated – for basic LAS data manipulation or analysis) and research methods to reduce the barriers to entry. This benefits not just local scholars in the USA and Europe but also academics in less developed countries who have fewer assets for purchasing software and methods (see Bezuidenhout et al. 2017; Kansa 2016).

No one wants to enshrine a lidar elite of established scholars (Fernandez-Diaz et al. 2018), but a local review of lidar publications indicates that what might be occurring is the opposite, an opening up of research opportunities for younger scholars. Within Belizean archaeology, lidar has often created new potential research areas for graduate students. A review of recent journal articles indicates that while the initial lidar articles framing the use of this technology in Mesoamerica came from established scholars (e.g., Chase et al. 2010, 2012), more recent ones, forming a majority of the studies, are written by junior scholars or by teams of junior and senior scholars (e.g., Brown et al. 2016; Cap et al. 2018; Chase 2012, 2016a, 2016b, 2017, 2019; Chase et al. 2017; Chase and Weishampel 2016; Ebert et al. 2016; Golden et al. 2016; Moyes and Montgomery 2016, 2019; Murtha et al. 2019; Thompson and Prufer 2015; Yaeger et al., 2016). Instead of creating an entrenched lidar elite in Belize, lidar data has provided research opportunities for graduate students when working on their Ph.D. dissertation research and for scholars working toward promotion in their academic positions. Although this pattern may not hold in other research areas, elsewhere in the Maya area, the Pacunam lidar consortium in Guatemala (following Canuto et al. 2018) seems to match the same pattern as the West-central Belize lidar consortium (Chase et al. 2014a). This provides a clear example of how the Institute of Archaeology in Belize has created and fostered the conditions necessary to open up research through their long-term plan for data accessibility, while at the same time protecting their heritage from being looted (Chase et al. 2014a).

Belize is a sovereign nation in control of its own archaeological research. The Institute of Archeology (IoA) has the sole authority to issue permits and grant access to lidar data (Chase et al. 2014a). Ergo, Belize through the IoA has sole authority to stipulate the rules and governance of lidar access to Belizean data. Just as Belize cannot give a

permit for excavation in the USA, the USA cannot grant a permit to excavate in Belize. By proxy, this means that enforcing any external digital data policy with regards to archaeological data generated in Belize would be a breach of sovereignty and an imposition of digital or new colonialism. Conversely, the idea of data sovereignty means that if the nation of Belize decided to make the data open – of its own volition – then those datasets would be open access while respecting the governance and national sovereignty of Belize.

Arguments for openness of lidar data often suggest that it creates access to the broader public as well; however, this does not hold up under scrutiny. While residents of the USA and Europe have access to high-speed internet and powerful computing hardware, the average Belizean does not. As such, open access data does not necessarily open the datasets to the broader public, but rather only to the public within developed countries perpetuating the “digital divide” between richer and poorer countries (Bezuidenhout et al. 2017). The argument creates a false sense of equality in technology and accessibility between countries that does not currently exist. In other words, creating the conditions to enable more open science does not rest in digitizing and hosting data online alone, especially as that requires greater access to technology.

There are examples of similar issues in sovereignty and suggestions of the practice of new colonialism within the USA. Two separate cases of DNA studies highlight these issues involving the modern-day Havasupai (Garrison, 2012) and skeletal research on ancient populations at Chaco Canyon (Claw et al. 2017; Kennett et al. 2017). In both cases, researchers carried out DNA analysis without properly consulting affected groups and sidestepped institutional review board (IRB) goals of informed consent designed to uphold academic ethics and accountability. Each example, while perhaps “legal,” highlights actions that are of ethical concern and display a lack of respect for the sovereignty of indigenous communities within the USA. The Chaco case occurred a decade later, suggesting the need to discuss and codify ethical concerns and dilemmas. Lidar analysis is not the same as DNA analysis; however, we wish to use the lessons learned through these forms of research to avoid a similar fate. Archaeologists should be aware of situations like these and keep the interests of indigenous groups and other peoples in mind (see also Carroll et al. 2019; Normark 2004; <https://www.gida-global.org/>).

