Documenting Gawr Tepe: remote sensing and 3D survey for mapping and monitoring a multi-period site in Iraqi Kurdistan

Domenico Andreucci

domenico.andreucci@unito.it - University of Turin

Veronica Castignani

veronica.castignani@phd.unict.it - University of Catania

Abstract

This study presents the integrated documentation of Gawr Tepe, a Sasanian–Islamic site located in the Khani Masi plain (Iraqi Kurdistan). It assesses the potential of 3D documentation, combined with remote sensing data and architectural analysis, to enhance the understanding of this multi-period site and to monitor transformations in its surrounding landscape. Drone-based 3D modelling and multiple visualisation techniques provide the first comprehensive mapping of the site, addressing a gap in regional research, while comparisons with historical imagery establish a baseline for heritage monitoring and interpretation.

Keywords

Iraqi Kurdistan, Gawr Tepe, remote sensing, 3D survey, CORONA imagery

Introduction

The documentation of Gawr Tepe was initiated in 2023 as one of the preliminary objectives of a three-year agreement between the MiSAK (Italian Historical and Archaeological Mission in Kurdistan)[1], ISMEO (International Association for Mediterranean and Oriental Studies), the International Institute of Kurdish Culture in Rome, the KRG General Directorate of Antiquities and Heritage, and the Garmian Directorate of Antiquities and Heritage. The project focuses on the archaeological investigation of Gawr Tepe within a broader research programme on the ancient landscape of the Garmian region.

Gawr Tepe is a large architectural complex located in the Khani Masi plain along the Upper Sirwan River Valley (Diyala in Arabic), which originates in the Zagros Mountains of western Iran and flows southward to its confluence with the Tigris River near Baghdad. The plain is bounded to the east by a series of anticlines in the Zagros piedmont, oriented northwest–southeast and intersected by snowmelt-fed streams and artesian springs (Laugier and Casana 2021, 1–4). The Upper Sirwan represents an important transitional zone between the Mesopotamian plains and the Zagros highlands, historically functioning as one of the principal routes of transportation and communication linking these regions. The site lies 8 km south of the modern city of Kalar, in the Sulaymaniyah Governorate (Iraqi Kurdistan) (Fig. 1). Gawr Tepe has been identified as a major Sasanian and Early-Middle Islamic settlement extending over 6 ha. The archaeological

[1] This article was prepared within the activities of the MiSAK. The authors wish to thank Dr. Luca Colliva, Director of MiSAK, for his support and availability during the preparation of the paper; Prof. Pierfrancesco Callieri for his valuable suggestions and observations; and Federico Izzi for his generous assistance in revising the text.



Fig.1: Map of the Garmian region indicating the location of the site of Gawr Tepe (V. Castignani)

complex comprises two principal mounds — Gawr Tepe A (5.8 ha) and Gawr Tepe B (0.2 ha) — together with several smaller mounds across an area of roughly 5 km² (Fig. 2).

The first fieldwork comprised a detailed topographic survey of the two central mounds and a systematic surface collection. Preliminary analysis of the assemblages indicates continuous occupation from the Sasanian period to the thirteenth century CE (Colliva *et al.* 2023). The combined topographic and aerial photogrammetric survey achieved centimetre-level accuracy and produced a high-resolution orthomosaic basemap for integrating, visualising, and managing archaeological and geospatial data. This approach compensated for the absence of medium- and large-scale cartography for the area, as the only available basemap from local authorities is a Russian military topographic map at a 1:100,000 scale. Additional data sources include freely accessible satellite imagery, offering ground resolution sufficient for preliminary landscape analysis[2], and declassified CORONA images providing extensive coverage of the Garmian region. Since the site was largely neglected in previous archaeological research, integrating these recent datasets with 1960s–1970s satellite imagery has proven effective for mapping features, monitoring landscape change, and assessing recent damage.

The Garmian area is characterized by a high density of archaeological sites, many of which have been identified but remain insufficiently studied. Given its historical significance, a systematic

[2] Besides traditional Google Earth, Esri, and Bing, further satellite imagery sources include Planet Explorer, the ESA Copernicus Program, and the USGS Landsat Program.



Figure 2. Aerial view of the site showing the main tell*, Gawr Tepe A, and the smaller mound, Gawr Tepe B, in the Khani Masi plain (N. Abdullatif - Garmian Directorate of Antiquities and Heritage).*

and comprehensive analysis is required. The present research was guided by a set of key questions: how to examine the site's internal organisation without large-scale excavation and to identify elements that could support a reconstruction of its currently unknown plan; how to assess the site's potential functions within its broader regional and historical context; how to establish a tentative chronology for the preserved architectural remains; and whether the site can be interpreted as part of a wider urban system.

To address these objectives and to evaluate the potential of 3D documentation for improving understanding of the ancient site, multiple remote sensing datasets were analysed alongside ongoing field-walking activities. Within this workflow, mapping and documentation derived from topographic survey provided the basis for data acquisition and organisation, while the aerial photogrammetry supported the subsequent archaeological analysis. High-resolution photogrammetric data were processed using a range of visualisation techniques to enhance the detection of archaeological features and to highlight subtle surface variations potentially related to the layout of the Sasanian and Islamic complex. Broader architectural and functional readings are therefore advanced only as working hypotheses. CORONA and modern satellite imagery were further analysed to document pre-modern landscape features no longer visible and to map the effects of looting and recent land use. In this sense, the added value of the approach lies in bringing these distinct levels of analysis — intra-site mapping of the Gawr Tepe complex and assessment of landscape transformation — together within a single georeferenced framework based on non-invasive survey techniques.

The article first outlines the archaeological and historical background of the site, then presents the survey methodology and results, and finally discusses the interpretative implications of the documented evidence.

(D.A., V.C.)

The archaeological site of Gawr Tepe and its historical background

Archaeological research at Gawr Tepe has long been hampered by political instability and conflict. Only after 2003 did new investigations become possible, though threats from urbanisation, vandalism, and looting remain. The earliest systematic documentation dates to the *Atlas of the Archaeological Sites in Iraq* (General Directorate of Antiquities, 1976), while the Sirwan Regional Project (SRP, since 2013) has greatly advanced knowledge of the region, consolidating survey data in a dedicated database and recording extensive evidence of damage (Laugier *et al.* 2022).

Archaeological evidence and historical context of Gawr Tepe as defined by previous studies

Gawr Tepe[3] is located in the central plain of Khani Masi, an area with dense concentrations of settlements from the Parthian and Sasanian periods. The survey conducted by the SRP identified the site as featuring a large rectangular architectural complex, at the centre of which stands a citadel, elevated approximately eighteen metres above the surrounding plain. Although damaged by clandestine excavations, the structure appears to constitute the platform of a monumental building (Casana and Glatz 2017, 58–62). Surface investigations suggest that its occupation primarily occurred during the Sasanian and Early Medieval periods. This complex is surrounded by numerous smaller tells, most of which show evidence of contemporaneous occupation, suggesting the possible existence of a vast urban settlement with Gawr Tepe at its core[4].

Contemporary sites south of Gawr Tepe yielded metallurgical slag, large storage jars, and grinding stones, indicating specialised production. The wider settlement pattern reflects dense occupation supported by Sasanian military forts and extensive hydraulic works, including a canal diverting Diyala waters for over 40 km to irrigate c. 14 km² of farmland (Casana and Glatz 2017, 60–62).

Historical context

The region of Gawr Tepe, from the mid-1st millennium BCE, was under the control of major empires, including the Achaemenids, Seleucids, Arsacids, and Sasanians, which established socio-cultural and economic links with Mesopotamia and the Iranian plateau. This position made the area a crossroads of imperial, cultural, and economic interactions, shaped by influences from Iranian, Mesopotamian, Greek, Roman, and later Arab-Islamic traditions (Colliva *et al.* 2023).

