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Reconstructing the Ancient Mihinthale Tank: A GIS and Remote Sensing Approach to Uncovering Historical Landscapes in Sri Lanka

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Abstract

The study employs Geographic Information Systems (GIS) and Remote Sensing techniques to reconstruct the inundation area of the ancient Mihinthale tank, providing a comprehensive understanding of its historical landscape. The methodology involved several key steps, including the acquisition of Advanced Land Observing Satellite (ALOS) data to create a detailed Digital Elevation Model (DEM) of the study area. The DEM was processed using ArcGIS to generate contour lines and determine the maximum water level. GPS locations of the old tank bund were collected and integrated into ArcGIS to reconstruct the ancient bund. The reconstructed bund and contour lines were then used to delineate the potential inundation area. A comparison of the ancient tank's dimensions and capacities with its present-day counterpart reveals substantial differences. The current tank bund measures approximately 720 meters, while the ancient bund was around 1700 meters. The current tank covers an area of about 0.25 square kilometers, whereas the ancient tank extended over 0.98 square kilometers. The surface volume of the present tank is approximately 1,024,000 cubic meters, compared to about 5,033,000 cubic meters for the ancient tank. The investigation highlights the significance of the Mihinthale tank within the broader context of Sri Lankan monastic and hydraulic infrastructure. Historical evidence suggests that the ancient tank played a crucial role in sustaining the large monastic population in Mihinthale, supporting the hypothesis of an extensive tank bund connecting the Mihinthale monastery and Wasammale.

Keywords: *ALOS, DEM, GIS, Mihinthale Tank, Remote Sensing*

Introduction

Archaeology, in conjunction with Geographic Information Systems (GIS) and Remote Sensing, offers powerful tools to uncover and understand ancient landscapes. Those techniques have been used for different purposes of archeology such as forecasting archeological site locations (Espa et al., 2006), modeling for the prediction of archeological sites (Nsanziyera et al., 2018), mapping archeological sites (Richason & Hritz, 2006), archeological data management (Mafredas & Malaperdas, 2021), understanding behavioral patterns using geostatistical methods (Katugampola, 2021) and reconstruction of the historical landscape (Alexakis et al., 2011).

Recreating historical landscapes has become urgent due to anthropogenic and environmental processes such as erosion and sedimentation, and new technologies now allow archaeologists to complete surveys in a shorter time, a process that once took decades (Krleža et al., 2018). One of the technologies facilitating these expedited archaeological surveys and tasks is the application of GIS and remote sensing.

Alexakis et al. (2011) focused on a multidisciplinary approach that combined field surveys, statistical analysis, and GIS and remote sensing techniques to detect Neolithic settlements and reconstruct the Neolithic landscape while Krleža et al. (2018) mostly depend on remote sensing technologies for precise reconstruction and preservation of the historical landscape of the island of Rab, Croatia, through the creation of interactive 3D models. Liu et al. (2021) employed GIS and remote sensing techniques to analyze the land-water distribution and reconstruct the historical landscape of the Panlongcheng site by generating DEM and TIN base maps with modern artificial features removed, allowing for detailed topographical analysis and visualization. In addition, Farinetti. (2011) utilized a GIS-based approach to integrate archaeological, historical, and environmental data to assess the long-term settlement history and landscape character of Central Greece for the reconstruction and interpretation of the archaeological datasets.

Although using GIS and remote sensing technologies in Sri Lankan archaeological studies has become common practice, most applications are limited to site mapping and archaeological data management. However, Fernando, (2005) underscored the value of GIS-based computer applications in archaeology, notably in reconstructing ancient cultural landscapes, as demonstrated in the study of the lower Kirindi Oya basin in the Hambanthota District, where a GIS application depicted the cultural landscape over the past 2000 years, revealing significant changes in settlement patterns and human impacts on the natural landscape. Although Fernando (2005) attempted to reconstruct the ancient cultural landscape, the study primarily compares the present and past landscapes. In addition, Madduma Arachchi, (2023) attempted to recreate the landscape of Colombo Fort, Sri Lanka using the Georeferencing technique in GIS with a historical Dutch map of the Colombo fort.