Two questions should be at the forefront when attempting to advocate for changes to the practices of another country. First, who benefits from this change, and second, does it deprive the local government of its sovereignty? Nations like Belize have full rights to manage their internal affairs, govern the use of their own archaeological material, and determine the best way to preserve the past. Foreign scholars remain guests who can provide information and work with local communities, institutes, and governments; but, they should not expect any ability to force their will over these other actors. True national sovereignty also entails national control over the disclosure of secure information within that country's legal framework.



If the situation were reversed, and Belize requested that the USA publicly release digital data of any kind and the USA desired to delay but still follow through, then the USA would likely turn to two of its legal methods already in place to prevent the release of secure data under its own sovereign laws and regulations: copyright law or declassification of information guidelines. Copyright for work in the USA can last the lifetime of the author(s) and an additional 70 years, 95 years from first publication, or 120 years from the date of a work's creation (USCO 2019). In the case of the lidar datasets in Belize, that 95-year deadline means that the data would not be available in the public domain until 2104 for the 2009 lidar flight. In the case of classified materials, after 25 years material of historic value can be automatically declassified (USDoJ 2016). This would make the data from 2009 publicly available in 2034. However, the USA retains the right to keep material classified forever. These dates and timeframes provide existing information, but should not be treated as a one-to-one method for how lidar data should be treated. In effect, their use highlights that even in the USA, public domain status of material and open accessibility is not always guaranteed in a short timeframe.

#### 4. Data Accessibility

Access to lidar datasets has the potential to impact a variety of stakeholders and satisfy disparate interests, but the nexus of this ethical issue revolves around access, use, and benefits in addition to who should serve as the gatekeeper, or if anyone should. Within the Maya region, scholars and archaeological institutes remain concerned with the potential for looting, logging, and other illicit uses of lidar datasets backed up by historical circumstances (e.g., Tremain and Yates 2019). While difficulties exist in studying illegal activity like looting, there are at least two forms of looting that exist: independent looters, who work at a small-scale, and organized looters, who act as part of a larger criminal enterprise. Advocates for open access argue that looters do not have the sophistication, resources, or ability to use these data (i.e., an inability to access the web), but this argument reveals both naiveté and a colonialist attitude embedded in inappropriate beliefs that local people are not as sophisticated as those in developed countries. There is no veracity to the argument that looters would not use public lidar data if it were easily available.

While the likelihood of individual looters using these data to organize their digging is open to question, there is no doubt that if the money exists in the private art market, then organized looting would be conducted as a criminal operation with dedicated specialists. In this context open source software and a single GPS unit would be all that are required to create a roadmap to archaeological sites. Historically, the removal of Maya stelae from sites with chainsaws was an effort that required some degree of specialization and organization (see Tremain and Yates 2019). When Google Earth was made public, the threat of remote sensing datasets and looting was established (Ur 2006). While it is impossible to tell how much looting has occurred as a result of Google Earth, its public release

certainly does not appear to have eliminated looting. Given the archaeological ethics against looting and the desire of governments to curb looting, this creates a serious stumbling block for making lidar datasets easily accessible by all, especially in areas that are difficult to protect because of their remoteness.

Even if lidar data moved solely into the public domain, access could be inhibited by a need for better free and open source software. Currently, GRASS GIS, FUSION, and CloudCompare might be the better options for open access programs facilitating lidar data analysis; however, archaeologists are beginning to acquire greater programming knowledge due to the modern necessities of the field. Long term, this will likely lead to the improvement and creation of new systems that will encourage us to work with and on these open source programs. Increasing their effectiveness and usability will lead to greater parity and equity between researchers of all income levels and nationalities, more so than just making more data accessible. Not everyone can afford to pay thousands of dollars for software but reducing that barrier to entry seems like a key imperative and lines up with open science goals for accessibility and reproducibility.

