UNIVERSITÀ DI TORINO

MESOPOTAMIA

RIVISTA DI ARCHEOLOGIA, EPIGRAFIA E
STORIA ORIENTALE ANTICA

LIX

2024

apice libri

«Mesopotamia» is an International Peer Reviewed Journal.

Indici storici e abstract sono consultabili sul sito della casa editrice
Indexes and abstracts are available on the publisher's web site
www.apicelibri.it/collana/mesopotamia/13

Iscritta al Tribunale di Torino n. 1886 del 20/6/67

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ISSN: 0076-6615

SOMMARIO

PROCEEDINGS OF THE WORKSHOP

DROWNING LANDSCAPES: MULTIDISCIPLINARY APPROACHES TO THE ARCHAEOLOGICAL HERITAGE OF DAM RESERVOIRS

XIII ICAANE Conference

Copenaghen, May 24th, 2023

The following papers are the results of a workshop entitled "Drowning Landscapes: Multidisciplinary Approaches to the Archaeological Heritage of Dam Reservoirs" held during the XIII ICAANE conference in Copenhagen on the 24th of May 2023 and organised by Paola Sconzo, Francesca Simi and Jesper Eidem.

We want to thank all the workshop participants and the scholars who contributed to these proceedings. We are also extremely grateful to the many reviewers who contributed to the quality of the contributions here presented.

THE EDITORS
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FROM THE TIGRIS TO THE BANKS OF THE EUPHRATES: POST-FLOODING ASSESSMENT AT THE TISHREEN DAM RESERVOIR, NORTH SYRIA

Abstract

The paper presents the application of a reproducible tool, already tested by the authors on Lake Mosul, for the post-flooding assessment of the heritage sites impacted by the construction of dam reservoirs. This study examines the Tishreen Dam Reservoir (Syria) on the Middle Euphrates as a case study. The dam's construction lasted from 1991 to 1999, resulting in a 60 km long artificial lake. Salvage surveys and excavations were carried out during the construction period, shedding light on the richness of the region's cultural heritage. This area has gained attention in recent years due to an unprecedented drought that revealed several archaeological sites and villages that were believed to be lost for good. Based on the results of a new set of cost-efficient tools for observing the 'emersion patterns' of archaeological sites, we present an overview of the dam construction impact and an assessment of damage timescales and extent at the various sites involved.

Keywords

Remote sensing, Change Detection Technique, Syria; Middle Euphrates, Tishreen Dam, Heritagescape

1. Introduction[1]

Dam construction constitutes a critical focal topic within contemporary archaeological discourse on Western Asia. Alongside major events like natural disasters and armed conflicts, it catalyses the transformation or obliteration of entire heritagescapes.[2] A single dam project has in fact the potential to wipe out countless archaeological sites and villages that once thrived along riverbanks. Many of these sites will remain submerged indefinitely, while others face a different destiny as they intermittently resurface due to fluctuating lake water levels. These sites suffer from water erosion processes and may become vulnerable to new threats. Their ongoing destruction demands urgent attention, emphasizing the necessity for a 'second phase' of salvage efforts. These initiatives must encompass multidisciplinary documentation, constant damage assessment through the development of monitoring programmes, and – when requested – salvage operations.

This paper explores this topic by testing a reproducible change-detection technique for post-flooding assessment in the area of the Tishreen Dam Reservoir in North Syria.

This tool is not entirely novel, having originally been conceived for a comparable dam environment in the Lake Mosul region of Iraq. Its inception was prompted by the onset of a series of droughts affecting the Tigris valley since 2018, spanning from its headwaters in the Taurus Mountains of central Turkey to the marshlands of southern Iraq, that starkly transformed half of the Fertile Crescent into a desolate expanse of sand and dust.

As a consequence of these environmental shifts and the sudden lowering of lake levels, several archaeological sites and villages previously deemed lost forever have resurfaced, thus unveiling a drastically altered – yet newly imperilled – landscape.

At these sites, the ebbing waters had performed a sort of natural excavation through continuous erosive action, thus exposing structures and related material cultural remains – to the benefit of research but also that of professional and occasional looters.

In 2018, with the onset of the initial drastic reduction in the water level of Lake Mosul, the two survey teams operating along its western shore, specifically in the Kurdistan Region of Iraq (henceforth KRI) – the Eastern Ḫabur Archaeological Survey (EHAS)[3] and the Land of Nineveh Archaeological Project (LoNAP),[4] – documented and catalogued over 70 previously unrecorded archaeological features.

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[1] The authors share the full responsibility of the content of the present contribution, §§ Introduction, Results, Discussion and Conclusions were written by the three authors; § The Tishreen Dam was written by Sconzo; § Dataset Creation by Simi; Workflow-Change Detection by Titolo.

[2] Regarding the concept of 'heritagescape' applied to dam reservoir landscapes, see Sconzo, Simi, this volume.

[3] On the EHAS work along the Mosul Dam: Sconzo 2019; Sconzo, Qasim 2021.

[4] On the LoNAP survey project: Morandi Bonacossi, Iamoni 2015.

This event has brought to the forefront a series of pressing inquiries: How can we swiftly and accurately identify archaeological sites affected by fluctuations in water levels? What are the consequences of prolonged submersion, such as erosion or sediment deposition? Is there a standardized protocol, a 'best practice', for documenting, monitoring, protecting, or even planning salvage operations in this evolving environmental context?

A novel approach was devised to address some of these challenges.

Firstly, we designed and compiled what could be deemed the most extensive archaeological dataset currently available for the Upper Tigris region of Iraq. This incorporated legacy data from earlier archaeological surveys and excavations, the results of the aforementioned EHAS and LoNAP endeavours, and a new remote survey specifically conducted across the inundated expanse of the lake basin.

This operation yielded an unprecedentedly detailed overview of the loss and rediscovery of a particularly significant landscape and culminated in the identification of 275 archaeological sites.

In the subsequent phase, to analyze the emergence patterns of these sites, we employed a bespoke change-detection technique tailored to this dataset that combines medium-resolution satellite images, a cloud computing platform and vegetation indexes.[5] In the context of Lake Mosul, this method emerged as a potent post-flooding assessment tool, characterized by its ease of reproducibility and affordability.[6] At a macroscopic level, it enabled precise delineation between sites potentially lost irretrievably and those still subject to water level fluctuations. Given the idiosyncratic response of each site to the lake's complex dynamics, this approach facilitated the identification – and subsequent awareness – of sites that resurface at varying water levels, and assessment of the extent to which this occurs. This had several practical implications, notably for refining field monitoring programs, guiding future targeted investigations, and enhancing comprehension of the survival mechanisms of submerged archaeological sites.

To test the applicability of this tool to other flooded landscapes beyond the Upper Tigris region of Iraq, particularly in South-West Asia (SWA) and beyond, we conducted a parallel investigation of the Tishreen Dam Reservoir in North Syria using the same methodology (Fig. 1).[7]

This area has been in the spotlight recently due to its increasingly dry environment and an unprecedented minimum of the lake water level. In 2023, the dam was temporarily closed as the water level plummeted to what is colloquially referred to as the 'dead zone'.

2. The Tishreen Dam

The construction of the Tishreen Dam on the northernmost stretch of the Syrian Euphrates lasted from 1991 to 1999, resulting in the creation of a 60 km long artificial lake that impacted – according to our final estimate – over 75 archaeological sites and a dozen villages (Fig. 2).

In the late 1980s, following established precedents,[8] the Syrian Directorate General for Antiquities and Museums called for an international rescue programme to help recover information from all threatened archaeological sites in the area affected by the new reservoir, in what is defined as 'first-phase salvage'.[9] It is noteworthy that prior to these interventions, the archaeological significance of this particular stretch of the river had been largely overlooked and neglected. Intermittently visited in the 19th and early 20th centuries by pioneering explorers and travellers such as F. R. Chesney,[10] George Smith,[11] Max von Oppenheim,[12] D. Hogarth,[13] and G. Bell,[14] the region only saw large-

[5] Titolo 2021; Titolo, this volume.

[6] Sconzo, Simi, Titolo 2023.

[7] The selection of this small reservoir was a natural homecoming for two of the authors, as PS worked for 17 years in the Euphrates Valley and AT focused his PhD research on the Iron Age occupation of this region.

[8] Reference is here made to the call on the occasion of the construction of the Tabqa Dam, built in the early 70s immediately downstream, at the behest of the Baath party and its president Hafiz al-Assad. On this occasion, Assad invoked the ancient civilizations and later Islamic history, utilizing cultural mobilization to construct an image of Greater Syria that contested existing political borders (Jones 2018). Additionally, he strategically linked modernity and the dam to demonstrate his dedication to Syria's future (Luke, Meskell 2019). For a reassessment of salvage excavations in the SWA region, see also Sconzo, Simi, this volume.

[9] Eidem 2020; Sconzo, Simi, this volume.

[10] Chesney in 1832 visited the region on a survey of the Tigris and Euphrates rivers (Chesney 1850).

[11] It was during this second journey in the Middle East in 1876 that G. Smith solved the controversial issue of the location of Carchemish, the last rich capital of the Hittites, and paved the way for further explorations and excavations at the site.

[12] Oppenheim 1899 cursorily mention the region in the account of a journey in 1898 from Aleppo to Abu Qalqal.

[13] This scholar visited the region in 1908 the year before applying to excavate the mound of Carchemish (Hogarth 1909).

[14] G. Bell 1910; 1911 embarked on a long journey along the Euphrates in 1909. After visiting Tell Ahmar, ancient Til Barsip, and Carchemish, she worked her way down the course of the river, passing through some of the sites which have later been submerged by the lake (Qubba, Dja'de el-Mughara, Qara Qozaq (her Kara Kazâk), Tell 'Abr, Tell Qumluq, Qalat Nejem, Tell Banat, etc.). Bell's photographic account of the riverbank and its villages offers valuable insights into a landscape that is now entirely transformed or lost. On the Euphrates journey, Cooper 2016, 42-59.