The present landscape of Sri Lanka's North Central and Northwestern provinces offers insight into the ancient landscape, particularly concerning the ancient irrigation systems. Several arguments exist regarding the origins of Tank irrigation systems in Sri Lanka. Among these, the popular belief that early Aryan settlers developed the irrigation system is questioned by various scholars (Panabokke, 2010). Within a few centuries of their origin, these tanks expanded significantly in size, and many of them became interconnected, forming intricate cascade systems. Tank cascades are connected series of tanks organized within a micro-catchment of the dry zone landscape, storing, conveying, and utilizing water from an ephemeral rivulet (Madduma Bandara, 1994).

Multiple invasions from South India into Sri Lanka compelled the kingdom to relocate further into the southwestern region of the island. This initiated the abundance of the Rajarata as the dominant political, economic, and agricultural hub of Sri Lanka. Insufficient attention resulted in a proliferation of ancient tanks throughout the region. Sri Lanka was under colonial rule from 1505, with the Portuguese making no attempts to reconstruct irrigation works. The Dutch restored some maritime irrigation works, and while the early British period saw neglect and destruction of these systems, significant attention was given to irrigation improvement from 1855 onwards, culminating in the establishment of the Irrigation Department in 1900 to repair and maintain ancient reservoirs and networks. Later, during the era of D. S. Senanayake, irrigation became central to agriculture, with the goals of increasing paddy production and relocating people from the wet zone to the dry zone (Weerasinghe & Navarathne, 2003).

By examining the ruins of tank bunds from some ancient tanks, it becomes evident that these tanks were once significantly larger than they are today. Although the remaining tanks and irrigation systems reveal how the historical irrigation landscape functioned in the Anuradhapura kingdom, parts of this sophisticated tank network have either been abandoned or modified. Therefore, it is difficult to determine the inundated area of a tank during the ancient time. However, interdisciplinary approaches like GIS and remote sensing techniques are capable of recreating these historical environments and gaining insights into the engineering and hydrological prowess of ancient civilization in Sri Lanka.

Determining the inundated area of a tank involves analyzing the length and height of the tank bund as well as the morphology of the associated surface. Khojiakbar et al. (2019) employed Remote Sensing and GIS technologies to assess the area and volume of the Tashtepa water reservoir. Tools such as Google Earth and Global Mapper were utilized to delineate dam alignments, create Digital Elevation Models (DEM), and quantify both the surface area and volume of the reservoir. Similarly, Taşkin & Irvem. (2014) utilized DEM to identify suitable reservoir sites and estimate their water surface area and volume, facilitating efficient surveying and future capacity analysis of reservoirs in the watershed in Turkey. Bhat et al. (2015) utilized multispectral images from sources like Landsat, IRS LISS III, and ASTER, along with DEMs to accurately assess reservoir water levels, calculate water volume based on empirical models, and convert water spread area into vector polygons. Nevertheless, all of these studies are based on modern reservoirs or those in the planning stages. None of these studies were focused on recreating the historical landscape by determining the inundation area of a historical reservoir.

The Mihinthale Tank, also known as Bulankulama, originally featured a much longer tank bund, whereas its present-day structure has a considerably shorter bund. Situated at a site of profound significance for Sri Lankan Buddhism, Mihinthale has been revered since the time of Mahinda Thero, whose presence solidified its status as a crucial Buddhist center. Over time, Mihinthale and its environs evolved into a prominent Buddhist monastic enclave, with the Mihinthale tank likely serving as a vital water source for daily activities. Hence, comprehending the extent of the Mihinthale tank during the Anuradhapura period is essential for unraveling the role of the Mihinthale landscape as a Buddhist monastery.

As mentioned above, utilizing GIS and remote sensing techniques to recreate the ancient landscape is not a highly explored area in the field of Archaeology in Sri Lanka. This research gap leads to the formulation of the following research question: How can modern GIS and remote sensing techniques be utilized to determine the inundation area of the Mihinthale tank during its prime stage in the Anuradhapura era?

Building upon this background, this research aims to delineate the inundation area of the Mihinthale tank during its peak period, possibly within the Anuradhapura era, by employing contemporary GIS and remote sensing methodologies. By doing so, it seeks to provide a detailed understanding of the tank's historical extent and its role in the ancient landscape.

