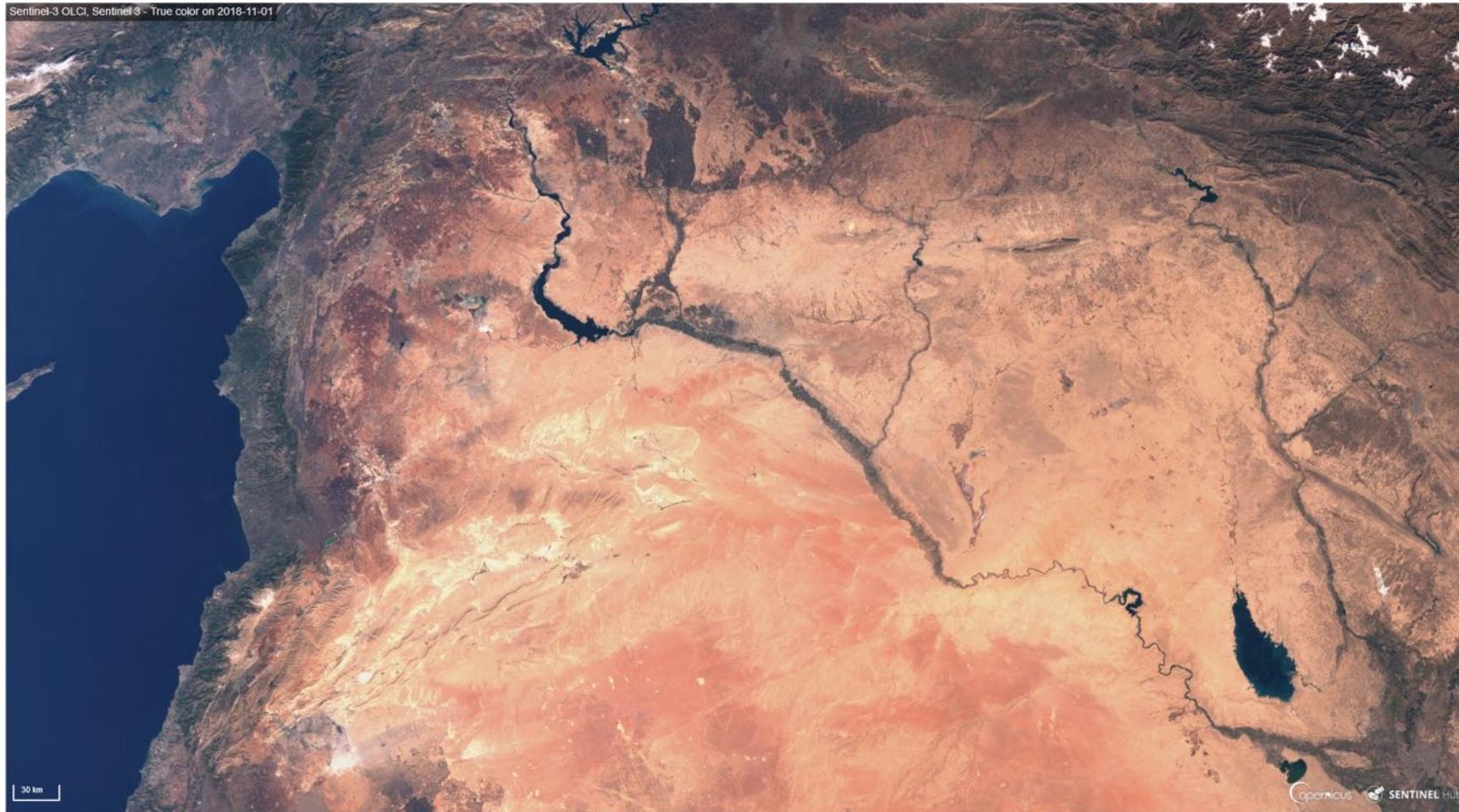


Monitoring Emerging Archaeological Sites Using Multitemporal NDWI: Case Studies from Iraq

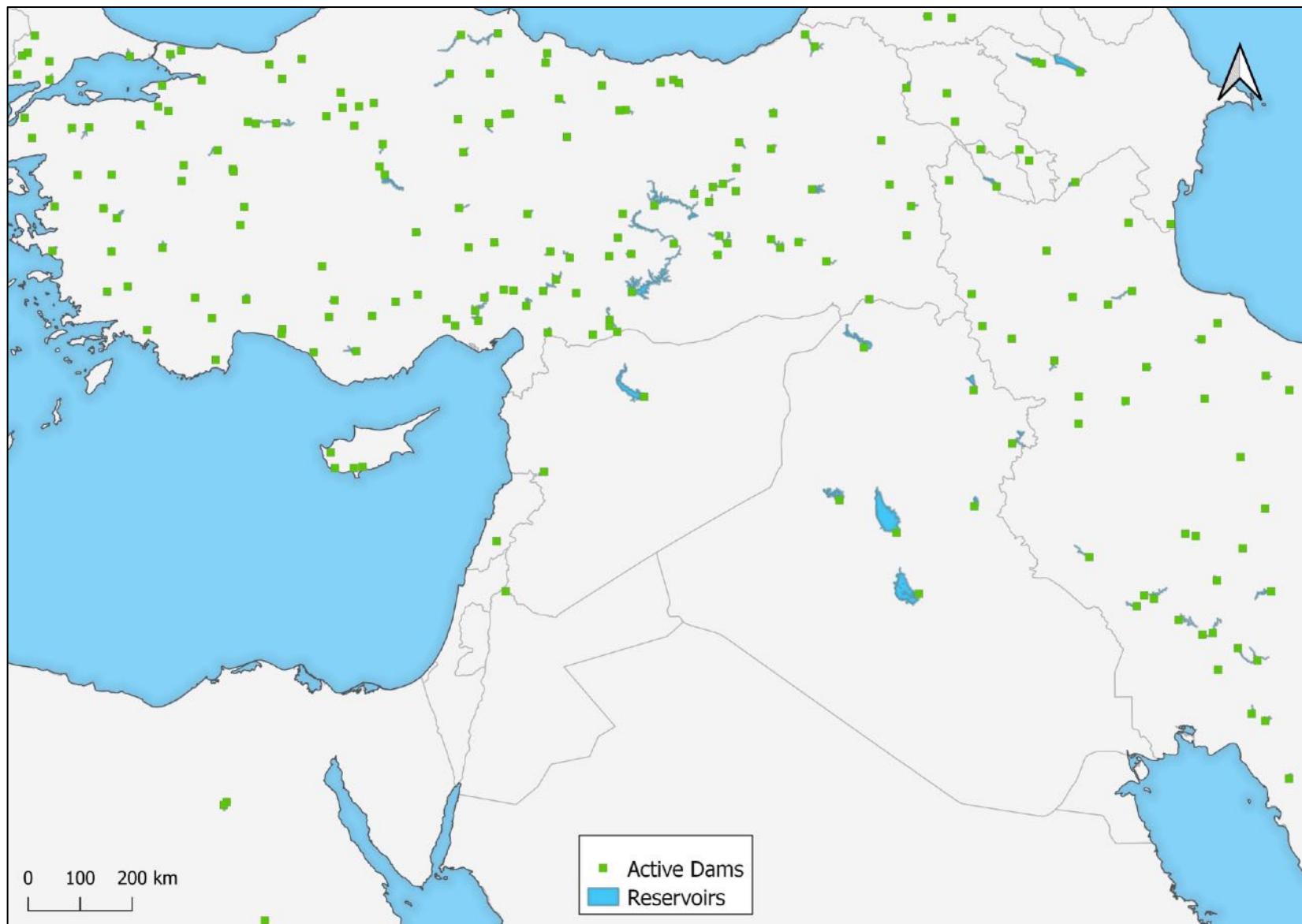
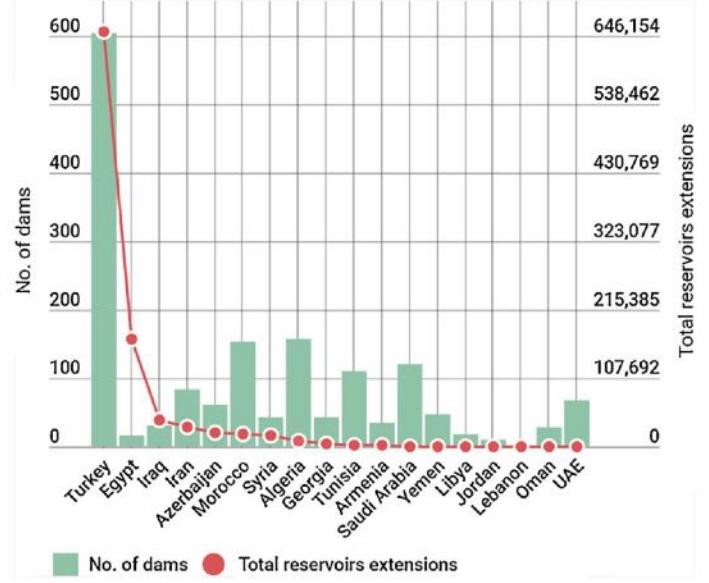


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UNIVERSITÀ DI ROMA

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BANEA
The British Association for
Near Eastern Archaeology

9th to 11th
January
2020



Above: No. of dams and total reservoir extensions in the MENA countries (Marchetti *et al.* 2019, Fig. 1)

Right: location of active dams (higher than 15 m) and related reservoirs (data FAO/ACQUASTAT).



Original article

A multi-scalar approach for assessing the impact of dams on the cultural heritage in the Middle East and North Africa

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Aswan dam

ABSTRACT

This paper provides a detailed assessment on the impact of dams on archaeological sites in the Middle East and North Africa (MENA) and emphasizes the lack of established protocols for documenting and preserving cultural heritage at the local, national and international level.

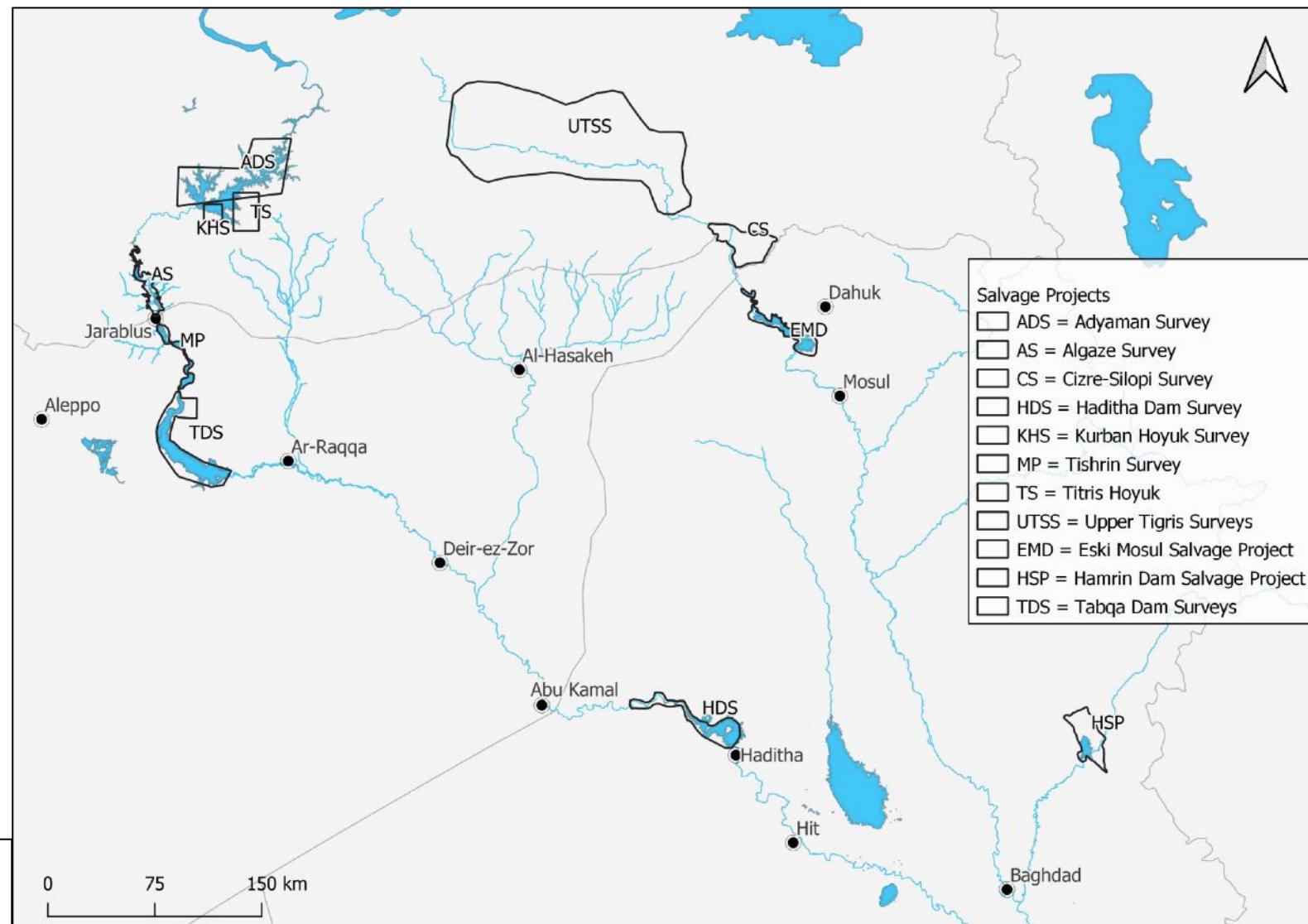
We considered four case studies at different scales – Turkey, the Euphrates river, the two Aswan dams and the planned Makhal dam – in order to identify different issues related to the construction of dams as well as to propose some best practices for pre-flooding assessment of dam impact on cultural heritage. Our method integrates archaeological and geo-spatial open-access datasets, organized in a GIS environment made available through the online platform <http://www.orientlab.net/orientdams/> in order to foster data sharing and research replicability.

We have mapped almost 2500 flooded archaeological sites and approximately 1300 km of ancient rivers submerged by dam reservoirs in the selected case studies across the MENA area. These numbers are actually incomplete, since large portions of the reservoir areas have not been systematically investigated.

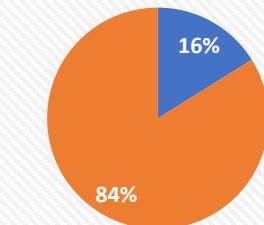
We conclude by underlining the urgent need for strategies for the documentation and protection of archaeological sites and monuments in the planning of hydraulic infrastructures at the international, national and local levels, as well as the need for a general operative protocol. Funders of development works, first and foremost the World Bank, should review their current policies, which do not offer sufficient protection of cultural heritage.

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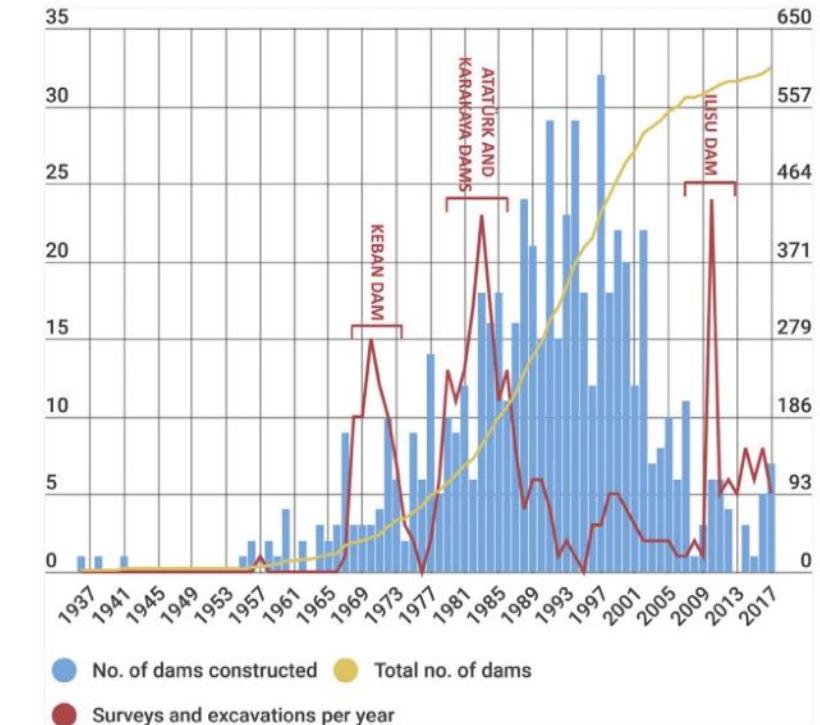
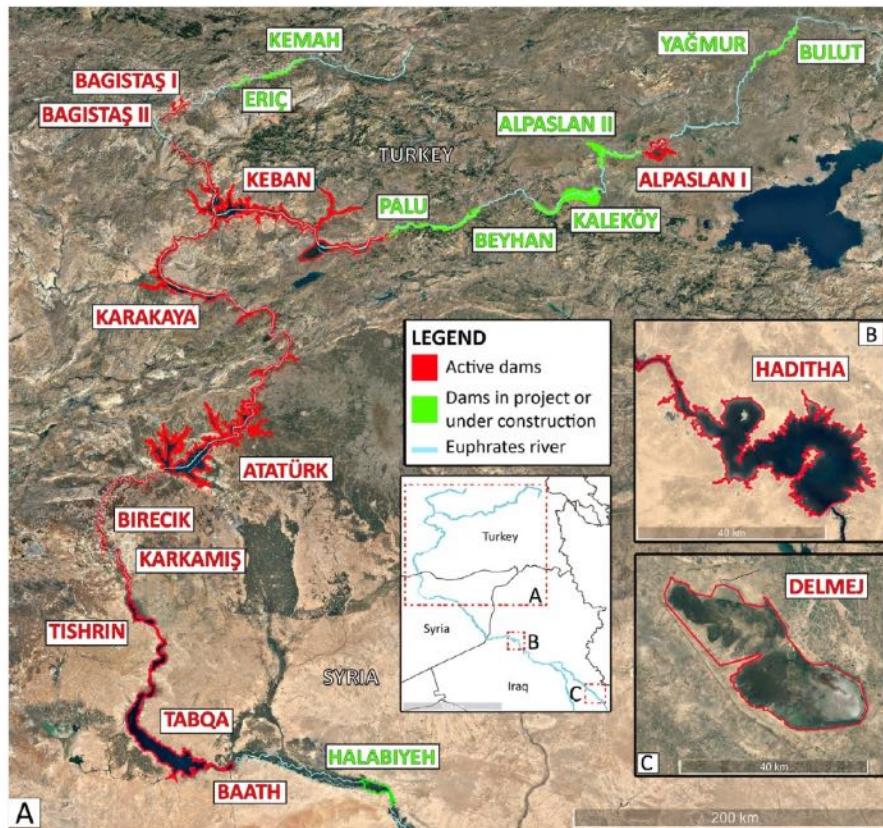
Location of main salvage projects undertaken from the late '60s along the Euphrates and Tigris rivers



Sites Flooded by Water Reservoirs



■ Excavated ■ Non Excavated



Above: Temporal breakdown of dams construction in Turkey and the Archaeological surveys promoted by the Ministry of Culture and Tourism (Marchetti *et al.* 2019, Fig. 3)

Top Left: Chart with ratio of Euphrates excavated and non-excavated sites before their flooding (data from Marchetti *et al.* 2019)

Left: Active dams, dams in project or under construction along the Euphrates river in Turkey, Syria and Iraq (Marchetti *et al.* 2019, Fig. 3).