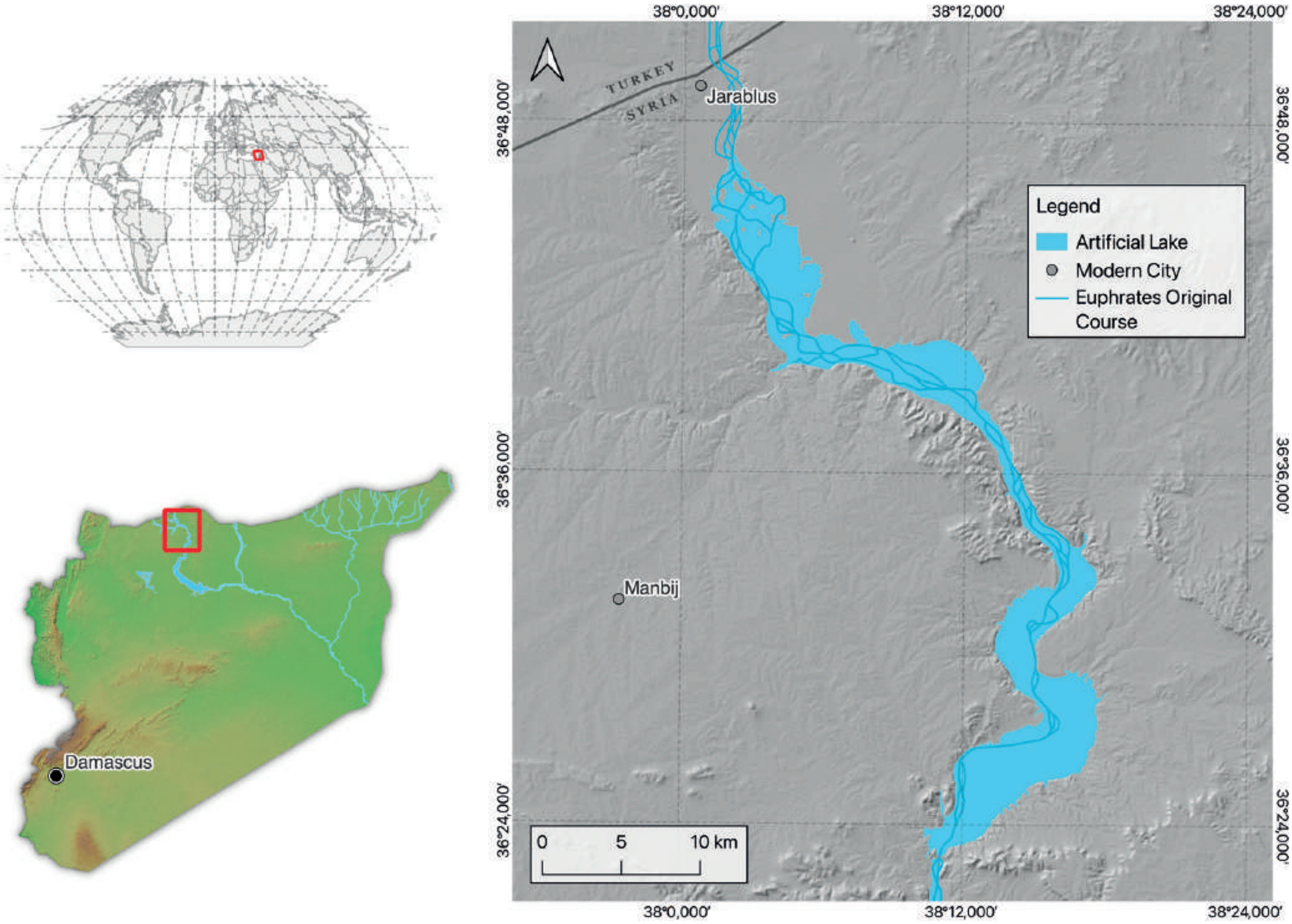

Fig. 1 - The Tishreen Dam in Northern Syria.

Fig. 2 - Resurfacing houses in the area of Tell Qumluq (courtesy of P. Sconzo).

scale excavations with the onset of the Carchemish[15] and Til Barsip[16] projects in the first three decades of the 20th century. Although these sites had very long occupation histories, originating sometime in the fifth millennium BC, early excavations focused mainly on the remains of the Iron Age,[17] a period in which both were important cities, respectively of the Neo-Hittite empire and the Aramean tribal kingdom of Bît Adini.[18]

Insights into earlier settlement patterns in the region, particularly during the Early and Middle Bronze Age, were derived from a significant collection of artefacts. These objects were primarily acquired by L. Woolley and T.H. Lawrence, and largely originated from burials that had been plundered by locals in the region, including sites such as Kara Hasan, Amarna, Qara Qosaq, and Hammam Saghir.[19]

The end of these pioneering excavations closed the first research phase. The region remained excluded from further investigations until the 1970s, when a major geomorphological and two systematic archaeological surveys were carried out.[20]

With the construction of the Dam, the Tishreen sector gained renewed interest from the international scientific community. A survey in the reservoir area conducted by T. McLellan and A. Porter[21] represented the primary method for selecting sites to be rescued. In the following years, other similar enterprises covered more limited areas[22] and/or had specific chronological targets (Fig. 3).[23] Given the urgency of the circumstances and the research objectives at the time, these endeavours primarily prioritized sites deemed most significant from both scientific and chronological standpoints, focusing particularly on tells and cemeteries.

During dam construction, excavations were conducted at 23 different archaeological sites.

The results, along with those obtained in nearby dam reservoirs such as Birecik and Carchemish to the north in Turkey, and Tabqa Dam downstream, provided a comprehensive picture of the settlement history of the Middle Euphrates region.[24] They emphasised the vital role of the river valley as major corridor for trade and communication throughout history.[25] They also underline its unity and uniqueness, strengthening its central position instead of considering it as a peripheral area at the socio-political frontier between great powers. Salvage excavations, moreover, played a crucial role in shifting the research focus from large mounds to smaller-scale sites and cemeteries, thus helping alter the spatial perspective on ancient Western Asia throughout its history. This was particularly significant for a reappraisal of the pre-and proto-historic periods, which led to significant progress in the reevaluation of the emergence of complex societies and the role played by the dynamic interaction between pastoral and sedentary elements in the shaping of this process. Regarding the third millennium BC, these excavations contributed to refining the relative and absolute chronology of the region by means of radiometric data and compared chrono-stratigraphies[26], leading to greater understanding of the phenomenon of 'second-urbanization in the Levant'.[27] Furthermore, it helped specify the role of Amorrite tribes in the formation of second-millennium state societies.[28]

With the completion of the barrage in 1999, some of the rescued sites disappeared underwater, and the first phase of salvage was concluded. A reservoir with a storage capacity of 1.9 km^3 was created, thus generating 1.6 billion kWh of electricity annually (Fig. 4).

Due to the absence of a pre-flooding risk assessment for the areas designated to be submerged,[29] 10 out of 23 excavated sites initially deemed vulnerable to inundation were found to lie outside the actual flood zones. As a result, the majority of these sites continued to be investigated until the onset of the Syrian civil war in 2011, leading to a significant dispersion of resources at the expense of other submerged ar-

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[15] The archaeological site of Carchemish, capital city of the second and first millennium BC, underwent thorough investigation under the auspices of the British Museum. The initial exploration was led by D.G. Hogarth in 1911 (Hogarth 1914) followed by subsequent excavations conducted by L. Woolley between 1911-1914 and 1920 (Woolley 1921; Woolley, Barnett 1952). Prior to these extensive excavations, preliminary soundings had been conducted at the site between 1878 and 1881 by P. Henderson, who served as the British Consul in Aleppo (Hogarth 1909).

[16] Tell Ahmar, ancient Til Barsip, opposite and downstream from Carchemish, was excavated between 1929 and 1931 on behalf of the Louvre by F. Thureau-Dangin, M. Dunand (1936). See also Bunnens 2022, with recent bibliography.

[17] Remains dating back to the beginning of the 3rd millennium BC were unearthed at Carchemish in cist burials recorded at the base of a deep sounding dug in the core of the citadel mound (Woolley, Barnett 1952; Falsone, Sconzo 2007). Til Barsip yielded a hypogeum approximately 500 years later in date, containing abundant funerary offerings (Thureau-Dangin, Dunand 1932; Bunnens 2022, with further bibliography).

[18] Both cities were then conquered and absorbed into the Assyrian empire at different times, Til Barsip in 865 BC and Carchemish more than a century later in 717 BC.

[19] Woolley 1914; Sconzo 2013; 2015.

[20] Besançon, Sanlaville 1981; Sanlaville 1985.

[21] McClellan, Porter n.d.

[22] Einwag 1994; Eidem, Pütt 2001.

[23] Vivancos 2005; Gaborit 2012.

[24] For a reappraisal of the significance of salvage excavation in Syria see Eidem 1998; for an overview of the main results: Mcclellan 1997.

[25] Cooper 2006.

[26] A valuable example is the work conducted by a multidisciplinary team as part of the ARCANE project, Finkbeiner *et alii* 2013.

[27] Akkermans, Schwartz 2003, 233-287.

[28] Cooper 2006; Peltenburg 2007; Porter 2012.

[29] On this issue and the possible consequences, see Marchetti *et alii* 2020.

