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An observational and theoretical framework for interpreting the landscape palimpsest through airborne LiDAR

Katharine M. Johnson[a,b,*], William B. Ouimet[a]

[a] Department of Geography and Center for Integrative Geosciences, University of Connecticut, Storrs, CT, 06269, USA
[b] Earth Resources Technology, Inc., NOAA National Centers for Environmental Information, 151 Patton Avenue, Asheville, NC, 28801, USA

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ABSTRACT

High resolution airborne Light Detection and Ranging (LiDAR) has become a commonly used resource on a global scale to study landscapes and associated cultural features, especially in areas covered by dense forest. While LiDAR allows for unprecedented views of the terrain beneath the forest canopy, and of landscapes at broad scales generally, few studies have provided an examination of features within theoretical frameworks used to describe landscapes, or have acknowledged LiDAR data as a palimpsest. Any derivative imagery from LiDAR data depicts a moment in time of a contemporary landscape with topographic traces of cultural and physical elements from a range of time periods within and beyond human history. In order to effectively interpret the landscape as represented through LiDAR, it is critical to supplement this data with multiple contextual sources and a more robust theoretical geographic framework. While the concept of landscape as a palimpsest is well known, for the first time in hyper-realistic form we can see and physically interpret that palimpsest, along with the traces of data processing and visualization that we ourselves add to the digital landscape palimpsest in an effort to interpret it. This study provides a critical examination of the LiDAR landscape as a palimpsest, summarizes studies that have used a combination of LiDAR and supplementary resources, and provides observational examples from the northeastern United States, thus providing a practice-based observational and theoretical framework from which other landscapes and associated cultural features can be studied using LiDAR.

1. Introduction

Light detection and ranging (LiDAR) datasets have been used over the course of more than a decade in examining cultural landscape features (Risbøl, 2013; Sittler, 2001), with an increasing popularity during the last several years (Doneus & Kühteiber, 2013; Opitz, 2013; Tarolli, 2014). LiDAR has become widely used in heavily forested areas internationally in Europe (Bewley, Crutchley, & Shell, 2005; Devereux, Amable, Crow, & Cliff, 2005; Doneus, Briese, Fera, & Janner, 2008; Lasaponara, Coluzzi, & Masini, 2011; Risbøl, 2013; Schindling & Gibbes, 2014; Sittler, 2001; Tarolli, Preti, & Romano, 2014), Asia (Evans et al., 2013), and North and Central America (Chase et al., 2011; Gallagher & Josephs, 2008; Johnson & Ouimet, 2014; Millard, Burke, Stiff, & Redden, 2009; Opitz, Ryzewski, Cherry, & Moloney, 2015; Pluckhahn & Thompson, 2012; Randall, 2014; Rosenswig, López-Torrijos, Antonelli, & Mendelsohn, 2013). Despite exciting new applications and an overwhelming number of recent case studies, any imagery derived from LiDAR data portrays the landscape and associated long-term processes occurring at varying temporal rates at the single point in time (or a short series of points in time (Nordström, 2017)) that the data were collected; not truly as they appeared during historical time periods that many of these studies examine (Harmon, Leone, Prince, & Snyder, 2006). The concept of landscape as a palimpsest or as an accumulation of physically-expressed events provides a theoretical framework based in human and physical geography, as well as anthropology (Harrison et al., 2004), through which to interpret LiDAR data and associated derivative raster data such as commonly-used hillshaded digital elevation models (DEMs), slope, relief, or a variety of other visualization types (e.g., Bennett, Welham, Hill, & Ford, 2012; Challis, Forlin, & Kincey, 2011). By processing and interpreting the LiDAR data, we provide an additional layer to the landscape palimpsest, creating a new digital LiDAR landscape palimpsest that must be further interpreted with processing techniques, interpretation biases, and supplementary datasets in mind.

