

Mapping Landscapes in Transformation

Multidisciplinary Methods for Historical Analysis

Edited by
Thomas Coomans, Bieke Cattoor, and Krista De Jonge

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Transformation: Multidisciplinary
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Thomas Coomans, Bieke Cattoor &
Krista De Jonge

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Mapping Historical Landscapes in
Transformation: An Overview
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8.

A High-Resolution Multi-Scalar Approach for Micro-Mapping Historical Landscapes in Transition

A Case Study in Texas, USA

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Texas Historical Commission)

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The European Landscape Convention (ELC) defines landscape as ‘an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors’ (Council of Europe 2000: article 1). The ELC calls for states to introduce landscape in the law ‘as an essential component of people’s surroundings, an expression of the diversity of their shared cultural and natural heritage and a foundation of their identity’ (Council of Europe 2000: article 5a). As such, a landscape reflects a history of environmental, social, and cultural engagements, and it inscribes material records of human activities in places over time (David and Thomas 2008).

Cartography and Geographic Information Systems (GIS) methods have commonly been used for regional mapping because the spatial resolution of most geospatial data is too coarse to catch local details. However, what remains from the changing engagements and related material records throughout landscape transitions can be subtle and demand attention to micro features at sites. High-resolution data collection techniques and multi-scalar data analytics are necessary to support micro-mapping local details and contextualising the local details with historical documents and maps to understand the transition of a landscape. A historical Caddo mound (M.S. Roberts site) is used here to demonstrate the high-resolution, multi-scalar approach.

In this chapter, we develop a general, multi-scalar approach for understanding the historical landscape in transitions within a small stream valley in East Texas. Although many of the tools we use for identifying site locations and researching historic records are commonplace in historic and archaeological studies, the novelty of our work resides in the integration of new rapid and high-resolution data collection techniques to help identify some of the local preservation concerns of historical and cultural resources in the region. Specifically, we discuss the collection of 3D photogrammetric mapping data at a relatively unknown Caddo mound, M.S. Roberts site. Archaeological sites in Texas are highly correlated with the current population distributions, and the remote location of the M.S. Roberts site contributes to its lack of public awareness [Map 1]. We combine the 3D photogrammetric data with historical documents and maps to estimate both natural and anthropogenic threats of erosion over the past century.

The site and archeological landscape

The M.S. Roberts site was recorded as an archaeological site in 1931 by J.E. Pearce and A.T. Jackson from the Department of Anthropology at the University of Texas at Austin. The site was reported to Pierce by a local informant, Jeff D. Reagan, who had heard about a nearby ‘Indian mound’ and rumours that the landowner, Mr. Roberts, had intentions of levelling the mound to fill in the adjacent borrow pit from which the earthen mound fill was obtained. In October 1931, both Pearce and Jackson visited the property and recorded the site as a ‘domiciliary mound with a surrounding village’ (Fig. 1a). They excavated two trenches in the mound. Since their efforts did not recover artifacts other than what they found walking the ploughed field, the Texas Archaeological Research Laboratory (TARL) only retained a short letter report and associated communication, including a sketch map showing the location of the borrow pit, excavations, and field roads in relation to distances to the nearby stream. The sketch map indicated the mound dimensions as a slightly oblong 24 m x 20 m area at 1.7 m above the natural terrace vaguely georeferenced to somewhere in the Caddo Creek watershed. In the early 2010s, a highway expansion project evoked a renewed interest in the M.S. Roberts site by both professional and avocational archaeologists, as well as the current landowners of the site. In the summer of 2015 (Fig. 1b), we started the collection and production of a high-resolution topographic map and orthophotography of the site in conjunction with the new archaeological excavations (Perttula et al. 2016).



Fig. 1a: Pearce and Jackson (1931) Photograph of Pearce Standing on the Mound [Courtesy of the Texas Archeological Research Laboratory].



Fig. 1b: Mark Walters (2015) Photograph of the Mound at M.S. Roberts Site.

