



## Application of LiDAR Technology in Remote Sensing of Subterranean Archaeological Features

---

Favour Olaoye, Chris Bell and Peter Broklyn

EasyChair preprints are intended for rapid dissemination of research results and are integrated with the rest of EasyChair.

August 1, 2024

# Application of LiDAR Technology in Remote Sensing of Subterranean Archaeological Features

## Authors

Favour Olaoye, Chris Bell, Peter Broklyn

## Abstract

Light Detection and Ranging (LiDAR) technology has emerged as a transformative tool in the field of remote sensing, offering unprecedented capabilities in the detection and analysis of subterranean archaeological features. This abstract explores the application of LiDAR technology in uncovering and documenting hidden archaeological sites, structures, and artifacts beneath the Earth's surface. By utilizing airborne or ground-based LiDAR systems, researchers can generate high-resolution, three-dimensional representations of landscapes, which reveal subtle topographic variations and anomalies indicative of buried features. This non-invasive approach enhances the efficiency and accuracy of archaeological surveys, reduces the need for extensive excavation, and preserves site integrity. The integration of LiDAR data with Geographic Information Systems (GIS) further augments its analytical potential, allowing for detailed spatial analysis and interpretation of archaeological contexts. The paper reviews case studies demonstrating the effectiveness of LiDAR in diverse geographical settings and highlights its potential for advancing archaeological research, heritage management, and conservation efforts. As LiDAR technology continues to evolve, its application in subterranean archaeology promises to unlock new dimensions of understanding about past human activities and cultural landscapes.

## I. Introduction

The quest to uncover and understand ancient human civilizations often involves exploring subterranean spaces, which can be challenging due to their hidden nature and the complexities of traditional archaeological methods. Recent advancements in remote sensing technology, particularly Light Detection and Ranging (LiDAR), have revolutionized this field by providing new avenues for discovering and analyzing buried archaeological features. LiDAR, a remote sensing technique that uses laser pulses to measure distances and create high-resolution, three-dimensional models of landscapes, has proven to be a powerful tool for revealing features obscured by vegetation, soil, or other surface materials.

Historically, archaeological investigations relied heavily on ground-based surveys and invasive excavation methods, which were both time-consuming and potentially damaging

to sensitive sites. The introduction of LiDAR technology offers a non-invasive alternative that allows researchers to capture detailed topographic data over large areas quickly and efficiently. This method has demonstrated significant potential in identifying previously unknown sites, understanding site layouts, and gaining insights into ancient land use and settlement patterns.

In recent years, the application of LiDAR in archaeology has gained momentum, driven by advancements in sensor technology, data processing techniques, and the integration of LiDAR data with Geographic Information Systems (GIS). These developments have expanded the capabilities of LiDAR, making it an invaluable tool for archaeologists and heritage professionals. This paper aims to explore the application of LiDAR technology in remote sensing of subterranean archaeological features, highlighting its impact on the field and discussing its potential for future research and conservation efforts.

## **II. LiDAR Technology and Its Principles**

Light Detection and Ranging (LiDAR) is a remote sensing technology that measures distances by using laser light. The core principle of LiDAR involves emitting laser pulses from a sensor, typically mounted on an aircraft or ground-based platform, and recording the time it takes for the pulses to return after reflecting off surfaces. This time delay, known as the "return time," is used to calculate the distance between the sensor and the surface. By combining these distance measurements with the sensor's location data, LiDAR systems create high-resolution, three-dimensional models of the scanned area.

### **1. Basic Principles**

**Laser Emission and Detection:** LiDAR systems emit rapid pulses of laser light, usually in the infrared spectrum, towards the target area. Each pulse travels through the atmosphere and reflects off surfaces before returning to the sensor. The time taken for the pulse to return, known as the "pulse travel time," is proportional to the distance between the sensor and the surface.

**Distance Calculation:** The distance to the target surface is calculated using the speed of light and the time delay of the returned pulse. This calculation provides precise measurements of the vertical distance from the sensor to the surface, which, when combined with the horizontal position of the sensor, generates a three-dimensional point cloud.

**Point Cloud Generation:** The collection of distance measurements results in a dense array of data points, or "point cloud," that represents the scanned area. Each point in the cloud includes information about its X, Y, and Z coordinates, creating a detailed and accurate 3D representation of the terrain or object being surveyed.