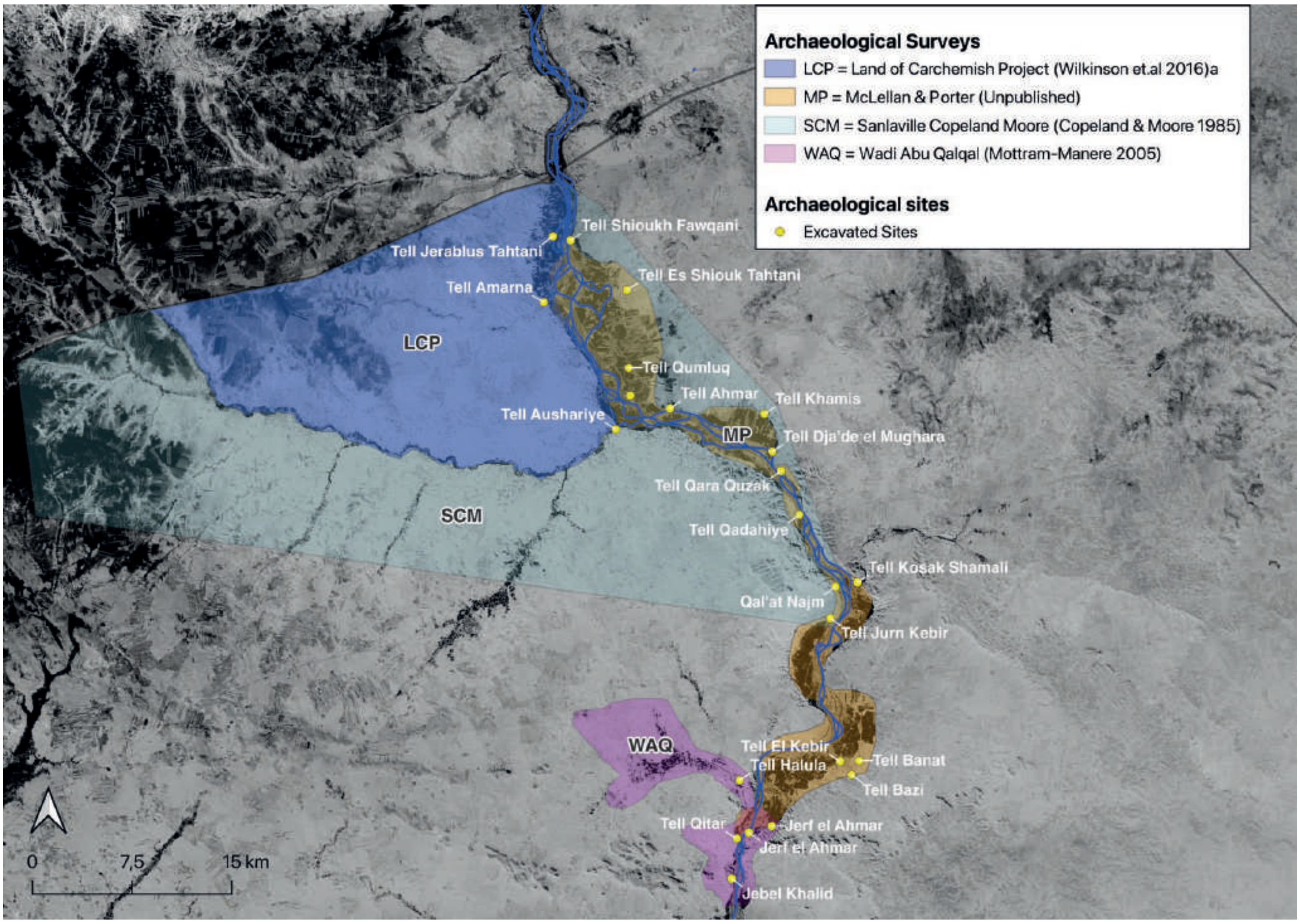

Fig. 3 - Map of the Tishreen Dam region showing the coverage of showing the coverage of five of the archaeological surveys (not represented on the map: Eidem, Putt 2001, Gaborit 2012, Vivancos 2005, Einwag 1994) and the excavated sites (basemap: CORONA 1105-1109 images, Nov 1968, from the Center for Advanced Spatial Technologies, University of Arkansas/U.S. Geological Survey).

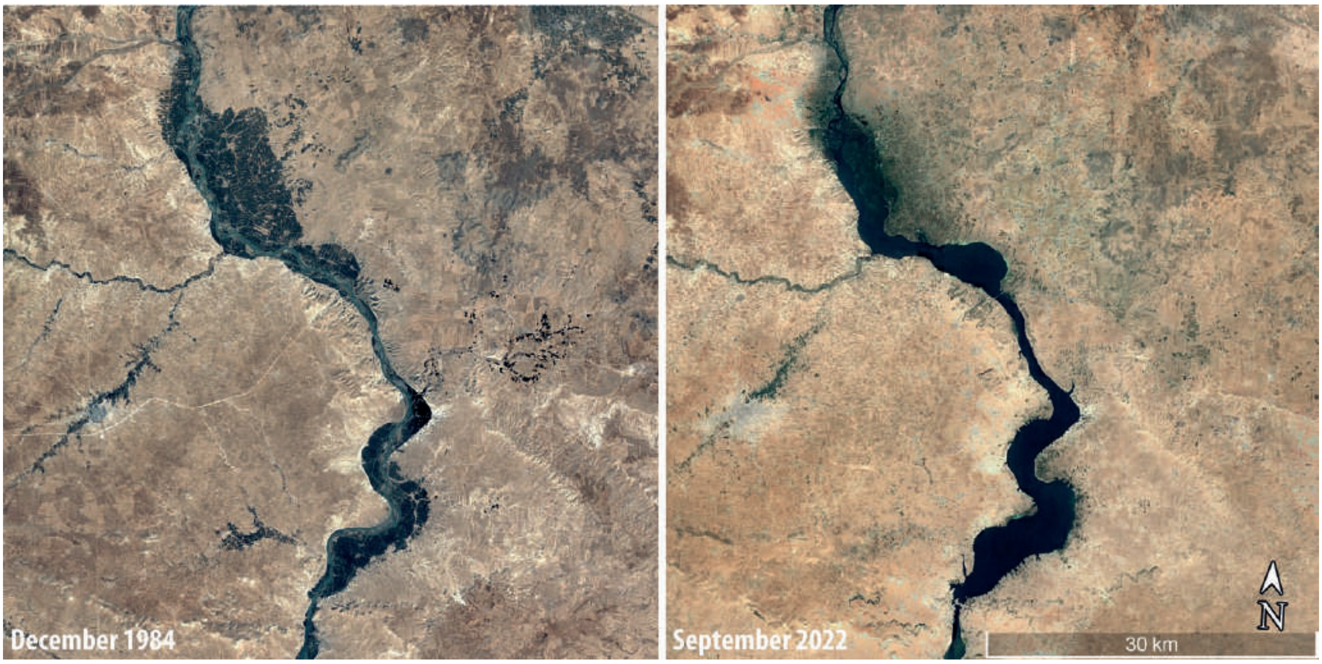

Fig. 4 - The Euphrates before and after the construction of the Tishreen Dam (Map data ©2024 Google Earth Pro, on the left Landsat/Copernicus imagery and on the right CNES/Airbus, Maxar Technologies.

chaeological sites that had yet to be explored. Notable examples include Tell Jerablus Tahtani, Tell Amarne, Tell Shiyukh Fawqani, and Tell Shiyukh Tahtani.[30] Additionally, some sites became geographically isolated, forming peninsulas or even islands within the reservoir, as observed in the cases of Tell Qumluq, Tell Qara Qozaq, and Tell Jurn Kebir (Fig. 5).

Subsequently, as we will explore later, these sites suffered significantly from the fluctuating lake water levels, leading to the exposure of architectural remains and artefacts to both erosion and looting. For instance, at Tell Qumluq, several Early Bronze Age graves with their accompanying inventories, as well as a section of a monumental Early Bronze Age structure, were exposed and documented in the early 21st century.[31]

In the first decade of this century, a final survey, the Land of Carchemish Project, introduced a change of perspective and methodology (Fig. 3).[32] By using remote sensing and intensive collection methodologies, it allowed the identification of several small new sites, thus extending our knowledge of the region beyond just tells.[33]

The period around the construction of the dam marked a significant era of heightened archaeological activity. An extensive international research network was established and rapidly solidified, facilitated in part by the organisation of numerous conferences and workshops held in Syria and abroad.

While the Lake Mosul area has undergone a new wave of archaeological ventures in the past ten years, the Tishreen region experienced the opposite trend. The onset of the Syrian civil conflict in 2011 effectively halted all archaeological activities in the country,[34] also significantly impacting related scientific study. Consequently, since 2015 only a few new publications have been dedicated to the region.[35]

Amid the same conflict, the Tishreen sector turned into a battleground between various groups vying for control over northern Syria. Among other consequences, this led to the displacement of many people,[36] and the loss of the community's memoryscape.

Additionally, as experienced in many conflict areas, looting and military destruction spread across the archaeological sites of the reservoir (Fig. 6).

The Tishreen Dam itself was one of the strategic targets during the conflict: initially seized by the Free Syrian Army rebels in 2012,[37] two years later it was taken over by Daesh.[38] In 2015, a significant push by the SDF, supported by the US coalition, succeeded in reclaiming control of the dam.[39] In late 2018, a Russian press agency reported that the Syrian Government had regained control of the dam.[40] However, this allegation has been denied by the Autonomous Administration of North and East Syria (AANES), which now controls the area and has renamed it 'Rojava Dam'.[41]

In the past few years, droughts have intensified, and the reservoir water level has dropped, often to the point that curtails electricity production.[42] In 2023, the Tishreen Lake reached the 'dead zone' several times, resulting in the dam being closed. This had disastrous consequences for the hundreds of villages that relied on it for their electricity.

This abrupt lake water-level reduction also entails the re-emergence of several archaeological sites, as our analysis has shown.

3. Methodology

3.1 *Dataset creation*

Under the pressure of the news concerning this severe drought that was hitting northern Syria and the consequential threat to all the heritagescapes of the Middle Euphrates valley, it became imperative to test the previously mentioned change detection system in this region as well.

To apply this tool in the Tishreen Dam context, it was first essential to assemble a robust archaeological dataset. The initial stage involved defining the research area, which was delineated on the basis of a buffer zone extending 250 metres from the maximum recorded lake margin (January 2000).

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30 Falsone, Sconzo 2016.

31 Jamieson, Kanjou 2009, 21-22, figs. 5-8.

32 The survey focused on the Euphrates north-west bank and its hinterland, an area less affected by flooding.

33 Ricci 2023.

34 These have been slowly resuming, mainly thanks to the contribution of local archaeologists and communities, Sabrine, Montgomery, this volume.

