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A Comparative Analysis of Non-invasive Exploration Techniques LiDAR vs. Aerial Photography – Kincaid Mounds Archaeological Site

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By

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Abstract

KINCAID MOUNDS - A Comparative Analysis of Non-invasive Exploration Techniques is a journal of my efforts to conduct non-invasive site investigations at the Kincaid Mounds Archaeological site in Southern Illinois. Through the utilization of tools such as; drones, photography, satellite imaging, light distance and ranging, and powerful analysis software, I will demonstrate a number of useful techniques which one can utilize to conduct independent site investigations without disturbing a sites landscape or structural integrity. Thus, illustrating differences between those techniques and pointing out their strengths and weaknesses in their various applications.

During this journey, I will also venture into the world of three-dimensional rendering and printing. This research will illustrate how data can be obtained to create three-dimensional models of a site which can then be emailed between research colleagues or hobbyist around the world. Thus, demonstrating how such models can then be printed, via a 3-D printer, for a more hands-on investigation of site structures.

The goal of this work is to bring to light a series of techniques that can be utilized by both the professional researcher and the archaeological hobbyist. By using these few non-invasive techniques, one can conduct exciting site explorations void of disturbing the historical or structural integrity of a site. And, with a bit of added determination and discipline one can further utilize such techniques to identify sites of unknown existence.

<u>**Disclaimer**</u>

This disclaimer is written to make the reader perfectly aware that under no circumstances am I endorsing, or will I endorse any of the software and/or hardware that was utilized in the creation of this project and/or the writing of this paper. The experimentation was not conducted in a controlled environment with precisely calibrated instrumentation.

The actual degree of error may be higher or lower than the values exhibited in the final conclusion. This paper is a mere documentation, comparison, and conclusion of my techniques. Therefore, researchers should use their own judgements prior to employing these techniques.

Introduction

When European settlers arrived on the shores of North America during the sixteenth century, they were met by the local native inhabitants. They noted how their villages were composed of hunters, fishermen, and gatherers. They also referenced the native's ability to domesticate plants such as goosefoot, which provided them with a reliable food supply (The Newberry 2018).

It wasn't until Europeans began exploring westward when they gained an understanding of the native people's strong relationship to the land. During these initial explorations, they discovered thousands of interesting earthworks now commonly referred to as mounds (Thomas and Kelly 2006).

Hernando de Soto (c. 1496-1542) a famous Spanish explorer, who landed in Florida in 1539, is one of the first to document the activities of the local natives and their relationship to such earthen structures. Credited with discovering the Mississippi River, he and his 620 men travelled nearly 4,000 miles across what is now the southeastern portion of the United States. It was during this journey when he learned the unique platform-like structures or mounds were primarily used for religious ceremonies and burials (History 2018).

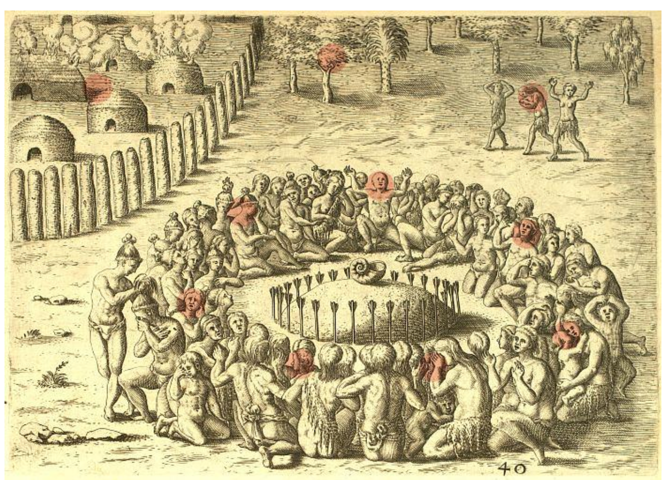

Fig. 1.1 – Plate XL of the Jacque le Moyne depicting the burial ceremony of a tribal chief *(le Moyne circa 1560).*

De Soto's findings on mound utilization were later substantiated in a series of drawings by artist Jacques le Moyne. He was part of a 1562 French expedition by explorers Jean Ribault and

René Laudonnière Le Moyne's drawing, seen in figure 1.1, depicts the burial of a tribal chief. Thus, reinforcing the Indian's utilization of mounds as a form of ceremonial entombment and religious celebration (University of South Florida 2002).

Explorers discovered that such mounds were as small as a few feet in height and diameter, like the mound depicted by Jacque le Moyne, up to sizes that are comparable to the great pyramids of Egypt. The early explorers found the majority of these earthworks were concentrated throughout the Ohio and Mississippi River valleys. They also noted that such earthworks also took various shapes which included conics, pyramids, and effigies. The effigy mounds were works constructed in the shapes of animals such as birds or serpents as depicted in figures 1.2 and 1.3. Despite the shape, the mounds possessed unique and precise geometric properties. Thus, adding an element of fascination and intrigue upon most who gazed at such a magnificent entity (Thomas and Kelly 2006).

Fig. 1.2 – Serpent Mound of Adams County, Ohio *(Jerrell and Farmer 2018)*

As centuries passed and people moved west encroaching on Indian territory, some settlers did not feel the same feelings of fascination about these magnificent earthworks as

Fig. 1.3 – Rock Eagle Mound of Putnam County, Georgia *(Hopkins 2005)*

their exploring predecessors. Many of whom leveled the mounds with plows and raided the earthworks for their plunder. These raiders unearthed a number of skeletal remains and artifacts; such as pottery, copper ornaments, carvings, arrowheads, and etc (Thomas and Kelly 2006).