The new archaeological excavations uncovered a ceramic assemblage dated to A.D. 1400-1680, or perhaps as early as A.D. 1320 (Perttula et al. 2016). This period spanned the latter part of the Middle Caddo and the entire Frankston phase in the upper Neches River valley (Perttula 2012). During this time, Caddo communities were scattered along stream valleys in a dispersed settlement system that might have stretched several miles. Caddo villages, hamlets, and farmsteads supported horticultural and agricultural farming of maize, squash, and other crops. While documents were lacking for Caddo settlements in the upper Neches River valley, Caddo settlements could be gleaned from the often reproduced Terán Map (Fig. 2) that depicts one such Caddo community along the Red River Valley as observed by the Spanish expedition of 1691-92 (Texas Beyond History 2003). Many of these communities had a mound centre where ceremonies, rituals, and burials of important persons in the community took place.



Fig. 2: Domingo Terán de los Rios (ca 1692), 'Terán Map' of Upper Nasoni settlement on Red River [Courtesy of Texas Beyond History, the J.P. Bryan Map Collection].

The Terán map showing settlements of a historical Caddo community along the Red River produced as a result of the 1691-92 exploration of eastern Texas led by Domingo Terán de los Rios, the first Governor of Spanish Texas. The map shows a village which is considered part of the Cadodhadacho alliance, with small farmsteads or extended family compounds separated by hedges or rows of trees or bushes. Although the Terán Map shows a compact village setting, a Caddo community might actually be distributed along several miles of the Red River.

Caddo Creek is a low-order stream that flows south-east into the Neches River. There are 44 prehistorical archaeological sites within the Caddo Creek watershed. Although many of the sites have not been radiometrically dated, the spatial pattern of these sites with Middle-Late Caddo artifacts fits well with a dispersed Caddo community centred on the Caddo Creek [Map 2]. In fact, Perttula and Walters (2016) pose the idea that this watershed represents one of only seven known distinct Late Caddo communities in East Texas. Although few sites have been confidently dated as exclusively Historic Caddo (post-1680), both reduction of populations and changes in land use resulted in two major changes to the settlement landscape: (1) clustering late-period archaeological sites closer to the larger confluence with the Neches River and (2) abandoning most of the upper reaches of the Caddo Creek watershed. By 1730, the Caddo likely entirely abandoned the area, but at least one Caddo community was known to be near the nearby community of Poynor [Map 1d] in the 1830s. At the end of the Cherokee War in 1839, in which the Republic of Texas' President Mirabeau B. Lamar (1798-1859) successfully ordered the expulsion of the Indians in East Texas, the Caddo were again driven from the region and the Caddo Creek watershed transitioned to rural agricultural land (Everett 1990).

One set of aerial photographs from the Tobin Aerial Archive from 1933 postdates Pearce and Jackson's initial site recording visit [Map 3]. These images allow easy identification of the borrow pit as a dark patch of vegetation near the northern end of a rectangular agricultural field. Two dark linear patches extend from the borrow pit to the north-west and south-east, which may have been artificial channels diverting water across the field while the land was being used for cotton. Additionally, extensive erosional rills are visible west and south-west of the mound and borrow pit that mark the edge of the flat terrain, while to the north-west there are clear artificial terraces to prevent further erosion. The fence lines partitioning the site into north and south fields were removed at some point between 1933 and 1966, but the fence east of the mound has been maintained in the same place until today. Additional gullying south of the borrow pit is apparent on the 1966 aerial photography, and by 1996 the gully was formalised as a small pond along with the establishment of the lake west of the site. Although the mound itself is hardly visible in the aerial photographs, the borrow pit is identifiable because it is accentuated by the channels extending from the feature and typically darker vegetation. Beginning with the 1996 imagery, north-south oriented plough marks are visible in many subsequent images, and many of the subtle low-lying areas appear to have been filled. Imagery taken in the early 2000s shows the area under residential construction with signposts marking the property into ten residential plots. The extensive erosion and gullying to the south and west, in combination with the establishment of modern property boundaries and consistent landscape maintenance, has certainly affected the preservation and character of the Caddo archaeological site. We have explored the site characteristics in greater detail through high-resolution drone mapping of the property.