35 An exception is the final report of the Tell Ahmar excavation (Bunnens 2022).

36 Since the beginning of the conflict, military operations in north-east Syria forced more than 900,000 persons to flee their homes (UNOCHA 2019). In the Tishreen Dam area most of the impacted villages were located in the southern sector of the reservoir, close to the dam itself. Despite prior notification, the sudden rise of the lake waters caught many off guard, compelling entire communities to hastily vacate their ancestral lands. They were mainly resettled in the area of Mimbej and Damascus. In the periphery of the latter city, they were still living in tents a decade later.

37 Mroue 2012.

38 As part of its expansion strategy, Daesh has taken control of several key water infrastructures along the Euphrates and Tigris rivers in Syria and Iraq, weaponizing both water resources and dams (von Lossow 2016).

39 Reuters 2015.

40 Enab Baladi 2019.

41 ANHA 2019.

42 Several reports suggest that the unprecedented decrease in the flow of the Euphrates is linked to Turkey's persistent pursuit of hydro-hegemony. Accusations have been made against Turkey for failing to adhere to the 1987 water control agreement, thereby jeopardizing food security, energy production, and the overall health of downstream populations (Zeitoun, Warner 2006; Sconzo, Simi, this volume).

Fig. 5 - Various phases of submergence of Jurn Kebir (courtesy of J. Eidem).

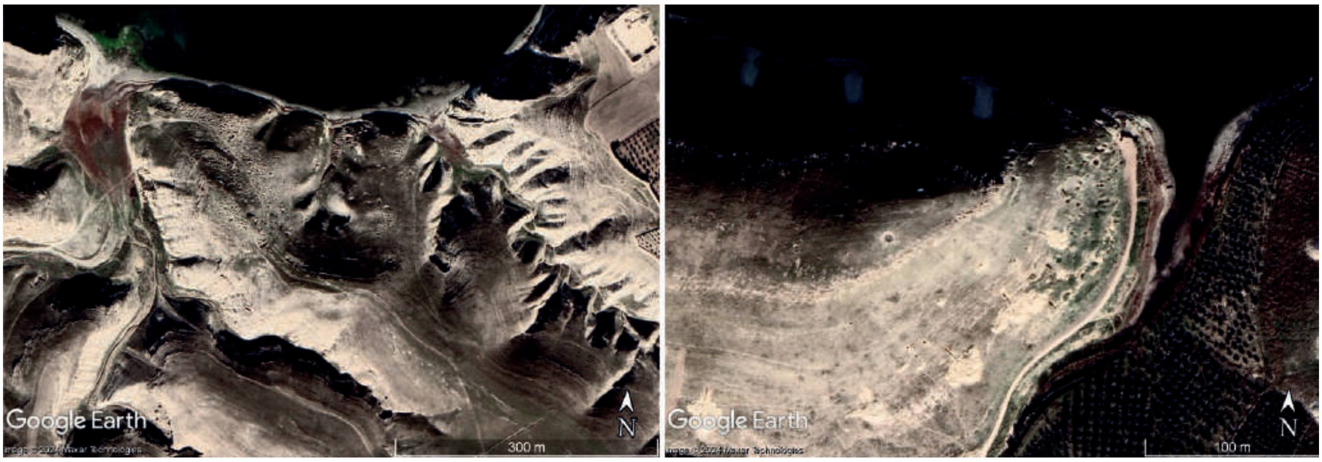

Fig. 6 - Extensive evidence of looting activities on the west bank of the lake (01/03/2021, Map data ©2024 Google Earth Pro and Maxar Technologies).

Fig. 7 - Militarization evidence at Tell Qitar (left image) and at a Tishreen Dam Remote Survey potential site (TDRS-3) (01/03/2021, Map data ©2024 Google Earth Pro and Maxar Technologies).

The dataset was compiled and enriched using CORONA declassified satellite images predating the flooding of the Tishreen Dam reservoir,[43] along with contemporary imagery accessible through Google Earth Pro.[44] The CORONA photointerpretation played a pivotal role in identifying and mapping all known and potential sites currently submerged. Meanwhile, the latest Google Earth Pro images aided in the general identification and precise positioning of potential sites, as well as in assessing the extension of some known sites and evaluating their state of preserva-

[43] Concerning the use of CORONA satellite imagery for archaeological site identification, see Casana, Cothren, Kalayci 2012 and Ur 2013.

[44] For a recent overview of Google Earth as a tool for archaeological investigations and heritage applications, see Luo *et alii* 2018.

Site Location or Identification	Surveys	Salanville (Copeland 1985; Moore 1985), Einwag 1984; Mclellan, Porter (unpublished); Eidem, Putt 2001; Wadi Abu Qalqal (Mottram-Manere 2005), Vivancos 2005; Gaborit 2012; Wilkinson *et alii* 2016
	Excavations	Published Reports
	CORONA Historical Satellite Imagery	Missions 1104 (August 1968) and 1038 (January 1967). Courtesy US Geological Survey
	Google Earth Imagery	2004-2021 (several third-party data providers) https://earth.google.com/

Tab. 1 - Archaeological data sources.

tion.[45] Given the region's recent conflict, the imagery also helped document numerous disturbances, ranging from extensive looting[46] to various forms of destruction due to the recent militarization (Fig. 7). These have been widely documented by several reports covering the entire country.[47]

Legacy data collection posed significant challenges due to the uneven, chaotic, and occasionally contradictory nature of the survey data available. These data stemmed from nine separate archaeological reconnaissance efforts conducted over more than 40 years in the same area, often resulting in overlapping or redundant surveys of previously identified sites (Table 1).

One particularly challenging aspect was identifying and mapping a specific funerary landscape, namely that of rock-cut tombs. Scattered either individually or in clusters, these tombs are distributed along the terrace cliffs directly overlooking the lake. While some of the previously mentioned surveys provided rough positioning information, they lacked details regarding their extent and absolute altitudes, which are crucial for evaluating the lake's fluctuating impact. Moreover, due to their vertical nature, integrating them into a 2D GIS environment proved difficult, requiring them to be represented as polygons. This methodological constraint has significant implications for analysis.

In contrast to the situation at Lake Mosul, where the majority of potential sites that emerged in the last decade could be verified on the ground by the new field surveys operating in the region, the sites identified in the Tishreen sector by the new remote survey could not yet be ground-truthed.[48] Consequently, the assessment of potential sites relies primarily on detecting soil colour changes and/or mounding,[49] with the presence of looting pits occasionally utilised to estimate site size.

A dataset consisting of 77 records was compiled, encompassing all known archaeological sites within the research area as well as those newly identified through the remote survey (totalling 15) (Fig. 8).

It included information such as coordinates, toponyms, typology, chronology, state of preservation and survey/excavation references. Additionally, it also contains a confidence indicator for site location[50] and extension.[51]

3.2 *Workflow - Change Detection*

The detection of the emergence patterns of archaeological sites was accomplished through the application of a change detection technique that integrates freely available medium-resolution satellite images, cloud-processing platforms, open-source GIS tools, and the NDWI Spectral Index to differentiate between water and land surfaces.

During the testing of this technique at the Tishreen Dam, a primary challenge arose from the extremely limited availability of water level data. This data is essential for extracting three key pieces of information: the years for analysis, the months corresponding to minimum (low water level - l.w.l.) and maximum (high water level - h.w.l.) water levels, and the actual water level measurements themselves.

While the Database for Hydrological Time Series of Inland Waters (DAHITI)[52] offered comprehensive data for the Mosul Dam spanning nearly its entire existence, the situation differed for the Tishreen Dam, for which the earliest available DAHITI data extended back only five years.

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[45] E.g. Parcak 2009; Lasaponara, Masini 2011; Bewley *et alii* 2016; Danti, Branting, Penacho 2017; Tapete, Cigna 2018; 2019; Rayne *et alii* 2018. Critical in this regard were the widespread looting activities (Fig. 7).

[46] Social and political instability, resulting from prolonged conflict, can encourage illegal excavation, looting, and trafficking of antiquities due to the breakdown of law-and-order institutions (Boylan 2002; Mahnad 2017).

[47] Casana 2015; Danti 2015; Cunliffe, Muhesen, Lostal 2016; Tapete *et alii* 2016; Casana, Laugier 2017; Masini, Lasaponara 2020; Mamo *et alii* 2022.

[48] This constitutes the most prominent difference from the Mosul Dam dataset, that instead has widely benefited from new field activities.

[49] For site signatures on historical satellite and aerial images see Ur 2010, 60-64.

[50] 'High', 'medium' and 'low'.

[51] 1= high, 2 = medium, 3 = low, 4 = buffer created automatically 5 = area identified through looting activities. In the most difficult cases for which it was completely impossible to determine the site area, due to the inaccuracy of its location or the impossibility of identifying its limits through photointerpretation, an arbitrary circular area of 1 ha was assigned to the site (only 15 sites).

[52] Schwatke *et alii* 2015.