Lidar data itself provides a palimpsest landscape frozen in time – the record received by the sensors on the day and time that the airborne lidar was flown. Without additional information, the context from past excavations and surveys, that data does not say very much archaeologically. Focusing on the accessibility of lidar data simply because they come pre-digitized does not solve the larger issues of open science in archaeology. The lidar data need to be contextualized with archaeological data that can provide context and dating; thus, these data also need to be provided. However, there is a generational-scale problem now being faced by multiple archaeologists and projects. How do we preserve previously excavated data and ensure that they remain accessible in the future (Beebe 2017, Bauer-Clapp and Kirakosian 2017; Huster et al. 2018; JD Richards 2017)? As open science and data comparability gain more widespread traction within archaeology, the desire to use historic datasets and generate more cross-cultural research (*sensu* Ek 2019; Smith 2015) will hopefully lead to long-term improvements in existing data infrastructures. Opening up lidar data, while easier to do on a technical level, does not solve much in terms of long-term desires to make archaeological investigation a completely open-sourced science. Instead, this will require blood, sweat, and tears while working in the archives.

#### 5. Stakeholders

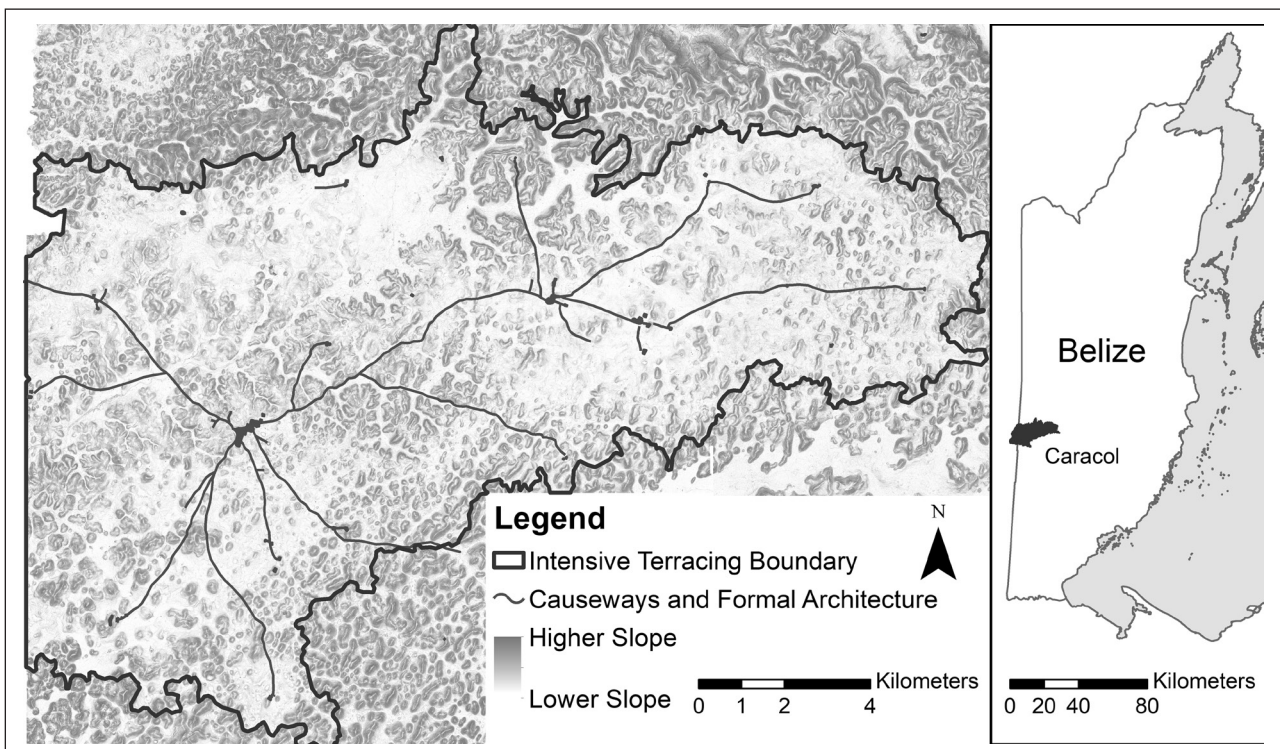
Within this complex methodological issue, many parties have potential interests in the outcomes and ramifications of archaeologically produced lidar datasets. Stakeholders involved include: dataset collectors (researchers, funding agencies, software developers, and lidar collectors); organizations (government, military, or private industry); local groups (tour guides and communities), and, everyone else (public, looters, etc.). Each group has different interests and goals in mind when they hear about archaeological lidar that can create conflagrations of conflict between

open access and open science, sensitive data and governmental security concerns, and long-term preservation of archaeological data, materials, and features.

