Journal of Archaeological Science: Reports 4 (2015) 252–263

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: http://ees.elsevier.com/jasrep

Adapting LiDAR data for regional variation in the tropics: A case study from the Northern Maya Lowlands

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ARTICLE INFO

Article history:
Received 2 February 2015
Received in revised form 11 August 2015
Accepted 22 September 2015
Available online 2 October 2015

Keywords:
LiDAR
Settlement patterns
Ancient Maya
Ground truthing
Political dynamics
Vegetation survey

ABSTRACT

Archeologists have used Light Detection and Ranging (LiDAR) as a remote sensing technique for creating high resolution and high accuracy elevation models of the earth's surface in forested areas. In the Maya area, LiDAR allows archeologists to conduct full-coverage regional surveys for the first time. Yet due to variation across space in the characteristics of vegetation, topography, and the kinds of archeological features that archeologists seek to locate, the use of LiDAR in the tropics will not meet the same level of success in every case study. Such variation in vegetation, topography, and archeological features also creates opportunities for archeologists to explore methodological adjustments that can maximize the usefulness of LiDAR data for a particular forested area. Using a case study from Northern Yucatan, Mexico, this paper explores a variety of techniques for visually rendering LiDAR data in an attempt to determine which technique works best for identifying low stone residential platforms given the local topography and vegetation. The most successful technique, a color-classified DEM, was then used to locate hundreds of previously undocumented platforms in the area of LiDAR coverage. Conducting a rapid vegetation survey showed that more features can be found in forested areas when there is less vegetation close to the ground. Vegetation surveys permit the calculation of vegetation-specific correction factors to be used in conclusions derived from LiDAR imagery.

1. Introduction

Articles highlighting the ability of Light Detection and Ranging (LiDAR, also called Airborne Laser Scanning (ALS)) to penetrate tree cover and render precise topographic maps appeared in flagship archeology journals as early as a decade ago (Bewley et al., 2005; Challis et al., 2008; Crutchley, 2006; Devereaux et al., 2005; Harmon et al., 2006). In the tropics, LiDAR caught fire more recently with the publication of groundbreaking results from the jungle-covered ruins of Caracol, Belize (Chase et al., 2011) and Angkor Wat, Cambodia (Evans et al., 2013). In the Americas, regional surveys covering hundreds and even thousands of square kilometers had only been possible in dry areas where vegetation does not significantly inhibit rapid, systematic pedestrian surveys (Blanton et al., 1982; Bauer and Covey, 2002; Sanders et al., 1979; Wilson, 1983). In tropical lowlands without modern agriculture, however, dense vegetation often makes regional-scale systematic pedestrian survey prohibitive in terms of cost and time. LiDAR has changed this situation, making it possible to identify residential platforms, agricultural terraces, and other features otherwise hidden by forest cover (Chase et al., 2014a; Rosenswig et al.2013; 2014; for other successful remote sensing techniques in the Maya area, see Garrison, 2010; Garrison et al., 2011). Yet LiDAR has only been used by a handful of archeology projects in the tropics thus far. Since vegetation and topography affect processing and interpretation of LiDAR data and vary significantly both between and within tropical regions, methods deployed in one area may require refinement when transferred to other areas.

The Maya area (Fig. 1), which encompasses Guatemala, Belize, eastern Mexico, western Honduras and western El Salvador, contains a great diversity of ecosystems and physiographic regions. The current study uses LiDAR on the coastal plains of northern Yucatan (see also Hare et al., 2014). The vegetation and topography of this region differ significantly from other Maya areas where LiDAR has been used, including the Vaca Plateau at Caracol, Belize (Chase et al., 2011), the Maya Mountains at Uxbenka, Belize (Prufer 2014), the Belize River Valley (Chase et al., 2014a), the Calakmul Biosphere Reserve at Yaxnocah, Mexico (Reese-Taylor et al., 2014), and the Soconusco area at Izapa, Mexico (Rosenswig et al., 2013).

In this paper I consider three methodological concerns in working with LiDAR data from the coastal plains of Yucatan, gathered as part of the Ucí–Cansahcab Regional Integration Project (UCRIP). The first topic concerns visualization techniques for presenting LiDAR data. I compare six different visualization techniques to see how well they make pre-Hispanic architecture visible. Second, I discuss criteria for differentiating natural features from artificial constructions using LiDAR imagery from the UCRIP area. The third topic pertains to the way in which height of vegetation, type of vegetation, and ground return density affect the success of using LiDAR imagery for locating ancient

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http://dx.doi.org/10.1016/j.jasrep.2015.09.012