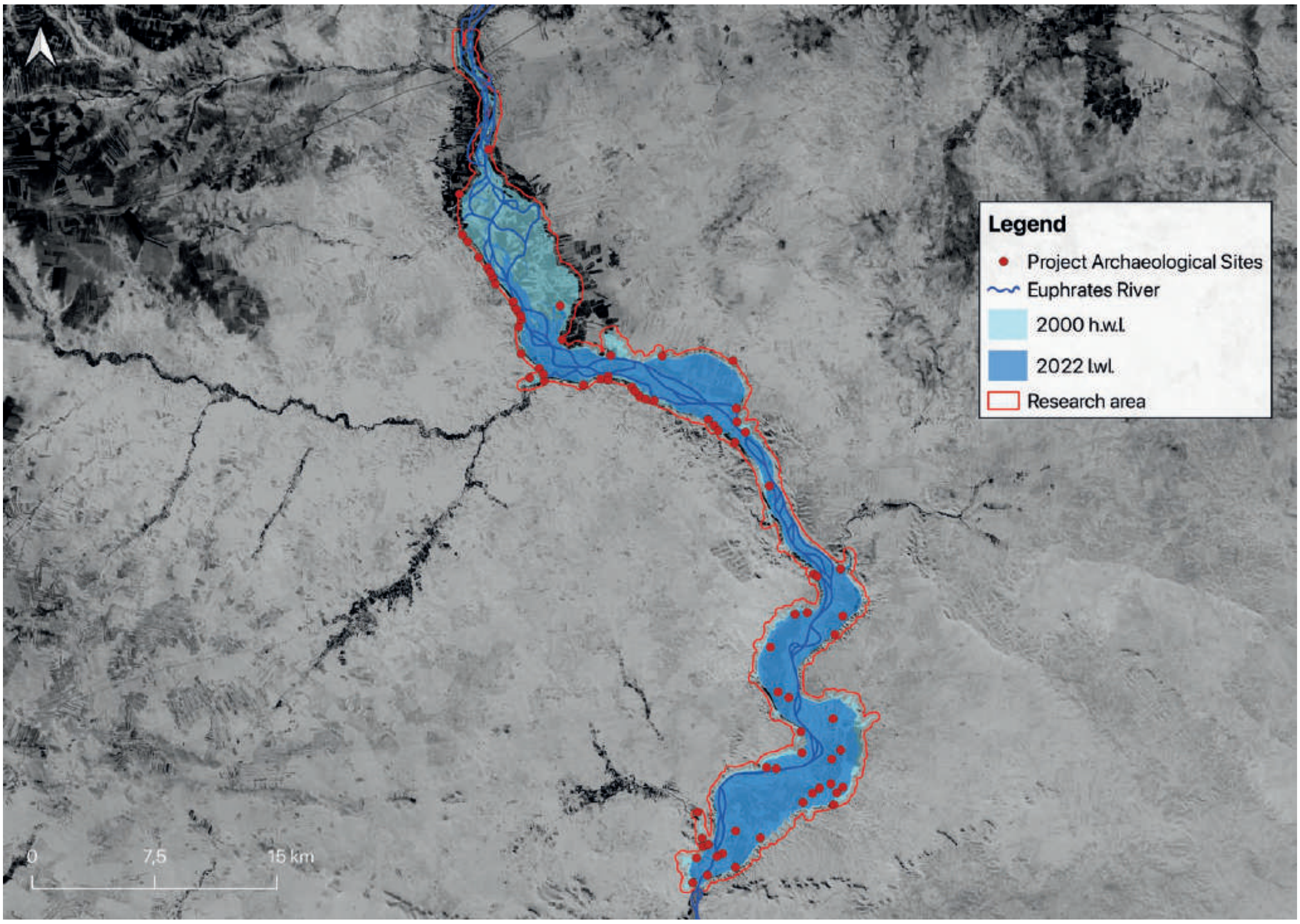

Fig. 8 - Area covered by Lake Tishreen at its maximum (2000) and minimum (2022). Basemap CORONA declassified satellite imagery (Mission 1102, Dec. 11, 1967), Center for Advanced Spatial Technologies, University of Arkansas/U.S. Geological Survey. (Map by A. Titolo).

Satellite (Sensor)	**Date Range**	**Spatial Resolution**	**Temporal Resolution**	**Total Number of Images**
Landsat 5 (TM)	2000-2011	30 m	16 days	24
Landsat 8 (OLI)	2013-2017	30 m	16 days	10
Sentinel-2 (MSI)	2018-2023	20 m	5 days	12

Tab. 2 - Satellite images used with their respective coverage, spatial and temporal resolution, and total number of images acquired.

To face this issue and to account for the missing information, the approximate lake surface was extracted by polygonising the Normalized Difference Water Index (NDWI) composites.[53] These were created in Google Earth Engine using a dynamic low cloud filter, a cloud-masking function and a median reducer on a collection of images taken at the Bottom-Of-Atmosphere (BOA) reflectance.[54] The NDWI composites were then reclassified using a threshold of 0.[55]

This enabled the acquisition of vector polygons representing the lake surface extension for each month, filling the gap for the years not covered by DAHITI (2000-2018), and facilitating the calculation of the corresponding lake surface area.

Subsequently, these data informed the selection of months with high and low water levels, thereby guiding the choice of images for each year.[56] For the remaining timeframe, the available DAHITI data was utilized.

As a result, the dataset comprises 46 images spanning the entire reservoir lifespan, with the exception of 2012 (Table 2).

[53] NDWI was used to discriminate between water and land surfaces. The raster NDWI images were converted to vectors using the 'Polygonize' algorithm in QGIS.

[54] Rayne *et alii* 2020; Sagar *et alii* 2017.

[55] This means that all the pixel values between -1 and 0 were counted as land, while all the values between 0 and 1 were counted as water. The resulting images were accurate enough that further tweaks seemed unnecessary.

[56] This solution was not ideal as the surface area does not represent the most precise indicator of lake variations. While

To obtain the percentage of resurfaced area, the calculations involving site polygons and raster images made use of the QGIS Zonal Histogram algorithm in R software facilitated by the Qgisprocess package.[57] The change detection procedure applied to these images is described in detail elsewhere.[58]

4. Results

4.1 *Water Level Observation*

The Tishreen Reservoir has demonstrated relatively stable water levels throughout its lifespan,[59] in contrast to Lake Mosul, which has undergone fluctuations of nearly 40 metres over the past four decades. Nonetheless, satellite imagery[60] and data from the past five years obtained from DAHITI[61] suggest a trend towards a reduction in the reservoir's water level since 2014.

Due to the overall steadiness of the water levels, each year approximately 47% of the total number of sites emerged from the water. However, with the onset of the new trend of decreasing water levels since 2014, this percentage has risen to 55%, as observed in 2021.

Additionally, Lake Tishreen exhibits minimal water level oscillation within the same year. This, combined with the aforementioned factors, has significant implications for the emergence pattern of archaeological sites, as discussed below.

4.2 *Categorization of the sites*

The Tishreen Dam Research Area was examined both at large and individual site scales. Employing the workflow facilitated the categorization of the 77 sites into three distinct groups based on their emergence patterns, allowing the determination of their frequency (Fig. 9):

- Sites that during the entire study period (2000-2023) were permanently submerged (*never exposed, **in black***) (n. 18)
- Sites that were constantly exposed (*never submerged, **in grey***) (n. 16)
- Sites that in the study period were affected by water-level fluctuation *(cyclically affected)* (n. 43), further subdivided into:
  - Sites always submerged at the year's h.w.l (*always submerged at h.w.l., **in red***) (n. 1)
  - Sites that emerged cyclically (*affected, **in yellow***) (n. 42 at h.w.l; n. 37 at l.w.l)
  - Sites that always re-emerged at the year's l.w.l (*always exposed at l.w.l., **in green***) (n. 6)

The primary focus of the analyses that we conducted has been centred on sites impacted by water fluctuations (*cyclically affected*). Given their heightened vulnerability to damage or destruction, these sites require particular emphasis on scientific documentation and protection measures. As part of the second phase salvage efforts, it is imperative to promptly integrate these sites into a comprehensive monitoring program. Such a program should include thorough documentation and emergency excavations in certain cases.

4.3 *Cumulative Results of the Time-Series Analysis*

The time-series analysis revealed that 18 out of 77 sites remained submerged by the artificial reservoir throughout the study period (2000-2023) (*never exposed*). These sites are all located at the end of the reservoir, close to the dam itself (Fig. 10a). Although the majority are mounded settlements/tells (Table 3), only one (Tell el-Kebir) was excavated during the first-phase salvage.

On the other hand, 16 sites remained untouched by the floodwaters, not even at the lake's maximum water level (*never submerged*) (Fig. 10b). These sites are predominantly situated in the north-west sector of the reservoir, perched upon elevated cliffs with commanding views of the lake below. Characterized by their flat terrain and modest size, they mainly date – on the basis of surface collections – to the Roman period onwards. Many of them were identified through modern surveys, notably the Land of Carchemish Project. One of the southernmost sites is Qal'at Najm, nestled atop a ford in the Qara Qozak gorge, and Tell Khamis, on the opposite bank of the river.

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the water level of a lake measures the vertical movement of water, the surface area of the lake measures the horizontal water movement and is influenced by the topography of the lake shores. If the shoreline is steep, the water will have less space to move horizontally, resulting in a minimal change in surface area, even if the water level drops significantly. On the other hand, if the shoreline is mostly flat, even a slight drop in water level can cause a more significant horizontal movement of the lake shores. Note that this solution may lead to a less accurate choice regarding the months of analysis. However, the validity of the tool itself and its results are guaranteed by the robustness of the change detection method.

[57] Dunnington *et alii* 2023. The code for the analysis is archived at: https://github.com/ReLandProject/ReLandTishreen.

[58] Sconzo, Simi, Titolo 2023; Titolo, this volume.

[59] According to DAHITI that provides data only for the last 5 years, the lake water level oscillated of only 5-6 metres between the highest (326.87 m in February 2020) and lowest (321.191 m in September 2022) levels recorded.

[60] It is important to note that the water surface plot replicates the water fluctuation pattern registered by DAHITI, providing proof that changes in the water surface reflect those in water level.

[61] A first phase (2018-beginning 2020) shows overall stability of the reservoir, with very minimal variation in water levels. The following second phase (until the end of 2022) is characterized by greater variations, with water level often dropping 3 metres in a few months. A third phase (from the beginning of 2023) again shows stabilization of the reservoir, at a lower water level and with a more consistent pattern of water fluctuation.