But, for a select few this fascination has stood the test of time. Thus, creating the same lasting impressions on many of today's generation and giving birth to the disciplines of Archeology and Anthropology.

Such a fascination was exhibited by myself, when I first gazed upon a site in southern Illinois known as Kincaid Mounds, the same kind of fascination that may have been felt by early explorers (figures 1.4 & 1.5). Kincaid Mounds brings out an amazement as if it was genetically encoded or handed down; like a family heirloom through the generations.

Fig. 1.4 – Ground photograph taken by Austin Valentine Jr.

Fig. 1.5 – Drone photograph taken by Austin Valentine Jr.

According to researchers the Kincaid mounds have been around since about 1050 A.D., laying vacant for well over 600 years and worn by exposure to the elements. The site, named after former owners, was a once thriving village of the Mississippian Indians for well-over 300 years, becoming abandoned sometime between 1200 A.D. and an event known as the little ice age. The little ice age was a period,

marked by lower temperatures and radical seasonal changes, which began about 1300 A.D. and continued until the late 1400's (Schwegman n.d.).

Some researchers feel a number of volcanic eruptions between 1275 A.D. and 1300 A.D. may have spread vast amounts of ash into the air decreasing solar radiation entering the earth's atmosphere. Thus, causing temperatures to drop and possibly forcing residents like those at Kincaid to move further south leaving the sites such as this forever vacant (Byrd 2012).

Fig. 1.6 – 1936 excavations by the University of Chicago at the Kincaid site *(Southern Illinois University n.d.)*

Initial excavations at the Kincaid site began in 1934 and continued until 1944, conducted by the University of Chicago. Their work provided valuable information about the site and its former inhabitants (Fig 1.6). Also, additional excavations were conducted by Southern Illinois University in the 1960's and recently in 2015 have provided additional data to further researcher's understanding of the site (Schwegman n.d.).

Despite previous methods of hands-on data collection, it is up to researchers to now find more non-invasive techniques to investigate sites like those at Kincaid. Such new methods and technological advancements will aid in forming new or reinforcing previous educated conclusions about the mounds and their past utilization. Thus, allowing us to possibly respond to a number of unanswered questions or questionable inquiries about the earthen structures at the Kincaid site.

Questions such as: *Is there a direct correlation between site elevations at Kincaid and elevations of other mound sites? Being situated in flood prone areas, did these sites double as protection from the elements? Furthermore, are there other mounds in close proximity hidden by ground cover? If so, how to we identify the location of such sites and what methods must we employ to conduct non-invasive investigations and site analysis of these areas? Can we more accurately determine how long it took to create the mounds at Kincaid?*

Through aerial photography, light detection and ranging (LiDAR), global positioning (GPS), and three-dimensional (3-D) modeling, I will attempt to answer these questions. I will furthermore demonstrate how these non-invasive techniques produce valuable measurements and site investigations which help us to better understand mound construction, site placement, and multi-site comparisons.

Table of Contents

Initial Site Investigations

Fig 2.1 – Aerial photograph taken from Google Earth Pro *(Google, Inc. 2018)*.

I started my research by utilizing a free online software tool known as Google Earth, which aided in the initial planning of an onsite investigation of the Kincaid Mounds Archaeological site. This was accomplished through the utilization of Google's Google Earth Pro software (see figure 2.1). This free downloadable software produced a very useful aerial image of the site; yielding GPS location (37° 04' 59.53"N – 88° 29' 33.91"W), an adjacent road (Newcut Rd.) and county boundary data (Massac/Pope County Line). Through this imagery I was able plan the initial trip, locate the site, and conduct my initial onsite investigation.

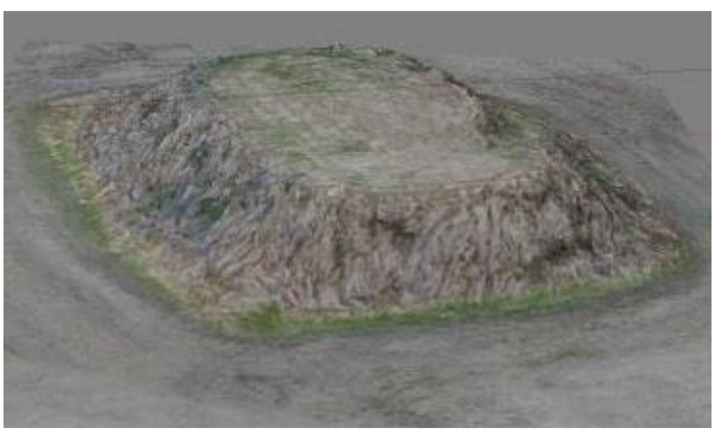
Fig 2.2 – 3-D model created by Austin Valentine Jr *(Valentine Jr. 2018)*.

During my initial visit I conducted a number of photographs from both the air and the ground, just over 700 in all. The ground photographs were taken using a Canon EOS Rebel T5 DSLR camera and the aerial photographs were taken by a DJI brand Phantom 4 Advanced drone. These photographs were used to create a rudimentary three-dimensional (3-D) model of one of the site's mounds (see figure 2.2).