[3] Within the Sirwan Regional Project survey, the site is also referred to as SRP 11. For a more detailed discussion of this site, as well as other sites in the area briefly mentioned in this article, see Casana and Glatz 2017: 58–62.
[4] For the tepe, see SRP 12, SRP 124, and SRP 125 in Casana and Glatz (2017: 59).

During the Sasanian period, archaeological evidence indicates Gawr Tepe served as a central hub for political, economic, and cultural activities, benefiting from its location along key routes. One route connected *Arbela* to Iran, tracing back to the Achaemenid period (Henkelman and Jacobs 2021, 720–722), while another Sasanian communication axis possibly followed the Sirwan (Diyala) valley, passing through Paikuli and perhaps Gawr Tepe before reaching Ctesiphon (Colliva 2025, 7; Cereti and Faticoni 2025, 47–50; Salih and Terribili 2025, 130–133). These routes facilitated trade and military movements.

After the Islamic conquest, the region retained its importance as a link between the Iranian plateau and the Levant, fostering intercultural exchanges. Archaeological findings indicate Gawr Tepe remained a significant centre of activity until at least the 13th century CE, with evidence of uninterrupted occupation.

(D.A.)

Materials and Methods

The use of spaceborne and airborne remote sensing for investigating historical landscapes at multiple scales and through time has been central to archaeological research for over a century (Luo *et al.* 2019; Hadjimitsis *et al.* 2020). More recently, unmanned aerial vehicles (UAVs) have greatly advanced the field, providing cost-effective, time-efficient tools for generating high-resolution orthomosaics and topographic models (Campana 2017). Remote sensing data have supported a wide range of applications, notably the monitoring of archaeological contexts in conflict-affected regions of North Africa and the Middle East. The 'Endangered Archaeology of the Middle East and North Africa' (EAMENA) project pioneered large-scale remote sensing for documenting and assessing endangered sites[5], while satellite-based monitoring has since been extended to Iraqi Kurdistan through the 'Archaeological Practice and Heritage Protection in the Kurdistan Region of Iraq' project, within the Sirwan Regional Project (Laugier and Casana 2021; Laugier *et al.* 2022).Within this broader methodological framework, the present study integrates historical satellite imagery with UAV-based survey data, as outlined in the following sections.

CORONA imagery

The CORONA imagery dataset available for the Gawr Tepe landscape derives from the United States photographic spy satellite mission between 1959 and 1972, which involved 145 launches and produced images of the study area between 1963 and 1972 (Fowler 2013). Originally classified for national security, the archive was declassified in 1995 and made publicly accessible through the US Geological Survey in 1998, enabling its use across a wide range of scientific disciplines (Day *et al.* 1998; Ur 2013, 28–29). Since then, CORONA imagery has been extensively employed in archaeological research because it preserves a record of landscapes prior to major transformations caused by industrialisation, urbanisation, dam construction, and large-scale agriculture. Its value for reconstructing archaeological landscapes has been particularly demonstrated in the Middle East (Casana and Cothren 2013, 35–40; Ur 2013, 31–

[5] Bewley *et al.* 2016; Zerbini 2018; Vafadari *et al.* 2019; Rayne *et al.* 2020; Fisher *et al.* 2021; Mamo *et al.* 2022; Izzo *et al.* 2022.

36), where extensive coverage exists, especially from the KH-4A and KH-4B mission series (Declass 1).

The KH-4A series (August 1963-October 1969) produced 517,688 frames with a ground resolution of 9 feet (2.74 m), while most available imagery derives from the KH-4B mission (September 1967-May 1972), which acquired more than 188,000 images with a higher nadir resolution of 6 feet (1.83 m), enabling stereo imagery and the extraction of topographic data (Fowler 2013; Casana and Cothren 2013, 31–33). Additional declassified datasets include Gambit KH-7 and Hexagon KH-9 imagery (1963–1980; Declass 2), and Keyhole KH-9 images (1971–1984; Declass 3).

For the Gawr Tepe area, 123 images are available through the USGS online archive[6]. The photographs used in this study were selected based on spatial resolution and visibility, assessed in terms of cloud cover. Additional georeferenced and orthorectified images were obtained from the 'CORONA Atlas' of the Center for Advanced Spatial Technologies at the University of Arkansas[7]. As recently observed, landscape analysis based on CORONA imagery and historical aerial photographs in the Sirwan River Valley is affected by a paradox of landscape taphonomy, defined as an inverse relationship between site preservation, water availability, and the survival of land-use features. While ancient settlements cluster in the fertile left-bank floodplain, the western bank, with its sparse occupation and limited water resources, preserves pre-modern land-use features more clearly (Laugier and Casana 2021, 9). This pattern limits large-scale reconstruction of the territorial organisation of the Gawr Tepe area, although local-scale observations remain possible.

Survey methodology and data visualisation

Given the considerable size of the site, the investigation included a UAV survey of its central sector, supported by a preliminary topographic survey of the main tell (Gawr Tepe A) and the smaller northern mound (Gawr Tepe B). The topographic survey combined GNSS and Total Station measurements to establish a network of ground control points in real-world coordinates, essential for accurately georeferencing the drone survey and further archaeological investigations (Fig. 3).

The UAV survey[8] was conducted at a flight altitude of 45 m, capturing 449 images over 9.38 ha and yielding a ground resolution of 1.13 cm/pixel. Photogrammetric data were processed in Agisoft Metashape Professional to generate a georeferenced point cloud, from which a high-resolution 3D model and orthomosaic of the site were produced. A digital elevation model (DEM) was then derived, with a resolution of 2.26 cm/pixel and a point density of 0.196 points/cm^2, serving as the basis for the analysis and interpretation of archaeological features.

To emphasise features potentially associated with human activity, multiple visualisation techniques (VTs) were applied using SAGA and GDAL algorithms within the QGIS platform (Bennett *et al.* 2012; Guyot *et al.* 2021). Although the VTs are typically applied to LiDAR data

[6] https://earthexplorer.usgs.gov/
[7] https://corona.cast.uark.edu/
[8] UAV survey courtesy of the Garmian Directorate of Antiquities and Heritage, with special thanks to our colleague Nawzad Abdullatif.

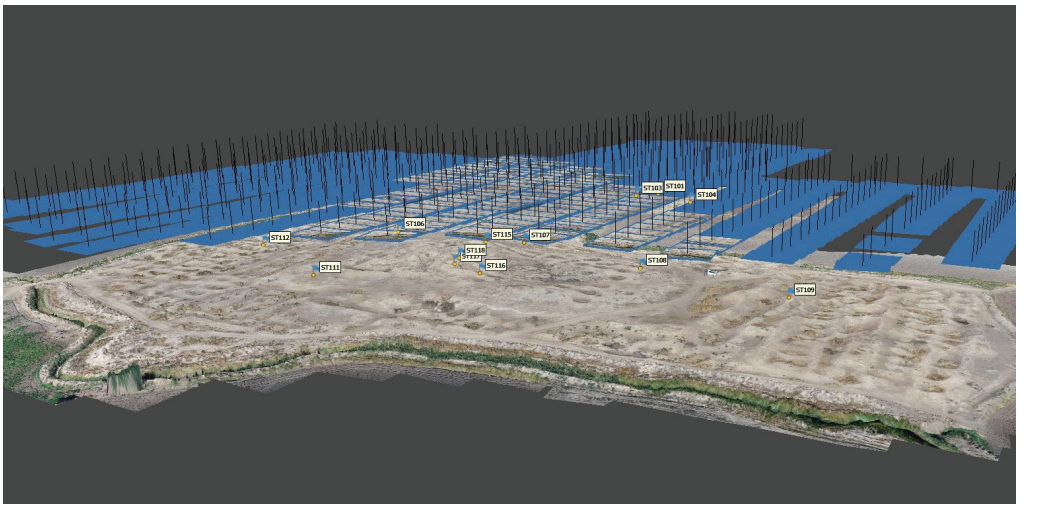


Figure 3. Drone-based 3D model showing the location of cameras and the distribution of ground control points (V. Castignani).