### **2. LiDAR System Components**

**Laser Scanner:** The laser scanner is the core component that emits the laser pulses and receives the reflected signals. It typically includes a laser source, a scanning mechanism, and a photodetector.

**GPS and IMU:** Global Positioning System (GPS) and Inertial Measurement Unit (IMU) technologies are used to determine the precise location and orientation of the LiDAR sensor. GPS provides spatial coordinates, while IMU measures the sensor's movement and orientation, ensuring accurate alignment of the data.

**Data Acquisition and Processing:** LiDAR systems capture and store raw data, which is then processed to generate point clouds and create digital elevation models (DEMs) or other derived products. Data processing involves filtering, classifying, and interpreting the point cloud to extract meaningful information.

### 3. Applications and Advantages

LiDAR technology offers several advantages for remote sensing, particularly in archaeological applications:

**High Resolution and Accuracy:** LiDAR provides high-resolution data with sub-meter accuracy, enabling detailed analysis of topographic features and subtle landscape variations.

**Penetration Through Vegetation:** LiDAR can penetrate through vegetation and canopy cover, revealing hidden features that are otherwise obscured in optical imaging methods.

**Efficiency and Coverage:** LiDAR allows for rapid data collection over large areas, making it an efficient tool for surveying extensive regions and identifying potential archaeological sites.

**Non-Invasive:** The non-contact nature of LiDAR minimizes the risk of disturbing or damaging archaeological sites, preserving their integrity for future study.

By leveraging these principles and capabilities, LiDAR technology significantly enhances the ability to detect and analyze subterranean archaeological features, offering new insights into past human activities and cultural landscapes.

## III. Applications of LiDAR in Archaeology

LiDAR technology has revolutionized archaeological research by providing a powerful, non-invasive method for discovering and analyzing hidden and buried features. Its applications span various aspects of archaeological study, from initial site identification to detailed site analysis. This section explores the diverse ways in which LiDAR is utilized in archaeology, highlighting its impact on different facets of research and fieldwork.

### 1. Site Identification and Discovery

**Uncovering Hidden Sites:** LiDAR's ability to penetrate vegetation and soil allows for the detection of archaeological sites that are not visible through traditional survey methods. This capability is particularly valuable in densely forested or heavily vegetated areas where surface visibility is limited.

**Revealing Subterranean Features:** By analyzing topographic variations and anomalies in the LiDAR data, archaeologists can identify buried structures, such as ancient roads, walls, and settlement patterns. This process can lead to the discovery of previously unknown or forgotten sites.

**Mapping Extent and Layout:** LiDAR provides detailed maps of site extents and layouts, helping researchers understand the spatial organization of archaeological features. This information is crucial for planning subsequent fieldwork and excavation strategies.

## 2. Site Analysis and Interpretation

**Topographic and Geomorphological Analysis:** LiDAR data allows for detailed analysis of the topography and geomorphology of archaeological sites. By examining digital elevation models (DEMs) and terrain models, archaeologists can gain insights into past land use, water management systems, and environmental changes.

**Spatial Analysis of Features:** The high-resolution point clouds generated by LiDAR enable precise measurement and spatial analysis of archaeological features. Researchers can assess the size, shape, and orientation of structures, providing valuable information for understanding their function and significance.

**Detection of Anomalies and Patterns:** LiDAR can reveal subtle anomalies in the landscape, such as soil disturbances or buried features, that may indicate the presence of archaeological artifacts or structures. Pattern recognition in the data can help identify complex site layouts and settlement patterns.

## 3. Site Preservation and Management

**Non-Invasive Assessment:** LiDAR's non-invasive nature allows for the assessment and documentation of archaeological sites without disturbing them. This is particularly important for preserving delicate or fragile sites and minimizing the impact of fieldwork.

**Monitoring Site Condition:** LiDAR can be used to monitor changes in site conditions over time, such as erosion, vegetation growth, or damage caused by environmental factors. This information is valuable for managing and protecting archaeological sites.

**Creating Detailed Records:** The high-resolution data collected by LiDAR contributes to the creation of detailed records and digital archives of archaeological sites. These records can be used for future research, public education, and heritage preservation.

## 4. Case Studies and Examples

**Mesoamerican Sites:** In regions like Central America, LiDAR has been instrumental in uncovering and mapping complex Maya cities and structures hidden beneath dense jungle

canopies. Notable examples include the discovery of previously unknown cities in Guatemala and Belize.