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06/07/2019

Archaeologists uncover palace of the Mittani Empire in the Duhok province of the Kurdistan Region/ Iraq

German-Kurdish research team came upon a surprising discovery as ruins emerge from the waters of the Tigris River



Aerial view of Kemune Palace from the west.

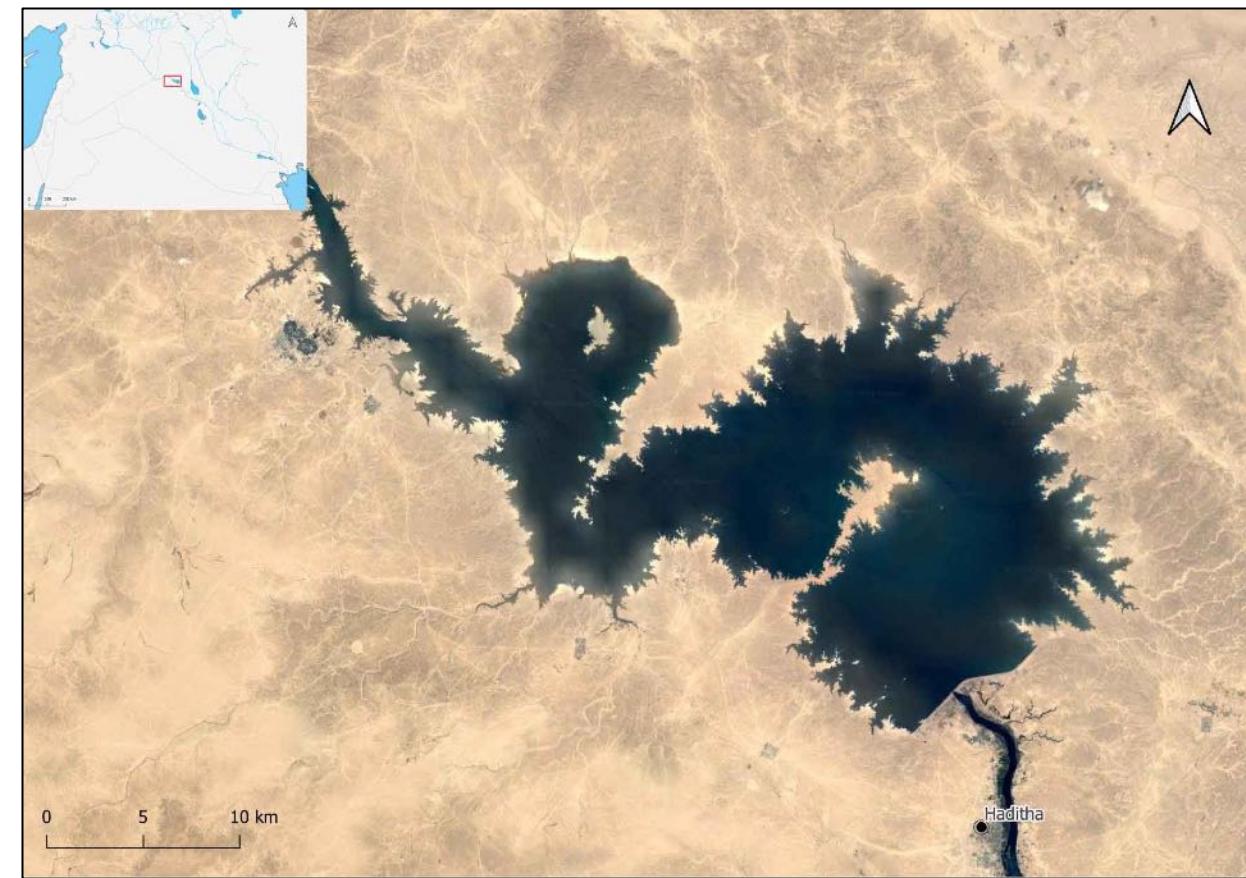
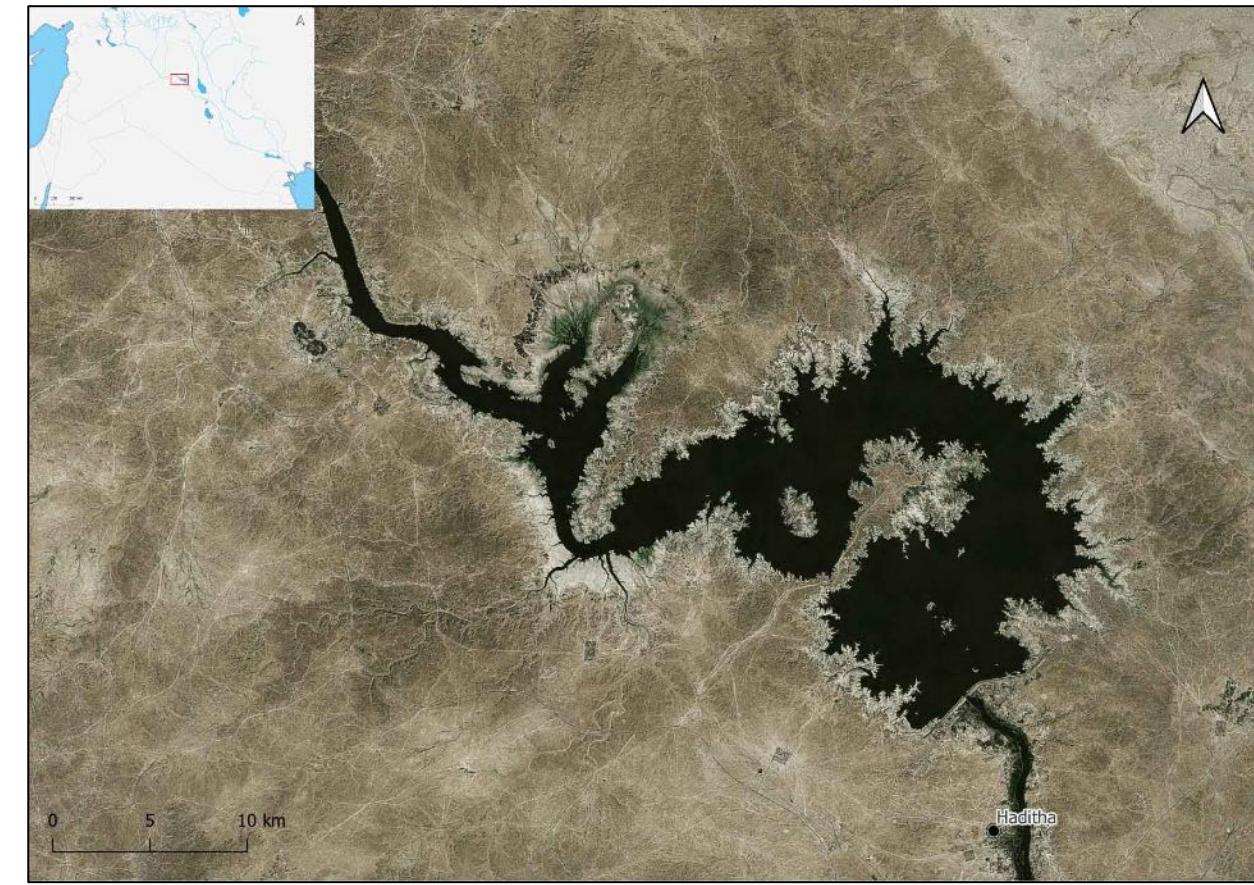
German and Kurdish archaeologists have uncovered a Bronze Age palace on the eastern bank of the Tigris River in the Kurdistan Region of Iraq. As the international research team reports, the site of Kemune can be dated to the time of the Mittani empire, which dominated large parts of northern Mesopotamia and Syria from the 15th to the 14th century BCE. The Mittani Empire is one of the least researched kingdoms of the Ancient Near East. The archaeologists now hope to obtain new information about the politics, economy, and history of the empire by studying cuneiform tablets discovered in the palace.



Left: Aerial view of the site of Kemune during the excavation in 2018 (©University of Tübingen, eScience Center, and Kurdistan Archaeology Organization).

Right (from top to bottom): Area around Kemune in a Bing Image (2011), Sentinel-2 (13/11/2018), and Sentinel-2 (08/11/2019).



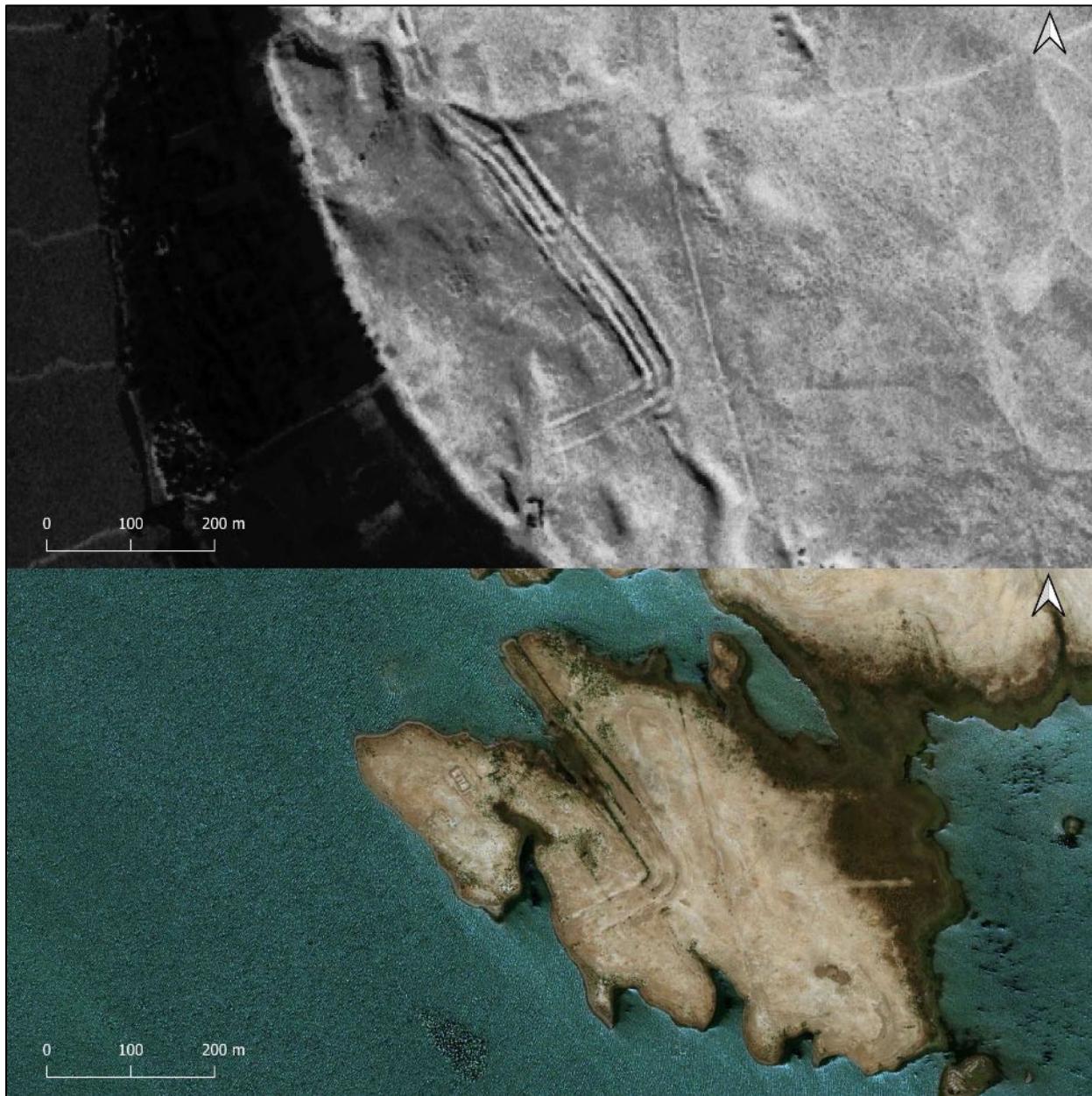


Haditha Dam Lake, Left: Bing Image (2011); Above: Google Earth image (2016)

Introduction: Resurfaced archaeological sites – Haditha Dam

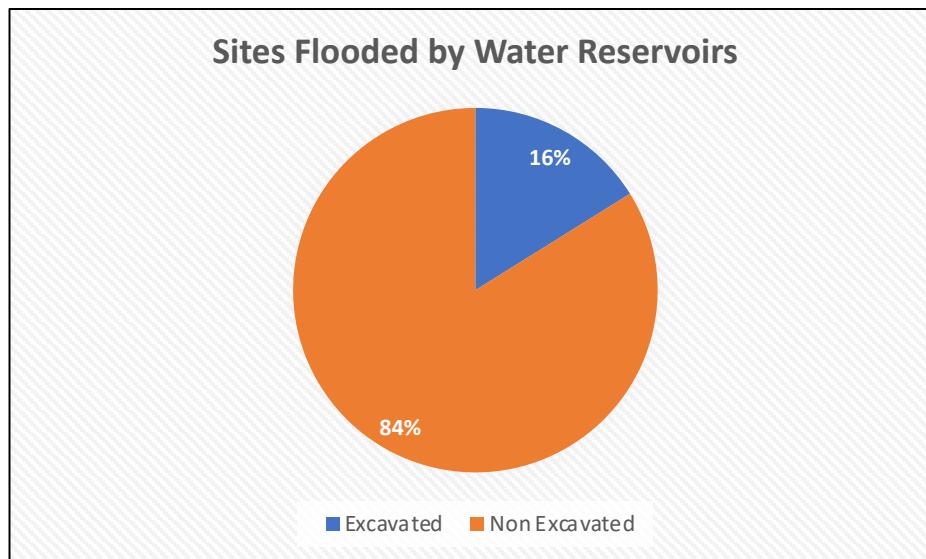
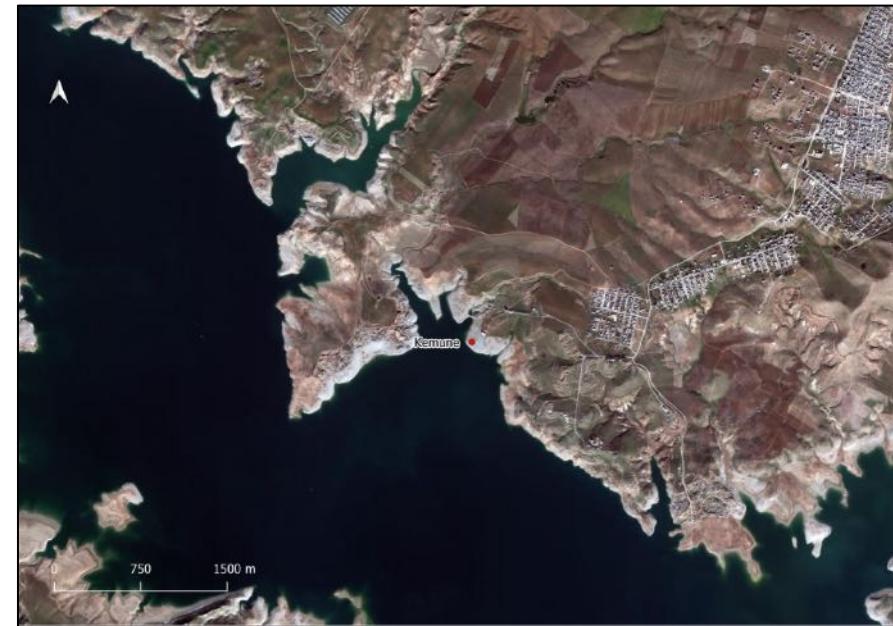


Above (from top to bottom): Area around the site of Kifrin (Haditha Dam) on a Bing Image (2011) and Google Earth Image (2016)
Right (from top to bottom): the site of Kifrin on CORONA image (Dec. 1967) and Bing Image (2011).