(Bennett *et al.* 2012; Doneus and Briese 2006; Doneus 2013; Campiani *et al.* 2022), the specific surface characteristics of the Gawr Tepe context — namely the minimal to absent vegetation cover and the generally limited depth of archaeological remains — make them equally suitable for application to a DEM derived from UAV photogrammetry. A traditional hillshade representation (Fig. 4, a) was applied to simulate shading based on incident light direction and elevation data (Yoëli 1967; Horn 1981; Chiba *et al.* 2008, 1072–1073), with an azimuth of 300°, light source elevation of 40°, and a Z-factor of 1. Hypsometric colours were overlaid on the hillshade map (Fig. 4, b), revealing linear, iso-oriented micro-relief features despite minimal surface elevation differences. Additionally, a sky-view factor representation (Fig. 4, f) was used to quantify the proportion of visible sky from each point. In this visualisation, light tones correspond to flat surfaces, ridges, or earthworks receiving more illumination, while dark tones indicate depressions such as trenches, plough furrows, ditches, or pits, which receive less light (Zakšek *et al.* 2011; Kokalj and Somrak 2019, 10).

The two main *tells* exhibit numerous surface concavities and convexities. To emphasize subtle elevation changes independently of light sources, the topographic attribute of openness was applied. Surface openness is defined as the mean of multiple zenith or nadir angles within a specified horizontal distance from each DEM cell (Yokoyama *et al.* 2002, 257–260; Doneus 2013). Positive topographic openness (Fig. 4, c) highlights convex elements above the surface, while negative topographic openness (Fig. 4, d) corresponds to concave depressions. From these, differential openness (Fig. 4, e) was calculated, combining convex and concave features in a single parameter without reliance on incident light (Chiba *et al.* 2008, 1073–1074). Bright areas indicate convex surfaces, and dark areas represent concave surfaces.

Differential openness was then combined with a slope model, representing in inverted grayscale the maximum rate of elevation change between each pixel and its neighbours (Doneus and Briese 2006, 102–104), to produce a Red Relief Image Map (RRIM) (Fig. 4, g). The RRIM reproduces fine-scale topographic variations, with light tones corresponding to convex

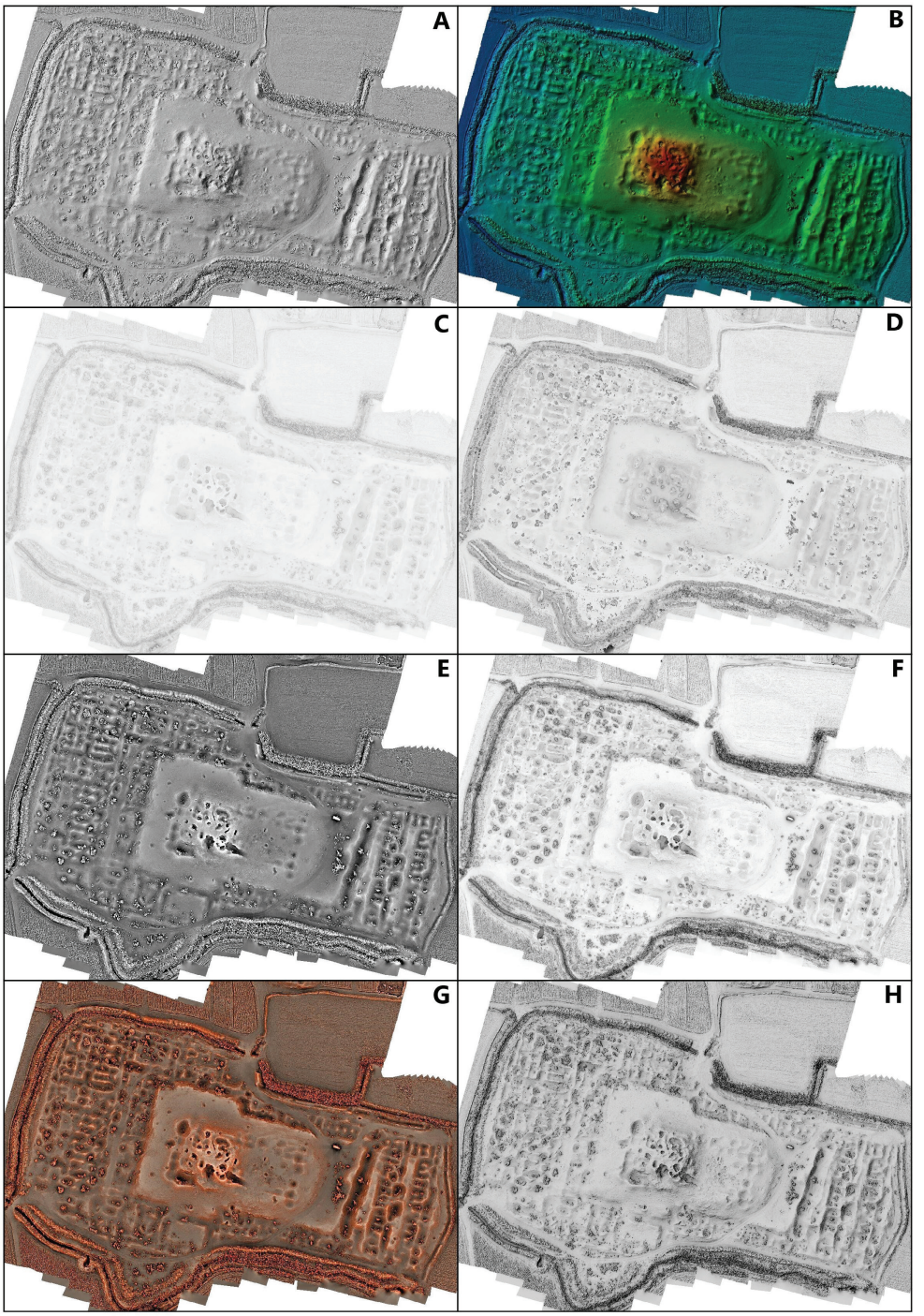


Figure 4. Composite image of data visualisations. a: traditional hillshade representation; b: hillshade with hypsometric colours; c: positive topographic openness; d: negative topographic openness; e: differential openness; f: sky-view factor representation; g: Red Relief Image Map (RRIM); h: Visualization for Archaeological Topography (VAT). Data processing and visualisation by V. Castignani.

surfaces and dark tones to concave features (Chiba *et al.* 2008, 1073–1074; Campiani *et al.* 2022, 276). The slope map was visualised as a single-band false-colour red ramp and blended with differential openness using a multiply blending mode to generate the final RRIM (Daxer 2020).

Finally, Visualization for Archaeological Topography (VAT; Fig. 4, h) — a composite method combining image fusion and blend modes — was employed to enhance topographic features related to archaeological remains. In this approach, the hillshade map serves as the base layer, combined with the slope map (luminosity blending, 50% opacity), positive openness (overlay blending, 50% opacity), and sky-view factor (multiply blending, 100% opacity) to maximise the detection of microtopographic features (Kokalj and Somrak 2019).

The table below summarises the method employed in the investigation and the analytical workflow, outlining for each procedure its objectives, key parameters, and resulting outputs.

(V.C.)