This sparked an interest within me, which led to the birth of this particular project. I wanted to take a more in-depth look at the Kincaid site and conduct a comparative analysis of non-invasive investigative techniques. Thus, comparing both utilization and limitation of satellite imagery, aerial light detection and ranging (LiDAR), and aircraft photography.

Fig 2.3 – NAIP image from the USGS Earth Explorer website *(USGS 2018)*.

I started this technique comparison project through the utilization of the United States Geological Survey's (USGS) online Earth Explorer website. Through the site, I was able to download a number of satellite images for this project. The first of which was a second aerial photograph from the National Agriculture Imagery Program (NAIP), which is in GEOTIFF format (see figure 2.3). I made note that both images were identical and contained six well defined mound structures situated in an open field as seen during my onsite investigation.

However, I wondered if additional satellite photographs would produce similar anomalies unseen by the naked eye. For this phase of the project I downloaded two infrared satellite images (figures 2.4 & 2.5).

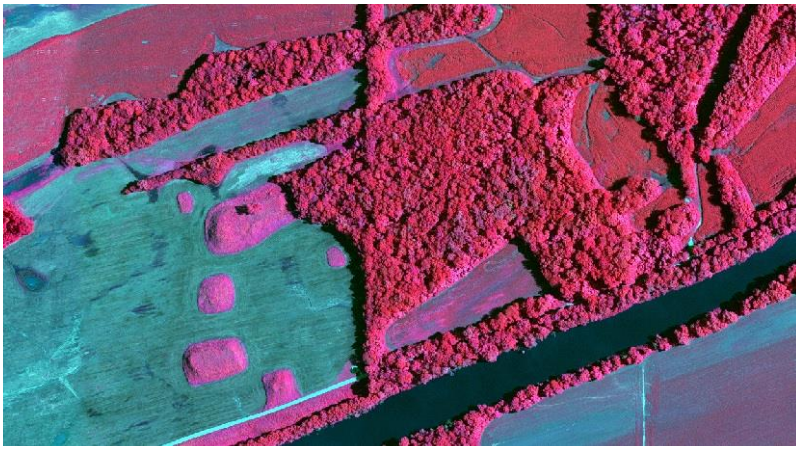

Fig 2.5 – Satellite image taken from USGS Earth Explorer *(USGS 2018)*.

Like the aerial photographs, figure 2.4 shows 6 well defined mounds covered with lush vegetation (4 large mounds and 2 small mounds). But, figure 2.5 shows a few questionable vegetative areas which could be mound related.

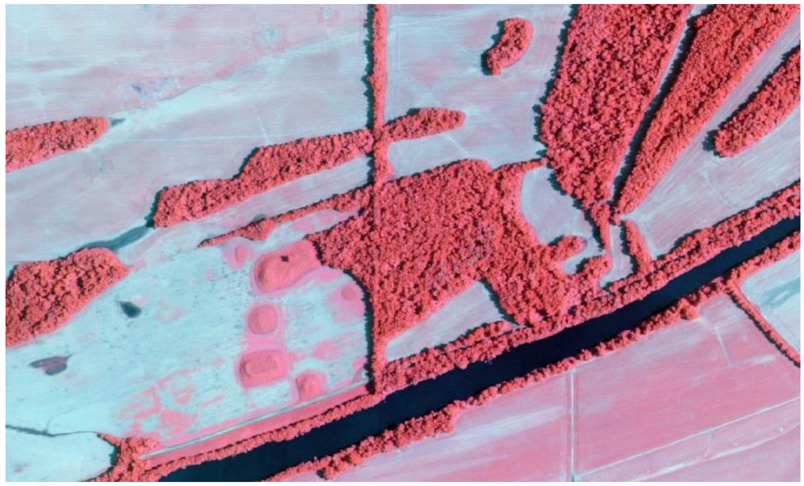

Fig 2.4 – Satellite image taken from USGS Earth Explorer *(USGS 2018)*.

Such results prompted me to conduct a supervised classification on figure 2.5 using ERDAS Imagine 2016 software, provide by Murray State University's Geosciences Department. By merging multiple test areas, I was able to run a supervised classification that accurately depicted, in solid yellow, mound structures as seen in the above images (see figure 2.6).