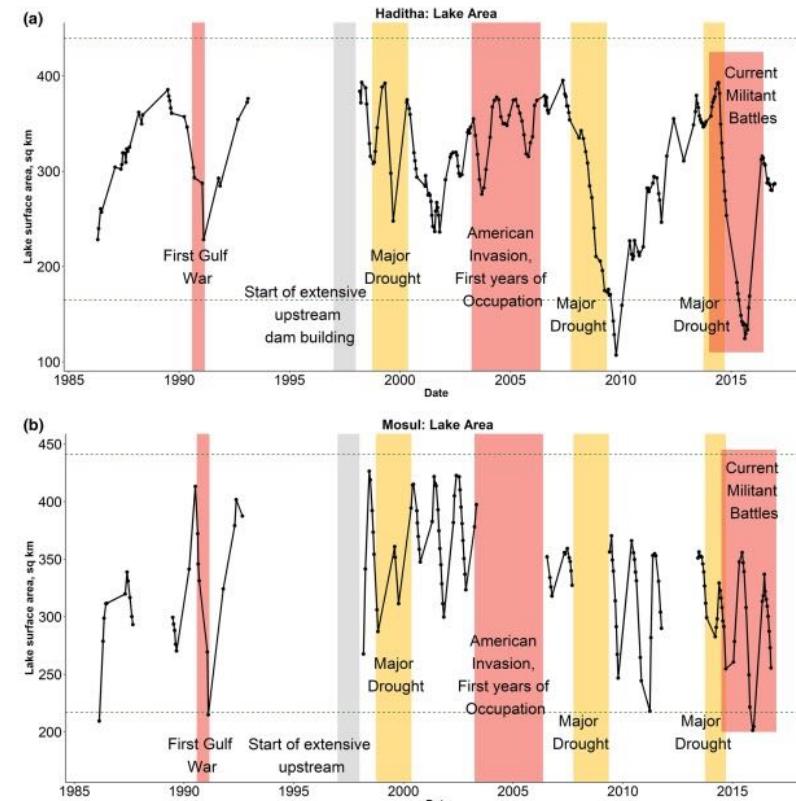
Research Questions:

- Is the resurfacing of archaeological sites a more widespread phenomenon?
- Is it possible to monitor these events by using remote sensing and a reproducible methodology?
- Monitoring might allow a more systematic approach to future rescue activities



How war, drought, and dam management impact water supply in the Tigris and Euphrates Rivers

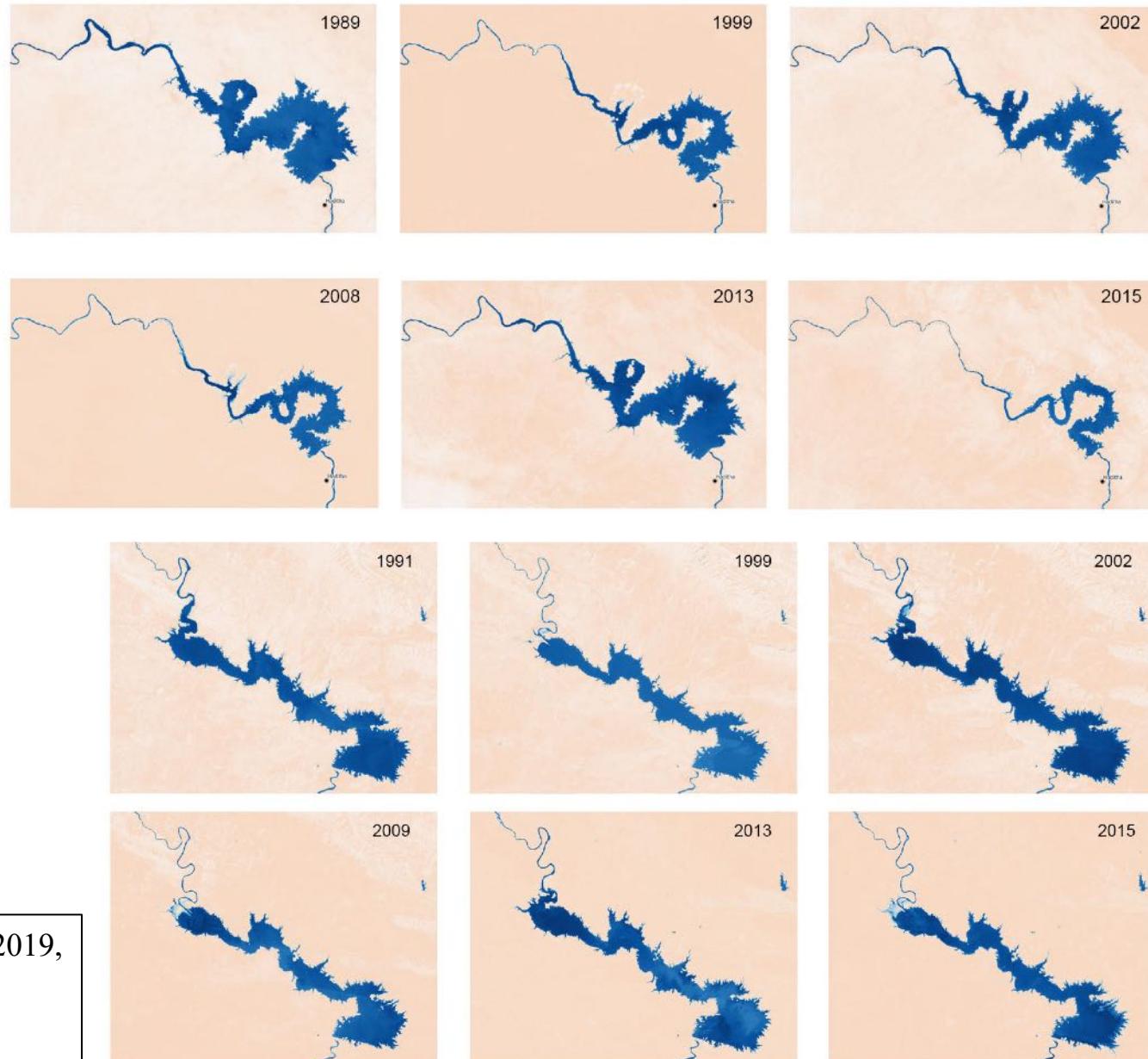
Mejs Hasan, Aaron Moody, Larry Benninger, Heloise Hedlund



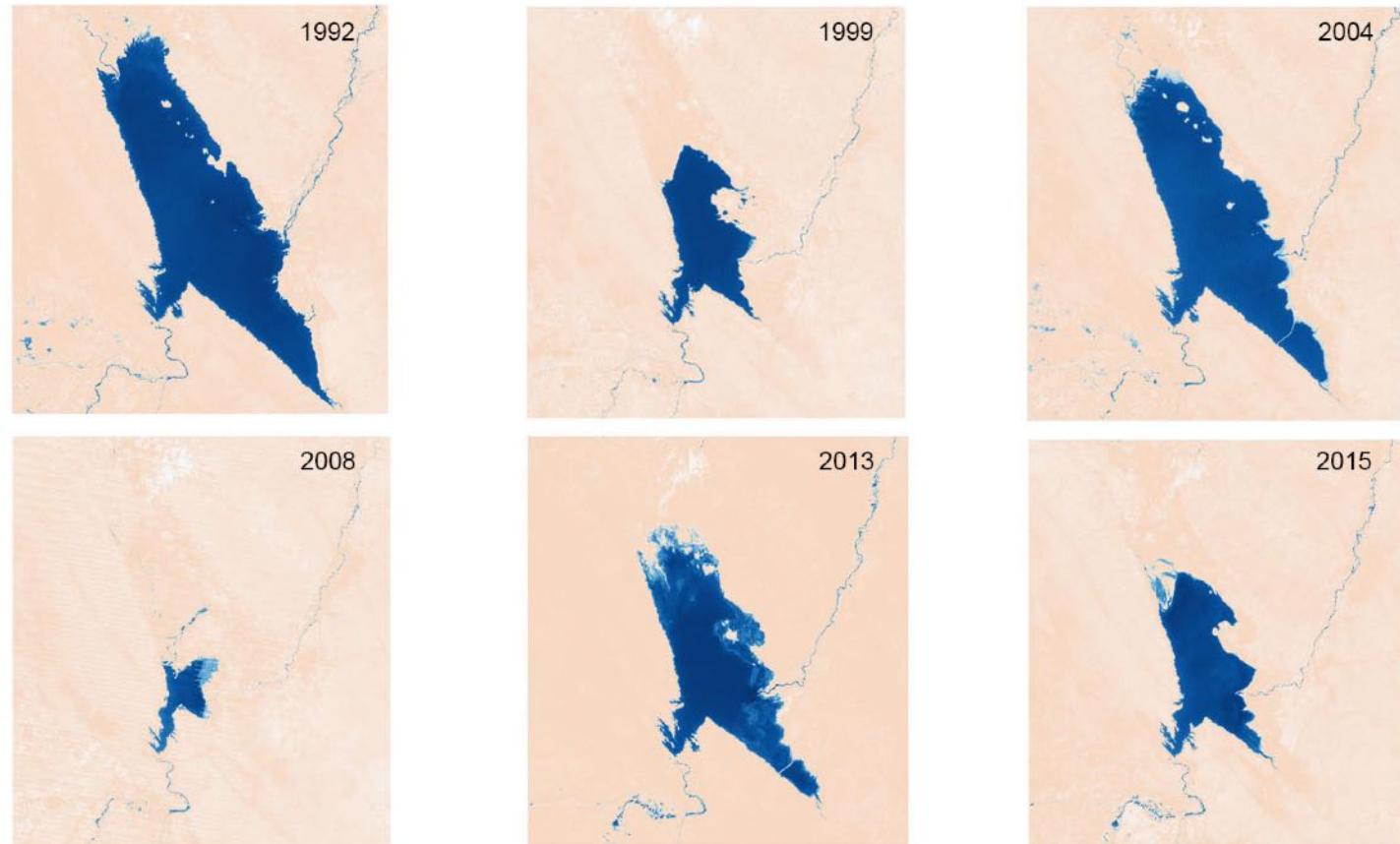
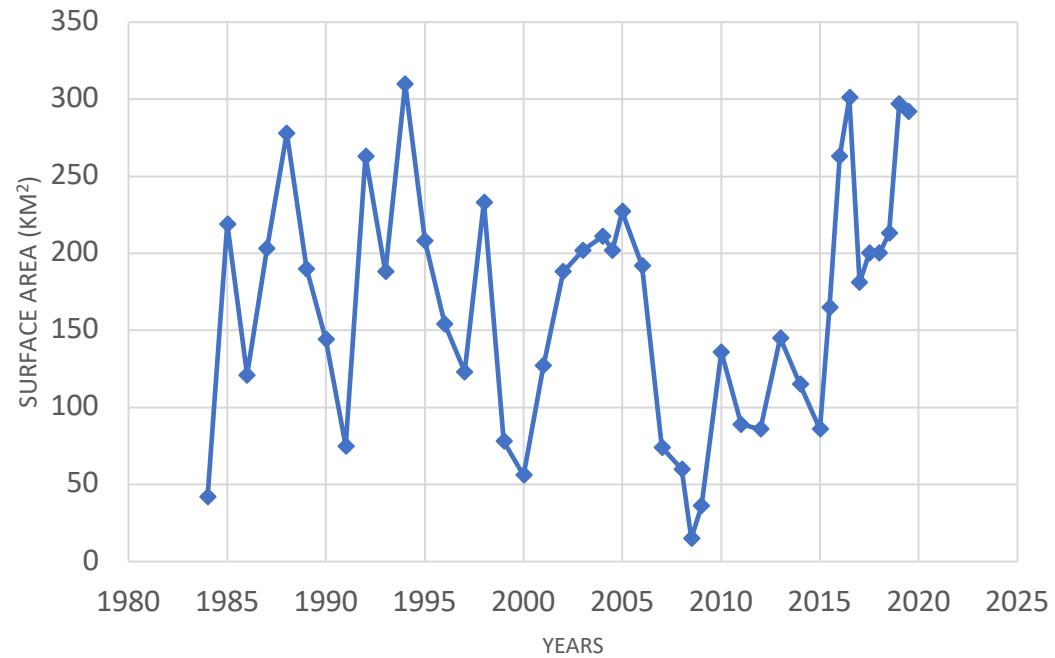
Above: Surface area of Haditha (a) and Mosul (b) reservoirs (Hasan et al. 2019, Fig. 3)

Top Right: NDWI images of Haditha lake surface changes over time.

Bottom Right: NDWI images of Mosul lake surface changes over time.

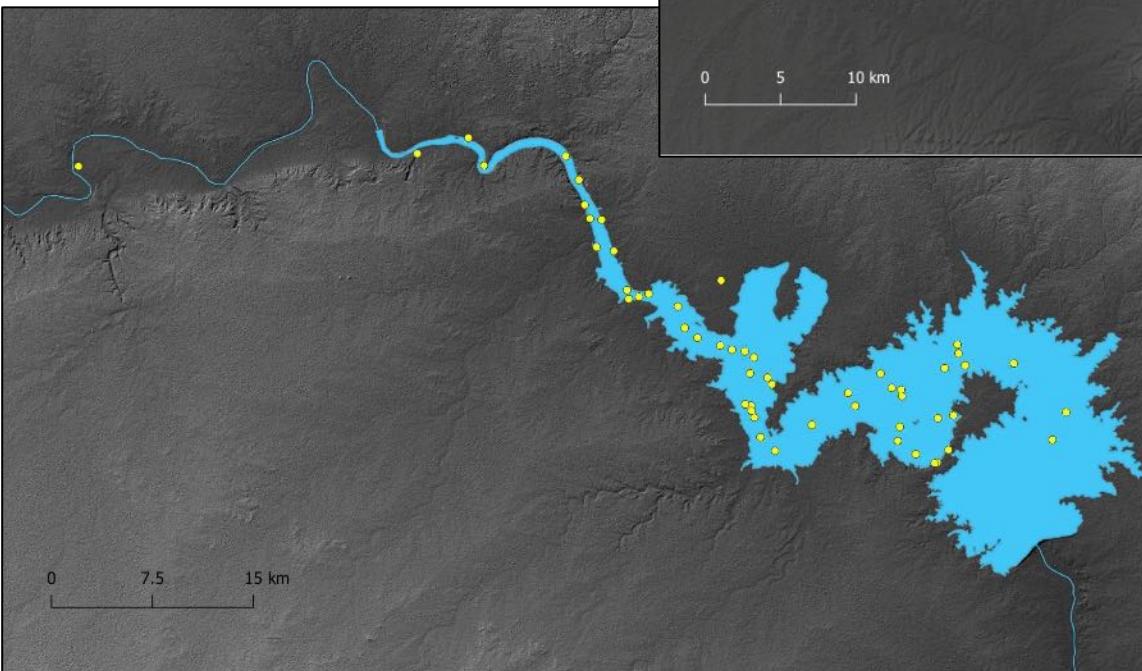
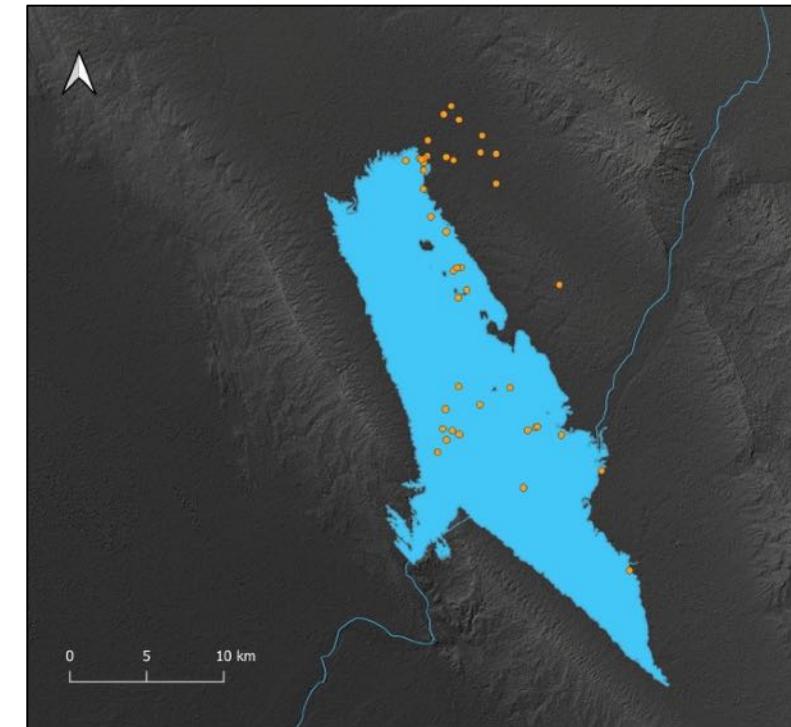
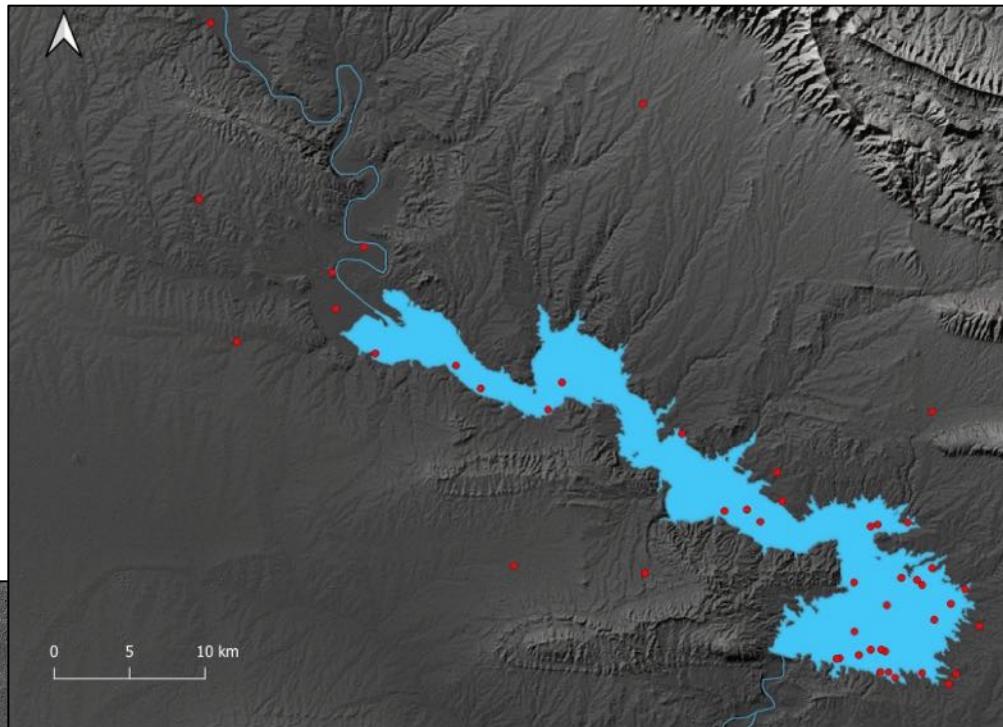
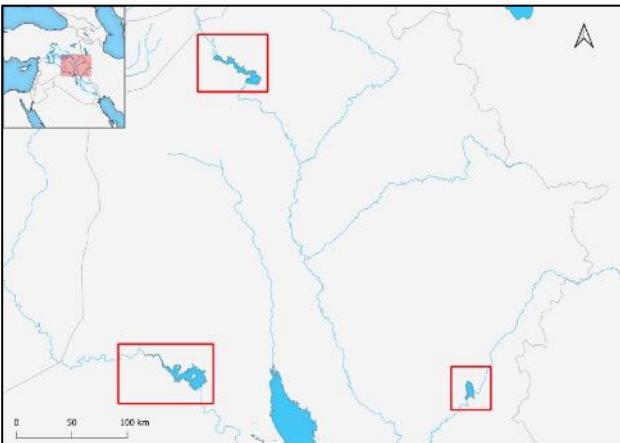