METHOD	PURPOSE	KEY PARAMETERS	OUTPUT
CORONA and modern satellite imagery	To analyse landscape changes, assess damage over time and detect possibly related mounds	Historical and modern imagery selected according to ground resolution and visibility	Identification of additional mounds in the area; basemap for damage assessment and monitoring
Topographic survey (GNSS and Total Station)	To establish the georeferenced network for the survey	Ground control points in real-world coordinates	Accurate georeferencing of the UAV survey and the archaeological data
UAV photogrammetric survey	High-resolution digital documentation of the archaeological site	Flight altitude of 45 m; survey area of 9.38 ha; 449 images; ground resolution of 1.13 cm/pix	Georeferenced point cloud; textured 3D model; orthomosaic
DEM generation	To generate an elevation model suitable for analysis of potential archaeological features	Point density of 0.196 points/cm²; resolution of 2.26 cm/pix	High-resolution Digital Elevation Model
DEM-based visualisation techniques	To emphasise subtle microrelief variations potentially associated with archaeological remains	SAGA and GDAL tools in QGIS: hillshade; hypsometric hillshade; sky-view factor; positive, negative and differential topographic openness; RRIM; VAT	Multiple raster maps for detection, comparison and analysis of microtopographic features with potential archaeological value
Targeted field survey	To verify remotely detected features (ground-truthing) and relate them to visible archaeological remains	Identification, documentation and positioning of TUs	Mapping of preserved structures and archaeological evidence

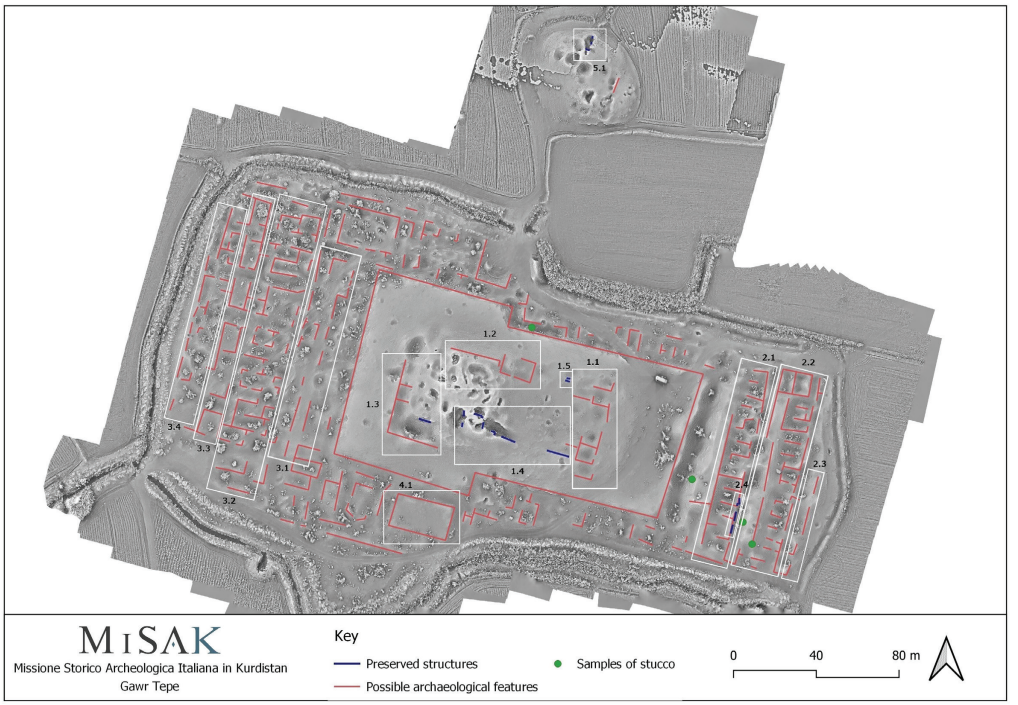


Figure 5. Results and interpretation of microtopographic variations detected on the drone-based Digital Elevation Model (DEM). The plan also shows the existing structures and the location of stucco samples (V. Castignani).

Results

Integrating multiple remote sensing datasets proved effective in mapping preserved remains, in detecting subtle ground variations potentially linked to archaeological features, and in monitoring modern land use impacts. Drone-based feature identification was complemented by targeted field surveys for ground-truthing, documentation of standing structures, and surface collection. Preliminary analysis revealed numerous microtopographic variations consistent in shape and orientation, which may inform reconstruction of the site layout. The results presented below therefore include the description of these recurring features and of the archaeological remains recorded during fieldwork (standing structures and stucco samples), indicated through a numbering system (e.g. 1.1, 1.2, etc) that facilitates their identification on the plans provided. The following section discusses interpretative hypotheses based on the results presented here.

The most prominent features occur on Gawr Tepe A, which is dominated by a central plateau oriented east–west, reaching 204.5 m asl and measuring about 160 m in length, 91 m in width on the west side, and 73 m on the east. Its central area shows linear features (207–208 m asl) aligned with the plateau. Orthogonal intersections define six quadrangular spaces on the east side (8.7 × 8.5 m) (Fig. 5, 1.1), a rectangular space (15.3 × 9.7 m) and a linear feature (24.2 m)



Figure 6. Composite image of existing structures on the central plateau of Gawr Tepe A. a: plan of the preserved structures (V. Castignani); b: TU002 (D. Andreucci); c: TU003 (D. Andreucci); d: view of TU002 and TU004 from the east (D. Andreucci); e: TU005 (D. Andreucci); f: TU006 and TU007 (D. Andreucci); g: TU020 (V. Castignani).



Figure 7. Detail of TU018 forming the extrados of a possible vault (V. Castignani).

to the north (Fig. 5, 1.2), and an L-shaped feature (61 m) with a central rectangular area (7.5 × 5.9 m) to the west (Fig. 5, 1.3).

These features exhibit the same alignment as seven topographic units (TUs) identified in the field (Fig. 5, 1.4). TU002 is a baked-brick wall with thick mortar, in stretcher bond and east–west orientation, connected to TU001 and built with a similar technique (Fig. 6, a-b). Both have vertically laid bricks, possibly in rowlock bond, producing walls resembling segmental arches — an unusual feature that invites several interpretative hypotheses. TU003 is a north–south wall over one metre thick, orthogonal to TU005 and structurally linked to it. TU004, a baked-brick masonry wall with thick mortar, shows its core clearly, but external profiles and orientation are uncertain; it probably forms a right angle between TU002 and TU003. TU005, oriented east–west, preserves at least twelve brick courses with a recess at the east end (Fig. 6, c-e). TU006, north–south, not perfectly parallel to TU003, preserves six courses, with orientation inferred from the western face. TU007, near TU006, is partly destroyed by spoliation but may follow the same alignment (Fig. 6, f). The absence of features on the terrace top (212 m asl) is likely due to looting and collapse.

North of TU001-002, two additional walls, TU018 and TU019 (Fig. 5, 1.5; Fig. 7), made of vertically laid bricks, may represent the extrados of a possible vault. West of TU006, TU020, also built of baked brick with mortar, runs east–west (Fig. 6, g).

East of the plateau, north–south linear microreliefs (204.5–205.5 m asl) intersected by east–west features define at least two rows of rectangular spaces (5.7 × 10.2 m to 7.6 × 4.2 m) (Fig. 5, 2.1–2.2).

The easternmost row (Fig. 5, 2.3) is poorly preserved due to an irrigation canal. The elevation of these microreliefs corresponds to that of the stucco samples at TU012–014 (204.5 m asl), where stratified plaster floors are preserved. These stratifications vary in thickness and, as shown in field photographs, can be considerable (Fig. 8). Decorative stucco was also found near TU012 (Inventory no. GT ST70567).

The microrelief marks align with, and partially correspond to, four structures identified as TU008–011 (Fig. 5, 2.4), consisting of baked bricks, often in rowlock bond. TU008 is the best preserved and may retain the haunch of a pitched vault (Fig. 9, a–c); TU011 resembles TU008 and TU010, which may suggest a structural relationship (Fig. 9, d–e).

West of the terrace, three north–south microrelief alignments (203.5–204 m asl), ca. 7 m apart, run parallel to the platform for 98 m (Fig. 5, 3.1). Numerous orthogonal intersections (202.5–203 m asl) define rectangular areas of varying size (5.8 × 6.9 m to 7 × 13.2 m) (Fig. 5, 3.2). Further west, linear features delineate a series of five north–south rectangular spaces (ca. 13 × 8 m) (Fig. 5, 3.3). At the western extremity, additional linear features are disturbed by an irrigation canal (Fig. 5, 3.4).