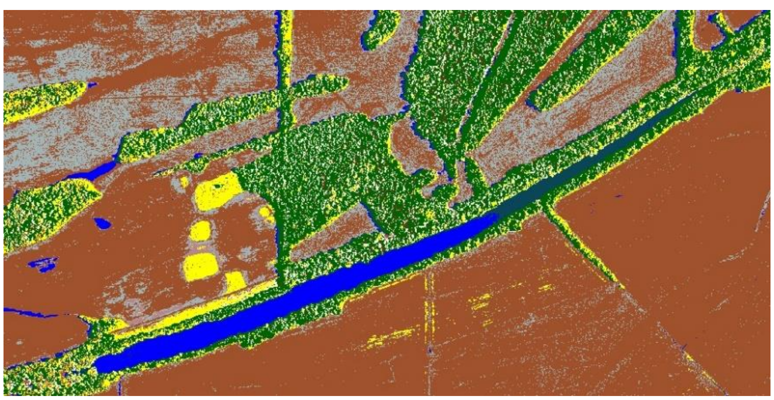

Fig 2.6 – Classified data conducted on figure 2.4

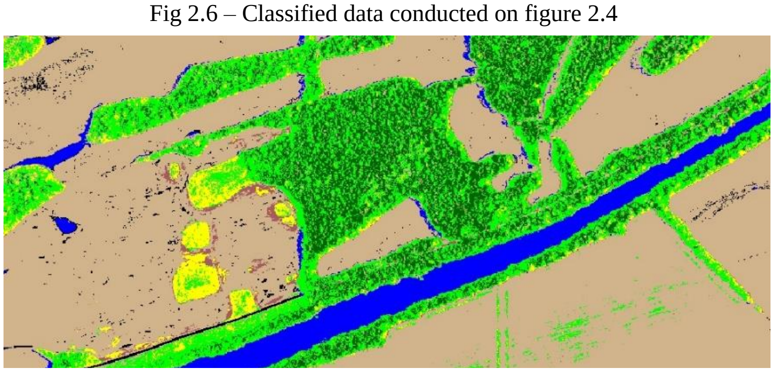

Fig 2.7 – Second classification on figure 2.4

However, there were some slight misclassifications along; bodies of water, tree lines, roads, and fence rows. But, after making some adjustments on the classification test areas, I was able to eliminate the majority of the misclassified data. The second supervised classification, seen in figure 2.7, failed to yield any other

additional mound-like features at the site other than those already present in the above images.

Thus, illustrating that both aerial and satellite photography must have a clear line of site to be useful in this capacity. One must then understand that an object can be obscured by various objects such as clouds, ground vegetation, trees, and shadows. Thus, limiting such applications to locations with a near-clear view.

Light Detection and Ranging (LiDAR) Modeling

Knowing that more mounds existed at or around the Kincaid Archaeological site and being unable to access the adjacent private property I was forced to seek other means of site investigation. For this I turned to light detection and ranging (LiDAR), a method of remote sensing that uses light in the form of a pulsed laser to measure variable distances to the earth's surface. This technology combined with global positioning system (GPS) data and altitude information have the ability to generate precise three-dimensional georeferenced datasets depicting the earth's surface characteristics (NOAA 2018).

The benefits of LiDAR in this application, is its ability to penetrate the vegetative canopy and produce results with a high degree of accuracy. In other words, if light can be seen from the ground, then LiDAR can penetrate from the air. Once the data is collected, software analysis can filter out the higher data points and excess noise displaying the terrain below (GISGeography 2018).

Unlike aerial photography, LiDAR can be used either day or night with no fear of geometric distortion. The collected data can then be combined with other data to create very accurate datasets with high sample densities. However, LiDAR does have some limitations such as the inability to be effective in heavy rain or low cloud cover. LiDAR data sources can also be large in size and sometimes limited in the amount of published content (LIDARRADAR 2018).

Both the advantages and disadvantages of LiDAR became evident during my search for datasets which included the Kincaid Archaeological site. Initially, I went to the USGS Earth Explorer website where I was able to locate three LiDAR datasets containing my area of interest. I downloaded all data, but only one set contained useful information pertaining to this project.

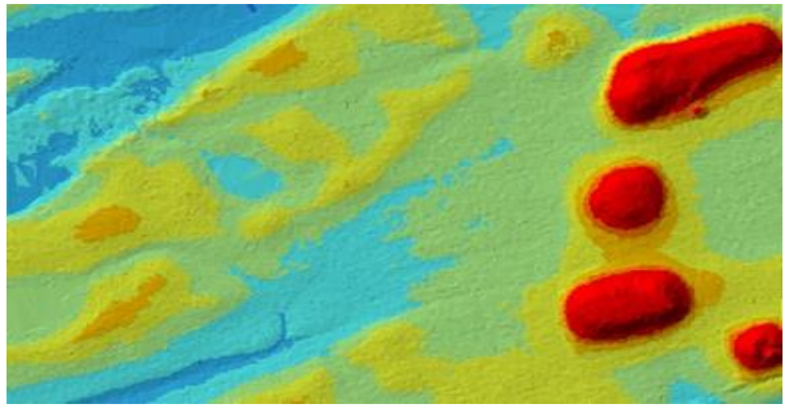

Fig. 3.1 – LiDAR data downloaded from Landsat Earth Explorer *(USGS 2012)*

This particular data set was created by USGS vendor Merrick and Company and was collected from February 02, 2012 to February 17, 2012 (USGS 2012). I opened this data in ESRI ArcMap version 10.5.1.733, software provided by the Geoscience Department of Murray State University. However, the results were very disappointing due to its lack of depicting the entire Archaeological site as seen in figure 3.1.

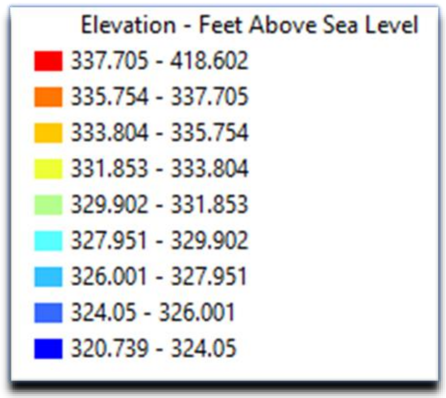

Fig 3.1a – Elevation Data

The data only depicted four very distinguishable earthen mound structures, which are located in an open field and could be detectable by any form of aerial or satellite photography as seen in a previous images. Hence, the only true benefit of this dataset was the georeferenced elevation information as seen in figure 3.1a and depicted in figure 3.2 as a three-dimensional rendering.