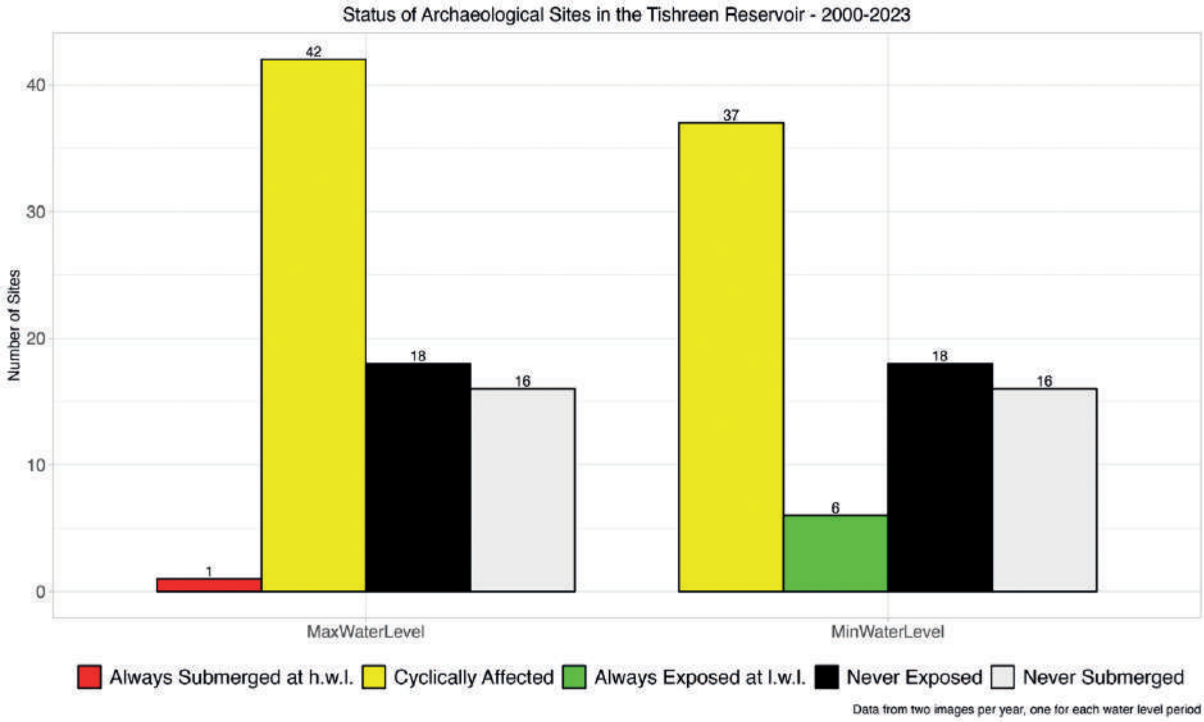

Fig. 9 - Emergence pattern categories.

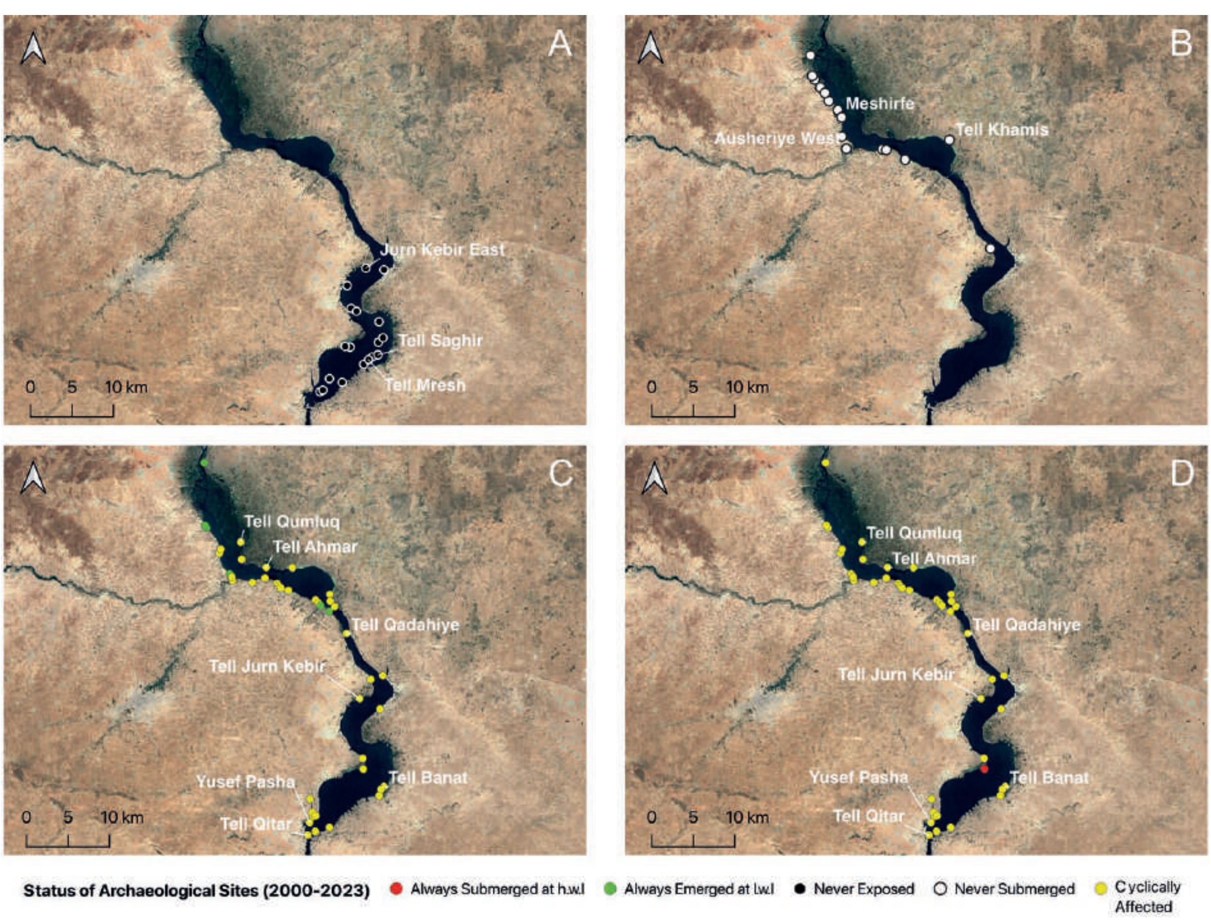

Fig. 10 - Spatial distribution of emersion pattern categories: (a) never exposed; (b) never submerged; (c) affected and always exposed at l.w.l.; (d) affected and always submerged at h.w.l. (Maps by A. Titolo).

	Mounded Sites	Flat Sites	Fortresses	Rock-Cut Tombs	Sherd Scatters	Uncertain	Total
Cyclically Affected	28	10	2	2	0	1	43
Never Exposed	15	2	0	0	1	0	18
Never Submerged	3	9	1	1	0	2	16
Total	46	21	3	3	1	3	

Tab. 3 - Number of Sites for Each Category and Each Site Type.

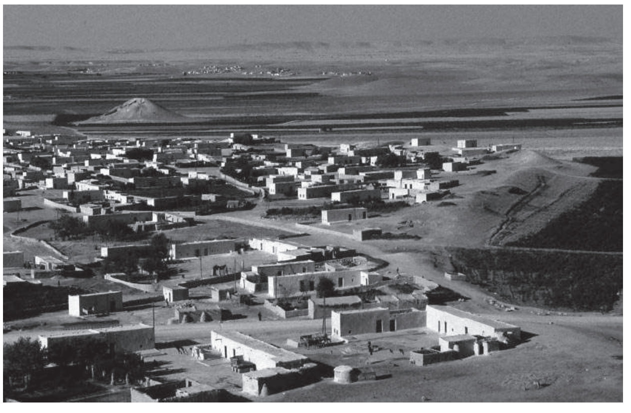

Fig. 11 - Tell Banat (Courtesy of McLellan).

The remaining 43 sites are affected by the water fluctuation process (*cyclically affected*) to different extents depending on the minimum (n. 37) or maximum water level (n. 42).[62]

As the lake level appears to have remained relatively stable, these sites undergo only minor variation in their exposure between minimum and maximum lake water levels each year. This consistency ensures that they can all be effectively incorporated into a regular monitoring and safeguarding program without significant challenges.

The *cyclically affected* sites are spread throughout the reservoir: during h.w.l. phases, the only site *always submerged* is located in a wadi gorge close to the old riverbed (Fig. 10d); in periods of l.w.l, *always exposed* sites lie in the northern sector of the reservoir or on the terraces close to the Qara Qozaq gorge (Fig. 10c). *Cyclically affected* sites include mostly multi-period mounds/tells, with some flat settlements and also clusters of rock-cut tombs (Table 3).[63]

4.4 *Reconstructing Site Histories*

Finally, the tool also facilitated the quantification of the exposed area for each of the 77 sites, carrying several practical implications, particularly for future targeted investigations and our comprehension of the survival of submerged archaeological features.

At one end of the spectrum, there exists a group of sites that have maintained at least 50% of their surface area above water since the reservoir's inception. These sites demonstrate a consistent pattern of emergence and submergence. Among them are Tell Qitar and Tell Qumluq. Conversely, at the other end of the spectrum, there are sites that resurfaced only during significant reductions in the lake volume, a trend that began in 2014 and peaked in 2018, 2021, and 2023. Examples from this group include the white monument at Tell Banat (Fig. 11), Tell Jurn Kebir, and Tell Qadahiye.

In between are additional sites that partially emerge each year, with less than 50% of their surface area exposed. However, over the past decade these sites have become more exposed due to the general reduction in water levels. Examples include Tell Qara Qozak and Tell Ahmar, particularly impacted in their extensive Lower Towns (Fig. 12).

Tell Ahmar provides valuable insights into analysis at individual site level. The bar chart depicting the resurfaced area of the site illustrates two significant phases (Fig. 13). From the initial filling of the reservoir until 2014, the site consistently remained above water, exhibiting a gradual but consistent increase in the total area exposed (from 32% to 47% of its surface). However, after 2014, the site data show significant fluctuations. During periods of low water level (minimum in 2014, 2017, 2018, 2021, 2022, and 2023), with 90% of the site revealed, it appears to have almost entirely resurfaced.

From satellite imagery, it became evident that the most recent fluctuations in the lake primarily impacted the site's lower town. Before 2014, the latter remained consistently underwater (Fig. 14:1-2). However, over the past decade, this area has experienced cyclical resurfacing (Fig. 14:3-8), with peaks of exposure occurring notably in September 2022 and February 2023. It's noteworthy that the rising water level can quickly submerge the lower town area; within just two months in 2023, the exposed surface of the site decreased from over 90% in February to slightly over 50% in April (Fig. 13 and Fig. 14:7-8). This observation raises the possibility that the site has undergone significant erosion and damage since 2014.