The first group of primary stakeholders are those more directly involved in data creation and curation. The researchers who propose and organize the collection of archaeological lidar data can work with other scholars in different fields to generate cross-disciplinary research (see for example Hightower et al. 2014; Swanson and Weishampel 2019; Weishampel et al. 2011; Weishampel et al. 2012). Ultimately the goals here often coincide with those of archaeological survey, but also incorporate the expertise of lidar collecting agencies and the needs catered to by existing software. Without the funding agencies, none of this research would be possible. The primary goals within data set creation and use vary by group. The archaeologists are interested in features on the ground, but collaboration with other scholars can provide synergistic research goals. Hydrologists might be interested in removing archaeological features and biologists might be more interested in the forest canopy, but there are multiple ways in which the collected data can be used. The funding agencies want to encourage good research; their goal is to support the discovery and curation of new knowledge and, as best practice, these agencies now require data management plans and public outreach of research results. Initial funding at Caracol, Belize (see **Figure 1**) occurred through a National Aeronautics and Space Agency (NASA) space archaeology grant in 2009 (Chase et al. 2010, 2011; Weishampel et al. 2010) with the aim of testing the technology, which had not been utilized by archaeologists in the Americas since Payson Sheets and Tom Sever's (1988) publication demonstrating lidar's early failure. The second grant from The Alphaswood

Foundation in 2013 (Chase et al. 2014a, 2014b) involved the creation of a consortium of scholars to work together to reduce costs of data collection and to establish a means of data accessibility through the Belizean Institute of Archaeology in order to gain data from a broad sector of the ancient Maya landscape. For these and other scholars, the motivation for collecting lidar data is to better understand the ancient anthropogenic landscapes with a goal of publishing results.

While charging for their output, lidar collection and processing specialists tend to be motivated by other factors, ranging from scientific advancement and publication to reputation and the growth of additional work projects. For example, many Maya research projects have utilized NCALM for their expertise (e.g. A. Chase and D. Chase 2017; Chase et al., 2016); they are often rewarded for excellent work through word of mouth recommendations or through popular publications (Preston 2017). Thus, open access not only provides greater ability for scientific data sharing, but also positive exposure for the company. While making the data accessible benefits this group by showing off the quality of their work, it also leads to future gains in reputation and contracts. Similarly, software developers have a financial incentive to increase the number of lidar dataset users, especially because each new user is another potential customer. When they advocate for making the data freely available, but still charge thousands of dollars per year for licensing software, the inherent conflict of interests between their desire to advance open science and their profit model is laid bare. These stakeholders involved in archaeological lidar data creation and processing possess multiple goals that often align, but that may be intrinsically at odds, with data accessibility issues.



**Figure 1:** Lidar derived map of Caracol, the ancient city in modern day Belize.

A second group of users includes the national governments and militaries of the countries that provide permission for lidar flights. These individuals and entities are concerned with national security and the preservation of cultural heritage and weigh these interests when considering public access. In the case of Belize, the Institute of Archaeology restricts access due to a vested interest in preventing looting. Entities concerned with national security may desire up-to-date maps and information but may not be as motivated to provide the same to outsiders. A good example of the conflict between military goals and data openness is provided by Adrian Myers (2010) who investigated the USA-owned prison in Guantanamo Bay, Cuba with Google Earth data demonstrating additional construction. In no sense would the USA military be interested in having information that contradicted their official statements about the facility being made public. Finally, assuming public domain lidar datasets, private industries may be interested in utilizing the information contained within. Logging and flood insurance companies would have the easiest means of using this data to turn a profit. However, in the case of archaeological lidar they would serve as free riders without having paid any cost inherent to the creation of the datasets. Logging or other industry near archaeological sites may also hamper long-term efforts at preservation. We can already see that within this set of stakeholders the interests for public access still seems misaligned with the direct archaeological goals of data collection. This may ultimately change if more entities decide to make lidar data accessible, as is occurring in some European countries.