2. Materials and Methodology

2.1 Research Area

This research focuses on the Mihinthale Tank (also known as Bulankumala), believed to have been built during the King Devanampiyatissa era (306 BC – 266 BC) (Wijayawardene, K., 2022), located in the Mihinthale DS division of the Anuradhapura district in Sri Lanka's dry zone (Fig 02).

Figure 01: *Remaining part of the old tank bund from the Mihinthale side*

There is a local saying that a monk could walk from Wasammale to the Mihinthale monastery along the Tank bund (Wijayawardene, K., 2022), indicating the historical length and significance of the tank bund. Today, the existing tank bund measures approximately 720 meters in length, with heights ranging from approximately between 02 to 08 meters. Despite its reduced length, remnants of the ancient bund can still be observed within the premises of Rajarata University to the north and near the Mihinthale Monastery to the south (Fig. 01). These remnants suggest that the original tank bund likely spanned between the Wasammale and Mihinthale mountains, creating a significant hydraulic structure.

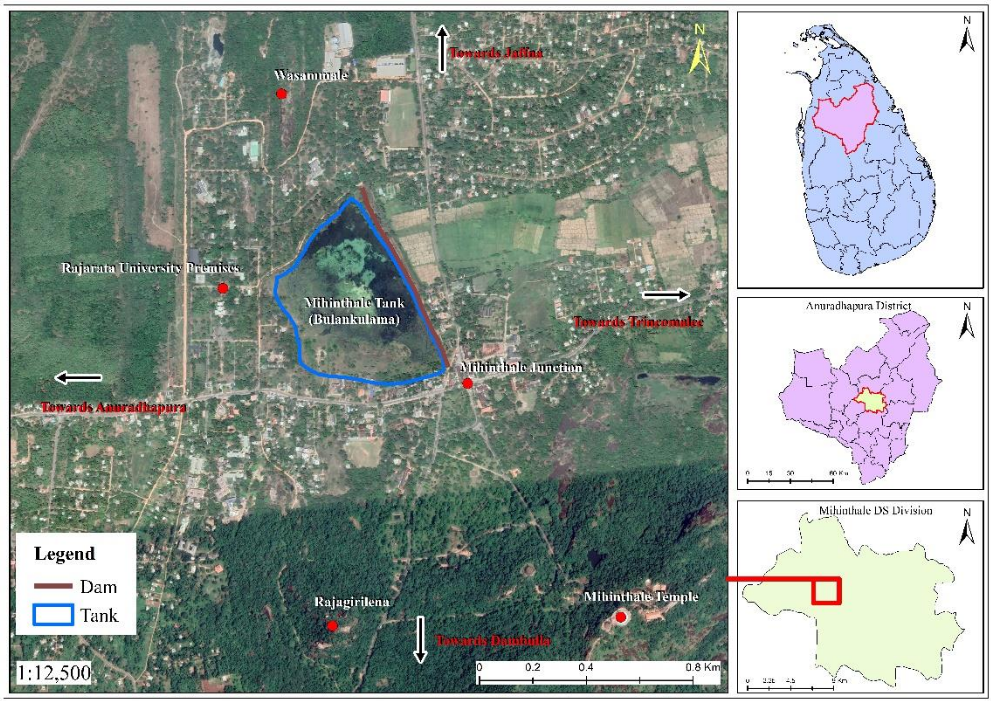

Figure 02: Location of the Mihinthale Tank (Image source: Google Earth)

The Mihinthale Tank is situated at the coordinates 8°21'44.21"N latitude and 80°30'29.56"E longitude. Currently, the tank supports the cultivation of approximately 42 acres of paddy fields (De Silva & Ranjith, 2017), covering a water area of about 0.25 square kilometers (km^2).

Materials

To accurately determine the inundation area of the Mihinthale Tank, a Digital Elevation Model (DEM) is essential. DEMs provide detailed information on the terrain elevation, which is critical for understanding the topography and hydrology of the area.