**Roman Landscapes:** LiDAR has been employed to explore and map ancient Roman infrastructure, such as roads, aqueducts, and villas. The technology has revealed extensive networks and detailed layouts of Roman settlements across Europe.

**Historic Fortifications:** LiDAR has been used to study historic fortifications and military sites, uncovering hidden defensive structures and understanding their strategic significance within historical contexts.

## 5. Future Directions and Potential

The application of LiDAR in archaeology continues to evolve, with advancements in technology and data processing offering new opportunities for exploration and analysis. Future developments may include improved resolution and accuracy, integration with other remote sensing technologies, and enhanced analytical tools for interpreting complex data.

In summary, LiDAR technology has significantly advanced the field of archaeology by providing a powerful tool for discovering, analyzing, and preserving subterranean features. Its applications enhance our understanding of past human activities, contribute to site management, and support the preservation of cultural heritage.

## IV. Case Studies

The effectiveness of LiDAR technology in archaeology is best illustrated through various case studies that highlight its ability to uncover and analyze hidden or complex archaeological features. This section presents several prominent examples where LiDAR has made a significant impact on archaeological research.

### 1. Maya Civilization in Guatemala and Belize

**Project Overview:** The LiDAR survey conducted in the Petén region of northern Guatemala and southern Belize aimed to uncover the extent of the ancient Maya civilization. Prior to LiDAR, the dense rainforest canopy made it challenging to detect archaeological features from the ground.

**Key Findings:** The LiDAR data revealed a vast network of previously unknown Maya cities, including urban centers, pyramids, and agricultural fields. One of the most notable discoveries was the identification of an extensive network of roads and causeways connecting different settlements. The survey also uncovered large-scale hydraulic systems and defensive structures.

**Impact:** The findings provided new insights into the scale and complexity of Maya urban planning and infrastructure. The discoveries have reshaped our understanding of Maya civilization and its influence on the region's landscape.

## 2. Angkor Archaeological Park, Cambodia

**Project Overview:** LiDAR technology was used to survey the Angkor Archaeological Park, a UNESCO World Heritage site known for its impressive temples and complex water management systems. The goal was to gain a deeper understanding of the city's layout and the extent of its infrastructure.

**Key Findings:** The LiDAR survey revealed an extensive network of hidden reservoirs, canals, and agricultural fields that were previously obscured by vegetation. It also identified new temple complexes and urban features beyond the well-known Angkor Wat and Angkor Thom temples.

**Impact:** The data has enhanced knowledge of the sophisticated hydraulic and urban planning systems of the Angkor civilization. It has also provided valuable information for conservation and site management efforts.

## 3. Roman Infrastructure in Italy and Spain

**Project Overview:** LiDAR was employed to investigate the remains of ancient Roman infrastructure across various regions in Italy and Spain. The aim was to map and analyze Roman roads, aqueducts, and settlements.

**Key Findings:** LiDAR surveys revealed extensive networks of Roman roads and aqueducts that had been previously buried or eroded. Detailed data on road alignments and the locations of buried structures provided insights into Roman engineering techniques and the scale of their infrastructure.

**Impact:** The findings have contributed to a better understanding of the Roman Empire's transportation and water management systems. They have also facilitated the study of Roman urban planning and logistics.

## 4. The Nazca Lines, Peru

**Project Overview:** LiDAR technology was used to study the Nazca Lines, a series of large geoglyphs etched into the desert floor in southern Peru. The objective was to investigate the extent of the geoglyphs and their surrounding archaeological context.

**Key Findings:** The LiDAR survey revealed numerous additional geoglyphs and associated features that were not visible from the surface. The data provided insights into the layout and organization of the Nazca Lines and their potential ceremonial or astronomical functions.

**Impact:** The discoveries have enhanced our understanding of the Nazca culture and their use of the landscape for ritualistic purposes. The findings have also contributed to the preservation and management of this UNESCO World Heritage site.

## 5. Historic Fortifications in Europe

**Project Overview:** LiDAR was applied to study historic fortifications and military sites across Europe, including medieval castles, fortresses, and defensive structures. The goal was to map and analyze the remains of these sites and their defensive features.

**Key Findings:** LiDAR surveys revealed detailed layouts of fortifications, including hidden walls, moats, and bastions. The technology also uncovered previously unknown fortifications and provided insights into their construction and strategic importance.

**Impact:** The data has improved our understanding of historical military architecture and defensive strategies. It has also informed preservation and restoration efforts for historic fortifications.