Drone micro-mapping

Drone-based photogrammetric micro-mapping has been proven to be an incredibly efficient method to produce datasets that are not easily obtainable by other methods (Nex and Remondino 2014). As an automated data collector, a drone allows a camera with an intervalometer to collect images at an overlap of 80 % both between image shots and transects. The drone mapping of the M.S. Roberts site was conducted with a commercially available DJI Phantom quadcopter equipped with a 16 MP Canon digital camera. Within two hours of field time, we collected over 1,000 photographs of the 20-acre site area at a camera height that allowed for less than 1 cm per pixel resolution. These images were processed in Agisoft Photoscan Pro with a technique named Structure-from-Motion Multi

Stereo-View (SfM-MSV) to align the set of images in an arbitrary 3D space and generate both a point cloud and solid model representing the ground surface and other visible objects (Carrivick et al. 2016; Smith et al. 2016). Horizontal and vertical control was established by placing aerial targets adjacent to the corner stakes of a 20 metre grid for geophysical data collection (McKinnon et al. 2017) and recording those ground points with a differentially-corrected GPS receiver. These GPS locations were identified on individual image in the 3D scene to apply scale and verify the accuracy of the dataset. This processing resulted in both a 1 cm orthorectified image and a 5 cm digital elevation model of the site.

Delineation of the site mound and borrow pit features was conducted in ArcGIS using the high-resolution digital elevation model (DEM) derived from the drone imagery. Although Pierce noted that the borrow pit was located near the mound, his field map of the site omitted this feature and instead mapped the mound in relation to the placement of his excavations. Nevertheless, the high-resolution dataset from drone imagery allows identification of the mound and borrow pit features in a semi-automatic fashion with relative elevations above and below the average terrace surface. We first removed the spatial trend of the data using a second-order Global Polynomial Interpolation, which also removed additional artificial curvature produced from the Agisoft Photoscan processing. High-frequency changes in local vegetation were removed by passing the DEM through a first-order Local Polynomial function with a filter radius of 1 metre. With much of the terrace then being represented by a relative elevation of zero metre, a simple threshold was applied to delineate the mound and borrow pit areas above or below the arbitrary terrace surface, respectively. Although these methods work well for a relatively small site area, such as the M.S. Roberts site, we have found that other methods, such as Topographic Position Indexing (TPI), are well-suited for aiding in the delineation of prehistoric cultural features in a variety of more complex settings (De Reu et al. 2013; Heilen 2015). The primary difference with TPI analysis from the polynomial smoothing we employed at M.S. Roberts is that with TPI both relative elevations and standard deviations are included in the analysis to aid in the delineation of features of different sizes. Given the relatively discrete features and relatively large sizes of the features compared to the 5 cm pixel size, the local polynomial filtering generated a sufficiently smooth surface relative to the average terrace height such that the more involved analyses were not needed.

This delineation of the mound revealed a slightly oblong feature that had a maximum height of 91 cm above the relative terrace surface and a general length and width of 43.5 metres by 26.6 metres. The borrow pit was defined as a clearly

isolated depression beginning about 50 cm below the terrace surface, though the depression grades to the remaining terrace gradually and is not clearly defined in the data between 0-50 cm below the surface. The DEM processing resulted in a relatively flat terrace surface at an arbitrary zero-metre mark as the base height, and the archaeological features were expressed as elevation differences above and below the base height. Henceforth, calculations of the volume of the mound and missing volume of the borrow pit were straightforward. We clipped the DEM to contain only the archaeological features and the positive and negative cell values above or below the base height, and used the number of cells, and cell size for volume calculations (cf. Chang 2009). We estimated the volumes of the mound and borrow pit as 313.68 and 270.82 cubic metres, respectively, with approximately 86 per cent of the estimated mound fill being represented in the borrow pit area [Map 4]. The gradual slope, especially near the edge of the borrow pit, made it difficult to delineate the exact feature boundary. Nevertheless, the calculated volumes of both the mound and borrow pit closely resembled each other. This correlation suggested that nearly all the fill comprising the mound was excavated from the borrow area.

The mound dimensions and shape in the drone data appeared to be elongated in the north-south direction compared to what was initially recorded by Pearce and Jackson in 1933. To understand these differences better, we use the current mound apex as a tie point to overlay the historic map and high-resolution 3D data from drone imagery. Although Pearce and Jackson reported the length, width, and height of the mound, they did not georeference the features on a topographic map. Consequently, we needed to generate a new digital elevation model by fitting a normal curve to the mound at a height of 1.7 metres and matching the 24 metre by 20 metre length and width to approximate the surface that may have been present when they recorded the site. By matching the apex of the 1933 mound map with the current site data, we estimated the volume of soil loss that had occurred throughout most of the twentieth century. Other studies of mound erosion used sediment flux diffusion models to depict the amount of degradation that occurred to areas where soil creep was the dominant mass wasting process (O'Neal 2005). Although those earlier studies utilised a two-dimensional sediment flux, we developed the following algorithm and implemented a python script to estimate soil loss in a 3D model by calculating the curvature in each time step.¹