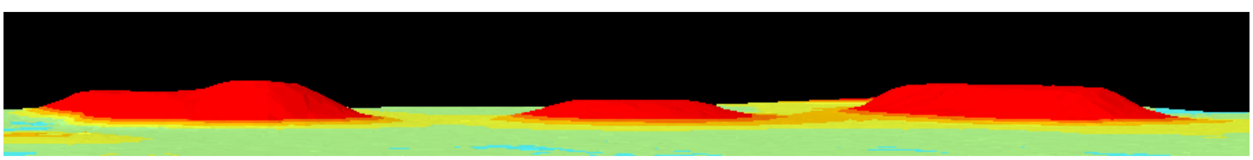

Fig 3.2 – 3D rendering of Landsat Data from Landsat Earth Explorer *(USGS 2012)*.

This lack of an adequate datasets forced me to seek other avenues to find needed data for my research. After a bit of searching, I was able to find additional LiDAR datasets through the Illinois Geospatial Data Clearinghouse for LiDAR. The interactive site consisted of a series of grids or tiles, which allowed users to download only small segments of data, which created manageable file sizes. Thus, eliminating large amounts of unnecessarily downloaded information. For this project, I downloaded a series of twelve different datasets and compiled the

information into a single .lasd file, which I opened in ArcGIS as illustrated in figure 3.3 (Illinois State Geological Survey 2015).

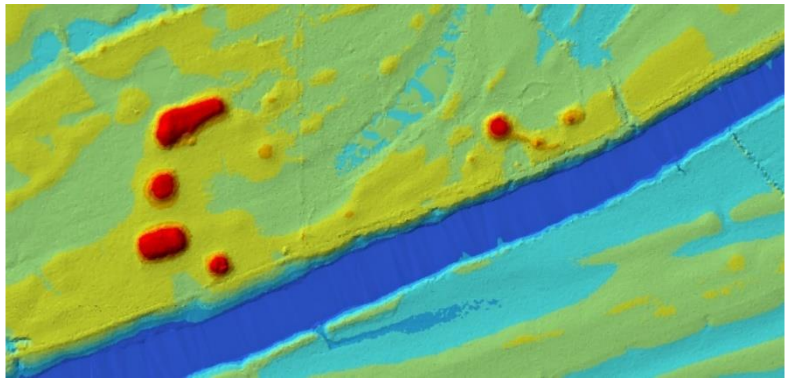

Fig 3.3 – LiDAR data downloaded from the Illinois Geospatial Data Clearinghouse *(Illinois State Geological Survey 2015)*.

Figure 3.3 yielded great results, displaying both visible earthen mounds as well as those covered by the site's vegetative canopy. One cluster of four mounds in particular, on the eastern or right-hand side of the image, are not visible in NAIP aerial photograph figure 3.4 or other aerial photographs or satellite images displayed in a previous sections. The LiDAR data also showed some areas that may be of questionable importance, displaying elevated mound-like features out within the open fields.

Fig 3.4– NAIP image from the USGS Earth Explorer website *(USGS 2018)*.

Further investigation of these anomalies is both warranted and required in an effort to prove or disprove their identity as structures of historical interest. However, through tools like ArcMap and Imagine we are able to conduct closer investigations using data such as LiDAR in an effort to obtain surface areas, volumetric measurements, and distance calculations. Such a task is accomplished while maintaining accurate georeferenced coordinates, which will aid in future on and offsite investigations of the site.

Drone Photography Modeling

During the course of the summer I made multiple trips out to the Kincaid Mounds Archaeological site in southern Illinois to take drone photographs. The model which I used was the DJI Phantom 4 Advanced Quadcopter. My software of choice was AGISoft Photoscan Standard Edition, as seen in figure 4.1.

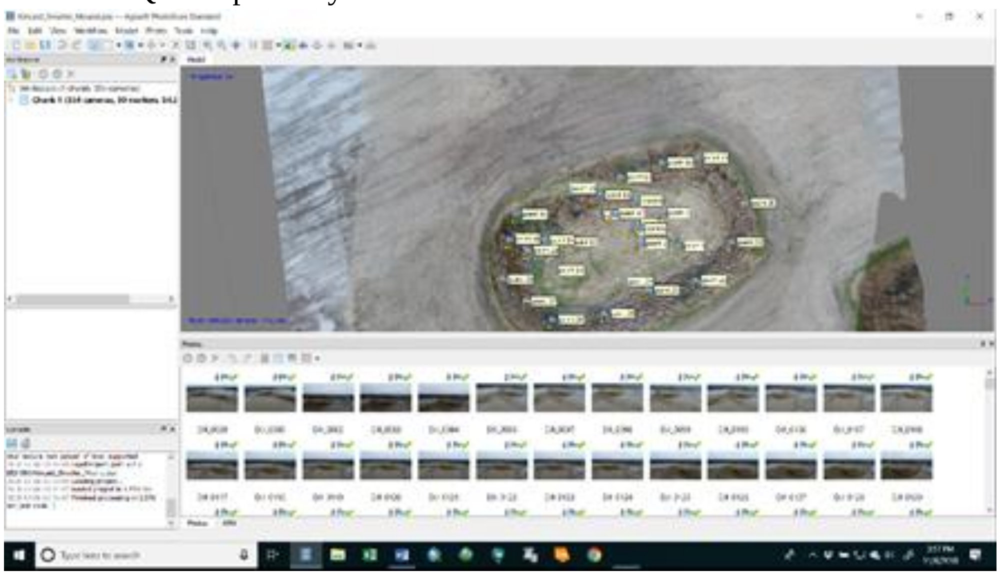

Figure 4.1

While I was at the site, I took hundreds of aerial images of the entire area. However, I did concentrate my modeling project on a single mound.