Landscapes have often been likened to palimpsests due to the rich history of physical and cultural events expressed on or below the surface (Anschuetz, Wilshusen, & Scheick, 2001; Brierley, 2010; Harmon et al., 2006; Holtorf & Williams, 2006; Hritz, 2014; Johnson, 2007;

* Corresponding author. Earth Resources Technology, Inc., NOAA National Centers for Environmental Information, 151 Patton Avenue, Asheville, NC, 28801, USA.
E-mail address: katharine.johnson@uconn.edu (K.M. Johnson).

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Kantner, 2008; Mlekuz, 2013a). This simile originates from manuscripts that were scraped clean and written over, though trace elements of the original script remained (Schein, 1997). Humans have altered their environments and landscapes for thousands of years (Foley et al., 2013; Smith & Zeder, 2013), indeed it has been argued that the concept of "place" is a "historically contingent process" (Pred, 1984) or that "the cultural landscape" contains a "series of sedimentary layers of social accretion, each cultural stratum reflecting particular ideological origins, intentions, and contexts" (Schein, 1997). It is thus critical to recognize the temporal range and possible cultural affiliations of features that might be observed or interpreted through examining data derived from high-resolution LiDAR.

Because LiDAR allows for such high resolution imaging of the ground surface, it often provides an overwhelming amount of data to interpret. The landscapes we see through it are often a "mess of temporalities," "traces" of events with "differential duration" (Mlekuz, 2013a, 2013b), an "assemblage" of materialized events that have remained resilient to disruptive forces (Aldred & Lucas, 2010), or a "temporal collage" (Holtorf & Williams, 2006). The current landscape is the continuously-changing cumulative result of complex processes involving coupled human-environment systems and feedbacks, and not necessarily always "scraped clean" like a true palimpsest (McDonagh & Daniels, 2012). Of note are events or processes that leave subtle or no topographic signatures on the land surface yet still result from human interaction with the landscape; these include the production of memory, mythologies, or experiences (Holtorf & Williams, 2006; Ingold, 1993), power dynamics (Given, 2004; Spencer-Wood & Baugher, 2010), as well as human settlements or activity sites that lack widespread or localized surficial topographic signatures. This makes it difficult or impossible to discern these processes using LiDAR, though recent studies have shown that in some cases microtopographic cultural features are in fact visible (Howey, Sullivan, Tallant, Kopple, & Palace, 2016), and that motion and contemporary movement through the landscape can be captured using laser scanning (Nordström, 2017).

The overwhelming number of remaining topographic features expressed as a collection on the land surface often make it difficult to interpret surface or elevation models derived from LiDAR data and locate or identify specific features of interest without supplementary information – in a sense, there is almost too much information to interpret without context. While also acknowledging that our own histories and worldviews influence our interpretations of landscapes (Holtorf & Williams, 2006), many limitations to landscape interpretation and the burden of excess information can be partially overcome for more recent time periods by using supplementary data such as sequential satellite or aerial photography, other remote sensing techniques, historical maps, oral histories, field validation studies, archival data, or other physical or environmental data for a broader range of time periods (e.g., Challis, Kokalj, Kincey, Moscrop, & Howard, 2008; Pluckhahn & Thompson, 2012).

While a number of studies have used these methods (primarily historical maps and aerial photography) with LiDAR (Crutchley, 2006; Gheyle et al., 2018; Harmon et al., 2006; McNeary, 2014; Millard et al., 2009; Randall, 2014; Stichelbaut et al., 2016; Werbrouck, van Eetvelde, Antrop, & de Maeyer, 2009), very few employ, but mention in passing, the concept of a palimpsest as a theoretical framework to examine LiDAR data (Cowley, 2011; Ladefoged et al., 2011; Mlekuz, 2013a, 2013b; Stichelbaut et al., 2016). Those studies that have used both LiDAR and supplementary sources generally have shown new (re)interpretations about the landscapes they were studying; for example, reinterpretations of feature ages, microtopographic features, landscape development, or previously-unknown features (McNeary, 2014; Millard et al., 2009; Randall, 2014; Werbrouck et al., 2009).