HAMRIN: LAKE AREA



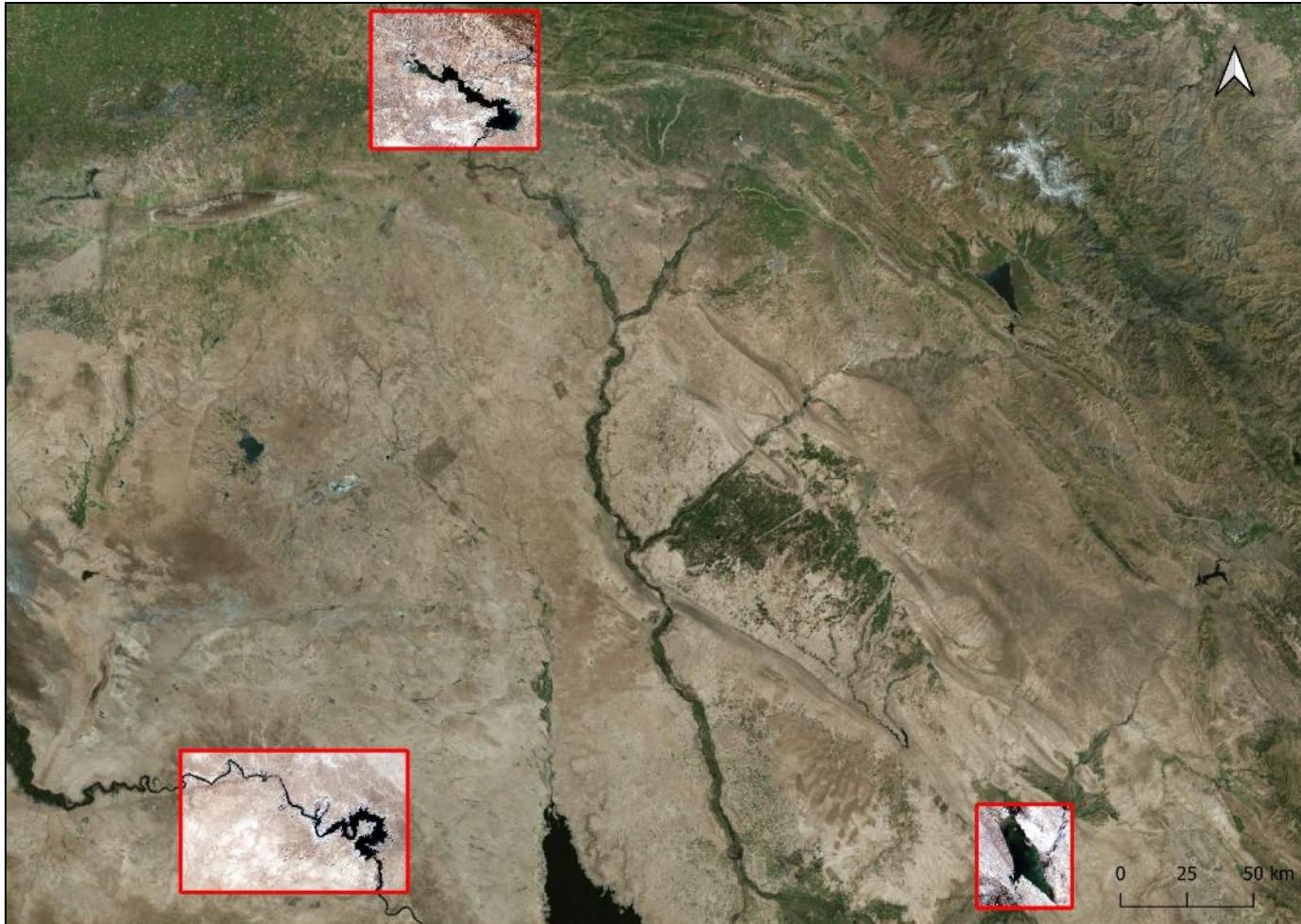
Above: Approximate surface area of Hamrin Lake (data from Landsat and Sentinel-2 NDWI; Background data UN-BGR-ESCWA 2013).

Right: NDWI images of Hamrin lake surface changes over time.



Area	No. Sites
Haditha	53
Mosul	47
Hamrin	42

Study areas and archaeological sites. Starting source of data for all areas were the ANE Placemarks (Pedersen 2010). Left: **Haditha dam** (after al-Shukri 1988) Top left: **Mosul dam** (after Killick-Roaf 1983; Killick-Black 1985; Ball-Black 1987). Top right: **Hamrin dam** (after Postgate-Watson 1979; Roaf-Postgate 1981).



Satellite	No. Images per area
Landsat 2	1 (Hamrin only)
Landsat 5	18-19
Landsat 7	14
Landsat 8	7
Sentinel-2	5

1984-1998
• Landsat 5

1999-2012
• Landsat 7

2013-2019
• Landsat 8

2015-2019
• Sentinel-2

Spectral Indexes:

- Quantitative measures obtained by spectral combinations of two or more bands , based on spectral properties of features of interest
- Most common for water bodies identification is the Normalized Difference Water Index (NDWI)

International Journal of Remote Sensing
Vol. 27, No. 14, 20 July 2006, 3025–3033



Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery

HANQIU XU

College of Environment and Resources, Fuzhou University; Key Laboratory of Data Mining and Sharing, China's Ministry of Education; Fuzhou, Fujian 350002, China

INT. J. REMOTE SENSING, 1996, VOL. 17, NO. 7, 1425–1432

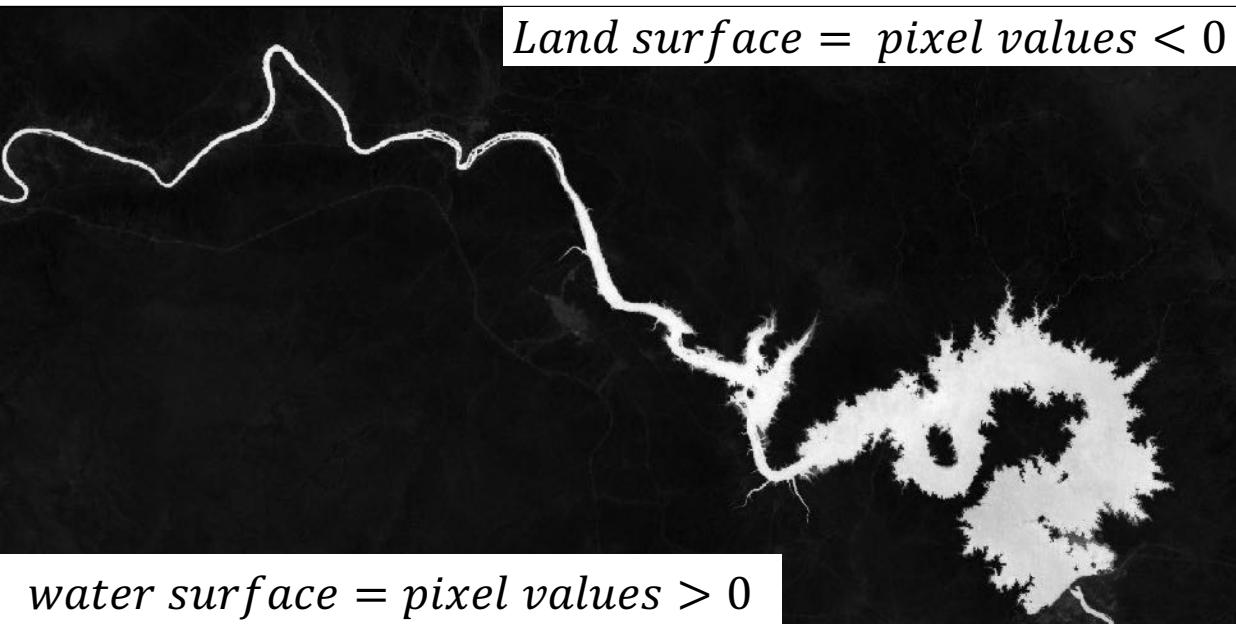
The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features

S. K. McFEETERS

Center for Advanced Land Management Information Technologies (CALMIT), Conservation and Survey Division, University of Nebraska-Lincoln, 113 Nebraska Hall, Lincoln, NE 68588-0517, U.S.A.

$$NDWI^{(McFeeters)} = \frac{(Green) - (NIR)}{(Green) + (NIR)}$$

$$NDWI^{(Xu)} = \frac{(Green) - (SWIR)}{(Green) + (SWIR)}$$



$$NDWI^{(Xu)} = \frac{(Green) + (SWIR)}{(Green) - (SWIR)}$$

Assessing methods of identifying open water bodies using Landsat 8 OLI imagery

Zhaofei Liu¹ · Zhijun Yao¹ · Rui Wang¹

Pol. J. Environ. Stud. Vol. 29, No. 2 (2020), 1–11
DOI: 10.15244/pjoes/110447

ONLINE PUBLICATION DATE: 2019-07-17

Advantages and Use:

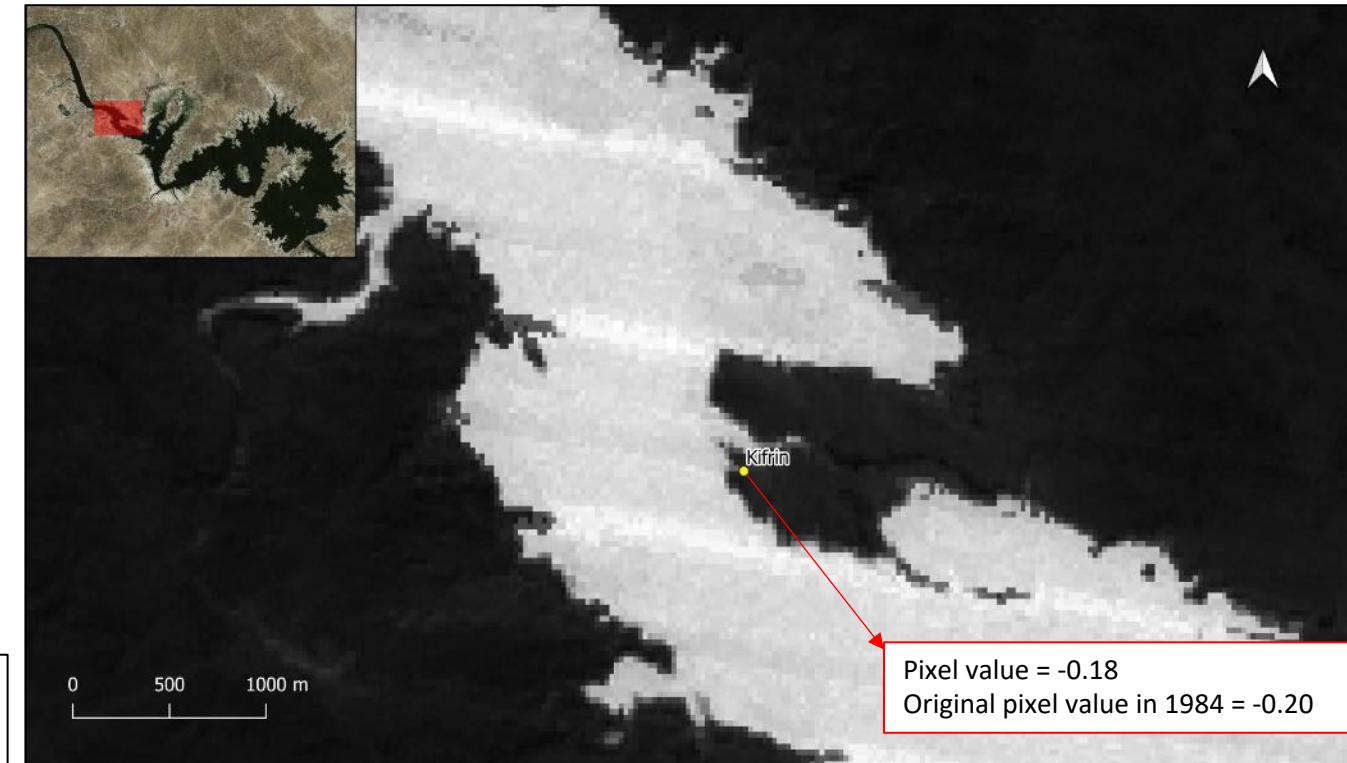
- Better discrimination between water and built-up areas thanks to the SWIR band
- SWIR performs generally better than the NIR if there is no dense vegetation around the water body
- If the location of a site has pixel value < 0, then it probably resurfaced at the time the image was taken

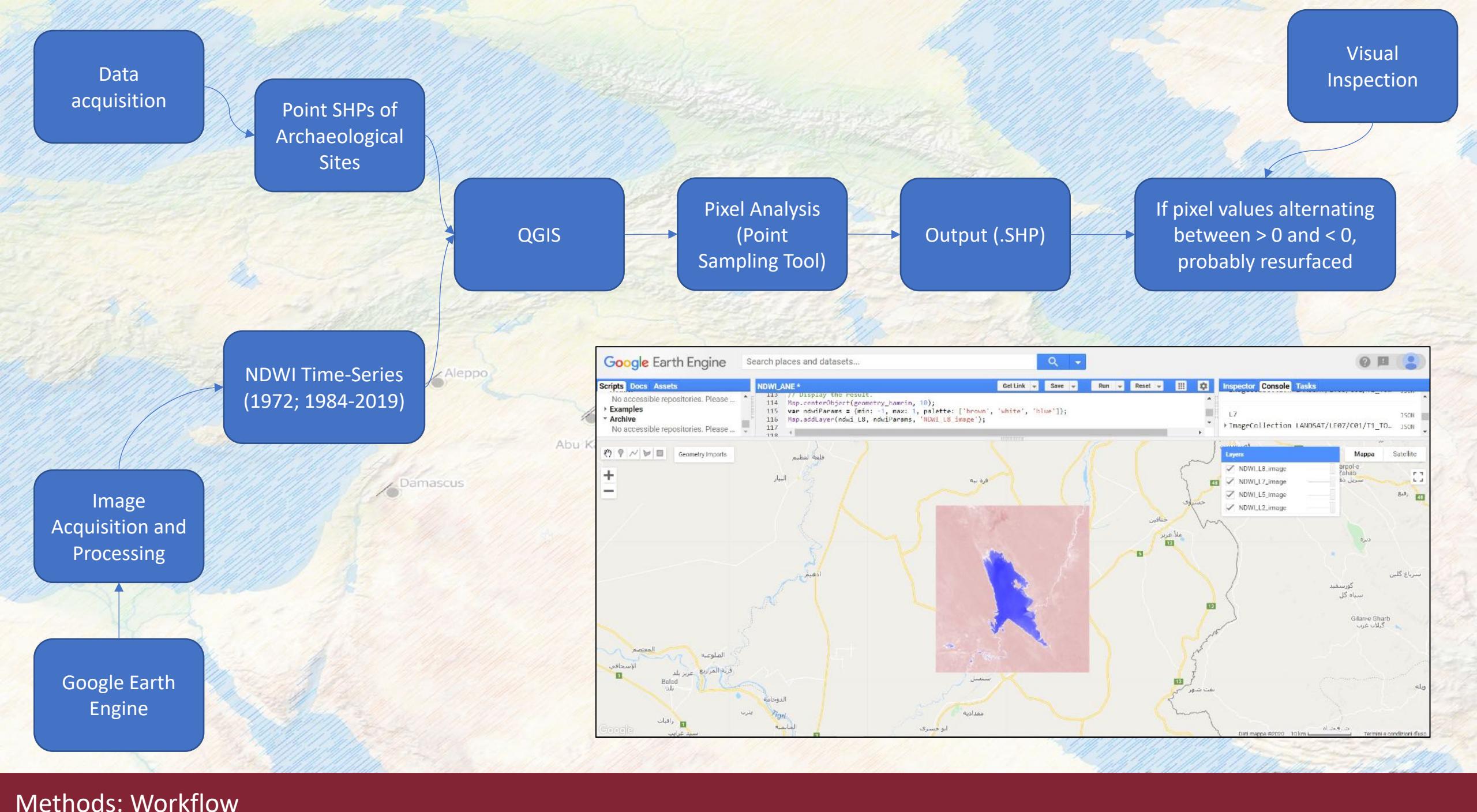
Landsat 7 NDWI image (July 2011)
with the pixel value of Kifrin