1. The python scripts are available at https://www.dropbox.com/sh/dc2ou8o76ttxwnq/AABni3Xa1_QdeDWzTVjlcGj1a?dl=0

The initial formulation of the sediment flux model to characterise soil creep on slopes was provided by Nash (1984) and later Pierce and Colman (1986) as $\frac{\partial y}{\partial t} = c \frac{\partial^2 y}{\partial x^2}$, where $\frac{\partial y}{\partial t}$ is the change in the surface at a given time step, c is the sediment flux, and $\frac{\partial^2 y}{\partial x^2}$ is the gradient of the slope. Using ESRI's arcpy python library, our script iterates through any number of years given a starting DEM. Operationally, this is performed by:

1. Starting with an initial DEM (T_0)
2. Calculating Curvature at T_0 ($Curv_0$)
3. Multiplying $Curv_0$ by the sediment flux to calculate the initial Flux Raster (F_0)
4. Calculating the DEM (T_1) by subtracting F_0 from T_0 .
5. Repeating steps 1–4 for as many time steps as needed using the new DEM(T_1) for starting inputs at each step

Based on the difference in height over an 85-year period, we estimated that the mound lost soil at a rate of 0.0035 m³/year. This was determined by matching the 1931 reported height of the mound to the height as observed in the drone data [Map 5]. By modelling erosion in this way, it became apparent that natural soil creep could not have been the only factor in the mound's erosion because the modern shape is too elongated to the south and south-east compared to what was reported. To account for this directional elongation an additional aspect calculation was added to each time step. For each time, the aspect of the initial DEM was calculated and classified according to general compass directions. A scalar value was then applied to the south, south-east, and south-west directions to match the modern observed shape of the mound. More than triple additional soil flux was added to each erosion step for the southern directions to account for both the current shape and volume distribution. Our interpretation is that modern agricultural practices and the establishment of a permanent fence have led the tendency to plough consistently in the north-south direction, which in turn has resulted in the elongation of the mound. Since active ploughing has not occurred recently, it is likely that further degradation has been minimised, however.

Conclusions

This study presented the use and integration of historical mapping with modern drone-based data collection to help one understand transitions within a rural landscape, using a historical site in East Texas, USA, as an example.

Transitions in the landscape were rarely abrupt and often reflected human-environment interactions. In this case study, we demonstrated ways to unearth past natural processes acting on the landscape and human processes on land preservation. To help elucidate many of these processes we took a multi-scalar approach, with roots in both qualitative human geography and quantitative physical geography. While the word limit of the chapter prohibited discussions on the findings from the associated archaeological excavation, the historical human aspects of the landscape change, combined with the excavated archaeological artifacts, drew insights into the historical changes that resulted in the expulsion of a once thriving agrarian Caddo settlement with a solitary ceremonial centre. Both historic American settlements in the area changed the character of the M.S. Roberts site from what was probably the community focal point during the Late Caddo period to sparsely populated agricultural land.

The landscape transitions continue. Recent urban population growth and the development of the immediate site area for suburban residences invoked archaeological studies at various sites in the region, and hence enriched our understanding of the historical landscape change. Meanwhile, while regulations would promote landscape preservation at sites, regional landscape transitions will never cease. Drone-based micro-mapping of historical landscape with historical documents and mapping helps to relate local and regional landscape transitions to reveal the underlying environmental and human processes that contributed to the change.

In tandem with, and in part resulting from, agricultural land use practices, geomorphic processes reshaped the character of the M.S. Roberts site. Our approach of collecting high-resolution site-level remote sensing data on the site characterised how the site features had changed throughout the twentieth century. Erosion modeling of archaeological mounds was not a new approach. What the drone-based micro-mapping approach added was the ability to calculate volume and the rate of erosion. It was shown to be extremely useful to understand what rates of degradation were expected and how this might affect our understanding of the original form, work involved with construction, and maintenance of these types of features in other settings (Bell et al. 1996; O'Neal 2005). In a quick comparison to the case of O'Neal's work at the Hopewell site in Ohio, a sediment flux of $0.0005 \text{ m}^3/\text{yr}$ was observed over a period of 1800 years. Given that the Hopewell earthworks was constructed from clayey soil and the mound at the M.S. Roberts site was a sandy fill, it was expected that a higher rate of erosion would occur at M.S. Roberts. However, it was surprising to learn from this study that the mound

had suffered from over seven times more degradation at M.S. Roberts than was observed at the Hopewell site. Furthermore, the changing shape of the mound would suggest that this was most likely due to twentieth-century ploughing practices at the site. While we developed the drone-based mapping in the case study, the quantitative modelling analysis developed for studying this site would be applicable to other sites in the region to help understand the transitions of other archaeological landscape features which would likely continue over the next century.