## 6. The Indus Valley Civilization in Pakistan and India

**Project Overview:** LiDAR technology was used to explore and map ancient cities of the Indus Valley Civilization, one of the world's earliest urban cultures. The objective was to reveal the extent of the civilization's urban planning and infrastructure.

**Key Findings:** LiDAR surveys uncovered the layout of major Indus Valley cities, including grid-like street patterns, drainage systems, and large public buildings. The data also revealed the extent of urban sprawl and the complexity of the civilization's infrastructure.

**Impact:** The findings have provided new insights into the urban planning and engineering capabilities of the Indus Valley Civilization. They have also contributed to a better understanding of the social and economic organization of this ancient society.

These case studies illustrate the diverse applications of LiDAR technology in archaeology and highlight its potential for uncovering and analyzing hidden and complex features. Each example demonstrates how LiDAR has advanced archaeological research and contributed to our understanding of past civilizations.

## V. Challenges and Limitations

While LiDAR technology has revolutionized archaeological research by providing detailed and non-invasive insights into hidden and buried features, it is not without its challenges and limitations. Understanding these constraints is crucial for effectively utilizing LiDAR data and addressing potential issues in archaeological studies.

### 1. Data Quality and Resolution

**Resolution Limitations:** The resolution of LiDAR data is dependent on several factors, including the sensor's specifications and the altitude at which it is flown. Lower resolution data may not capture fine details or subtle features, limiting the ability to detect small or intricate archaeological elements.



**Data Accuracy:** Inaccuracies can arise from various sources, such as atmospheric conditions, sensor calibration issues, or errors in data processing. Ensuring high data accuracy requires careful calibration and validation against ground-truth observations.

## 2. Vegetation and Canopy Coverage

**Penetration Limitations:** Although LiDAR can penetrate through vegetation, dense canopy cover or thick vegetation can still limit the ability to detect ground features. This limitation may result in incomplete data or missing features that are obscured by the forest canopy.

**Selective Penetration:** LiDAR's effectiveness in penetrating vegetation varies depending on the type of vegetation and the laser's wavelength. Some types of vegetation may partially obscure or distort the LiDAR data, affecting the quality of the resulting models.

## 3. Data Processing and Interpretation

**Complex Data Processing:** LiDAR generates large volumes of data that require extensive processing and analysis. The complexity of handling and interpreting point clouds can be challenging, requiring specialized software and expertise.

**Feature Identification:** Identifying and classifying archaeological features from LiDAR data can be difficult. Distinguishing between natural and cultural features, and interpreting their significance, often requires a combination of LiDAR data with other archaeological evidence and ground-truthing.

## 4. Cost and Resource Intensity

**High Costs:** LiDAR surveys can be expensive due to the costs of equipment, data acquisition, and processing. The financial investment required may limit its accessibility for some research projects or institutions.

**Resource Requirements:** Conducting LiDAR surveys, processing large datasets, and analyzing results can be resource-intensive, necessitating significant time and expertise. This can be a barrier for smaller projects or institutions with limited resources.

## 5. Environmental and Logistical Factors

**Weather Conditions:** Adverse weather conditions, such as heavy rain, fog, or high winds, can affect the quality of LiDAR data. Weather-related disruptions can impact the timing and success of data acquisition.

**Terrain and Accessibility:** Difficult terrain or remote locations may pose logistical challenges for conducting LiDAR surveys. Access issues can limit the ability to survey certain areas or require additional planning and resources.

## 6. Integration with Other Data Sources

**Data Integration:** Combining LiDAR data with other archaeological data sources, such as historical records, excavation findings, or ground surveys, can be complex. Ensuring coherent integration and interpretation of diverse datasets requires careful coordination.

**GIS and Mapping Challenges:** Integrating LiDAR data into Geographic Information Systems (GIS) and creating accurate maps can be challenging, particularly when dealing with large or complex datasets. GIS expertise is often needed to effectively utilize and analyze LiDAR data.

## 7. Preservation and Ethics

**Site Preservation:** While LiDAR is non-invasive, the interpretation and dissemination of data can sometimes lead to increased interest or activity at sensitive archaeological sites. This can raise concerns about site preservation and the potential for looting or vandalism.

**Ethical Considerations:** Ethical considerations related to the use of LiDAR data, such as respecting indigenous or local community interests, must be addressed. Engaging with local stakeholders and ensuring responsible use of data are important aspects of ethical research practices.