For this research, the Advanced Land Observing Satellite (ALOS) data was utilized. The ALOS satellite provides terrain-corrected DEM with a spatial resolution of 12.5 meters (ESA, n.d.), offering a more detailed and accurate representation of the terrain compared to other freely available DEM products. Although the Shuttle Radar Topography Mission (SRTM) DEM, with a 30-meter spatial resolution (EOS, n.d.), is commonly used, but its resolution was insufficient for this study. Furthermore, the Survey Department of Sri Lanka does not provide maps of the study area with sufficiently small contour intervals. Therefore, the ALOS satellite data was chosen to ensure a higher precision in terrain modeling. Table 01 shows the details of the used ALOS image.

Satellite and Instrument	Acquired date	Image ID
ALOS PALSAR	26.01.2007	ALPSRP05363015

Table 01: *Details of the ALOS image used*

Google Earth images were employed as base images to assist in visualizing the study area. These images also facilitated the acquisition of locational data for various features, including the current extent of the Mihinthale Tank. Additionally, the locational data for the remnants of the old tank bund was collected using the CTDroid Sri Lanka mobile app. This application allows for the precise gathering of GPS coordinates, which is crucial for mapping the historical extent of the tank bund.

Methodology

The methodology for determining the inundation area of the Mihinthale Tank during its prime stage in the Anuradhapura era involves several steps, incorporating GIS and remote sensing technologies (See Fig.03). ALOS DEM data was downloaded from the “Alaska Satellite Facility” website to create detailed topographic maps and analyze the historical landscape of the Mihinthale Tank area.

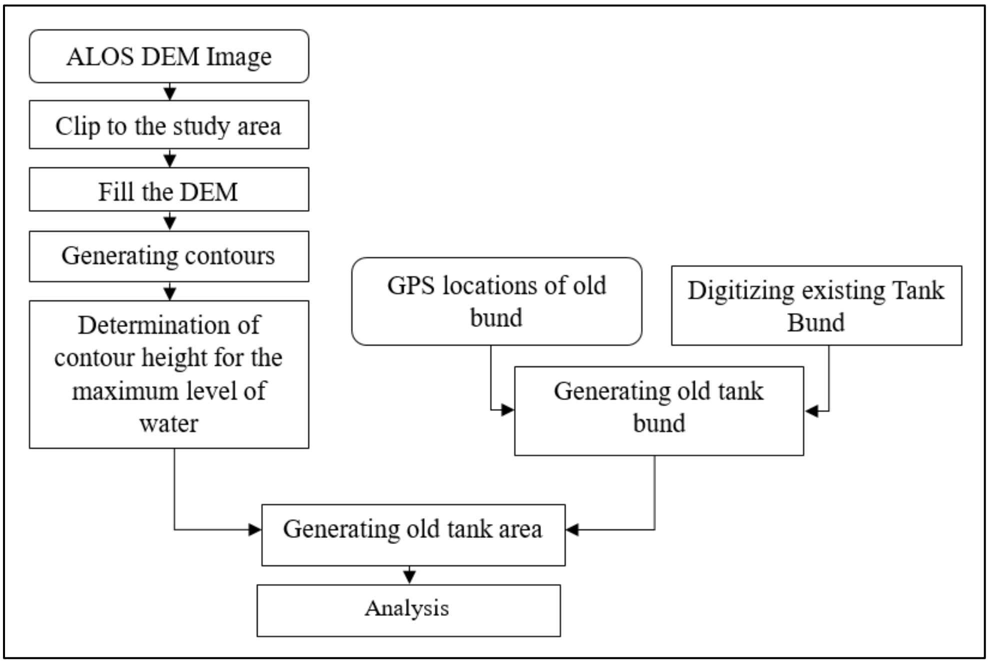

Figure 03: *Methodology*

The preprocessing phase began by clipping the ALOS DEM image to the study area using ArcGIS to focus on the relevant geographical region. The DEM was then processed with the Fill tool in ArcGIS to eliminate any sinks or depressions, ensuring a smooth surface for accurate hydrological analysis. Contours were generated from the DEM with a 10-meter interval, providing a detailed representation of the area's topography. The maximum height of the water level was determined by examining the elevations at both ends of the old tank bund, near Wasammale to the north and Mihinthale to the south, which were approximately 23 meters.