Original Research

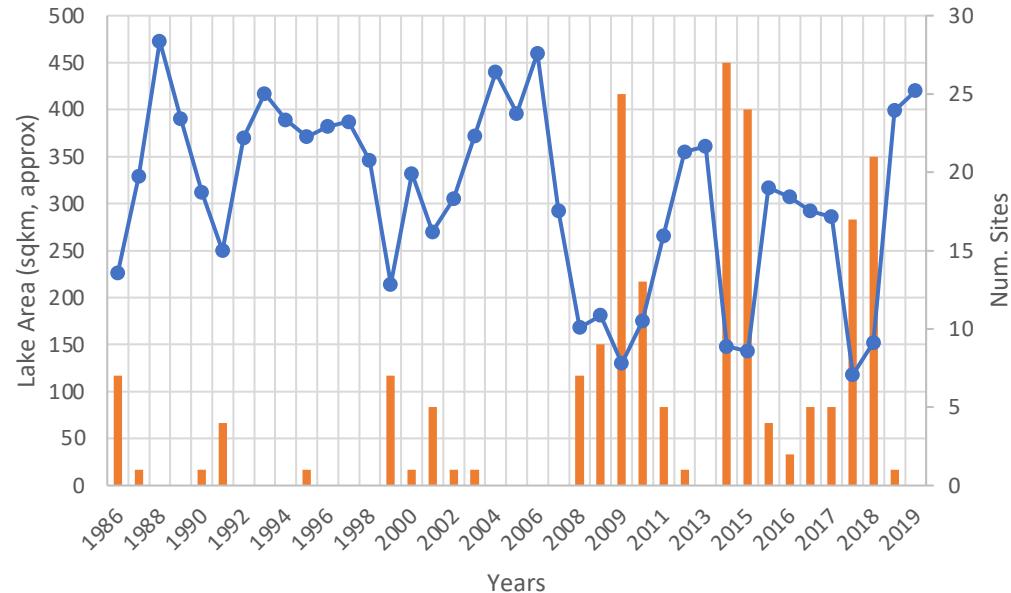
Water Body Detection Analysis Using NDWI Indices Derived from Landsat-8 OLI

Emre Özlekhan*

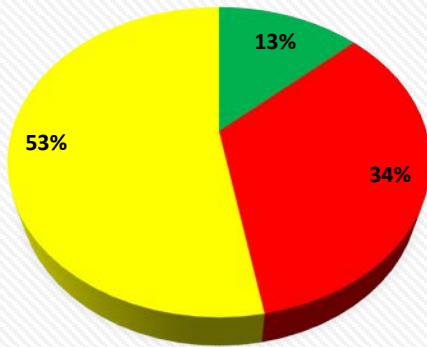




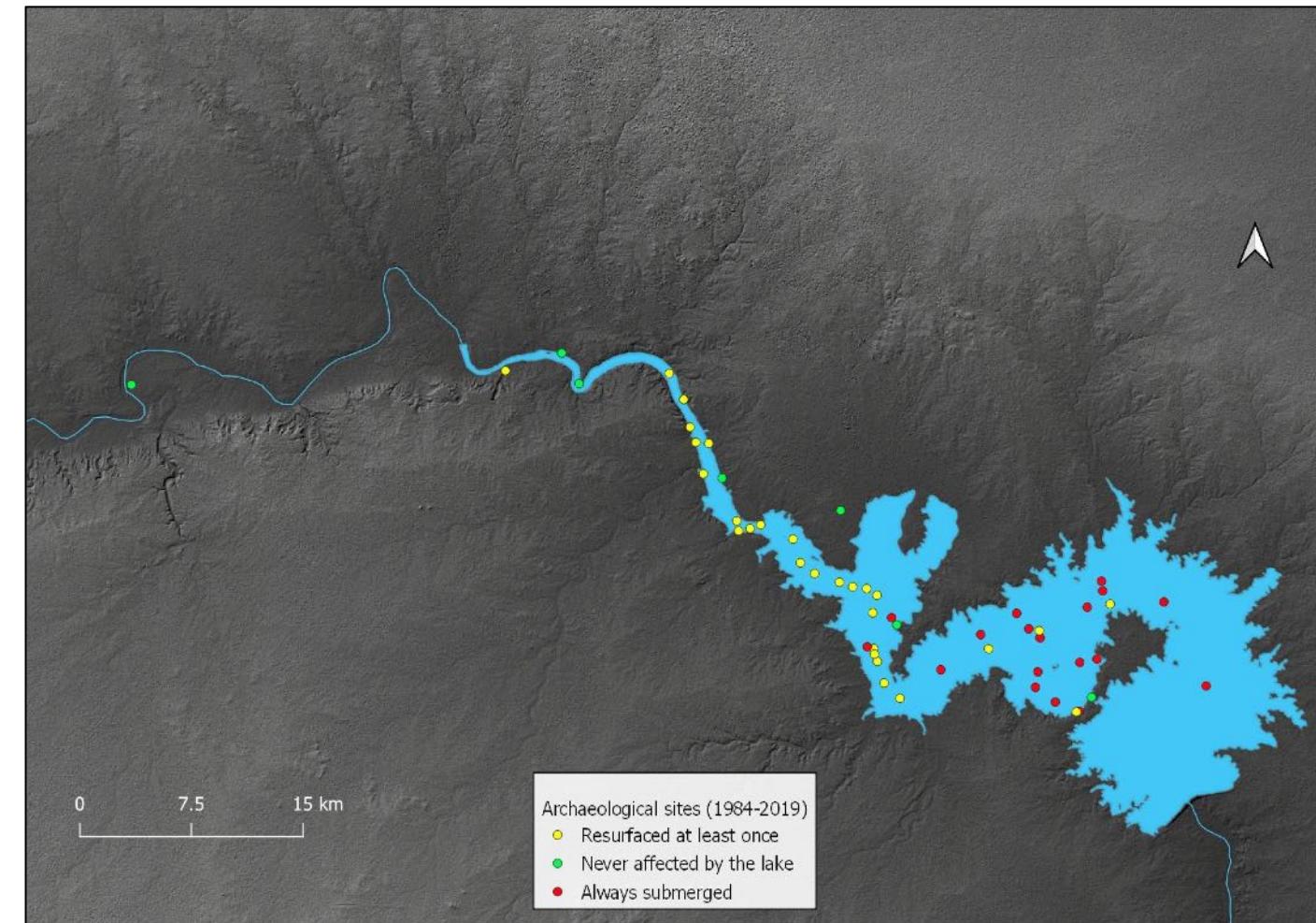
Haditha Dam – Lake Extent and Resurfaced Sites

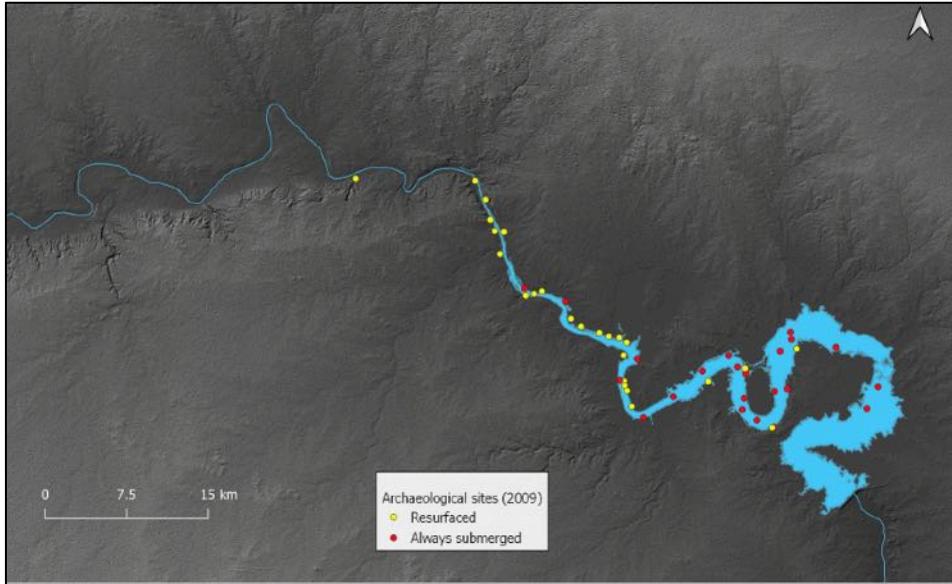


Haditha Dam – Archaeological Sites

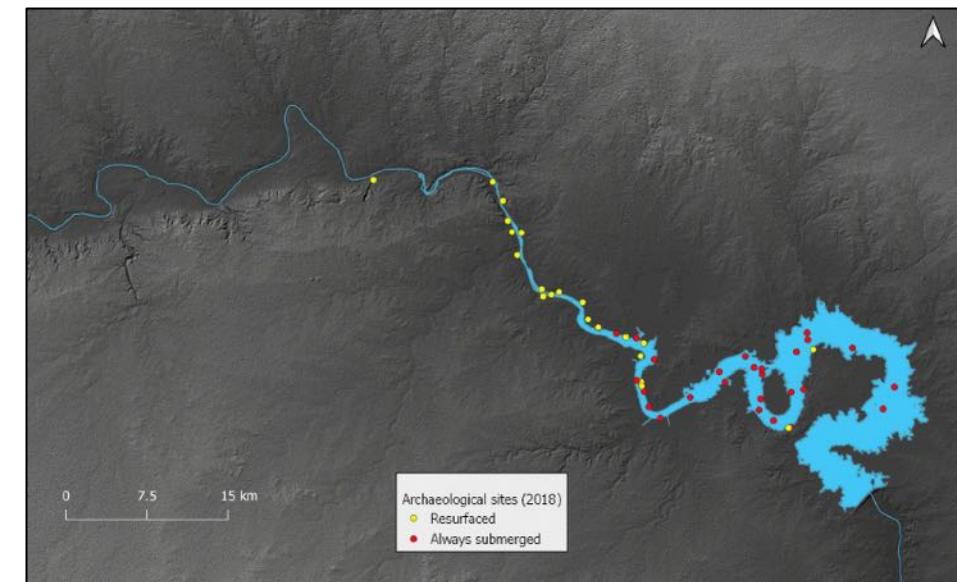
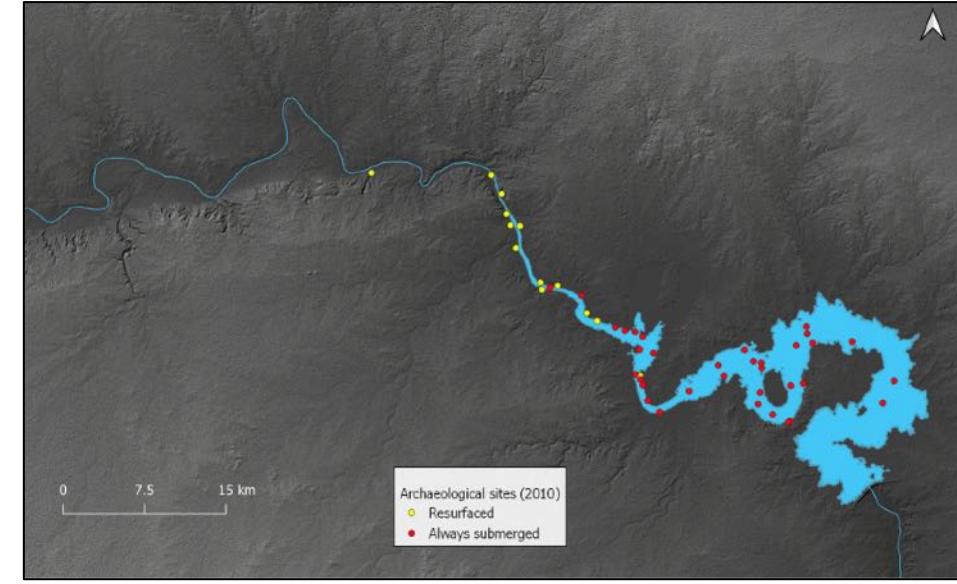
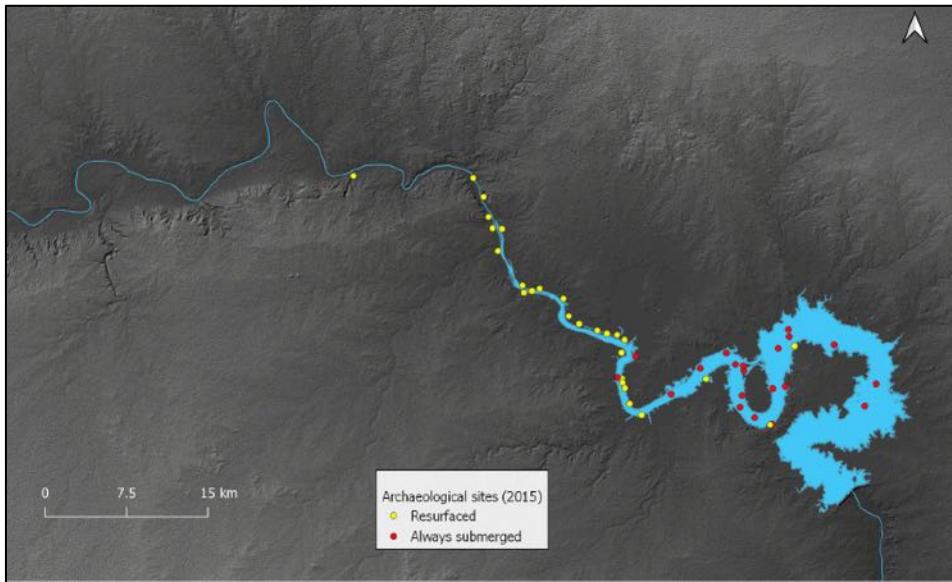


■ Sites Never Affected ■ Sites Always Submerged ■ Sites Resurfaced

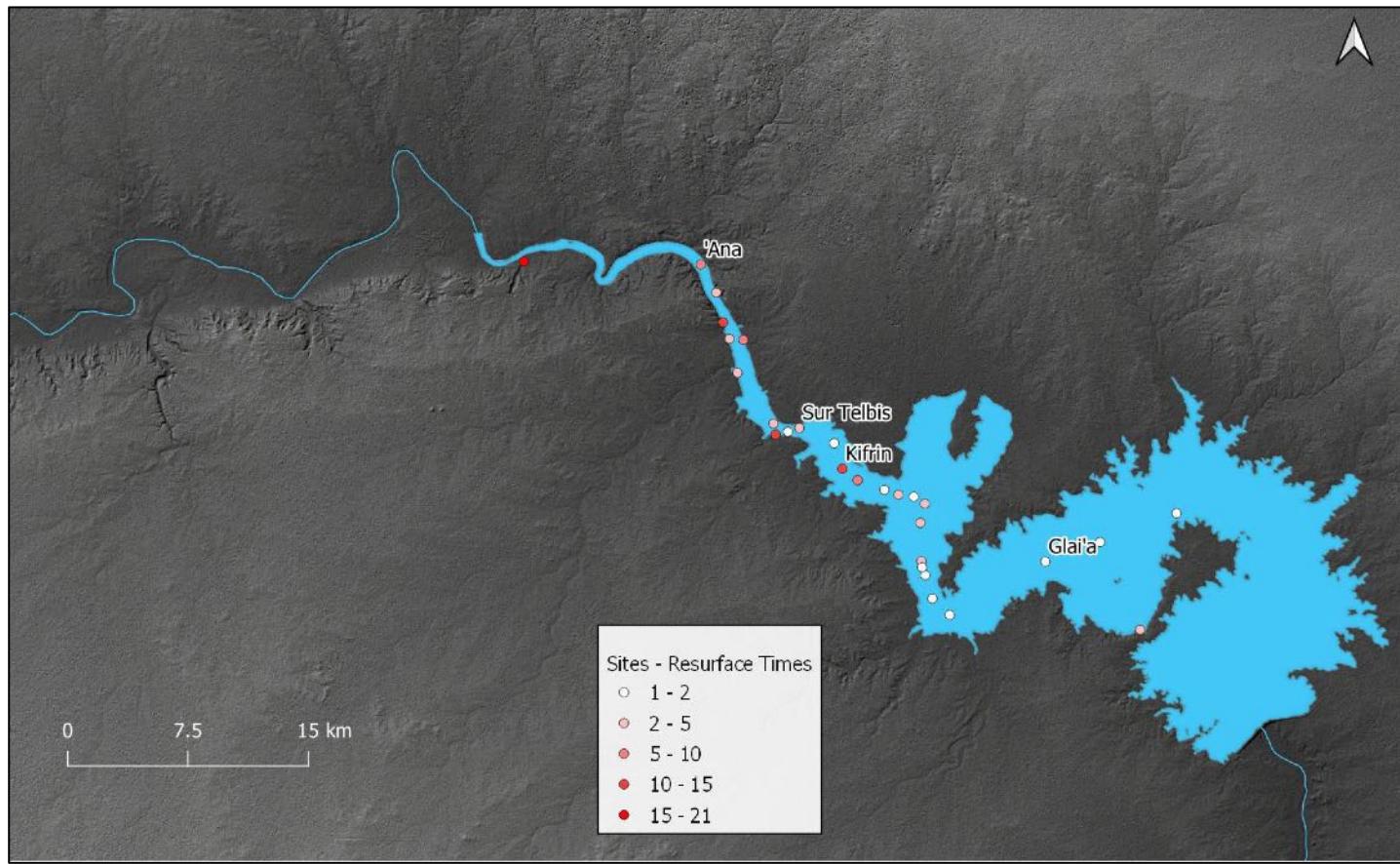
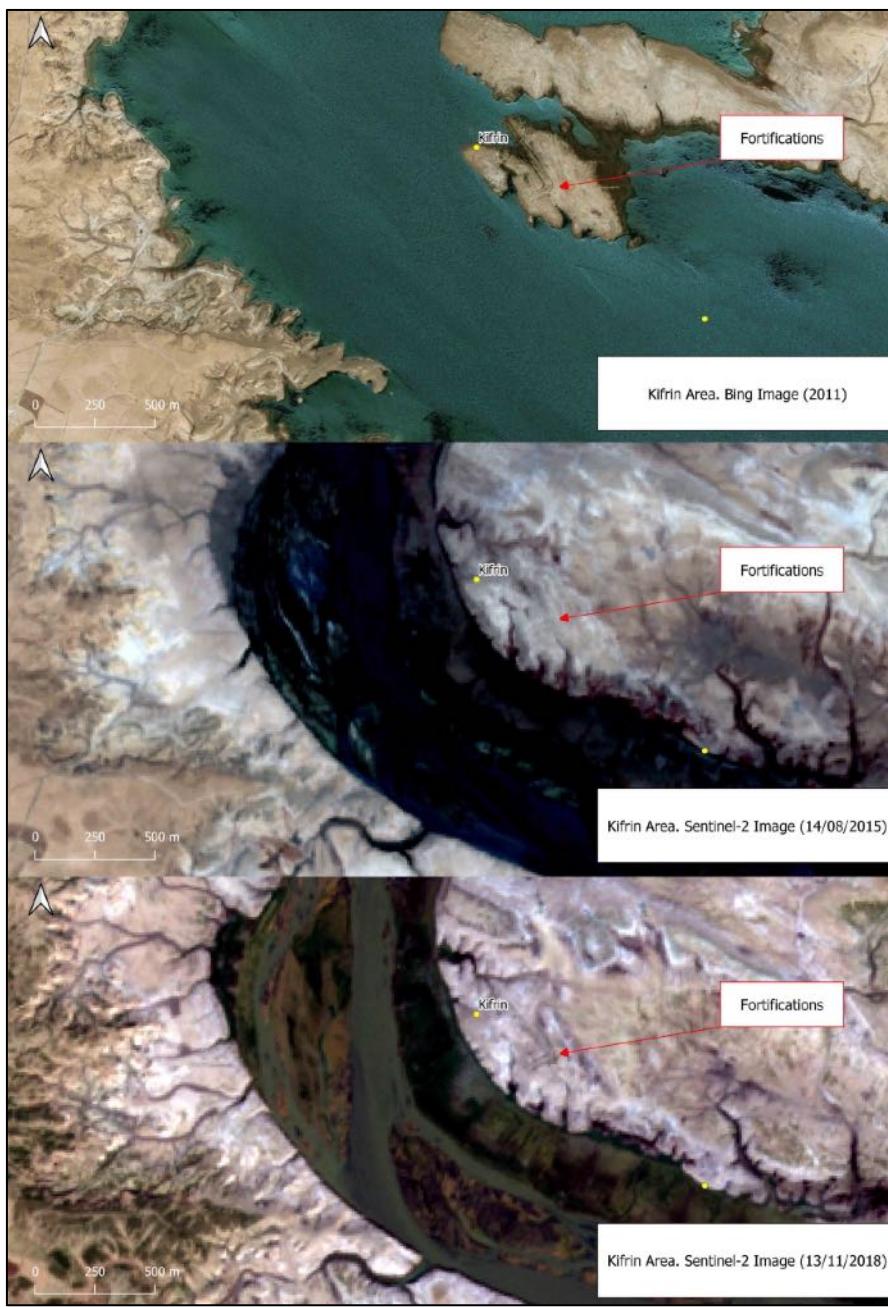