The mound's north and south edges are similarly affected by the irrigation system. The only clearly detectable feature is a large rectangular element (16 × 28.4 m) at 203 m asl, 8 m south of the platform (Fig. 5, 4.1). It is oriented consistently with the platform and with the numerous other microrelief traces that border the terrace to the south.

On Gawr Tepe B no distinct features were detected, but three wall sections are visible (Fig. 5, 5.1): TU015, east–west masonry with multiple plaster layers, was revealed by a trench (Fig. 10, a, c); TU016, oriented north–south and also plastered, shows several thick layers; TU017, angular with saw-tooth plan, aligns with TU016 but is separated from it by an opening (Fig. 10, d).

Comparison with CORONA imagery highlights modern damage to the site. Following EAMENA's classification (Bewley *et al.* 2016; Zerbini 2018), five categories are recognised: agriculture, construction, looting, conflict, erosion. At Gawr Tepe, only agriculture, construction, and looting are evident (Fig. 11). Construction damage (0.6 ha, 6.4%) mainly results from vehicle tracks across the terrace and northern mound. Since no tracks appear in 1966–1969 CORONA imagery, this disturbance must have occurred within the last fifty years. Agricultural impact (0.47 ha, 5%), largely from irrigation canals, is comparable to that visible in CORONA images. Looting is limited (0.1 ha, 1.1%) but concentrated on the plateau and at Gawr Tepe B, where exposed walls were targeted. While CORONA's resolution cannot identify small pits, SRP data indicate most looting occurred before 2011, as it is already visible in WorldView-2 imagery from that year (Laugier *et al.* 2022, 13–15). For future monitoring, this assessment can be updated through periodic comparison between the 2023 dataset, newly acquired UAV data, and time-series satellite imagery, with particular attention to new tracks, canal cuts, and looting scars, identified as the most impactful forms of damage affecting the site.

Analysis of the surroundings in CORONA imagery shows additional mounds. A small mound 250 m south of Gawr Tepe A hosted a 1.5 ha village (Fig. 12, e), identified as Sherawan, destroyed under Saddam Hussein and later abandoned. Local interviews revealed that after



Figure 8. Composite image of stratified plaster floors. a: plaster layers with baked bricks (TU021) on the northern side of the central plateau of Gawr Tepe A (S. Mancini); TU014 (D. Andreucci).

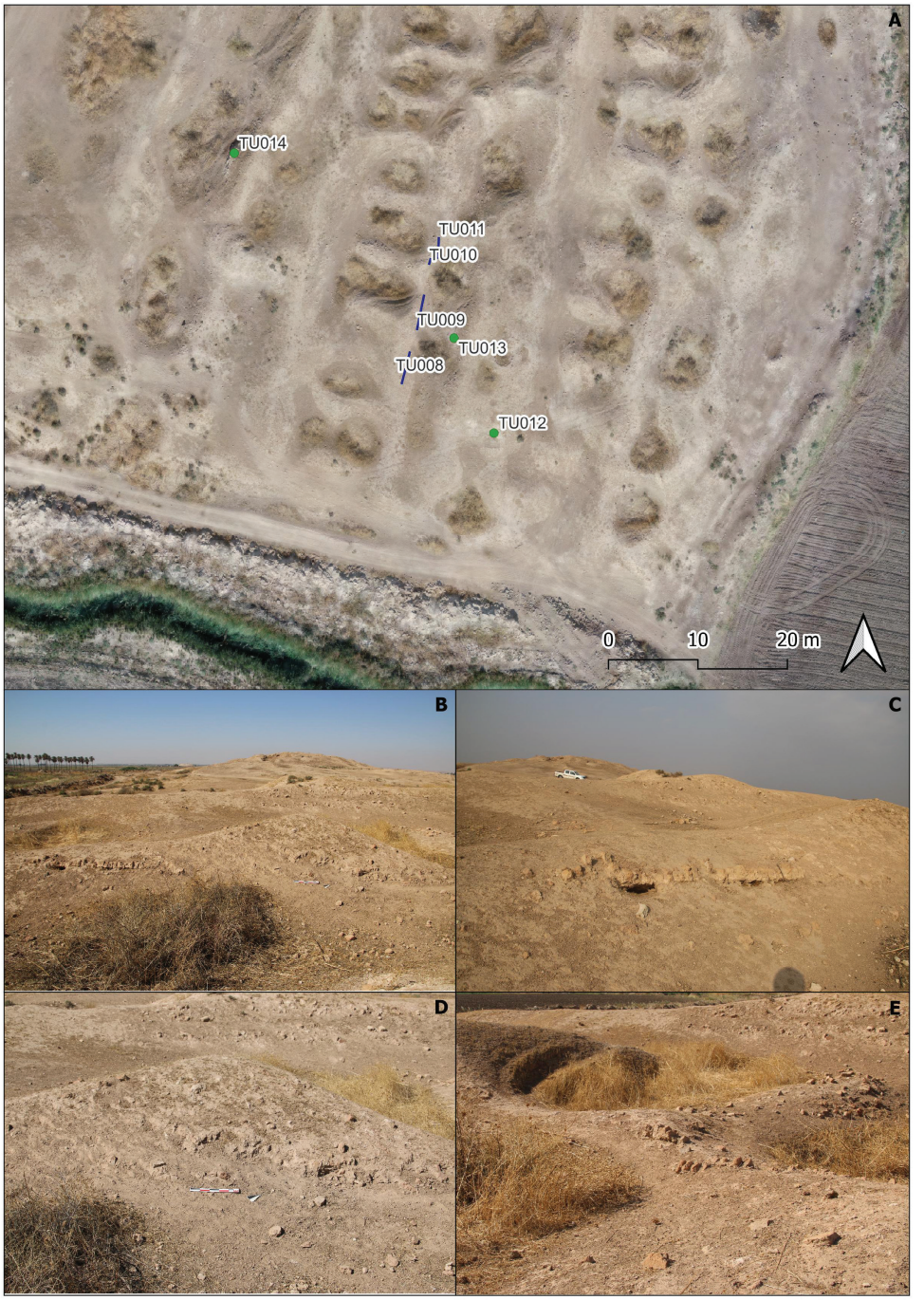


Figure 9. Composite image of existing structures on the eastern terrace of Gawr Tepe A. a: plan of the preserved structures and location of the stucco samples (V. Castignani); b: view of TU008 and TU009 from the east (D. Andreucci); c: detail of TU008 (D. Andreucci); d: detail of TU009 (D. Andreucci); e: view of TU010 and TU011 from north-east (D. Andreucci).



Figure 10. Composite image of existing structures at Gawr Tepe B. a: plan of the preserved structures (V. Castignani); b: plaster layers visible at Gawr Tepe B (D. Andreucci); c: detail of TU015 (S. Mancini); d: detail of TU017 (D. Andreucci).