GPS locations of the old tank bund and the digitized existing tank bund were imported into ArcGIS for the reconstruction of the old tank bund. Using the imported data, the old tank bund was reconstructed by connecting the identified fragments and the existing bund segments, forming a continuous polyline that represents the presumed original tank bund. A contour line was then generated at the determined maximum water height of 23 meters. This contour was combined with the reconstructed old tank bund to delineate the potential inundation area of the Mihinthale Tank during its prime.

ArcGIS 10.8 was used to conduct this study including the area and volume calculation of the tank.

Results and Discussion

Fig.04 illustrates the results of this study, the reconstructed possible inundation area of the Mihinthale Tank during its prime stage in the Anuradhapura era. The results reveal two distinct sections of the ancient tank: a larger inundation zone towards the top and a smaller section near the Mihinthale mountain. Consequently, there is a dry area between these two zones, despite the presence of the potential old bund. This could be attributed to modifications of the terrain through human activity, possibly an infill.

A comparison between the ancient and present-day extends of the Mihinthale tank reveals significant differences in their dimensions and capacities.

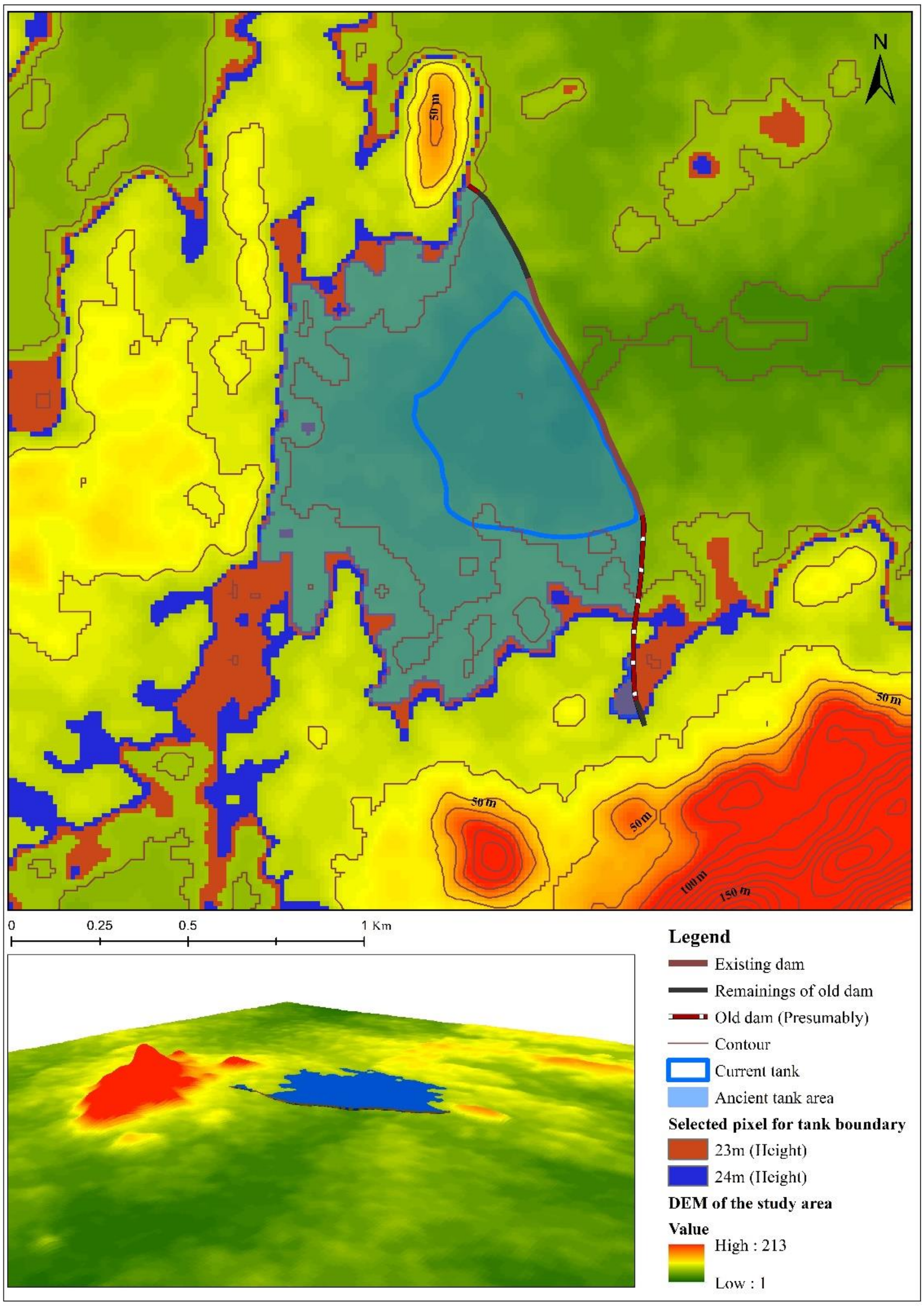

***Figure 04: Up:** Possible ancient Mihinthale Tank, **down:** 3D representation of the area with the possible ancient tank.