Years	No. Sites Resurfaced
2009	25
2010	13
2015	27
2018	21

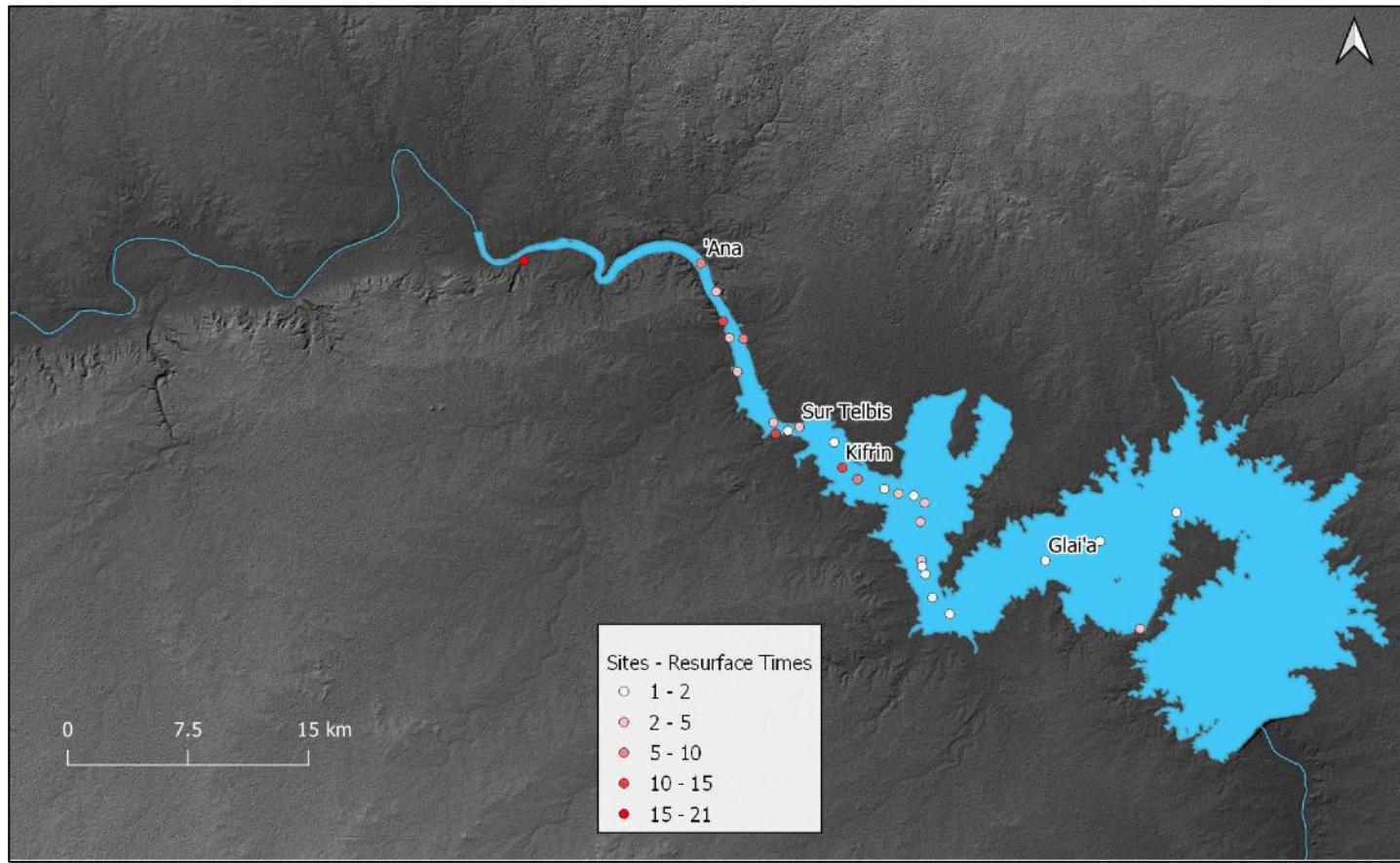


Results: Haditha Dam – Sample Years



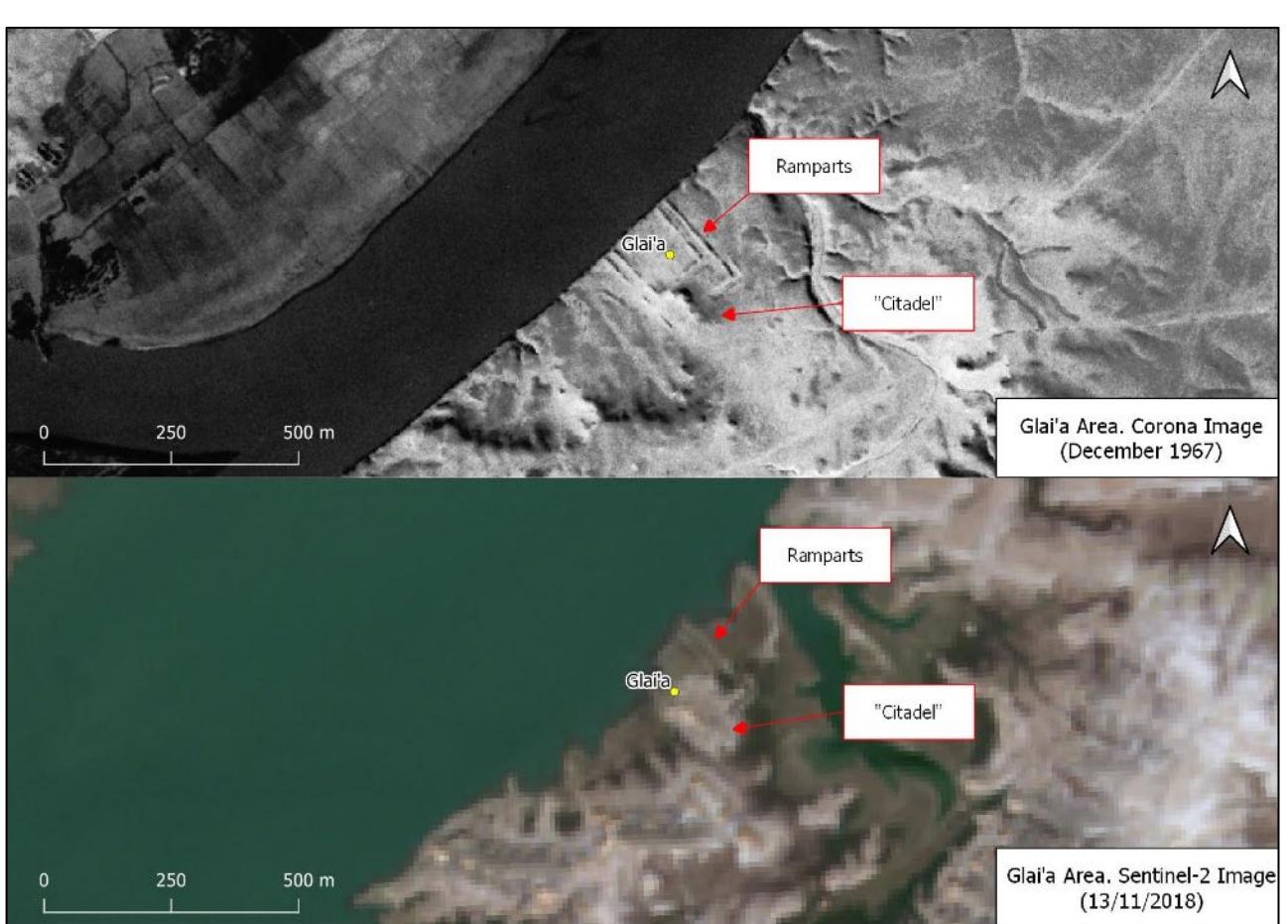
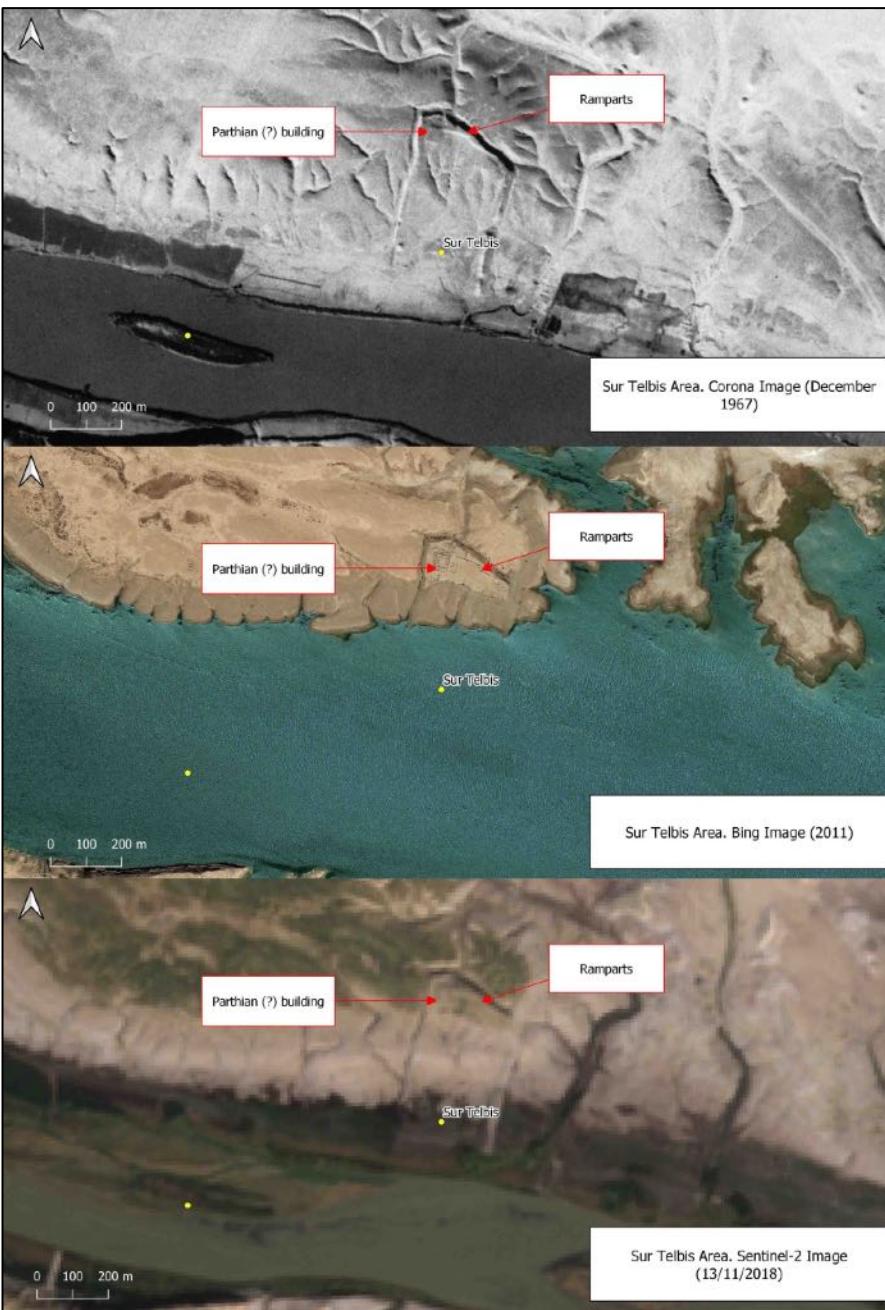
Year	Pixel Value (Kifrin)
1984	- 0.20
2011	- 0.18
2015	- 0.20
2018	- 0.23