[62] Within this large group, six sites consistently resurface (*always exposed at l.w.l.*) yearly at the time of minimum water level (usually spring or autumn), while only one (Sandalyie Kebir) is constantly underwater during high water level periods (*always submerged at h.w.l.*).

[63] As already mentioned above, the reliability of the results of change detection applied to this specific type of site is biased by the lack of basic/determining data concerning their extension and altitude.

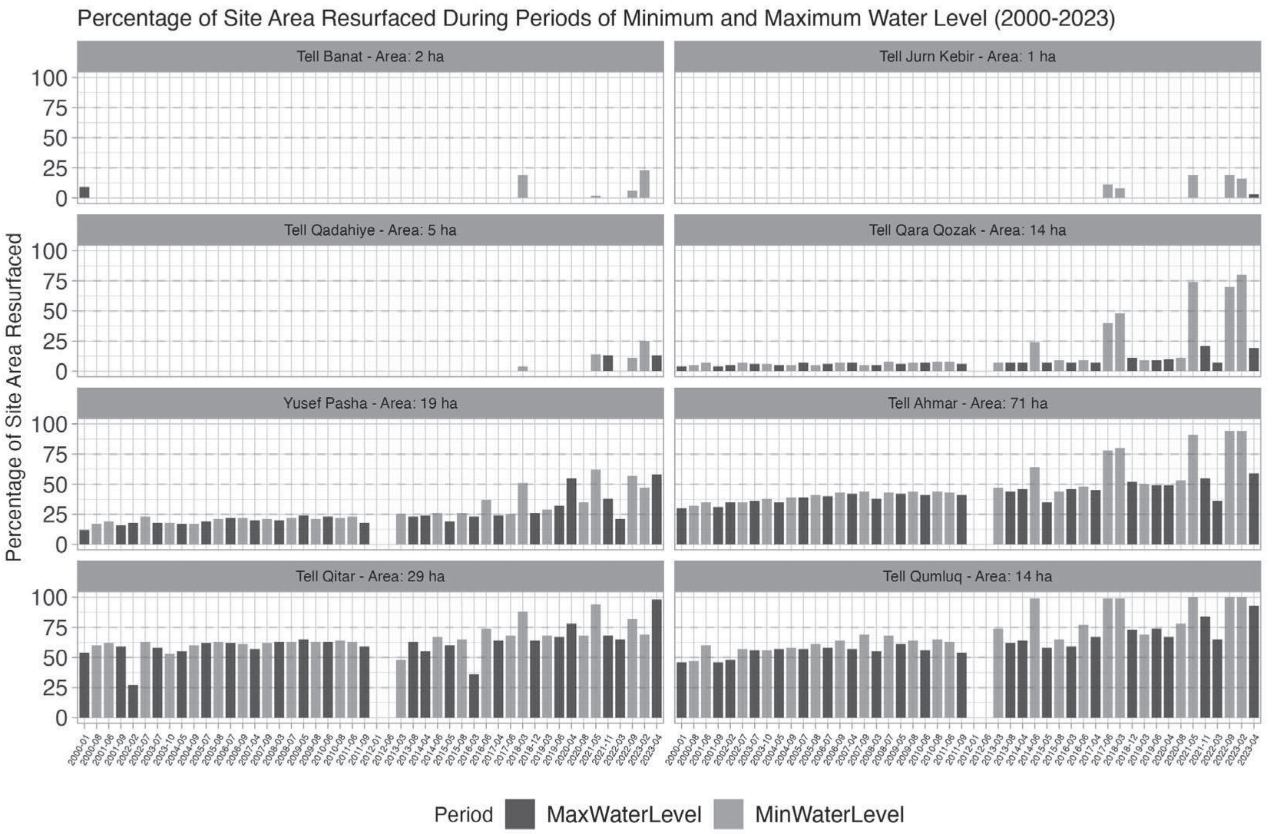

Fig. 12 - Emergence patterns of selected sites (Chart by A. Titolo).

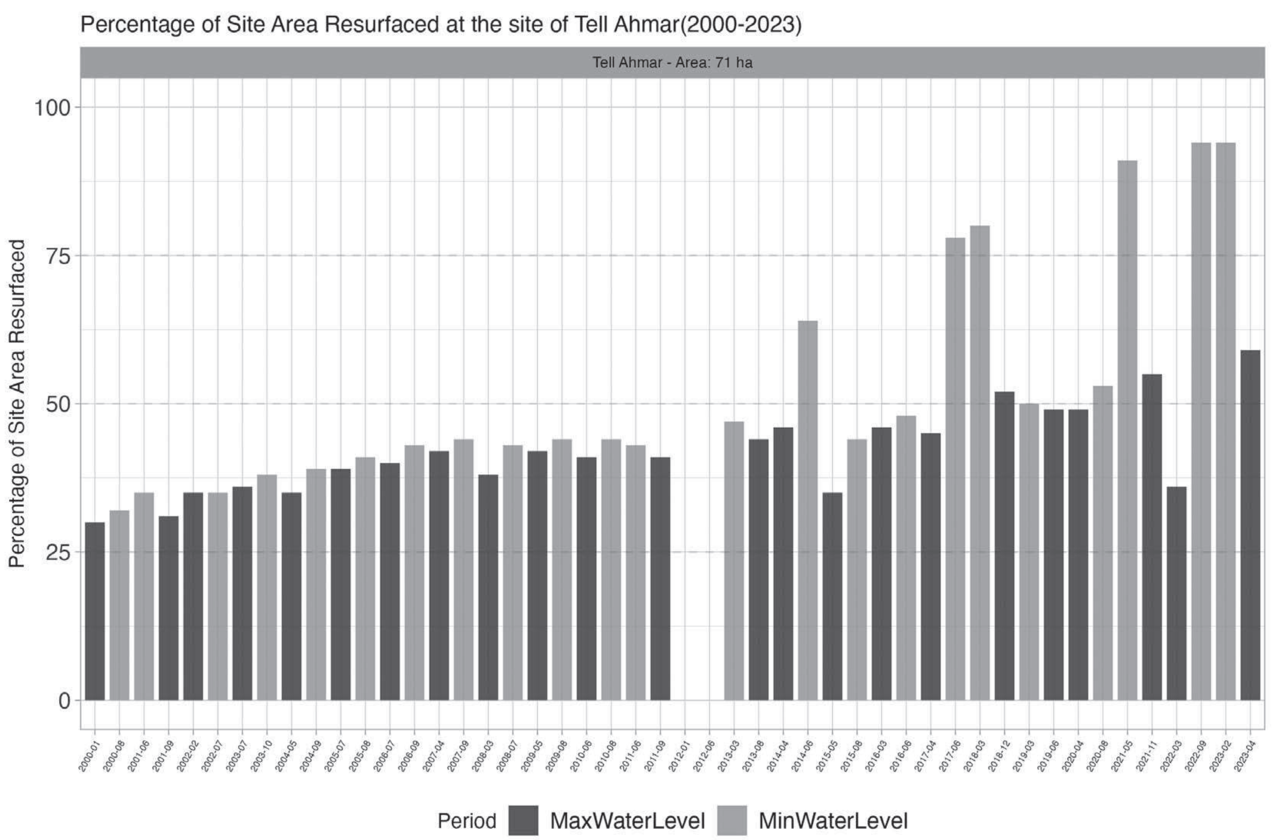

Fig. 13 - Emergence patterns at Tell Ahmar (2001–2023). Bar plot with resurfaced site area percentages (Chart by A. Titolo).

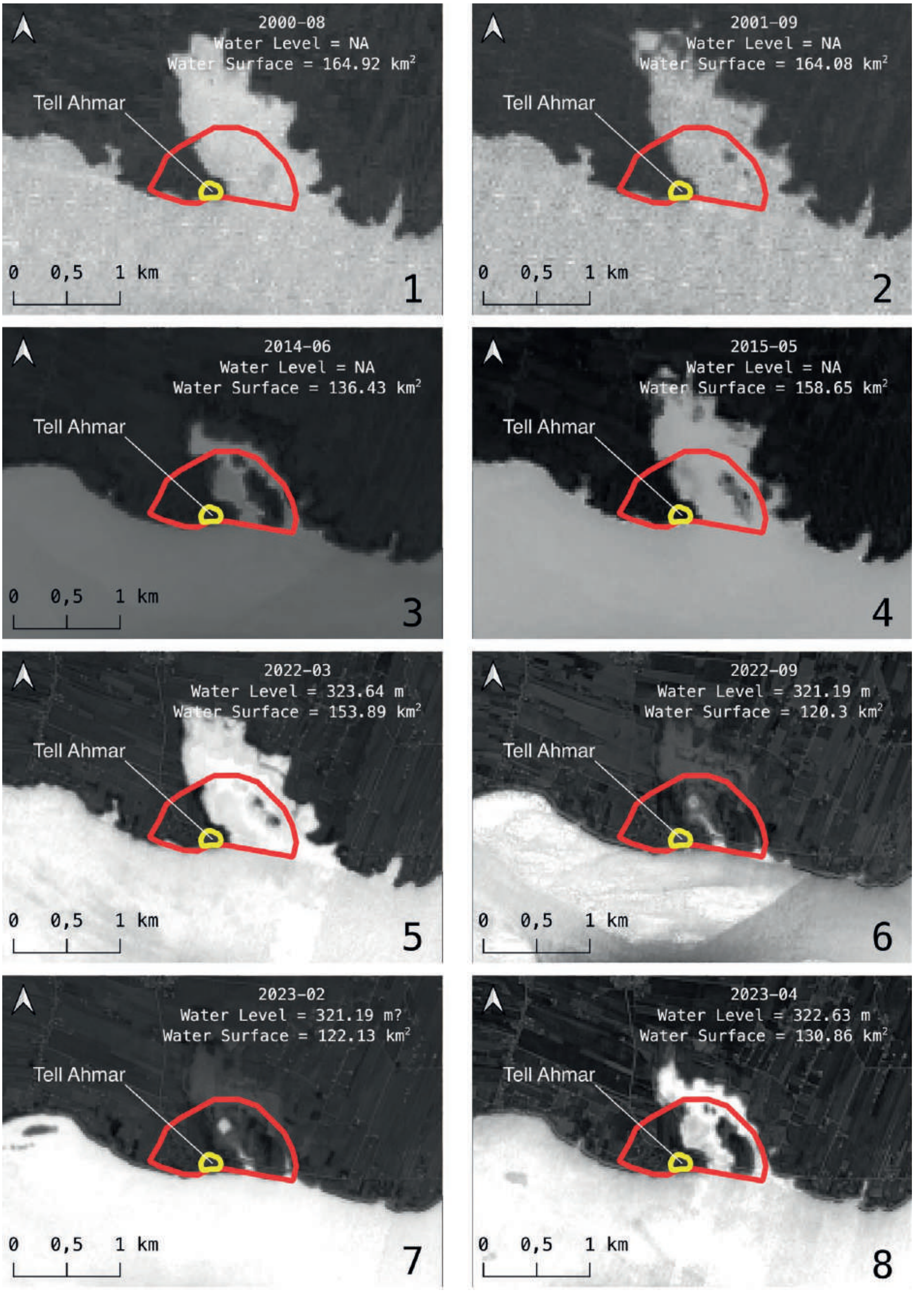

Fig. 14 - Emergence patterns at Tell Ahmar (2000–2023). Satellite images showing the exposed site areas at different water levels (Map by A. Titolo).