*

The current tank bund stretches approximately 720m, whereas the potential length of the ancient bund was about 1700m making the ancient bund 980 meters longer than the current one. The height of the current bund varies approximately between 2 to 8 meters. In contrast, remnants of the old bund range from about 1 to 3 meters in height. Given that the ancient tank was constructed using the 23 - 24 meter height contours, with the lowest part of the tank at around 12 meters in height, it can be inferred that the maximum height of the ancient tank bund was around 10 meters. The current tank covers an area of about 0.25 km^2, while the ancient tank extended over approximately 0.98 km^2, indicating that the ancient tank was 0.73 km^2 larger than the current tank. The approximate surface volume of the present tank is around 1,024,000 cubic meters (m^3), whereas the ancient tank possibly had a volume of about 5,033,000 m^3 (See Table 02).

	Current Tank	**Ancient Tank**
Height of the bund (Approx.)	2 to 8 m	Max. 10m
Length of the bund (Approx.)	720m	1700m
Inundation area (Approx.)	0.25 km^2	0.98 km^2
Surface Volume (Approx.)	1,024,000 m^3	5,033,000 m^3

Table 02: *Past and present comparison of Tank characteristics*

The ancient tank encompassed much of the eastern and southwestern parts of the present-day Mihinthale town area, including the Mihinthale Divisional Secretariat, Pradeshiya Sabha, Mihinthale Maha Vidyalaya, the northern part of the Rajarata University premises, and the Mihinthale railway station (Fig.05). Although not explicitly shown in the results, it is likely that the area where the present-day Mihinthale hospital is located was also within the inundation zone of the ancient tank, as the ancient bund was situated in front of this area.

Based on current tank classifications (Murray & Little, 2000), the present Mihinthale tank can be considered a small-scale village tank, with a typical water spread ranging from 4 to 50 hectares (0.04 to 0.5 km^2). However, with an area of 0.98 km^2, the ancient tank could be classified as a medium-scale tank.