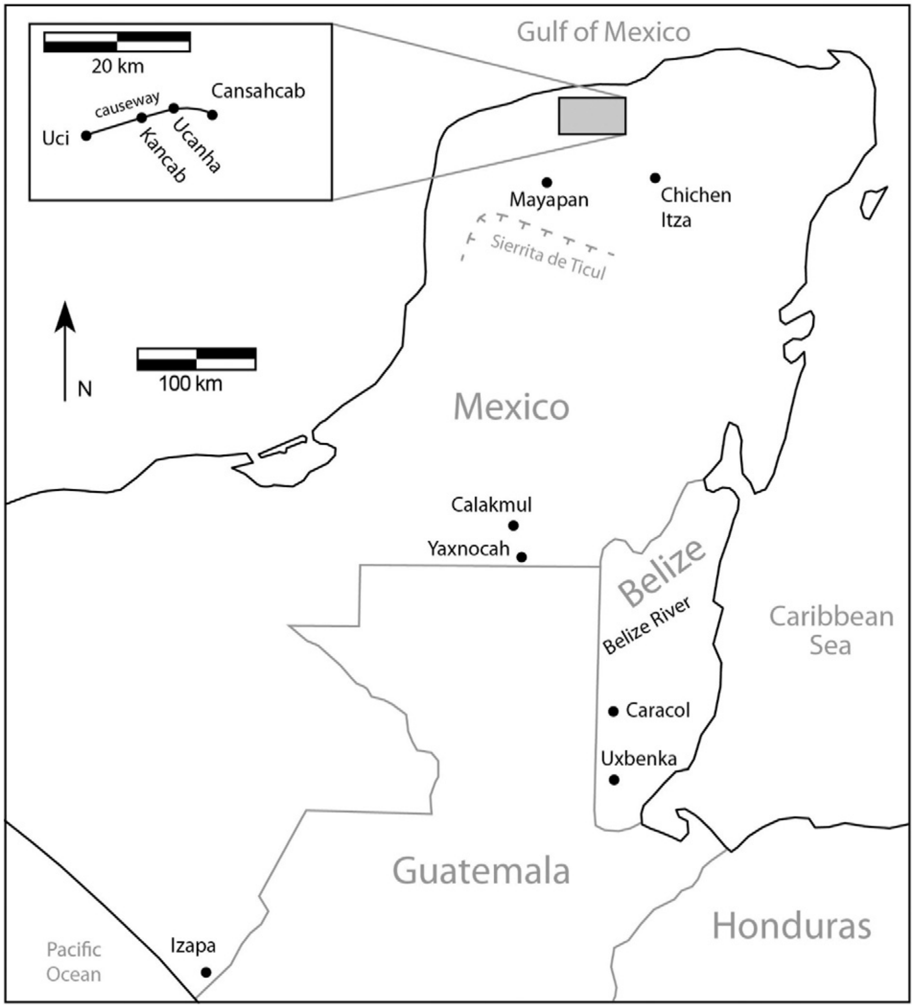

Fig. 1. Map of the Maya area showing the location of sites mentioned in the text.

architecture. I make the case that vegetation has important effects on the visibility of ancient features on LiDAR imagery, thus justifying a rapid pedestrian vegetation survey in areas with LiDAR coverage.

2. Background

2.1. Geology and ancient architecture of the UCRIP area

The UCRIP study area consists of a series of ruins located in the vicinity of an 18 km long causeway that connects the ruins of Ucí, Kancab, Ucanha, and Cansahcab (Maldonado, 1979) (Fig. 2). The geology of the northern plains of Yucatan presents both advantages and disadvantages for using LiDAR to locate built features. The causeway between Ucí and Cansahcab lies on a 100 km wide swath of low-relief, karstic plain between a range of hills (the Sierrita de Ticul) to the south and the coast to the north (Fig. 1) (Isphording and Wilson, 1973). Fig. 3 shows a sample of the terrain at the site of Ucanha and in the figure, the only substantial rises are artificial pyramids, which reach elevations of 10 m above the natural ground surface. Fragments of the causeway between Ucí and Cansahcab are also visible in Fig. 3, not to mention low platforms (see below). Solution features and fractures in the carbonate surface create low bedrock outcrops and depressions. In the vicinity of Ucí, the largest depressions are 5 m deep, cover less than half a hectare, and are rare; the depressions visible in Fig. 3 are the only ones of their kind in the entire 26 km^2 of LiDAR coverage.

Bedrock outcrops decrease in elevation from about 5 m high on the south edge of the plains, at the base of the Sierrita de Ticul, to less than 1 m high as one nears the Gulf of Mexico (Beach, 1998:764; Dahlin et al., 2005:235). Unfortunately, these small bedrock outcrops have the same height range and horizontal dimensions as artificial platforms. Fig. 3 shows over one hundred platforms. Platforms are raised stone surfaces that supported other structures such as houses, shrines, storage structures and kitchens. Typically these other structures were made mostly of materials—wood, thatch, daub—that are no longer preserved. In the Ucí–Cansahcab area, previous research shows that most platforms are generally lower than 2 m with surface areas ranging from 25 to 650 m^2 (Hutson and Welch, 2014). Section 4.2 discusses techniques for distinguishing artificial platforms from natural outcrops that also show up as “bumps” in LiDAR imagery.

2.2. Vegetation of the UCRIP area

Over 80% of the land where LiDAR data were collected is covered in scrub forest that has not been significantly altered by humans in over a decade. Locals call this *monte*, and the most common tree species are Chukum (*Phitecolobium albicans*), Catzin (*Senegalia gaumeri*), Huaxin (*Leucaena leucocephala*), Chakah (*Bursera simaruba*), Habin (*Piscidia piscipula*), and Dzidzilche (*Gymnopodium antigonoides*). Canopy height is approximately 6 m high and underbrush is thick. The area receives an average of 1000 mm of precipitation per year. The rest of the terrain features a mosaic of different types of vegetation resulting from recent land use, including pasture, plots burnt for farming (*milpa*) at various times before data collection (see also Prufer et al., 2015), and more (see below). The vegetation in the UCRIP region differs markedly from