For this particular mound, I used 354 individual photographs which based modeling on 30 individual markers and a total of 54,859 points of commonly shared data. This is illustrated in figure 4.2, which shows the model in relation to the numerous tiled photographs. This particular model had a very excessive compilation time due to the large number of common points.

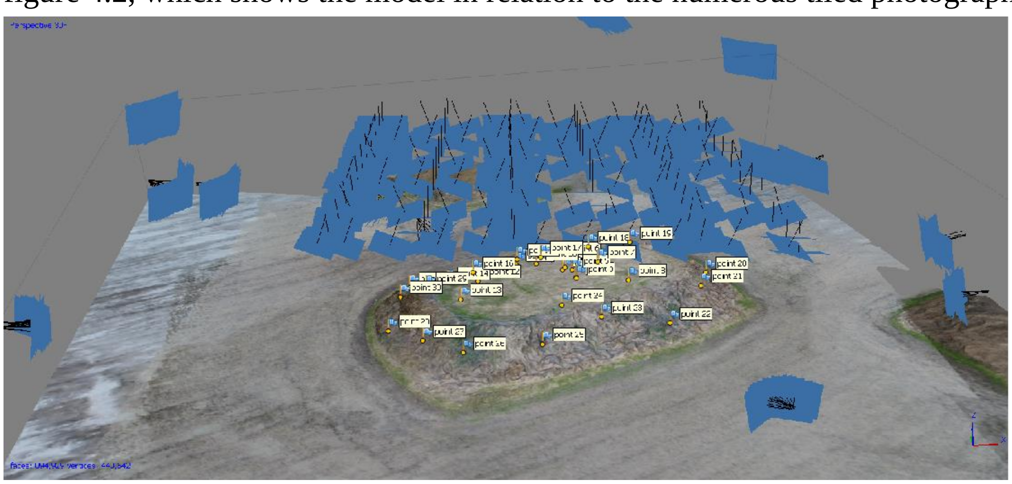

Figure 4.2

Once the model was compiled, the file could then be exported into a number of three-dimensional object files as seen in figure 4.3. This particular software platform supported a number of image formats such as .obj, .stl, .wrl, .dxf, and many more.

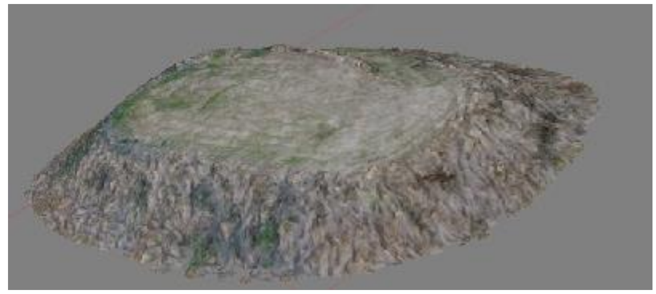

Figure 4.3 *(Valentine Jr. 2018)*

I was also able to have a chance to use the AGISoft Photoscan professional addition which allowed me to export a Digital Elevation Model or DEM file as seen in figure 4.4.

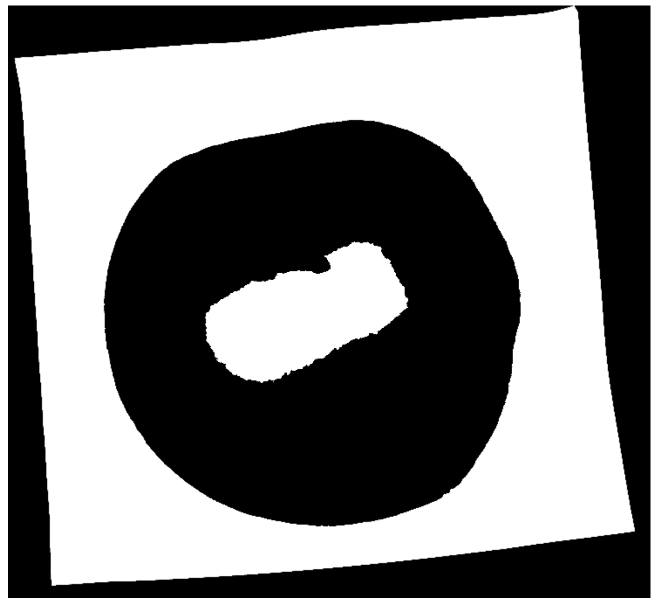

Figure 4.4

The professional package has a lot more functionality than the standard edition. This particular package is tailored toward a more professional utilization. However, it has impressed me greatly with its functionality and user interface.

Aside from the software that created these models, at the click of a button, we now have a data set that can either be printed with a 3D printer or can be emailed around the world for analysis by other research professionals. From these models we can calculate a number of values such as volume to aid in calculation of the time it to create such phenomenon from home.

Never has it been so easy to create a three-dimensional rendering of an object. With today's software packages, one can only imagine how far technology will evolve as we progress into the future.

Comparing The Dimensional Models Made by LiDAR and Aerial Photography

The utilization of both aerial photography and Light Detection and Ranging (LiDAR) data has been used extensively in modeling to construct three-dimensional figures. However, in combination they have yielded amazing geometric models that possess accuracy as well as exhibit very fine architectural detail. Researchers found that one technique complements the other. Therefore, where aerial photography falls short, LiDAR data picks up the slack and vice versa (Cheng, et al. 2011).