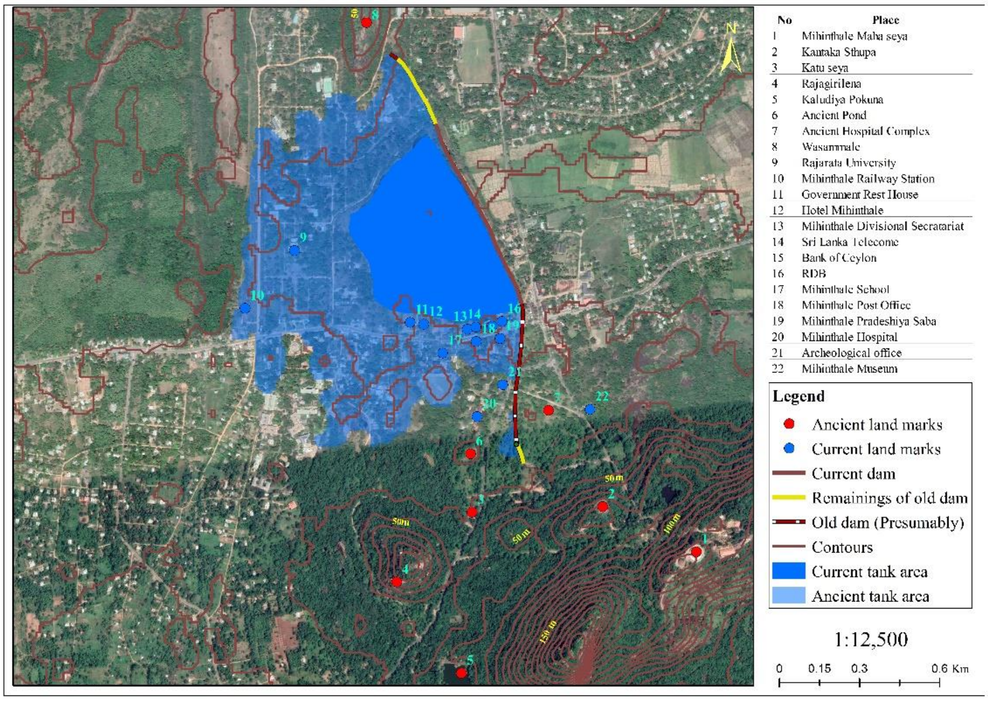

Figure 05: *Inundation area of ancient Mihinthale tank overlayed on current satellite image (Image source: Google Earth)*

Unlike tanks in a cascade system, the Mihinthale tank is not part of such a system, with surplus water directly flowing to the Mahakanadarawa tank located to its east. Currently, the Mihinthale tank is a small-scale tank situated between two large-scale tanks: Mahakanadarawa to the east and Nuwarawewa to the west. However, the ancient Mihinthale tank was significantly larger and could have been the most important tank between these large-scale tanks (Fig.06).

Figure 06: *Ancient Mihinthale tank with comparison to Mahakanadarawa and Nuwarawewa (Image source: Google Earth)*

Historical records, such as those by Fa-Hien, indicate that by 410 AD, 2000 monks were residing in Mihinthale (Legge, 1886). While several small tanks and ponds are located near the Mihinthale monastery, they would not have sufficed to meet the daily water needs of such a large population. However, the vast ancient tank would have been capable of fulfilling their water requirements.

The reliability of the research findings can be assessed by examining the distribution of ancient landmarks around the area. No ancient landmarks were located within the reconstructed ancient tank area (Fig.05). The closest historical site is the large pond at the Indikatuseya premises. Therefore, the reconstructed tank area is likely accurate, and the local saying that "a Monk can come to Mihinthale monastery via tank bund from Wasammale," which supports the hypothesis of a longer tank bund, is validated.

Mihinthale Tank GIS**Conclusion**

This research successfully reconstructed the ancient Mihinthale Tank using GIS and remote sensing techniques, providing a clearer understanding of its historical extent and significance. The study demonstrates the advantages of combining DEM data with modern GIS tools to recreate ancient landscapes, offering a detailed view of the tank's past structure and capacity. One of the key findings is the substantial difference between the ancient and present-day tank dimensions, highlighting the potential scale and importance of the tank in historical times.

The reconstructed ancient tank was significantly larger, with a bund length of approximately 1700 meters compared to the current 720 meters, and a surface area of 0.98 square kilometers versus the present 0.25 square kilometers. This indicates the ancient tank was almost four times larger in area and held nearly five times the water volume of the current tank. These findings suggest that the Mihinthale Tank played a crucial role in supporting the local population, particularly the large monastic community in the region during its prime.

However, the study has some limitations. The accuracy of the reconstruction is dependent on the quality and resolution of the available DEM data and the precision of the GPS coordinates used to map the remnants of the old bund. Furthermore, the study assumes the tank's maximum height based on existing topographical features, which might not account for all historical modifications to the landscape.

Despite these limitations, the methodology demonstrated in this research has broad applications for archaeological studies, particularly in regions with rich historical landscapes. By employing similar techniques, other ancient irrigation systems and landscapes can be reconstructed, offering valuable insights into the engineering and hydrological practices of ancient Sri Lanka.

Exploring the social and economic impacts of such large-scale water management systems on ancient communities would provide a more comprehensive understanding of their significance. This study not only underscores the value of GIS and remote sensing in archaeology but also emphasizes the importance of preserving and studying ancient infrastructures to appreciate their contributions to historical and modern societies.

Recommendations

Further investigation could broaden this study by integrating supplementary data sources, such as historical sources, while utilizing high-resolution contours, such as those derived from field measurements or drone surveys, to improve the precision of the reconstruction.

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