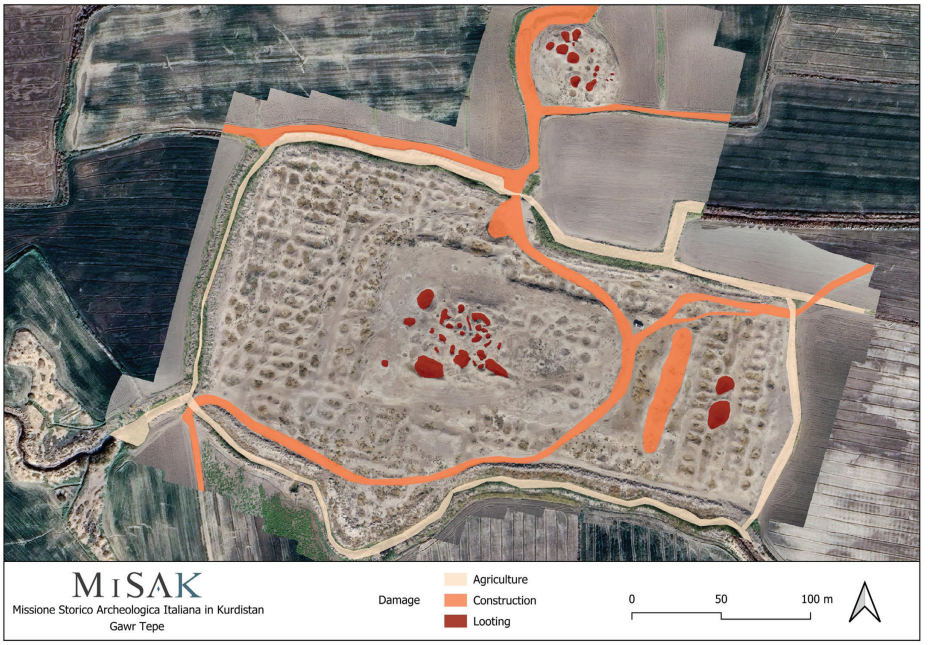


Figure 11. Map of Gawr Tepe showing the initial damage assessment. The basemap is the 2023 orthomosaic (V. Castignani).

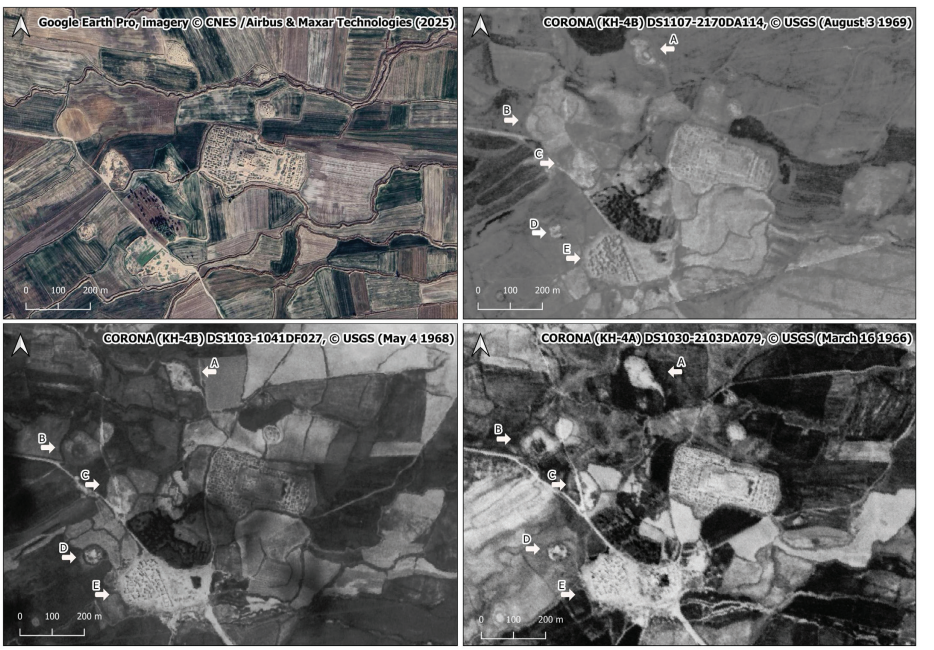


Figure 12. Composite image of Google Earth and CORONA imagery, with additional small mounds indicated (V. Castignani).

the destruction, the site was not rebuilt; instead, inhabitants resettled nearby, reusing former military structures. A small mound to the west (0.3 ha) (Fig. 12, d) and Gawr Tepe B likely formed part of a larger settlement (Casana and Glatz 2017, 59); contemporary occupation of Gawr Tepe B is confirmed by MiSAK surveys (Colliva *et al.* 2023, 30–42). Three further mounds (0.4–0.9 ha) (Fig. 12, a–c) may represent satellite centres. Notably, the northwestern mound (0.8 ha) (Fig. 12, b), though poorly preserved, was surveyed by SRP and yielded mud brick, pottery, and artefacts suggesting a specialised use (Casana and Glatz 2017, 59–60).

(D.A., V.C.)

Interpretation

With no prior detailed studies, the interpretative hypotheses proposed here rely on MiSAK data, UAV survey results, and comparisons with Parthian, Sasanian, and Islamic architecture to establish potential chronological parallels and functional analogies; they are therefore presented as working hypotheses derived from the documented topographic units and recognised microtopographic patterns, pending stratigraphic verification.

In analysing the site's architecture, it is useful to recall Callieri's (2014, 63–66, 194) foundational observations on Sasanian building traditions. Palatial and religious architecture often overlap, with complexes serving both functions. Huff (1993, 50) distinguishes buildings with linear plans, associated with palatial architecture and greater elevation complexity, from those with multi-axial plans, typical of religious architecture and involving less vertical complexity. Beyond material availability, geographical context significantly shaped architectural choices in the pre-Islamic period. Buildings reflect climatic and environmental differences between the Mesopotamian plain and the Iranian plateau. Even palatial architecture, though ideologically motivated, shows planimetric adaptations and varied use of materials (Callieri 2014, 64). Another key aspect is cultural continuity across the Arsacid, Sasanian, and Islamic periods: despite limited documentation, the available evidence challenges the Sasanian propaganda of discontinuity with earlier traditions (Callieri 2014, 194–197).

Topographically, royal palaces were often located outside inhabited centres, e.g. Ardashir I's palaces and the Ṭāq-e Kesrā, in continuity with Arsacid tradition, though exceptions exist with some residences inside cities (Callieri 2014, 60; Ghirshman 1962, 180–182). Similar patterns are found in the Abbasid period, with urban palaces and fortified complexes in enclosed estates (Bell 1914). The interpretation of the data is therefore based on a limited set of comparisons with sites within the chronological range proposed by Colliva, Mancini and Sameen (2023).

The visible remains show the almost exclusive use of fired bricks (ca. 35 × 35 × 7.5 cm) *in situ* on Tepe A. At Tepe B, bricks of the same dimensions are scattered across the surface, although the masonry is covered by thick plaster layers. Plaster coatings, probably hydraulic, are attested on both mounds. Stucco decorations, noted by Colliva, Mancini and Sameen (2023), are widespread but not *in situ*. The exclusive use of fired brick suggests parallels with Susiana (e.g. Ayvān-e Karkheh) and Mesopotamia (Ctesiphon). Fired bricks are also attested, though not throughout entire structures, at nearby sites such as Emārat-e Kosrow (24 km away; Moradi 2023) and Hāwš Kurī (13 km away).

The most prominent feature is the large terrace occupying much of Tepe A. It may rest on vaulted spaces (TU008–011) filled with soil and plastered, comparable to Hāwš Kurī and Emārat-e Kosrow. The structural use of barrel and domed vaults in brickwork corresponds to Sasanian architectural solutions (Callieri 2018, 90–92). Although no traces of stairways have been identified, reconstructions such as that proposed by Moradi (2023) for Emārat-e Kosrow, with double converging ramps over vaulted spaces, offer a plausible hypothesis. Some northern and southern spaces, together with heavily damaged eastern areas, may have given the terrace its apparent 'T' shape. However, later reoccupations, ploughing, and vehicle traffic may have altered its original form. The proposed 'T'-shaped plan remains tentative pending stratigraphic verification. However, comparisons with Hāwš Kurī suggest that the internal vaulted spaces may not have supported stairways directly. Terraces were used in both palatial and religious contexts during Arsacid–Sasanian times, but they are scarcely attested in Abbasid architecture.