Results: Haditha Dam – Sample Sites - Kifrin



Year	Pixel Value ('Ana)
1984	- 0.20
2018	- 0.24

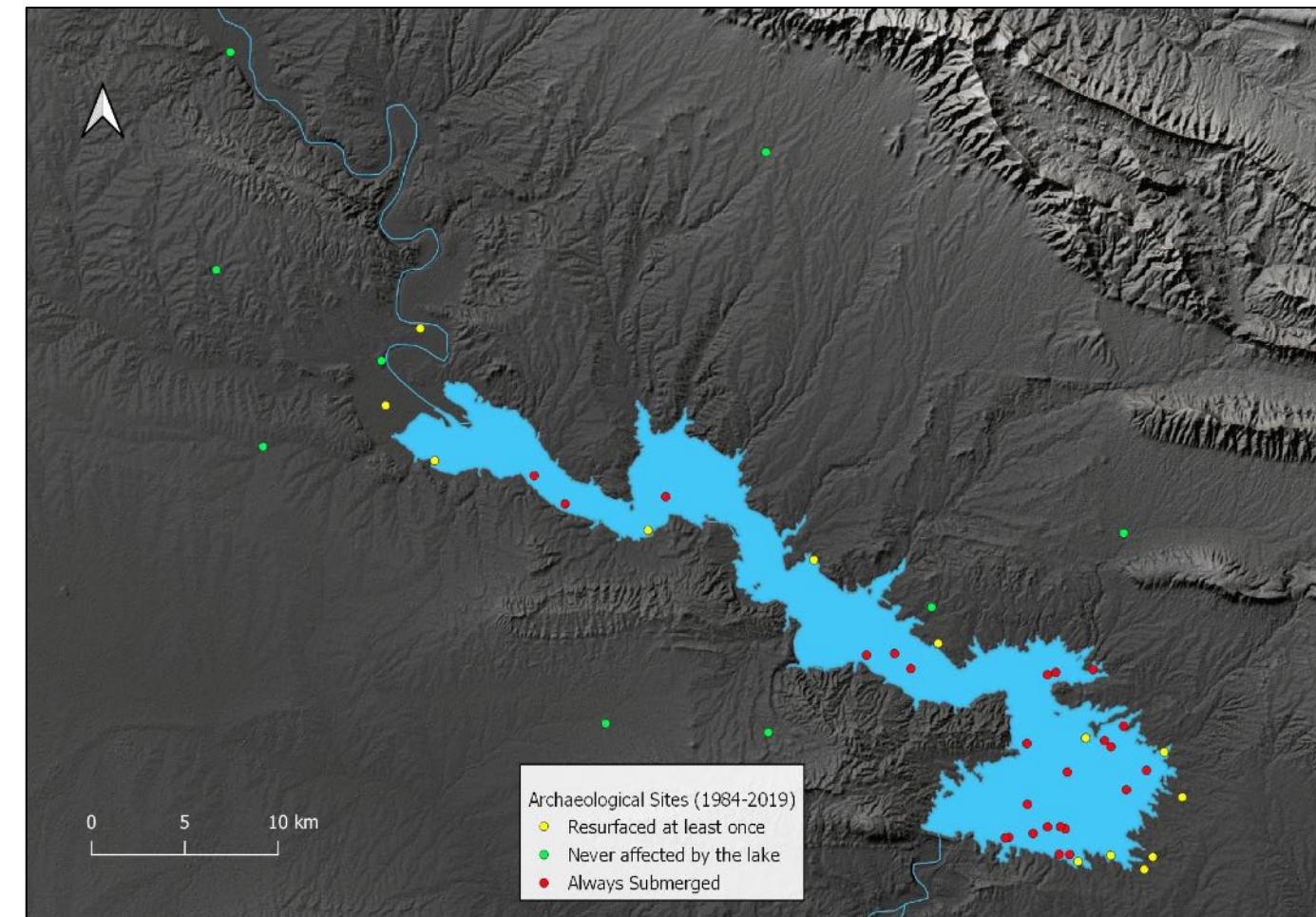
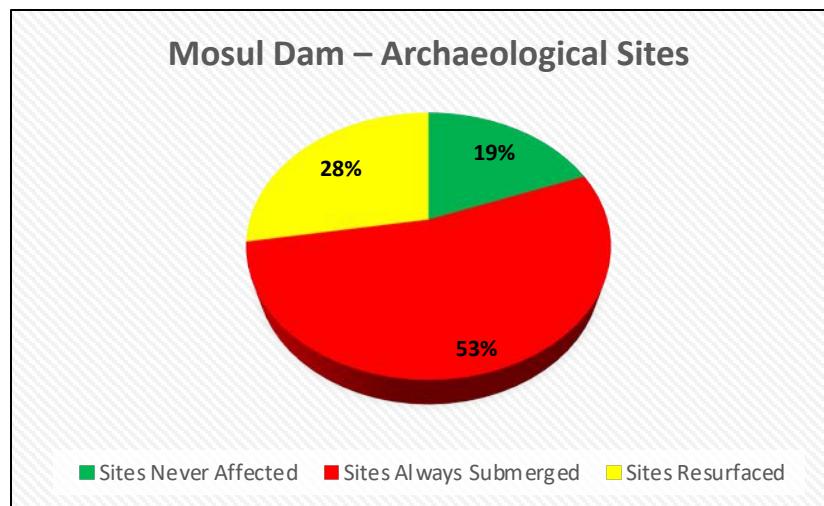
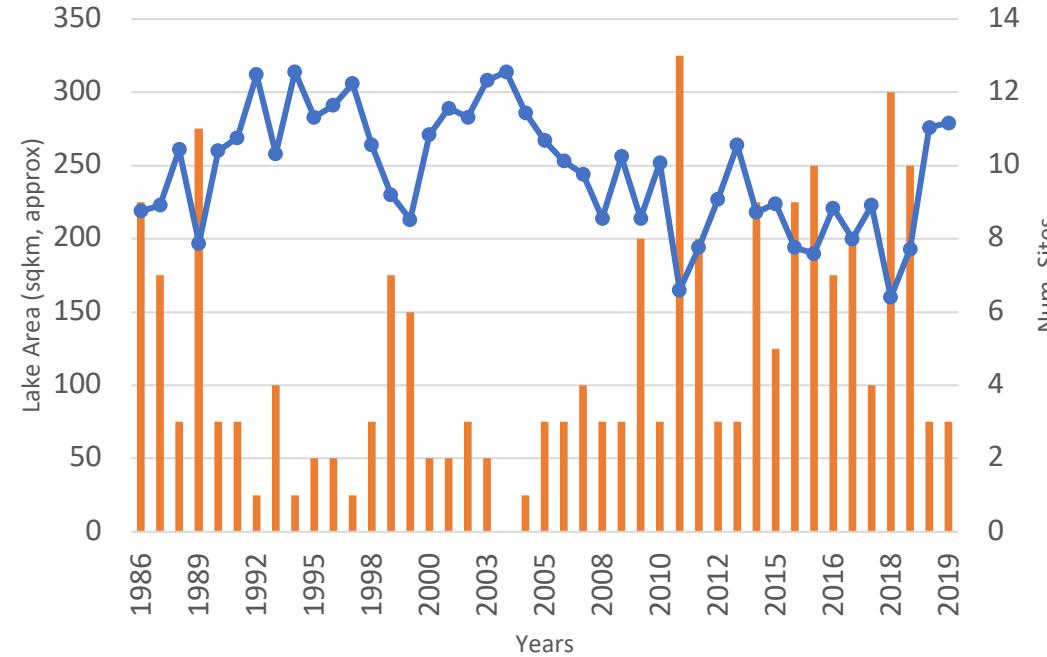
Results: Haditha Dam – Sample Sites

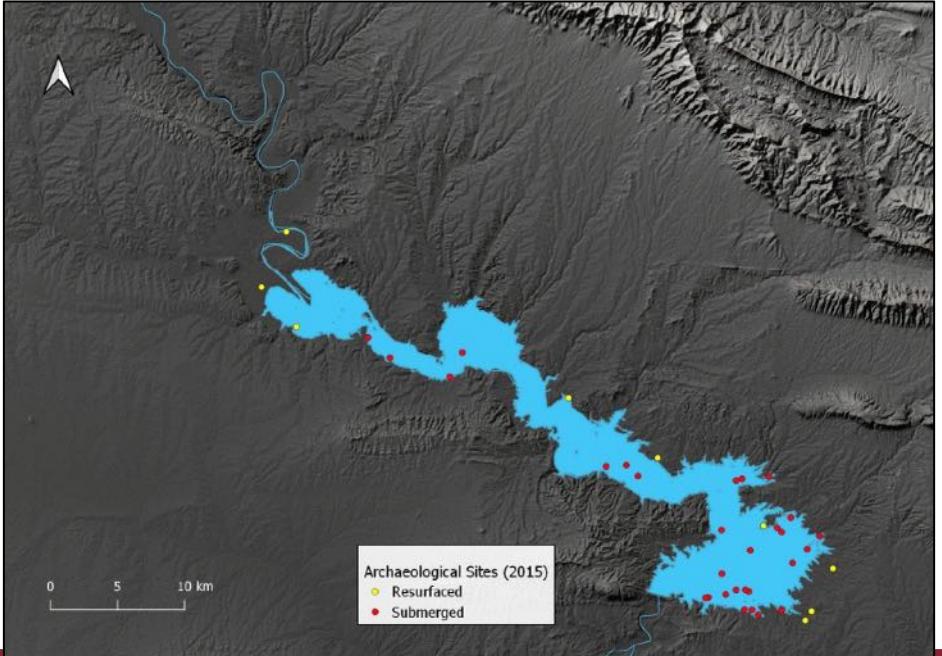
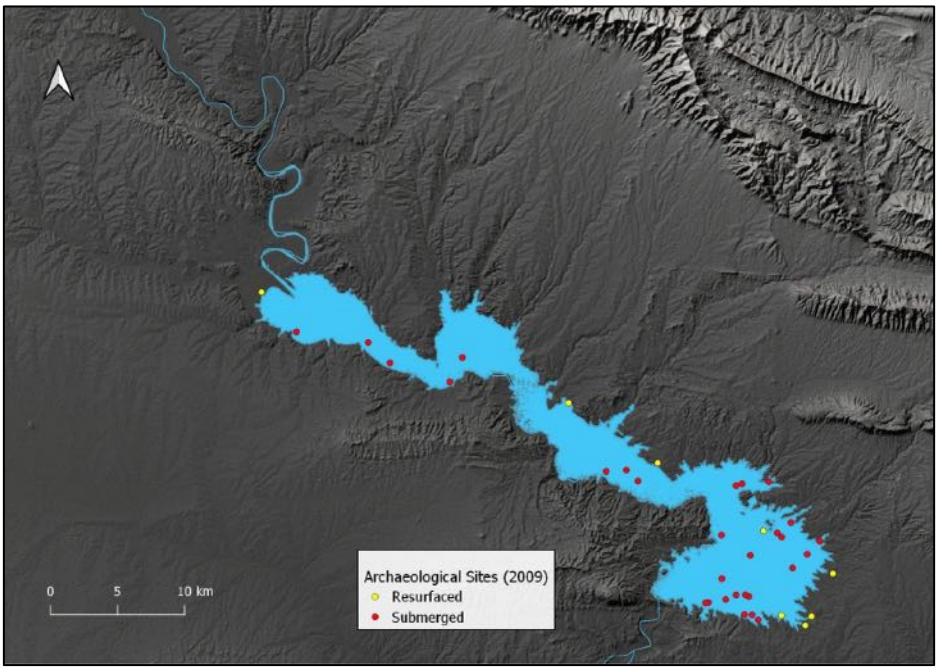


Year	Pixel Value (Sur Telbis)	Pixel Value (Glai'a)
1984	- 0.22	- 0.23
2018	- 0.24	- 0.15

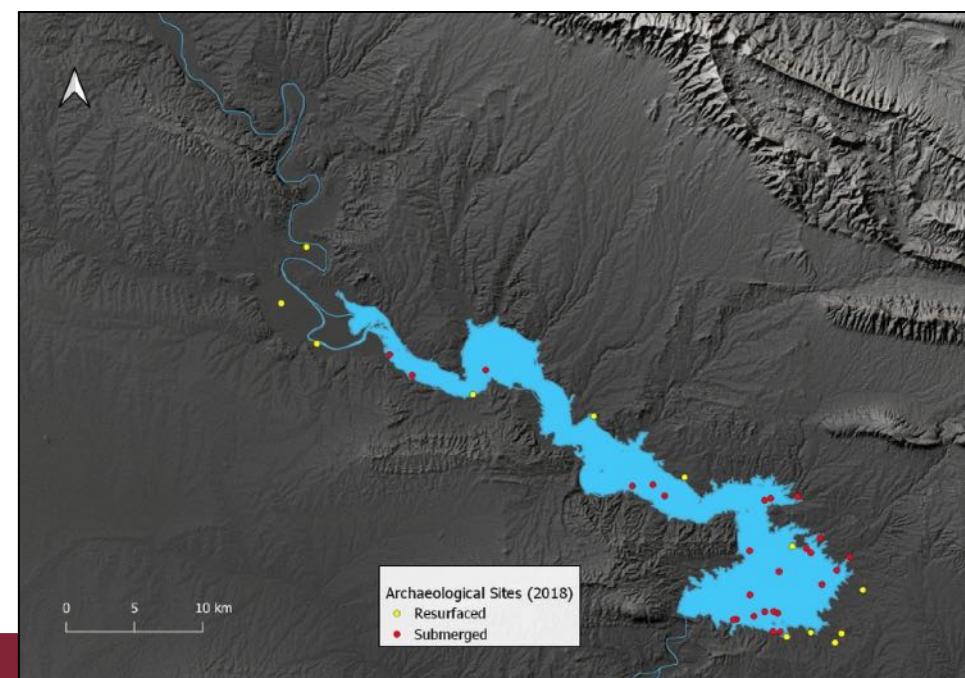
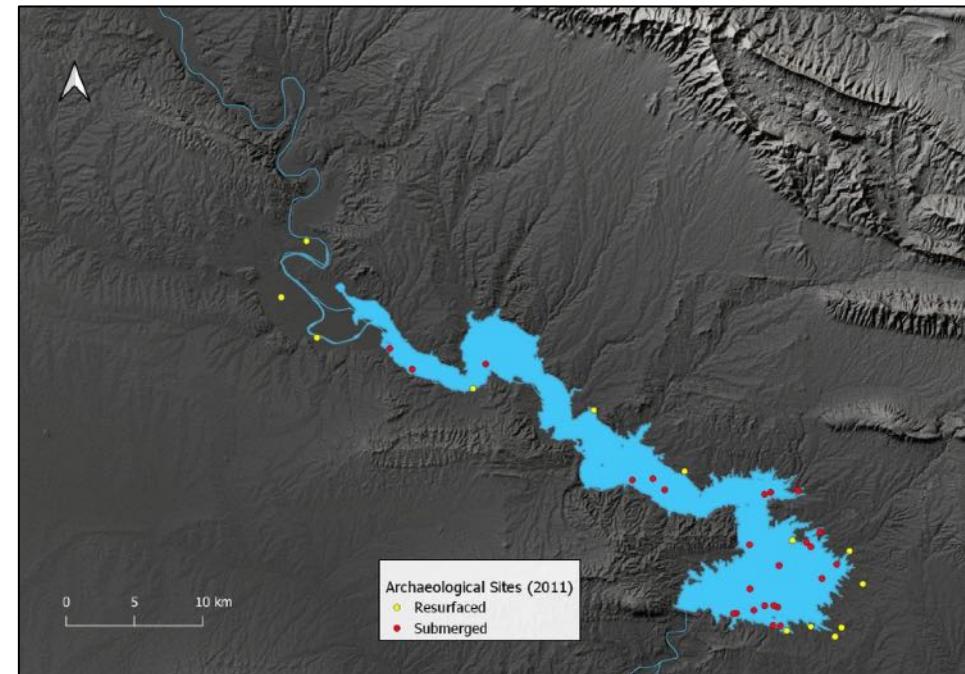
Results: Haditha Dam – Sample Sites – Sur Telbis, Glai'a

Mosul Dam – Lake Extent and Resurfaced Sites

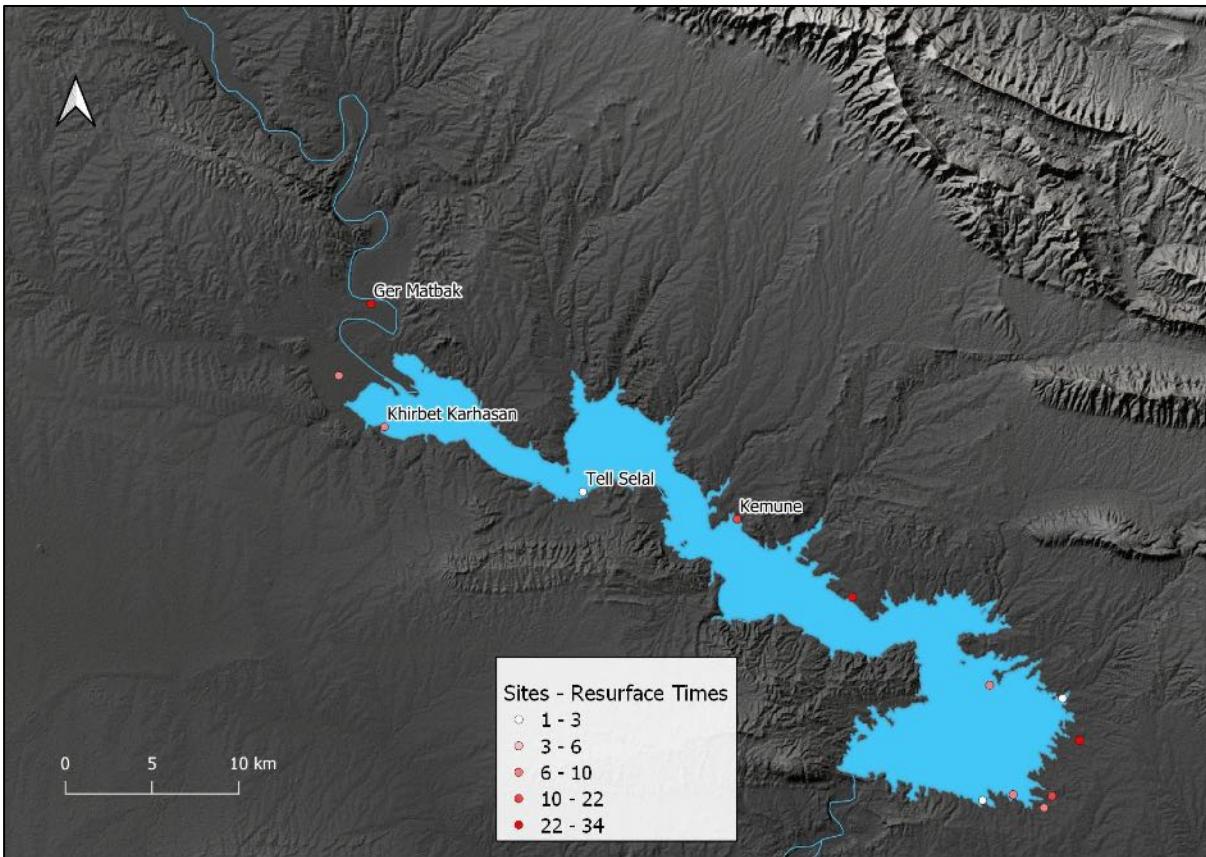




Years	No. Sites Resurfaced
2009	8
2011	13
2015	9
2018	12



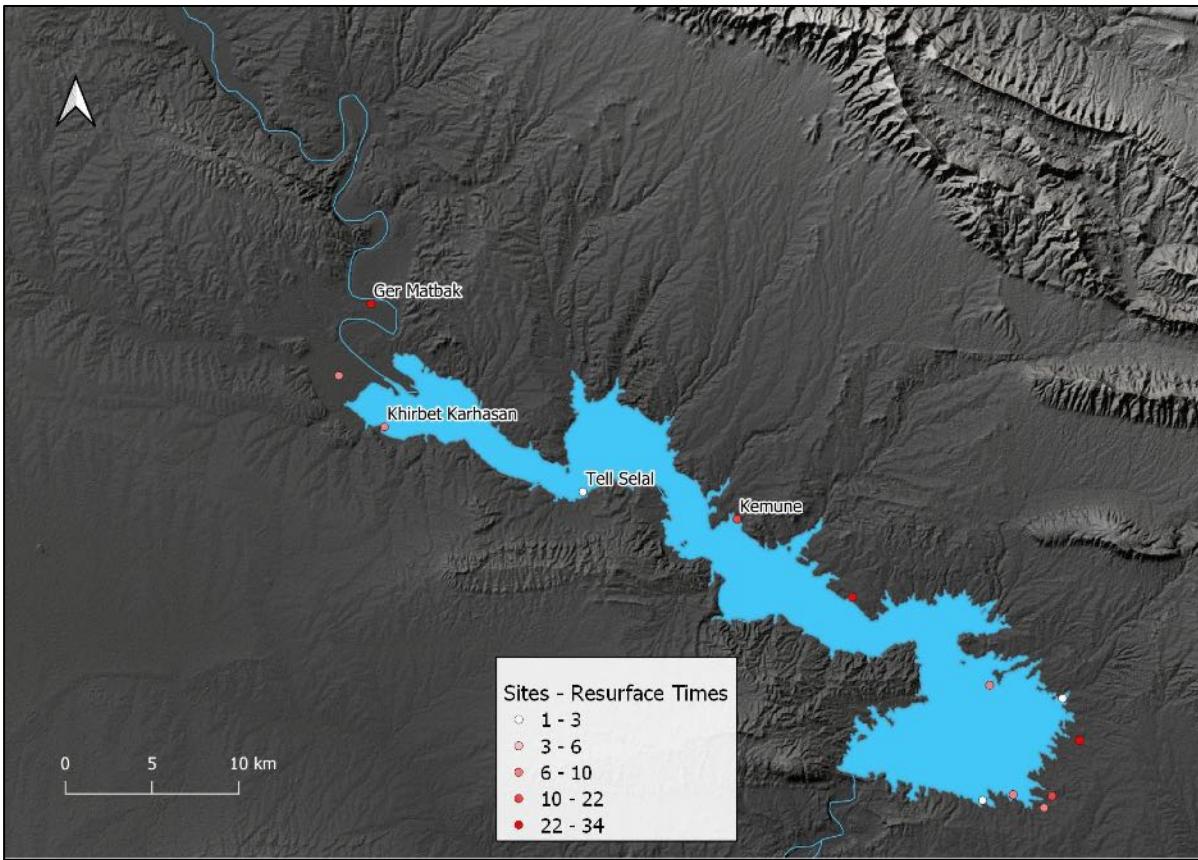
Results: Mosul Dam – Sample Years



Year	Pixel Value (Tell Ger Matbak)
1984	- 0.29
2011	- 0.23
2015	- 0.26
2018	- 0.29