Landscapes also represent a range of dynamic geological events and processes, and often are comprised of numerous landforms that did not originate at the same time though they now exist concurrently (Knight & Harrison, 2013). Conceptually, palimpsests are often used in geology to discuss the dynamics of landscape evolution and change (e.g., Kleman, 1992). Landscape-scale analyses with both historic aerial photography and LiDAR have also revealed complex topographic relationships amongst geologic features that intersect with those created by humans (Panno & Luman, 2012; Shilts, Berg, Luman, & McKay, 2010). Humans and their land use practices have shaped landscapes drastically, to such extents that the term "Anthropocene" has been introduced as a geological epoch to capture such dramatic geomorphological and climatic change (Chin, Fu, Harbor, Taylor, & Vanacker, 2013; Crutzen & Stoermer, 1999; Harden, 2014; Hooke, 1994, 2000; Hooke, Martin-Duque, & Pedraza, 2012; Tarolli & Sofia, 2016).

2. Contextualizing the landscape palimpsest and airborne LiDAR

Though the studies that emphasize various visualization techniques are numerous (Bennett et al., 2012; Challis, Forlin et al., 2011; Doneus, 2013; Hesse, 2010; Kokalj, Zaksek, & Ostir, 2011; McCoy, Asner, & Graves, 2011; Štular, Kokalj, Oštir, & Nuninger, 2012), few provide critiques of LiDAR landscapes as palimpsests and their correlation (or difference from) associated historical materials such as aerial or satellite imagery, or historic maps, though these are the time periods that many landscape studies seek to examine. Comprehensively understanding or interpreting the full temporal span of the landscape itself can be challenging (Risbøl, 2013), especially in instances where extant landscape features predate documentary evidence or in regions where field conditions are challenging. It may seem relatively straightforward to identify certain features of interest on the landscape using LiDAR, but it is difficult to interpret the derivative imagery objectively, or even at all, without the proper context (Cowley, 2012; Crutchley, 2006; Doneus & Kühteiber, 2013; Harmon et al., 2006).

2.1. Palimpsests and the landscape

The term "palimpsest" has been used for decades to describe landscapes in a range of disciplines including archaeology, geography, and geomorphology (Bailey, 2007; Brierley, 2010; Clevis et al., 2006; Goudie & Viles, 2010; Hunt & Royall, 2013; Johnson, 2007; Massey, 2005; Schein, 1997). The term has also been used generally to refer to the landscape as seen using LiDAR (Barnes, 2003; Bernardini et al., 2013; Ladefoged et al., 2011; Megarry & Davis, 2013; Mlekuz, 2013a, 2013b). A palimpsest is a "manuscript or piece of writing material on which the original writing has been effaced to make room for later writing but of which traces remain" (OED, 2017). Interpretations of landscape palimpsests have ranged from the above-defined remnant traces of past activity, to the more cumulative "superimposition[s] of successive activities" or "assemblage of dispersed and gathered eventful objects" (Aldred & Lucas, 2010; Bailey, 2007; Lucas, 2008; McDonagh & Daniels, 2012).

Landscapes are complex and constantly evolving, and are physical expressions of both human and natural processes, having been termed "artifacts" in and of themselves (Rubertone, 1989). Dynamics of colonization, power, and human perception are often also present in understanding processes of resistance or erasure, production of memory, and other aspects of human-landscape interaction that are not topographically expressed (Given, 2004; Hirsch and O'Hanlon, 1995; Holtorf & Williams, 2006; Spencer-Wood & Baugher, 2010; Tuan, 1977). Over centuries these landscapes often become "messy" (Mlekuz, 2013a) in that they become an assemblage of various events and processes both topographically expressed, and not (Aldred & Lucas, 2010; Beck Jr. et al., 2007). Understanding the history of a region's landscape is integral in understanding its present (Sauer, 1941) because the landscape that exists today is the result of "particular circumstances [that] determine the survival of remnant forms" as well as the magnitude of those circumstances or events (Brierley, 2010).

These activities, circumstances, and their physical expressions represent complex human-environmental or sociocultural interactions