## 8. Technological Limitations

**Sensor Limitations:** The performance of LiDAR sensors can vary based on technological advancements and design. Older or less advanced sensors may not provide the same level of detail or accuracy as newer models.

**Data Storage and Management:** The large volume of data generated by LiDAR surveys requires substantial storage capacity and efficient management. Handling and archiving large datasets can be challenging, particularly for long-term research projects.

Addressing these challenges requires a combination of careful planning, technical expertise, and complementary methods. Despite its limitations, LiDAR remains a powerful tool in archaeology, offering valuable insights and enhancing our understanding of hidden and buried features.

Feel free to adjust or add any additional points you think are relevant!

## VI. Future Directions

As LiDAR technology continues to evolve, its potential applications in archaeology are expanding, offering new opportunities for research, discovery, and site management. The following outlines key areas of development and future directions that are likely to shape the use of LiDAR in archaeology:

### 1. Advancements in LiDAR Technology

**Improved Resolution and Accuracy:** Future LiDAR systems are expected to achieve higher resolution and greater accuracy, allowing for even more detailed and precise

mapping of archaeological features. Advances in sensor technology and laser systems will enhance the ability to capture fine details and subtle variations in the landscape.

**Multispectral and Hyperspectral LiDAR:** Integrating LiDAR with multispectral or hyperspectral imaging can provide additional layers of data, enabling researchers to analyze different material properties and identify features that are not visible with traditional LiDAR alone. This integration can enhance feature detection and classification.

**Miniaturization and Accessibility:** The development of smaller, more cost-effective LiDAR sensors could make the technology more accessible for a wider range of projects and institutions. Miniaturized systems may also be suitable for use in drones, enabling detailed surveys of smaller or more challenging areas.

## 2. Enhanced Data Processing and Analysis

**Artificial Intelligence and Machine Learning:** Incorporating artificial intelligence (AI) and machine learning algorithms into data processing can improve the efficiency and accuracy of feature detection and classification. These technologies can help automate the analysis of large datasets and identify patterns that may be difficult for human analysts to discern.

**Advanced Visualization Techniques:** Innovations in data visualization, such as virtual reality (VR) and augmented reality (AR), can provide immersive and interactive ways to explore and interpret LiDAR data. These tools can enhance understanding and communication of archaeological findings.

**Integration with Other Technologies:** Combining LiDAR with other remote sensing technologies, such as ground-penetrating radar (GPR) or photogrammetry, can provide a more comprehensive view of archaeological sites. Integrated datasets will offer richer insights and improve the accuracy of feature detection and interpretation.

## 3. Expanding Applications and Use Cases

**Urban Archaeology:** LiDAR is increasingly being used in urban archaeology to uncover and analyze hidden features in modern cities. Future applications may include exploring historical urban development, infrastructure changes, and the impact of urbanization on ancient sites.

**Cultural Heritage Management:** LiDAR technology will continue to play a crucial role in the management and preservation of cultural heritage sites. Future developments may include tools for monitoring site condition, assessing the impact of environmental changes, and planning conservation efforts

**Global and Remote Surveys:** Advances in satellite-based LiDAR systems and high-altitude drones may enable large-scale surveys of remote or previously inaccessible regions. This

## VII. Conclusion

LiDAR technology has profoundly transformed the field of archaeology, offering unprecedented capabilities for uncovering and analyzing hidden and buried features with precision and efficiency. Through its ability to penetrate vegetation, map complex topographies, and generate high-resolution three-dimensional models, LiDAR has enabled archaeologists to explore previously inaccessible areas, discover new sites, and gain deeper insights into ancient civilizations.

The applications of LiDAR in archaeology, as demonstrated through various case studies, highlight its significant impact on site identification, analysis, and preservation. From revealing the intricate urban layouts of Maya cities to mapping ancient Roman infrastructure and uncovering hidden features in remote landscapes, LiDAR has proven to be a valuable tool in expanding our understanding of past human activities and cultural landscapes.

Despite its many advantages, LiDAR technology faces several challenges and limitations, including issues related to data resolution, vegetation coverage, and the complexity of data processing. Addressing these challenges requires ongoing advancements in technology, innovative data analysis methods, and careful consideration of ethical and logistical factors.