This is the same kind of scenario which I encountered with the Kincaid Mounds Archaeological site project. So long as the object was visible from the air, the aerial photography did a spectacular job producing three-dimensional objects. However, if the object in question was covered by any ground canopy, then LiDAR was the only viable way to produce an accurate model.

First, I created two three-dimensional models. One was constructed using readily available LiDAR data which was downloaded from the Illinois Geospatial Data Clearinghouse. The data was then incorporated into a powerful software package called ArcMap, where it could be transformed into the desired model.

The second model was created with aerial photographs taken from a DJI Phantom 4 Advanced drone and compiled using another powerful software package called AGISoft Photoscan. However, this second model needed to be referenced to a geographic coordinate system, through a process known as georeferencing. This referencing had to be done to conduct a proper comparative analysis of LiDAR based models and aerial image based models.

During this process I made sure both models had the same projection and was based on the same geographic coordinate system. I then used the AGISoft Photoscan to create a Digital Elevation Model or (DEM), as seen in figure 5.1, which was the file that needed to be georeferenced.

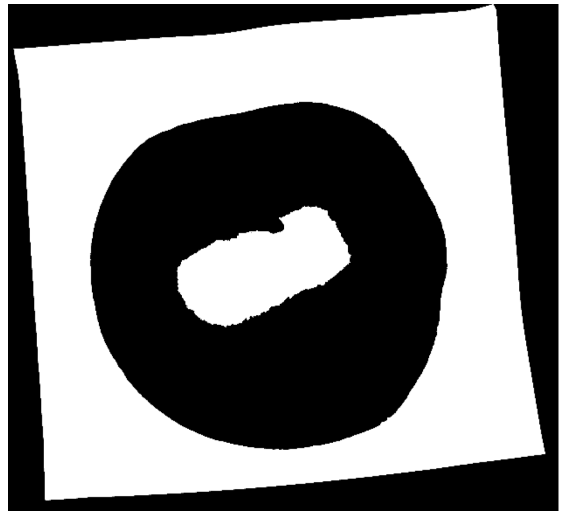

Figure 5.1

My two georeferencing points were (88 29’32.165” W 37 4’44.873”N) and (88 29’35.365”W 37 4’47.799”N). Once I had my model georeferenced, I then imported the DEM into ArcMap and did an overlay, with a slight percentage of transparency, onto the LiDAR model as shown in figure 5.2.

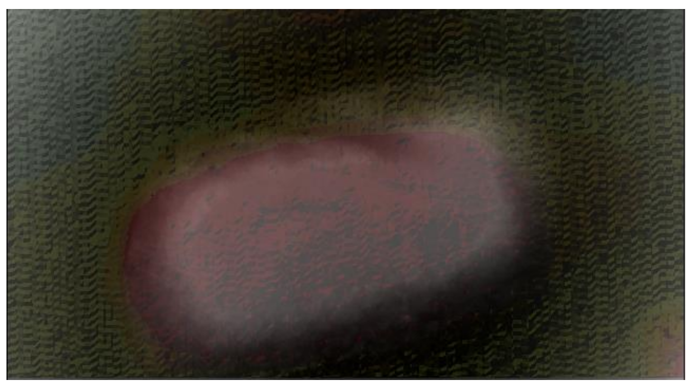

Figure 5.2

I was surprised to see that both models appeared to be the same in size and shape. I then picked five random points from the DEM to compare to the corresponding points on my LiDAR map as seen in figure 5.3. These points were converted to decimal degrees for easier calculation of relative error.

Accepted LiDAR Coord.		Georeferenced Aerial Coord.	
-88.4939	37.079874	-88.4939	37.079879
-88.49388	37.079857	-88.49383	37.079857
-88.493086	37.080011	-88.493089	37.080004
-88.493015	37.079827	-88.493011	37.079827
-88.497413	37.07945	-88.492416	37.07955

Figure 5.3

I found that by georeferencing with two points the data produced a relative error of $5.41x10^{-6}$. Which produced an approximate error of (+ or –) 3.08 inches of difference between the assumed values of the LiDAR model and the georeferenced values of the aerial photograph model. Therefore, one

could assume based on these results that a model georeferenced with more than two points could potentially produce little if any difference in model accuracy with respect to a geographic coordinate system.

Therefore, I can say with a certain level of confidence that there is little difference in accuracy between a LiDAR based model and a georeferenced model constructed through the utilization of aerial photographs.

Conclusion

Both Aerial Photography and Light Detection and Ranging Data are tools. And, like all tools each have their own specialized area of utilization. Furthermore, certain conditions also must be met to ensure a particular tools success in completing a given task. One must look at the advantages and disadvantages to both LiDAR data and Aerial Photography in order to decide a tool's proper application.

Advantages of LiDAR	**Disadvantages of LiDAR**
Data is Highly Accurate	*Very Expensive to Collect*
Has a High Sample Density	*Ineffective During Heavy Rain*
Can be Collected Day or Night	*Ineffective During Low Cloud Cover*
Doesn't Have Any Geometric Distortions	*Very Large Data Sets*

Advantages of Aerial Photography	**Disadvantages of Aerial Photography**
Pictorial View of the Ground	*Hard to Identify Some Features*
Easily Obtained	*Must Have Clear Line of Sight*
Cost Effective	*Must Have Lighting*
Can Show Features Not on Maps	*Must be Georeferenced*

Based on the following, it would simply be impossible to choose one method over the other without weighing the facts at play. For example, if one is looking to produce a three-dimensional model of an object that is out in the open where aerial photographs can be easily and legally obtained, then an aerial image based three-dimensional model would be the best choice. Especially if LiDAR data does not already exist.