Acknowledgments

We are indebted to the current landowners of the M. S. Roberts site, Jim and Denise Renfro. Without their permission and encouragement, we could not have conducted these investigations. We are also grateful to Dr. Timothy K. Perttula for his support and openness with research collaboration on this site and others.

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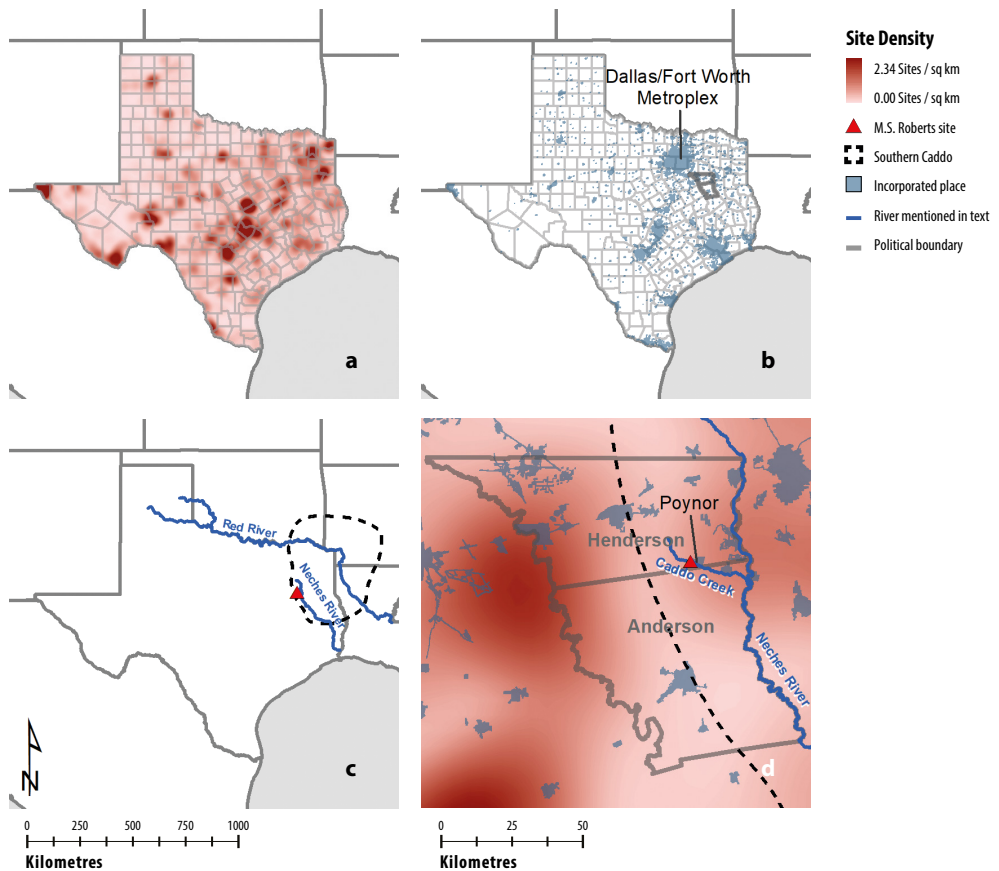
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Maps