Above the terrace floor, regular depressions (TU001–002, 018–019) may indicate collapsed vaulted rooms supported by pillars and walls. These depressions, likely structural collapses rather than spoliation pits, extend over a rectangular 35 × 45 m area in front of the upper part of Tepe A. This layout may suggest a central rectangular space, possibly covered, flanked to the north and south by corridors defined by walls and pillars, and bordered to the east by rooms now heavily damaged. An example of a preserved vaulted room may be TU018–019. Such an arrangement first recalls Sasanian complexes (Moradi 2023), while a broader later comparison may be drawn with Abbasid courtyard-*iwān* palaces such as Ukhaidir. Anomalies such as 1.2 could represent a *tarma* and a large *iwān* in front of a quadrangular structure, better preserved in elevation. The overall scale may suggest a single palatial complex, although the exclusion of *bayt*-type residential structures on the terrace itself remains a working hypothesis. A useful additional comparison may be drawn with Ayvān-e Karkheh, which shares similar materials and possibly *iwān* elements.

To the west, north, and south of the terrace, parallel lines and rectangular units (e.g. features 3.2–3.3) show a degree of regularity, with spaces ranging from 5.8 × 6.9 m to 7 × 13.2 m and larger blocks of ca. 34 × 13.7 m. These may represent *bayt*-type residential units, oriented consistently with terrace structures. While perhaps belonging to later phases, their alignment may suggest continuity with the palatial layout. It is also possible that palace and *bayt* phases overlapped: one may have been built while the other was still visible. Corridors, such as anomaly 3.1, may have separated the palatial from the residential areas, comparable to Ukhaidir.

The interpretation of Tepe B is more difficult. It preserves at least one plastered room (TU015–017), which may suggest an autonomous pavilion or secondary structure aligned with Tepe A.

At a larger scale, insufficient data prevent defining the full context of the palace and terrace. The absence of an enclosure may suggest an urban rather than an isolated complex, especially considering nearby mounds. Comparison with sites such as Ayvān-e Karkheh (still unpublished) may prove particularly useful.

(D.A.)

Conclusive remarks and research perspectives

The Garmian region — rich yet under-investigated — emerges as a historical crossroads, as indicated by canal systems and monumental remains (Colliva *et al.* 2023). Such works imply substantial elite investment in resource management and underscore the area's strategic and cultural significance.

At Gawr Tepe, the integration of UAV data, remote sensing and field observation provides a georeferenced basis for mapping and documentation, supports the identification of microtopographic features, and permits new, testable hypotheses on plan, function and chronology, which remain working hypotheses pending stratigraphic verification. Despite the scarcity of close parallels, two points stand out: axiality and symmetry on Tepe A, consistent with Callieri's (2014) elaboration of Huff's (1993) scheme for secular architecture; and the role of stucco, following Kröger (1982), in signalling elite, celebratory programmes.

The monumental terrace of Gawr Tepe A — built with fired-brick substructures that may have been vaulted, filled with earth and coated with gypsum plaster, and likely repaired over time — recalls nearby complexes such as Emārat-e Kosrow and Hāwš Kurī, though differing in scale and construction. An apparent "T"-shaped configuration has been noted, but this may result from later surface alterations, and its original design remains uncertain pending stratigraphic verification. Reconstructions with access ramps on three sides, as at Emārat-e Kosrow, reinforce the comparison, while anomalies above the terrace may suggest a quadrangular palace, at least five metres high, with multiple rooms arranged around a rectangular courtyard, possibly corresponding to an *iwān*. Eastern access would imply frontality, with a sequence of *bayt*-type units or dwellings behind the palace, connected by corridors. Unlike Emārat-e Kosrow and Hāwš Kurī, these dwellings appear external to the terrace, a layout closer to early Islamic examples such as Mshatta and Ukhaidir. Tepe B, showing plastered structures and similar orientation, may have been connected.

The quality of materials and the orthogonal east–west orientation, maintained across multiple construction phases, suggest elite patronage and sophisticated planning. The orientation may also be consistent with the seasonal use of spaces according to climatic conditions, a practice documented at Emārat-e Kosrow and Hāwš Kurī and later continued in early Islamic architecture. Yet the absence of enclosures leaves uncertain whether the complex was isolated — perhaps a hunting palace — or integrated into a broader urban setting. CORONA imagery and nearby mounds, however, make the urban hypothesis plausible.

Although SRP surveys (Casana and Glatz 2017, 58–61) documented the site, the absence of a detailed plan limited the integration of spatial data with interpretative analysis. This study addresses that gap by providing high-resolution mapping and establishing a methodological framework that systematically integrates documentation, microtopographic analysis, and archaeological interpretation. Within this approach, Gawr Tepe emerges as a multi-period complex occupied from the Sasanian period to the 13th century CE, reflecting long-term cultural and political transitions. Nonetheless, stratigraphic excavation remains essential to refine chronology, clarify functional aspects, and better define the settlement within its broader regional context.

From a methodological perspective, the study highlights the value of an integrated workflow combining drone-based 3D documentation, remote sensing, and architectural analysis for the systematic recording of heavily transformed landscapes. This approach is particularly suited to frontier and marginal contexts, where traditional field methods are often constrained by limited visibility and preservation conditions. The resulting dataset also provides a baseline for future monitoring. Updated UAV data and time-series satellite imagery can be compared with the 2023 orthomosaic, DEM, and damage assessment, thereby enabling the quantitative detection of landscape changes, including new vehicle tracks, irrigation interventions, and looting scars.

In sum, Gawr Tepe's architectural complexity, strategic position, and long occupational sequence make it a key case study for Garmian settlement dynamics and a priority for future stratigraphic investigation.

(D.A., V.C.)

References

Bell, Gertrude. 1914. *The Palace and Mosque at Ukhaidir.* Oxford University Press.

Bennett Rebecca, Kate Welham, Ross A. Hill and Andrew Ford. 2012. "A Comparison of Visualization Techniques for Models Created from Airborne Laser Scanned Data". *Archaeological Prospection* 19: 41–48.

Bewley, Robert, Andrew Wilson, David Kennedy, David Mattingly, Rebecca Banks and Michael Bishop. 2016. "Endangered Archaeology in the Middle East and North Africa: Introducing the EAMENA Project". In *CAA2015 Keep the Revolution Going: Proceedings of the 43rd Annual Conference on Computer Applications and Quantitative Methods in Archaeology*, edited by Stefano Campana, Roberto Scopigno, Gabriella Carpentiero and Marianna Cirillo. Archaeopress.

Callieri, Pierfrancesco. 2014. *Architecture et représentations dans l'Iran sassanide*, Cahiers de Studia Iranica 50. Association pour l'Avancement des Études Iraniennes.

Callieri, Pierfrancesco. 2018. "Terra e pietra nell'architettura dell'Iran degli imperi pre-islamici." In *Civiltà dell'Iran. Passato Presente Futuro*, edited by P. Callieri and A. V. Rossi. Scienze e Lettere.

Campana, Stefano. 2017. "Drones in Archaeology. State-of-the-Art and Future Perspectives". *Archaeological Prospections* 24: 275–296.

Campiani, Arianna, Nicola Lercari, Gerardo Jiménez Delgado, Javier López Mejía, Scott McAvoy, Rodrigo Liendo Stuardo and Mirko De Tomassi. 2022. "LiDAR, proximal sensing, and data visualization at the Maya city of Palenque and its surrounding region". *Archeologia Aerea* 16: 273–284.

Casana, Jesse and Jackson Cothren. 2013. "The CORONA Atlas Project: Orthorectification of CORONA Satellite Imagery and Regional-Scale Archaeological Exploration in the Near East". In *Mapping Archaeological Landscapes from Space*, edited by Douglas C. Comer and Michael J. Harrower. Springer. https://doi.org/10.1007/978-1-4614-6074-9_4

Casana, Jesse and Claudia Glatz. 2017. "The Land Behind the Land Behind Baghdad: Archaeological Landscapes of the Upper Diyala (Sirwan) River Valley". *Iraq* 79: 47–69.

Cereti, Carlo G., and Barbara Faticoni. 2025. "The Paikuli Monument in Its Territory." In *Eranshahr. Man, Landscape, and Society in Arsacid and Sasanian Iran*, edited by Carlo G. Cereti, Pierfrancesco Callieri and Vito Messina, 45–55. Sapienza Università Editrice.