However, if objects are situated beneath trees or in areas that are difficult to get, then LiDAR may be your only option. Before going out and making an expensive LiDAR purchase, one might check to see if LiDAR data already exists. Chances are that data may already be floating around out in cyberspace just awaiting your download.

In conclusion, I would first check to see if LiDAR data exists for a given area of interest. If so, then I would look at that data to see if it will produce the results I am seeking. If not, then I would suggest looking into drone photography coupled with some powerful software such as AGISoft or PIX4D. Together both methods can produce wonderful results, taking research to a new level of portability and three-dimensional understanding.

Works Cited

Byrd, Deborah. 2012. *What Caused The Little Ice Age?* August 09. Accessed May 26, 2018. http://earthsky.org/earth/volcanoes-might-have-triggered-the-little-ice-age.

Cheng, Liang, Jianya Gong, Manchun Li, and Yongxue iu. 2011. "3D Building Model Reconstruction from Multi-view Aerial Imagery and Lidar Data." *Photogrammetric Engineering & Remote Sensing* 77 (2): 125-139. Accessed November 03, 2018. http://docserver.ingentaconnect.com/deliver/connect/asprs/00991112/v77n2/s1.pdf?expires=1541528596&id=0000&titleid=72010567&checksum=08A1C32C3AD9475D2F9A8964EB56376B.

Davidson, Robert. 2008. *Aerial Photographs.* Accessed November 06, 2018. http://www.map-reading.com/chap8.php.

GISGeography. 2018. *A Complete Guide to LiDAR: Light Detection and Ranging.* Accessed May 30, 2018. https://gisgeography.com/lidar-light-detection-and-ranging/.

Google, Inc. 2018. *Google Earth Pro.* 7.3.1.4507. Software. February 06. Accessed June 01, 2018. kh.google.com.

History. 2018. *Hernando De Soto.* Accessed May 26, 2018. https://www.history.com/topics/exploration/hernando-de-soto.

Hopkins, Ina Cook. 2005. *Rock Eagle: Centerpiece of Georgia 4-H.* Accessed May 26, 2018. http://georgia4h.org/rehistorybook/.

Illinois State Geological Survey. 2015. *Illinois Height Modernization (ILHMP): LiDAR Data.* Accessed May 30, 2018. https://clearinghouse.isgs.illinois.edu/data/elevation/illinois-height-modernization-ilhmp-lidar-data.

Jerrell, Jason, and Sarah Farmer. 2018. *Symbolism of the Great Serpent in the Adena and Hopewell Cultures - Part I.* April 15. Accessed May 26, 2018. http://www.ancient-origins.net/ancient-places-americas/symbolism-great-serpent-adena-and-hopewell-cultures-part-009900.

le Moyne, Jacques. circa 1560. *Exploring Florida - Plate XL.* Accessed May 26, 2018. https://fcit.usf.edu/florida/photos/native/lemoyne/lemoyne9/lemoy909.htm.

LIDAR AND RADAR. 2018. *LIDAR and RADAR Information.* January 19. Accessed November 06, 2018. http://lidarradar.com/info/advantages-and-disadvantages-of-lidar.

LIDARRADAR. 2018. *LIDAR and RADAR Information* . January 19. Accessed June 01, 2018. http://lidarradar.com/info/advantages-and-disadvantages-of-lidar.

NOAA. 2018. *What is LIDAR?* Accessed June 01, 2018. https://oceanservice.noaa.gov/facts/lidar.html.

Schwegman, John E. n.d. *Kincaid Mounds A Prehistoric Cultural and Religious Center In Southern Illinois.* Accessed May 26, 2018. http://www.kincaidmounds.com/history.htm.

Southern Illinois University. n.d. *About Kincaid Mounds.* Accessed May 26, 2018. https://cola.siu.edu/anthro/_common/documents/courses-and-field-schools/about-kincaid.pdf.

The Newberry. 2018. *Indians of the Midwest.* Accessed May 26, 2018. http://publications.newberry.org/indiansofthemidwest/people-places-time/eras/moundbuilders/.

Thomas, David Hurst, and Robert L. Kelly. 2006. *Archaeology.* 4th. Edited by Lin Marshall, Sherry Symington, Nicole Root and Kelly McMahon. Belmont, CA: Thomson Higher Education.

University of South Florida. 2002. *Jean Ribault Claims Florida for France.* Accessed May 26, 2018. https://fcit.usf.edu/florida/lessons/ribault/ribault1.htm.

USGS. 2012. *IL_JOHNSON-PULASKI_MASSACCOS_2012-2014.LAS.* Comp. Merrick & Company. Illinois. Accessed May 28, 2018. https://earthexplorer.usgs.gov/metadata/10480/860472/.

USGS. 2018. *USGS - Earth Explorer*. May 17. Accessed May 30, 2018. https://earthexplorer.usgs.gov/.

Valentine Jr., Austin. 2018. Accessed June 01, 2018. http://digitalcommons.murraystate.edu/cgi/viewcontent.cgi?article=1000&context=sscw.