Introduction

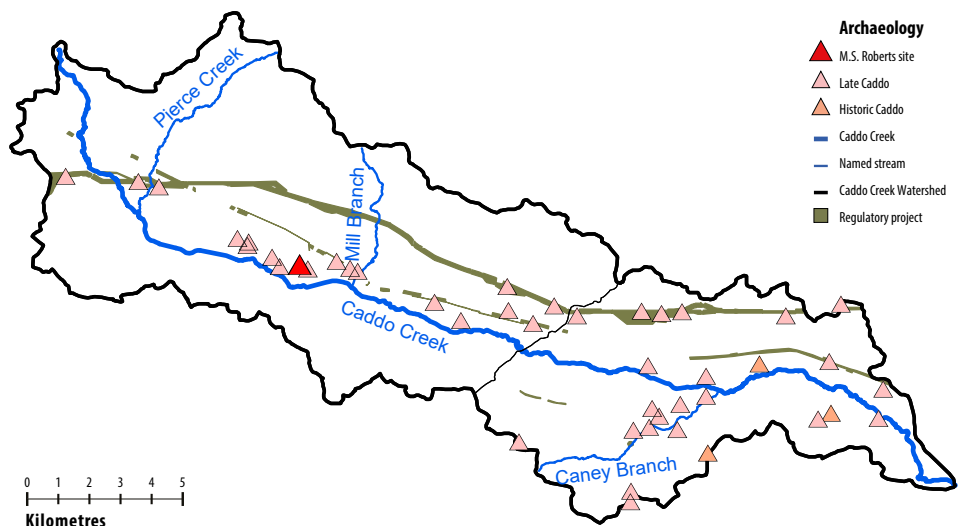
This study examined the transitions of a historical landscape at the M.S. Roberts site in East Texas. A ceramic assemblage excavated from the archaeological site placed this site to AD 1400-1680, a later part of the Middle Caddo and the entire Frankston phase in the upper Neches River Valley. A historical sketch map highlighted the spatial distribution of Caddo villages, hamlets, and farmsteads along the upper Neches River. The site would be a part of the settlements on the sketch map. Based on information from historical documents at the Texas Archaeological Research Laboratory, we created a GIS map to contextualise this site spatially along with other Caddo settlements in the Caddo Creek watershed. Through aerial photo interpretation, we zoomed into the M.S. Roberts site and identified landscape features in 1933, 1966, 1996, and 2015 and cross examined the changes in the landscape features across the four images. We then used drone photogrammetry techniques to develop a 3D model of the site at a spatial resolution of less than 1 cm. The micro-mapping approach provided us with the high-resolution data necessary to calculate changes in landscape features at the site. Specifically, we developed algorithms and python scripts to calculate the volumes of a mound and a pit and the soil loss rate.²

2. The scripts are available at https://www.dropbox.com/sh/dc2ou8o76ttxwnq/AABni3Xa1_QdeDWzTVjlcGj1a?dl=0



Map 1: Arlo McKee (2018), *The Texas Archaeological Sites Atlas*. a: *Density of Recorded Archaeological Sites in Texas, USA*; b: *Population Density in Texas, USA*; c: *Geographic Location of the M.S. Roberts Site*; d: *Zoom-in View of the of the M.S. Roberts Site Showing Density of Recorded Archaeological Sites, Population Density and Main Geographic Features*.

The Texas Historical Commission and the Texas Archeological Research Laboratory maintain a GIS database with location information of archaeological sites in Texas with restricted access via a WebGIS, named The Texas Archaeological Sites Atlas (a.k.a. *Atlas*). Currently, there are over 80,000 sites recorded in the state. Submissions of new sites approximate at 1,000 per year. The *Atlas* is ideally suited to identifying archaeological sites or areas that may be threatened by landscape transition from increasing population.

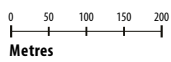
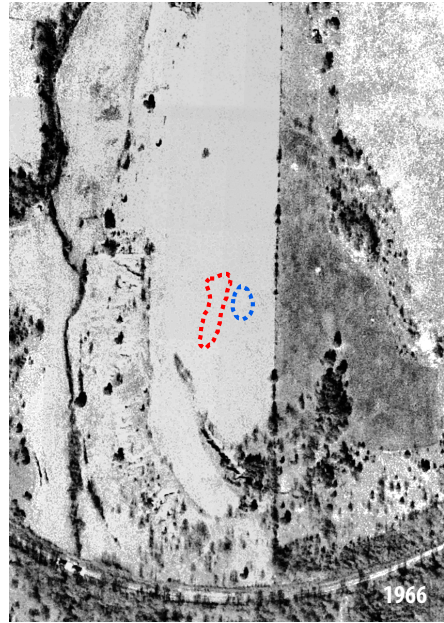


Map 2: Arlo McKee (2018), *Archaeology in the Caddo Creek Watershed*.