Chiba, Tatsuro, Shin-Ichi Kaneta and Yusuke Suzuki. 2008. "Red relief image map: new visualization method for three-dimensional data". *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXVII: 1071–1076.

Colliva, Luca. 2025. "Garmian (KRI, Iraq) tra Iran e Mesopotamia: indagini preliminari sul paesaggio storico-archeologico di periodo partico-sasanide." *Quaderni di Meykhane* XV/1: 1–12.

Colliva, Luca, Serenella Mancini and Salih Mohammed Sameen. 2023. "Gawr Tepe, A New MiSAK Project in Iraqi Kurdistan". *East and West* 4.2: 25–45.

Day, Dwayne A., John M. Logsdon and Brian Latell. 1998. *Eye in the sky: The story of the CORONA spy satellites*. Smithsonian Institution Press.

Daxer, Christopher. 2020. *Topographic Openness Maps and Red Relief Image Maps in QGIS*. University of Innsbruck. DOI: 10.13140/RG.2.2.18958.31047

Doneus, Michael. 2013. "Openness as visualization technique for interpretative mapping of airborne lidar derived digital terrain models". *Remote Sensing* 5.12: 6427–6442. https://doi.org/10.3390/rs5126427

Doneus, Michael and Christian Briese. 2006. "Full-Waveform airborne laser scanning as a tool for archaeological reconnaissance". In *From Space to Place: 2nd International Conference on Remote Sensing in Archaeology*, edited by Stefano Campana and Maurizio Forte. BAR International Series.

Fisher, Michael, Michael Fradley, Pascal Flohr, Bijan Rouhani and Francesca Simi. 2021. "Ethical considerations for remote sensing and open data in relation to the endangered archaeology in the Middle East and North Africa project". *Archaeological Prospection* 28.3: 279–292.

Fowler, Martin J.F. 2013. "Declassified Intelligence Satellite Photographs". In *Archaeology from Historical Aerial and Satellite Archives*, edited by William S. Hanson and Ioana Oltean. Springer. https://doi.org/10.1007/978-1-4614-4505-0_4

General Directorate of Antiquities. 1976. *Atlas of the Archaeological Sites in Iraq*. Baghdad.

Ghirshman, Roman. 1962. *Iran. Parthes et Sassanides*. Gallimard.

Guyot, Alexandre, Marc Lennon and Laurence Hubert-Moy. 2021. "Objective comparison of relief visualization techniques with deep CNN for archaeology". *Journal of Archaeological Science: Reports* 38, 10.1016/j.jasrep.2021.103027

Hadjimitsis, Diofantos G., Kyriacos Themistocleous, Branka Cuca, Athos Agapiou, Vasiliki Lysandrou, Rosa Lasaponara, Nicola Masini and Gunter Schreier. 2020. *Remote Sensing for Archaeology and Cultural Landscapes. Best Practices and Perspectives Across Europe and the Middle East*. Springer.

Henkelman, Wouter F.M. and Bruno Jacobs. 2021. "Roads and Communication". In *A Companion to the Achaemenid Persian Empire*, edited by Bruno Jacobs and Robert Rollinger. Wiley Blackwell.

Horn, Berthold K. P. 1981. "Hill shading and the reflectance map". *Proceedings of the IEEE* 69.1 14–47.

Huff, Dietrich. 1993. "Architecture sassanide." In *Splendeur des Sassanides. L'empire perse entre Rome et la Chine (224-642)*, 45–61. Musées Royaux d'Art et d'Histoire.

Izzo, Pierfrancesco, Michael Fradley and Andrea Zerbini. 2022. "Snapshots from the past: discoveries and destruction in the Jericho Oasis". *Levant* 53.3: 315–335.

Kokalj, Žiga and Maja Somrak. 2019. "Why not a single image? Combining visualizations to facilitate fieldwork and on-screen mapping". *Remote Sensing* 11.7, 747, https://doi.org/10.3390/rs11070747

Kröger, Jens. 1982. *Sasanidischer Stuckdekor.* Baghdader Forschungen, 5. Philipp Von Zabern.

Laugier, Elise J. and Jesse Casana. 2021. "Integrating Satellite, UAV, and Ground-Based Remote Sensing in Archaeology: An Exploration of Pre-Modern Land Use in Northeastern Iraq". *Remote Sens*ing 13, 5119. https://doi.org/10.3390/rs13245119

Laugier, Elise J., Nawzad Abdullatif and Claudia Glatz. 2022. "Embedding the Remote Sensing Monitoring of Archaeological Site Damage at the Local Level: Results from the "Archaeological Practice and Heritage Protection in the Kurdistan Region of Iraq" Project". *PLoS ONE* 17.6. https://doi.org/10.1371/journal.pone.0269796.

Luo, Lei, Xinyuan Wang, Huadong Guo, Rosa Lasaponara, Xin Zong, Nicola Masini, Guizhou Wang, Pilong Shi, Houcine Khatteli, Fulong Chena, Shahina Tariq, Jie Shao, Nabil Bachagha, Ruixia Yang and Ya Yao. 2019. "Airborne and spaceborne remote sensing for archaeological and cultural heritage applications: A review of the century (1907–2017)". *Remote Sensing of Environment* 232, https://doi.org/10.1016/j.rse.2019.111280

Mamo, Adnan R., Ismael M. Ibraheem, Amal Al Kassem, Ahmed Al-Khalil and Kristen Hopper. 2022. "The impact of the Syrian conflict on archaeological sites in Al-Hasakah province". *Journal of Archaeological Science: Reports* 43, 10.1016/j.jasrep.2022.103486

Moradi, Yousef. 2023. "'Emārat-e Ḵosrow on the High Road: Recent Archaeological Excavations". *ANES* 60: 93–147.

Rayne, Louise, Maria Carmela Gatto, Lamin Abdulaati, Muftah Al-Haddad, Martin Sterry, Nichole Sheldrick and David Mattingly. 2020. "Detecting change at archaeological sites in North Africa using open-source satellite imagery". *Remote Sensing* 12, https://doi.org/10.3390/rs12223694

Salih, Bahra, and Gianfilippo Terribili. 2025. "Four Clay Sealings from the Slemani Museum (KRG Iraq): The Province of Ērān-āsān-kar-Kawād and Kawād I's Interest in Western Zagros." In *Eranshahr. Man, Landscape, and Society in Arsacid and Sasanian Iran*, edited by Carlo G. Cereti, Pierfrancesco Callieri and Vito Messina. Sapienza Università Editrice.

Vafadari, Azadeh, Graham Philip and Richard Jennings. 2019. "A tool and methodology for rapid assessment and monitoring of heritage places in a disaster and post-disaster context: Syria as a case study". In *Heritage Under Pressure – Threats and Solutions. Studies of Agency and Soft Power in the Historic Environment*, edited by Michael Dawson, Edward James and Michael Nevell. Oxbow Books.

Ur, Jason A. 2013. "Spying on the past: Declassified intelligence satellite photographs and near eastern landscapes". *Near Eastern Archaeology* 76.1: 28–36.

Yoëli, Pinhas. 1967. "The mechanisation of analytical hill shading". *The Cartographic Journal* 4.2: 82–88.

Yokoyama, Ryuzo, Michio Shirasawa and Richard J. Pike. 2002. "Visualizing topography by openness. A new application of image processing to DEMs". *Photogrammetric Engineering and Remote Sensing* 68: 257–265.

Zakšek, Klemen, Kristof Oštir and Žiga Kokalj. 2011. "Sky-view factor as a relief visualization technique". *Remote Sensing* 3: 398–415.

Zerbini, Andrea. 2018. "Developing a Heritage Database for the Middle East and North Africa". *Journal of Field Archaeology*, 43 (sup1), S9–S18. https://doi.org/10.1080/00934690.2018.1514722.