	Total Site No.	Cyclically Affected	Never Exposed	Never Submerged
Tishreen Dam	77	43 (55.84%)	18 (23.38%)	16 (20.78%)
Mosul Dam	275	193 (70.18%)	53 (19.27%)	29 (10.55%)

Tab. 4 - Comparative Results of the Emergence Pattern Categories.

Fig. 15 - Tweet showing some resurfacing rock-cut tombs in the Tishreen region.

5. Discussion

The results presented above have clearly shown that the tool first developed for the Mosul Dam case study may be successfully applied to other flooded landscapes in the SWA region and beyond. This tool has demonstrated remarkable flexibility and adaptability. However, it is crucial that the qualitative criteria for creating archaeological and remote sensing datasets are met, although this does not necessarily mean that these criteria must be uniform in every context or case study.

For instance, in the case of the Tishreen Dam, the absence of DAHITI data for absolute water level has been easily bypassed, not affecting the final results of the analysis.

The application of change detection to two reservoirs allowed us to compare the results from the two dams.

What is immediately evident (Table 4) is that the percentage of cyclically affected sites is much lower in the Tishreen Dam. This is possibly due in large part to the topography of the area that resulted in 20% of never submerged sites and on the other hand also to the different behaviour of the lake water level fluctuations. The latter might also be related to the different socio-political contexts of the two regions; as we will see below, politics has had an important impact on the Tishreen Dam lake's history.

The research across the two reservoirs, which share similarities yet exhibit different behaviours over the past 25 years, has highlighted its effectiveness and relevance at both macro and micro scales.

At the macro or landscape level, the tool adeptly identified sites that are always submerged, those that are constantly exposed, and those which resurface according to the fluctuations in water levels, even if minimal. On a micro or site scale, it enabled the reconstruction of a site's history of emergence and submersion. This allowed us to observe the destructive/erosive impact of water level oscillations, as exemplified by the case of Tell Ahmar Lower Town mentioned earlier.

An unavoidable loss of detail and precision, instead, resulted from the almost complete lack of recent surveys employing state-of-the-art methodologies and technologies.[64] This was observed in the case of the rock-cut tombs, which constitute a landmark of the Tishreen region's heritagescape (Fig. 15). The lack of data concerning their altitudes and horizontal and vertical extension, coupled with the absence of information on the lake water level usually supplied by DAHITI, have, in fact, hampered our ability to record and understand the impact of water fluctuations on each of these features. In the future, site visits and in-field monitoring could help overcome this issue.

The imperative to compile a dataset that integrated modern remote surveys of the area under investigation has, moreover, uncovered yet another dimension linked to the devastation of local heritage. As previously emphasized, the utilization of recent satellite imagery has exposed the extensive damage stemming from the regional social and political upheaval instigated by the Syrian Civil War. The widespread looting and militarization of numerous archaeological sites bear testament to the vulnerability of these peripheral regions. Situated beyond the reach of centralized authority, these areas have been caught in the crosshairs of various factions vying for control along contested borders. This underscores the urgent need for concerted efforts to safeguard cultural heritage in such precarious environments.

Furthermore, beyond its immediate relevance for other flooded landscapes, the tool has proved to be useful in understanding the relations between the reservoir water level changes and the events driving them.

[64] An exception is the Land of Carchemish Project mentioned above.

The fluctuating dynamics of dam lakes on a global scale, alongside the intermittent re-exposure of formerly submerged archaeological sites, reflect the interplay of overarching aridification trends and the regular management of dams. However, in Southwest Asia, notably Syria and Iraq, the sway of military and political forces is profound.

Our investigation into the emersion history of Tishreen's heritage sites unveils the historical roots of the lake's recent behaviour, elucidating the intricate interplay between dam operations and periods of conflict. This examination has revealed the connection between past events and their environmental aftermath, spotlighting the pervasive influence of geopolitical and strategic factors.

Specifically, we are inclined to link the notable decrease in Lake Tishreen's water level noted from 2017 to 2018, with what happened at the Tabqa Dam, immediately downstream, around the same time.

Tabqa Dam, situated just 40 km upstream of the city of Raqqa, is Syria's largest dam. Much like the Tishreen Dam, control over it has been a strategic goal for all factions entangled in the Syrian conflict. In 2014, ISIS seized control of the dam, prompting efforts by SDF/US forces and the Syrian government to reclaim it. Despite being on the no-strike list, the dam was bombed by the US in 2017.[65] An unexpected truce was brokered between the Islamic State, US forces, and the Syrian government to allow engineers to conduct urgent repairs on the dam, which faced the threat of failure.[66] Turkish authorities lent support by coordinating the closure of upstream dams including those feeding Lake Tishreen, to prevent downstream calamity.[67]

This deliberate water management likely contributed to the observed decline in Lake Tishreen's water level, leading to the re-exposure of archaeological sites. This event highlights the intricate interplay between hydrological infrastructure, conflict, and environmental impacts, directly affecting cultural heritage preservation efforts in the region.

Understanding these connections is crucial for assessing the broader implications of historical events on the region's water resources and ecosystems and developing integrated management strategies that address immediate crises while prioritizing long-term sustainability. At a broader level, this emphasizes the crucial role that archaeology can currently play in the broader discussion on climate change in these landscapes.

6. Conclusions

This study has shed much-needed light on a region that had been overshadowed since the onset of the Syrian Civil War, yet which urgently requires attention for protection and further investigation.

Among the archaeological sites that have recently begun to emerge, several had been already recognised and extensively studied for their pivotal role in reconstructing the heritagescape of the region, such as the Bronze Age Banat-Bazi Complex and the Iron Age capital city of Tell Ahmar/Til Barsip. Their resurfacing underscores the critical need for the immediate implementation of a comprehensive framework for on-the-ground documentation of the damage incurred and the establishment of new safeguarding practices. Besides these sites, many more that have never been investigated are being flagged by the change detection tool as potentially under threat. These sites deserve a comparable effort in future endeavours to avoid further losses.

Moreover, it is important to recognize that comprehensive work on the impact of dams on heritagescapes and subsequent preservation activities can no longer rely only on standard archaeological approaches. As the research has shown, it is advantageous to make use of the full toolkits available (remote sensing, fieldwork, etc.), also including a careful reconstruction of recent water history and environmental events.

The recent implementation of second-phase salvage projects along the banks of Mosul and Dokan Lakes offers a promising model that could be effectively adapted to address similar challenges in the context of the Tishreen Dam region. Here, in the last few years, local archaeologists have already started fieldwork-based documentation to record the sites' preservation states and potential illegal activities that have affected the region.[68]

While our current work on the Tishreen Dam has only addressed the first of the research questions outlined at the beginning of this paper, the authors are optimistic that the results, when shared with Syrian colleagues, will serve as a foundation for the implementation of a systematic monitoring program aimed at preserving this invaluable heritage.

The ultimate goal of testing the change detection technique presented in this paper is to demonstrate how such a cost-efficient tool may be used by all local antiquities departments and international institutions involved in cultural protection efforts worldwide.

By fostering collaboration and knowledge sharing, this initiative will empower stakeholders to effectively safeguard and manage cultural heritage sites amidst ongoing challenges and disruptions.

[65] Philipps *et alii* 2023.
[66] BBC 2017.
[67] UNOCHA 2017.
[68] Sabrine, Montgomery, this volume.

Fig. 16 -Two pics taken by Tell Qumuq at the Tishreen Lake (left) and by Wadi Baqaq at the Mosul Lake (right) the same day (19/4/2024, courtesy P. Sconzo).

Addendum

The torrential rains of the past months have raised exponentially both the Tishreen and Mosul Dam lakes water levels, thus once more submerging many previously exposed archaeological sites, villages and communication routes (Fig. 16). Rampant vegetation has taken over the adjacent fields. A drastic change in the lakeside landscapes is occurring. Acknowledging the devastating impact of this new deluge, we also hope that this unexpected abundance of water will bring relief to the communities living around and also downstream of the reservoirs. Added on the 19/04/24.

Acknowledgement

First, we would like to express our gratitude to Isber Sabrine, president and co-founder of Heritage for Peace NGO, who is trying to create a bridge between our work and the Syrian Archaeologists engaged in safeguarding the Tishreen Dam Lake heritagescape.

The Durham Archaeology Informatics Laboratory has kindly provided data related to the Land of Carchemish Project; our special thanks go to its director, Dan Lawrence.

Thanks are also due to Jesper Eidem and Thomas McClellan who shared some of the photos presented here.

We are also grateful to the two anonymous reviewers for their valuable input. Their comments have greatly improved this paper in many respects, and any errors are the authors' sole responsibility.

Last, a particular debt of gratitude is owed to Jim Bishop, who took on the burden of the English editing and proofreading of the draft of this manuscript.

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Finito di stampare nel mese di gennaio 2025 dalla tipografia ABC, Sesto Fiorentino (FI)