Moving to more local concerns, communities under and nearby lidar flight paths, or tour guides working at archaeological sites would also have an interest in lidar data. While they may not become direct users of the datasets, they are often interested in the results of the data or other aspects provided by this data collection (i.e. accurate local maps). In the case of technologies like this, local communities and individuals are not always consulted but generally wish they could be included. For example, if you live in the USA, were you ever asked by Google if they had your permission to photograph your property and upload the images in Google Street View or Google Maps? Thus, another question for archaeological lidar is when researchers should obtain informed consent – i.e. consult with and consider the views and impacts on the modern or descendant communities – to record any lidar data in addition to acquiring governmental permissions and permits. In addition, archaeologists have also been guilty of new colonialism in exporting views from the USA and applying them to local communities in other countries (see the example in Overholtzer and Argueta, 2018). However, the definition of community itself is important. Because of its remote location, at Caracol, we have a slightly different focus on community than some projects. While there is no local town or city at Caracol today, we do have a community comprised of the members of the Institute of Archaeology, the park rangers on-site, the Belize Defense Force stationed in camps nearby, and the tour guides. All of these groups of individuals spend time

at Caracol. Other individuals who spend time on site are those focused on more illicit operations: looters, poachers, and illegal loggers. Our version of community archaeology focuses on the needs and desires of the former groups and not on those of the latter.

Next, the general public, in a global sense, can also be a stakeholder in data use. An engaged public might be interested in perusing raw lidar data, but often people like free services that simplify the use of these datasets – for example, Google Maps over traditional road maps and satellite photos. In many cases the public at large is rarely informed by the archaeologists themselves; instead, tour guides, museum curators, journalists, and television crews generate the information consumed by the public at large. Their interests in the data revolve around the stories told with or about its collection; the primary issues there involve the common projection of sensationalized stories and television shows, even some of those framed in the guise of educational documentaries or as public service programs. More invested members of the public might go to public talks by academics to obtain additional information about lidar, but the tour guides will share more information with the public than most archaeologists ever will. For this group, public dissemination of results remains more useful than the raw data.

The final group of users is intentionally separated from the rest of the stakeholders because their activities are completely unauthorized or illegal. If the data were made completely public, this also opens use to those interested in looting and other illicit activities. Illegal behaviors are difficult to study by nature, and the true rates of looting will be unknown for certain; however, looters have an interest in locating places to dig and lidar can provide them with a direct map. In the cases of illicit logging or other vegetation planting or removal for profit, which had been a large issue at Caracol for much of the last decade, public lidar data could have been used by these individuals not only to loot artifacts, but also to identify areas where more profitable tree species (i.e. mahogany) were located. If there is profit to be made through illicit activity, then any tool that lowers the barrier to entry (i.e. showcasing places to dig or exploit) will incentivize these actions and thereby violate the preservation goals of archaeologists and watchdog permitting agencies.

## 6. Discussion

Archaeologists have a myriad of ethical guidelines and goals when engaging in their profession. These are not always in alignment, however, and scholars place different weights on the various aspects of ethical concerns. In the case of archaeological lidar, within the scholarly community disagreement exists concerning: the amount of looting that could be caused by making lidar data public; the potential benefits of open science; and, the role of local governments in determining the appropriate levels of access to lidar data. Importantly, archaeologists are not the only stakeholders with a say in data management. Permitting agencies have an interest in protecting the past and may prioritize barriers to data access in order to prevent looting. In addition, we should pay attention to where the



voices for open access come from and whether they reflect for-profit or non-profit motives. Individuals who receive a material benefit from making the data public may not have the interests of archaeologists, local governments, or archaeological sites at the center of their thoughts. There is also almost certainly no single solution for how data should be managed, distributed, and accessed. While a general set of guidelines might be desirable as a framework, it is important to consider the differences between global and local needs and concerns.