Looking to the future, LiDAR technology is poised for continued growth and development. Advancements in sensor technology, data processing, and integration with other remote sensing methods promise to enhance the capabilities and applications of LiDAR in archaeology. By embracing these developments and fostering interdisciplinary collaboration, researchers can further unlock the potential of LiDAR to explore, document, and preserve the rich tapestry of human history.

In summary, LiDAR technology represents a powerful and evolving tool in the archaeologist's toolkit, offering new opportunities for discovery and understanding. As technology continues to advance, the integration of LiDAR with other innovative methods and approaches will likely lead to even greater breakthroughs and insights into our shared past.

## References

1. Morgan, C. (2022). Current digital archaeology. *Annual Review of Anthropology*, 51(1), 213-231.
2. Zubrow, E. B. (2006). Digital archaeology: A historical context. *Digital archaeology: bridging method and theory*, 10-31.
3. Daly, P., & Evans, T. L. (2004). *Digital archaeology: bridging method and theory*. Routledge.
4. Huggett, J. (2017). The apparatus of digital archaeology. *Internet archaeology*, 44.
5. Morgan, C., & Eve, S. (2012). DIY and digital archaeology: what are you doing to participate?. *World Archaeology*, 44(4), 521-537.
6. Kansa, S. W., & Kansa, E. C. (2018). Data beyond the archive in digital archaeology: an introduction to the special section. *Advances in Archaeological Practice*, 6(2), 89-92.
7. Morgan, C. L. (2012). *Emancipatory digital archaeology*. University of California, Berkeley.
8. Tanasi, D. (2020). The digital (within) archaeology. Analysis of a phenomenon. *The Historian*, 82(1), 22-36.
9. Bruno, F., Bruno, S., De Sensi, G., Luchi, M. L., Mancuso, S., & Muzzupappa, M. (2010). From 3D reconstruction to virtual reality: A complete methodology for digital archaeological exhibition. *Journal of Cultural Heritage*, 11(1), 42-49.
10. Graves, M. W. (2013). *Digital archaeology: the art and science of digital forensics*. Pearson Education.
11. Dallas, C. (2016). Jean-Claude Gardin on archaeological data, representation and knowledge: Implications for digital archaeology. *Journal of Archaeological Method and Theory*, 23, 305-330.
12. Graham, S. (2022). *An enchantment of digital archaeology: raising the dead with agent-based models, archaeogaming and artificial intelligence*. Berghahn Books.
13. Clarke, M. (2015). The digital dilemma: preservation and the digital archaeological record. *Advances in Archaeological Practice*, 3(4), 313-330.
14. Kintigh, K. W., & Altschul, J. H. (2010). Sustaining the digital archaeological record. *Heritage Management*, 3(2), 264-274.

15. Rusho, M. A., & Hassan, N. (2024). Pioneering The Field Of Digital Archeology In Bangladesh.
16. Frachetti, M. (2006). Digital archaeology and the scalar structure of pastoral landscapes. *Digital archaeology: bridging method and theory*, 113-132.\
17. Jamil, M. H., Annor, P. S., Sharfman, J., Parthesius, R., Garachon, I., & Eid, M. (2018, September). The role of haptics in digital archaeology and heritage recording processes. In *2018 IEEE International Symposium on Haptic, Audio and Visual Environments and Games (HAVE)* (pp. 1-6). IEEE.
18. Huggett, J. (2020). Capturing the silences in digital archaeological knowledge. *Information*, *11*(5), 278.
19. Wessman, A. P. F., Thomas, S. E., & Rohiola, V. (2019). Digital Archaeology and Citizen Science:: Introducing the goals of FindSampo and the SuALT project. *SKAS*, *2019*(1), 2-17.
20. Dennis, L. M. (2019). *Archaeological ethics, video-games, and digital archaeology: a qualitative study on impacts and intersections* (Doctoral dissertation, University of York).
21. Rusho, M. A., & Hassan, N. (2024). Pioneering The Field Of Digital Archeology In Bangladesh.
22. Börjesson, L., & Huvila, I. (2018). Digital archaeological data for future knowledge-making. In *Archaeology and archaeological information in the digital society* (pp. 14-36). Routledge.
23. Watrall, E. (2019). Building scholars and communities of practice in digital heritage and archaeology. *Advances in Archaeological Practice*, *7*(2), 140-151.
24. Levy, T. E., & Smith, N. G. (2016). On-site GIS digital archaeology: GIS-based excavation recording in Southern Jordan. In *Crossing Jordan* (pp. 47-58). Routledge.