The GIS map was created using archaeological sites from Atlas to contextualise the M.S. Roberts Site geographically in relation to other prehistoric sites in the Caddo Creek watershed. While the distribution of sites is more dispersed than the Terán map, the Caddo Sites within this watershed resembles a loose clustering of small communities or hamlets that would have been connected by a common mound ceremonial center (the M. S. Roberts Sites). In this way, the dispersed Late Caddo site distribution resembles what was depicted on the Terán map, with Historic Caddo Sites tending to be located closer to the trunk stream to the east.

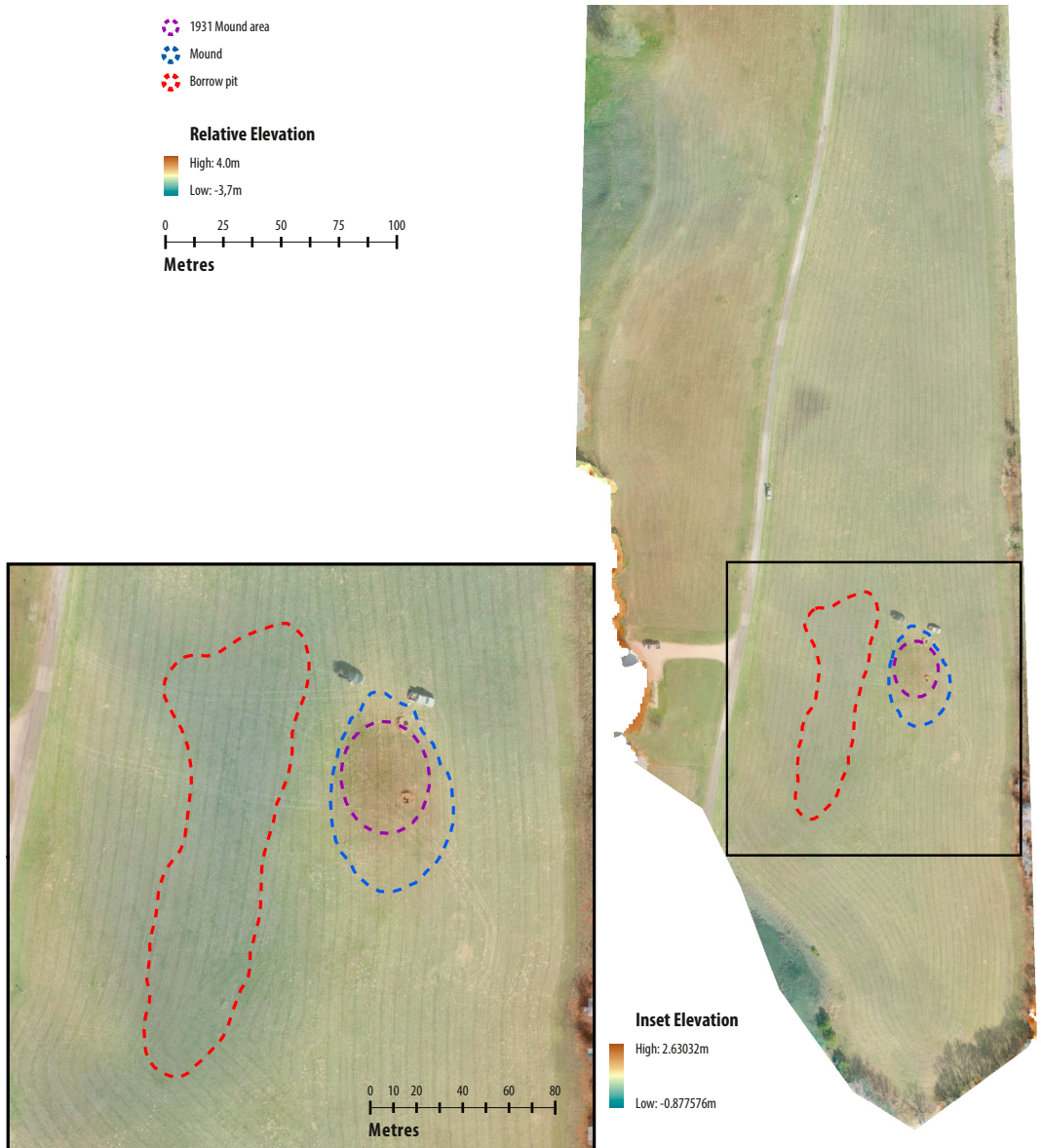
Map 3: Arlo McKee (2018), *Historic Aerial Photographs of the M. S. Roberts Site Area* [1933 and 1966 aerial images courtesy of Tobin Archives, 1996 and 2015 aerial images courtesy of TNRIS].