The primary issue at hand remains the novelty of digital data to archaeological ethical guidelines. Long term data storage – digital and other forms – has not been thoroughly vetted and addressed; there also remains a generational-scale level of work in digitizing and distributing data from historical excavations. Lidar data will be part of that dataset, but it will still require archaeologists to act as stewards of the past while preserving these records for the future. In addition, archaeologists should not act alone, but should consult with local communities including government agencies, institutes of archaeology, and the people with whom they work and live on-site. Otherwise, archaeologists aid and abet a form of new colonialism. It should be noted that this respect for national sovereignty and a need to avoid new colonialism remains a greater concern for archaeologists who work outside of their countries of nationality. Regardless of the benefits to science, desire for forward progress does not replace or negate the need for cultural relativism and sensitivity to local rules and regulations. We cannot export our cultural values without due process for the interests of local groups (Claw et al. 2017). Archaeology has been a collaborative science and still requires maintaining various dialogs with all the potential stakeholders involved in our research.

In terms of moving forward with lidar data and accessibility, for now we hold that the model used in Belize has been successful. It has allowed for junior scholars to access lidar datasets for their research and avoided the primary pitfalls of entrenching or establishing a lidar elite in Belize. We believe that our goals, at least for now, should be focused on the construction of better tools and teaching techniques to facilitate the increasing technical requirements of computational archaeology. Without a basic understanding of computer science, lidar analysis requires the use of black-box tools and off the shelf programs. The future of archaeology will require greater computational training, and the use of lidar data will be only one of many techniques for future archaeologists' toolkits. As such, creating and sharing better open source tools for analysis of archaeological data will become more important. In addition, a generational shift will be required to fully digitize current existing and historic datasets to permit more open science in archaeology.

## 7. Conclusion

As with most ethical considerations, there are clear-cut areas as well as those in between. The ethical use of lidar data remains in flux. Currently the discussions around openness versus protection of sites, for-profit versus open-source data analysis software, and international norms

versus local circumstances show how these issues are complex and intertwined. We are not arguing here for public or non-public access, but rather for considering sovereignty, greater use of open access software, decreased costs for storage, and the potential applicability of creative commons licenses over public domain status for lidar datasets. In addition, while accessibility is paramount, the need to understand the context of lidar cannot be sufficiently underscored. Few anthropogenic landscapes are generated at a single point in time. There is a need not only for excavation to determine date and function of archaeological features, but also for the appropriate use of excavation reports to study ancient land-use and modification. Access to lidar alone will not solve these problems. Similarly, the current debate over access to lidar may become mute as satellite technology further develops and makes the possibility of widespread high-grade locational data a reality, potentially altering concerns about physical boundaries and national sovereignty. In the meantime, however, it is imperative for the field to continue decolonizing archaeology and avoiding the pitfalls of new colonialism by respecting national sovereignty and working with local communities. At the same time, there is a need to create more openness and data sharing in archaeology; this goal, however, requires more than making lidar datasets accessible. It requires a substantial investment in open source software and the digitization of historic excavation records. In addition, simply putting information online does not guarantee its long-term persistence or the ability of everyone to afford use of the data. These issues extend beyond archaeology itself and there is no specific right and wrong, and the best practices and solutions may differ from country to country and region to region. Instead, archaeologists must respect national sovereignty, while simultaneously working toward the underlying infrastructure required for better data management and data sharing in the future.

## Acknowledgements

The authors wish to thank Anna Cohen, Sarah Klassen, and Damian Evans for organizing both the Paris Dialogue on Archaeological Lidar as well as this JCAA special issue. Publication funds were provided by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No 639828).

## Competing Interests

The authors have no competing interests to declare.

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**How to cite this article:** Chase, ASZ, Chase, D and Chase, A. 2020. Ethics, New Colonialism, and Lidar Data: A Decade of Lidar in Maya Archaeology. *Journal of Computer Applications in Archaeology*, 3(1), pp. 51–62. DOI: <https://doi.org/10.5334/jcaa.43>

**Submitted:** 15 October 2019

**Accepted:** 24 March 2020

**Published:** 10 April 2020

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