Historic and modern aerials of the M.S. Roberts site show fence pattern changes, agricultural use, channelised disturbance through the borrow pit, and the transition to a manicured and platted land ready for suburban residential development.



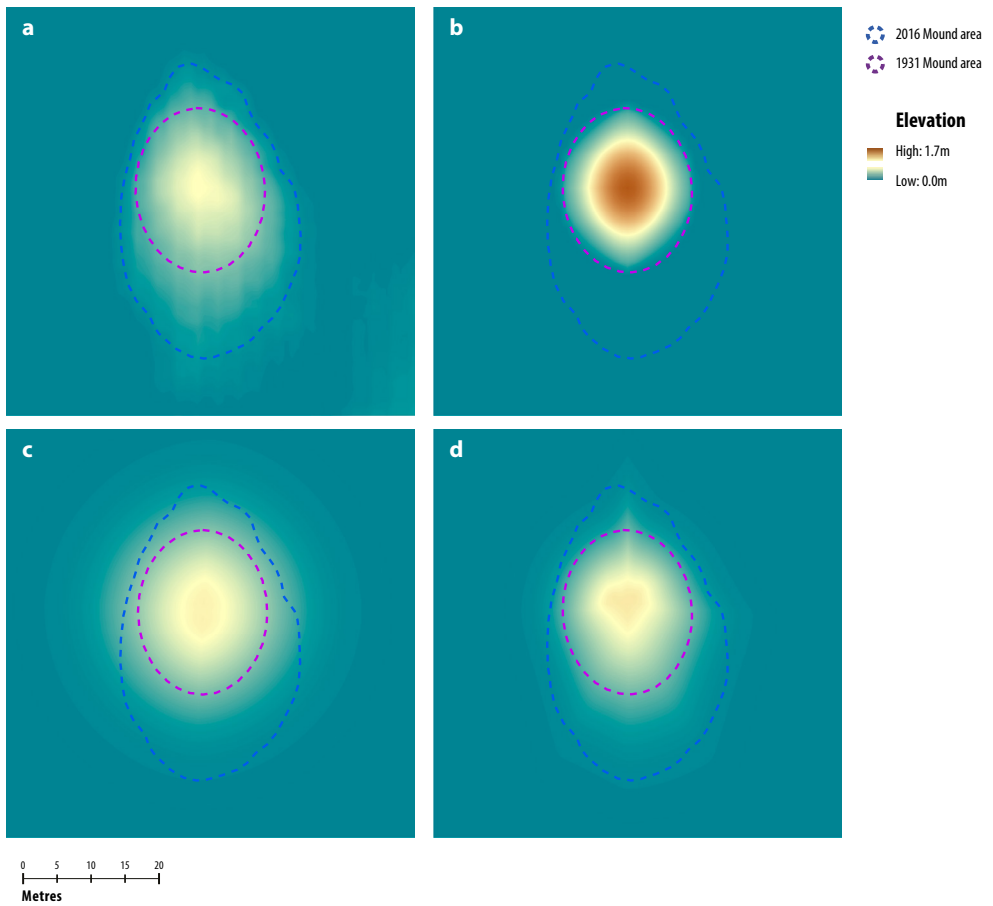
-  Mound
-  Borrow pit

Map 3: Historic Aerial Photographs of the M. S. Roberts Site Area.



Map 4: Arlo McKee (2018), *Digital Elevation Model of the M.S. Roberts Site*.

Using drone-based photogrammetric techniques, we created a high-resolution (< 1 cm) digital elevation model (DEM) of the M.S. Roberts site to identify a mound, a borrow pit, and other natural features.



Map 5: Arlo McKee (2018), *Soil Erosion Modeling of the M.S. Roberts Site*.

We developed a soil erosion model and estimated the soil loss rate at $0.0035\text{m}^3/\text{year}$. Results of the erosion modelling show a: the 2016 drone surveyed mound height; b: the DEM estimated from the 1931 dimensions; c: the final erosion model result with uniform erosion in all directions; d: the final aspect-dependent erosion model result.