Results: Mosul Dam – Sample Sites



Year	Pixel Value (Kemune)
1984	- 0.27
2011	- 0.17
2015	- 0.13
2018	- 0.18



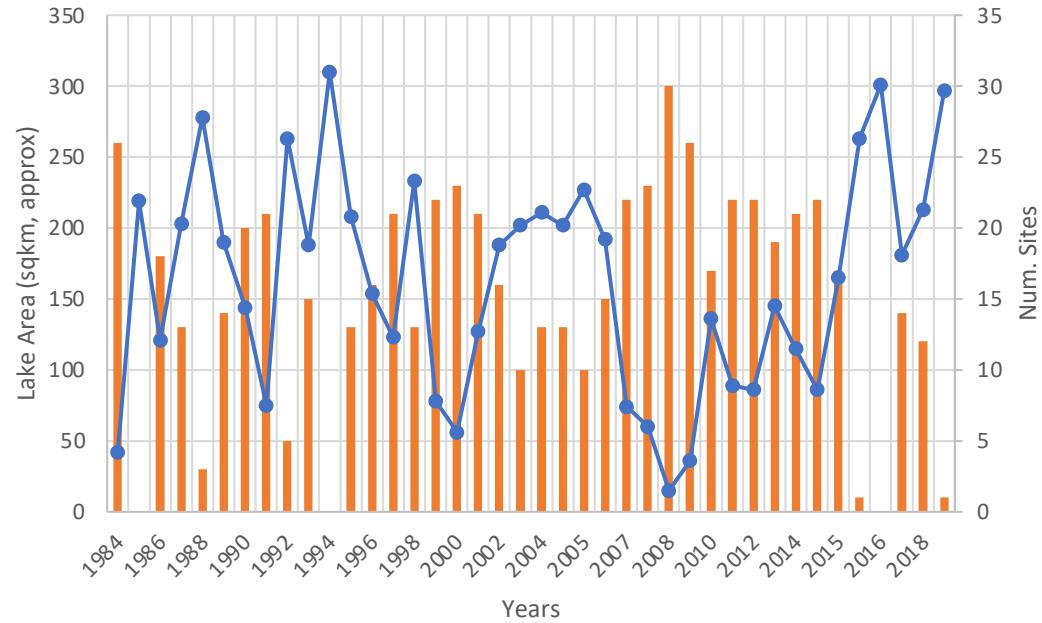
Results: Mosul Dam – Sample Sites



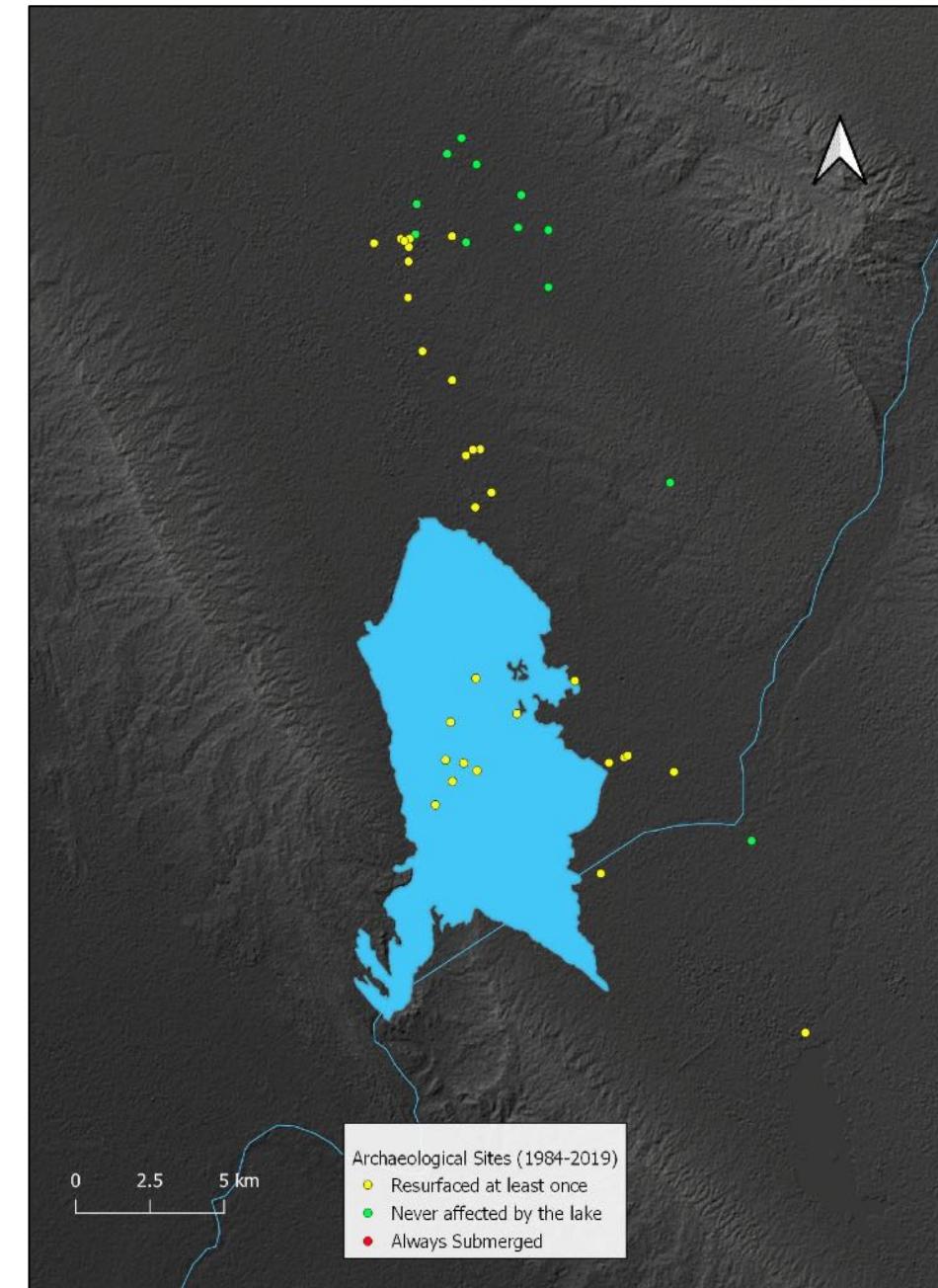
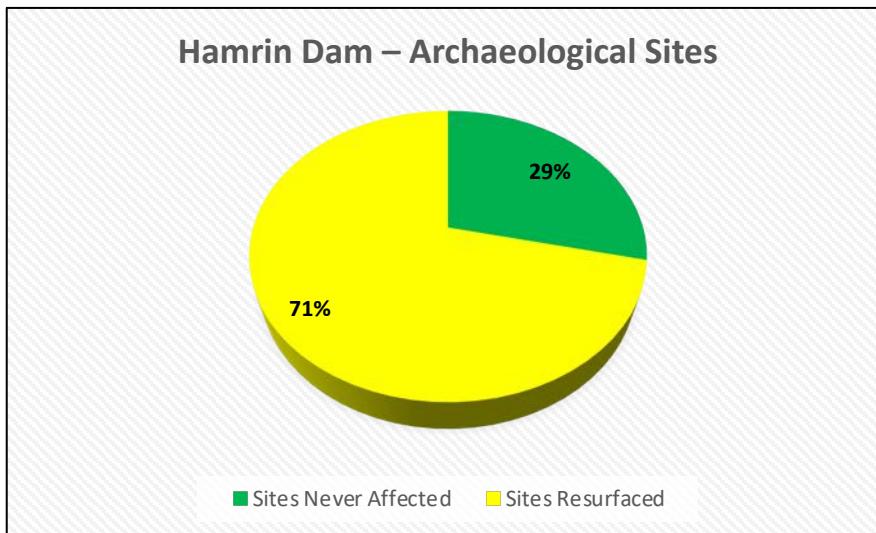
Year	Pixel Value (Tell Selal)	Pixel Value (K. Kharasan)
1984	- 0.31	- 0.26
2018	- 0.24	- 0.18

Results: Mosul Dam – Sample Sites

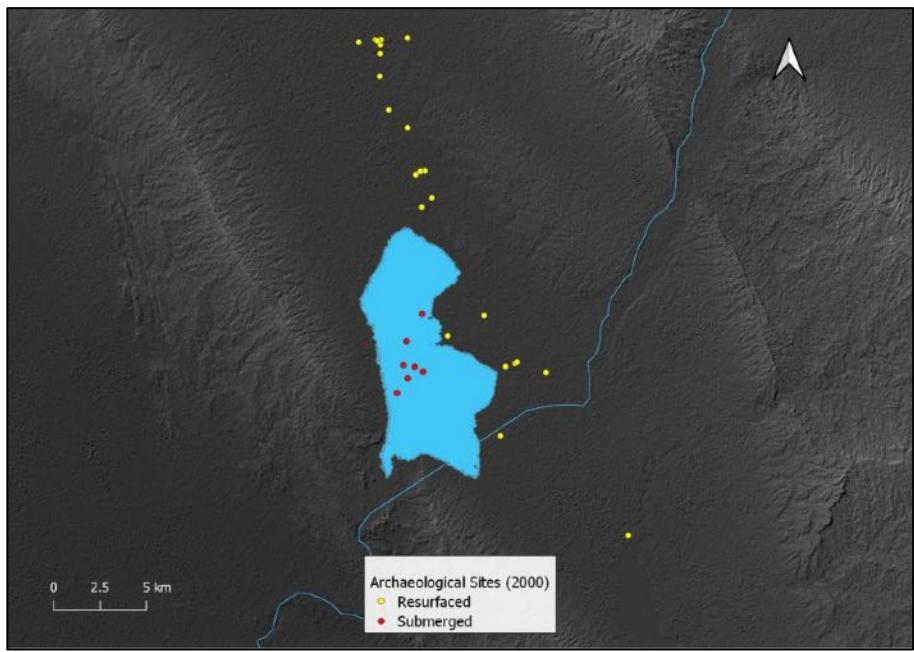
Hamrin Dam – Lake Extent and Sites Resurfaced



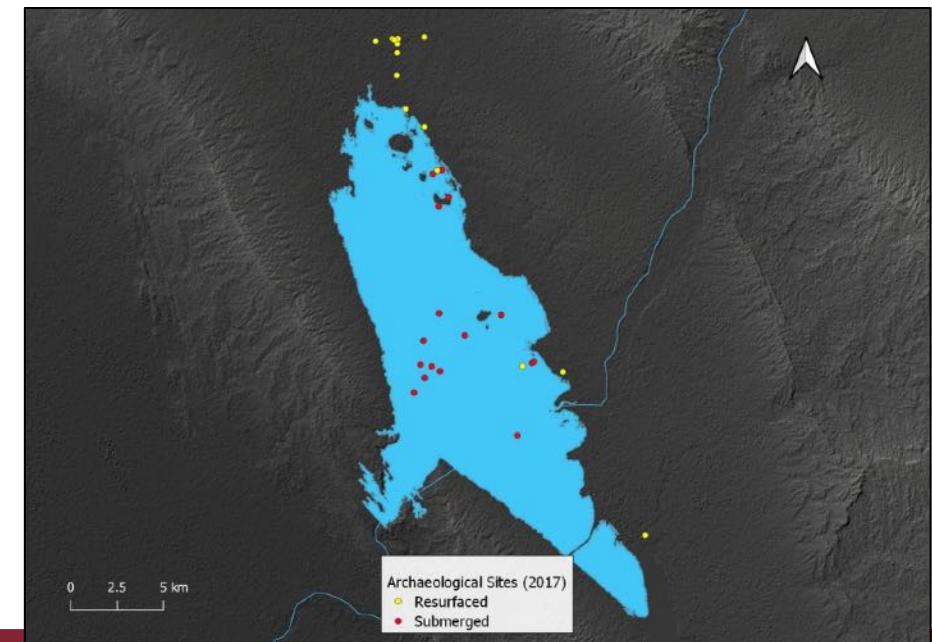
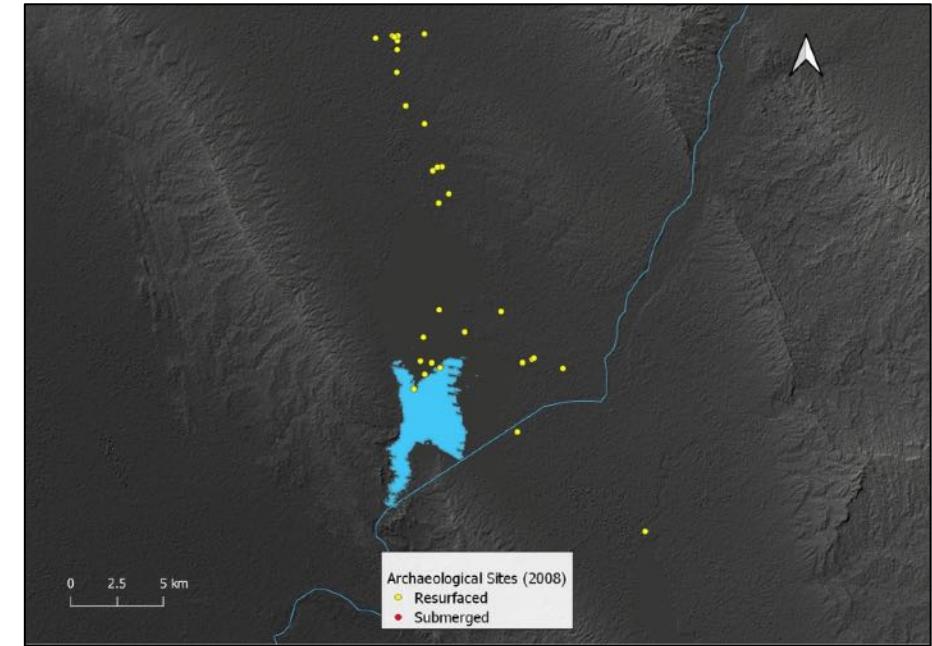
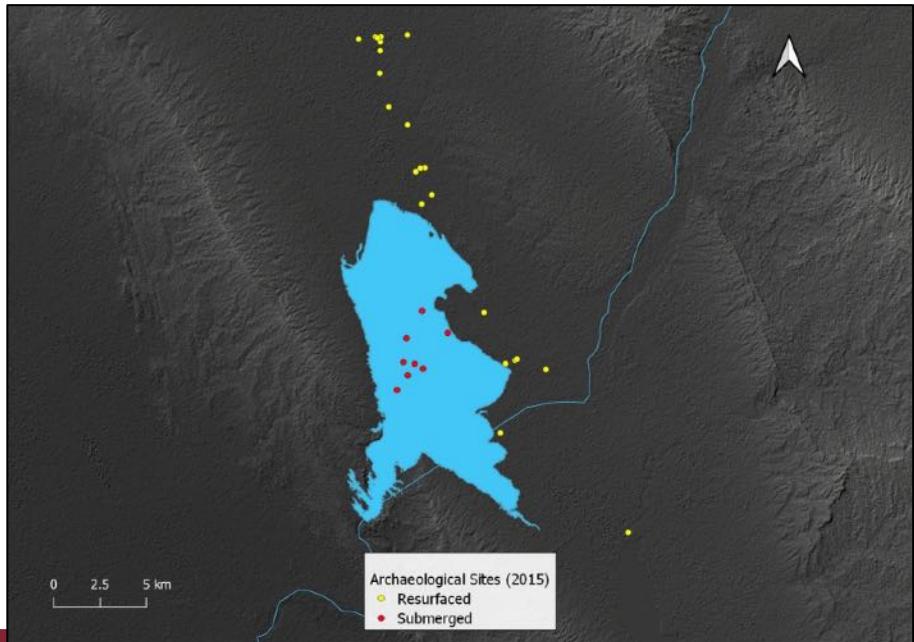
Hamrin Dam – Archaeological Sites



Results: Hamrin Dam – Overview



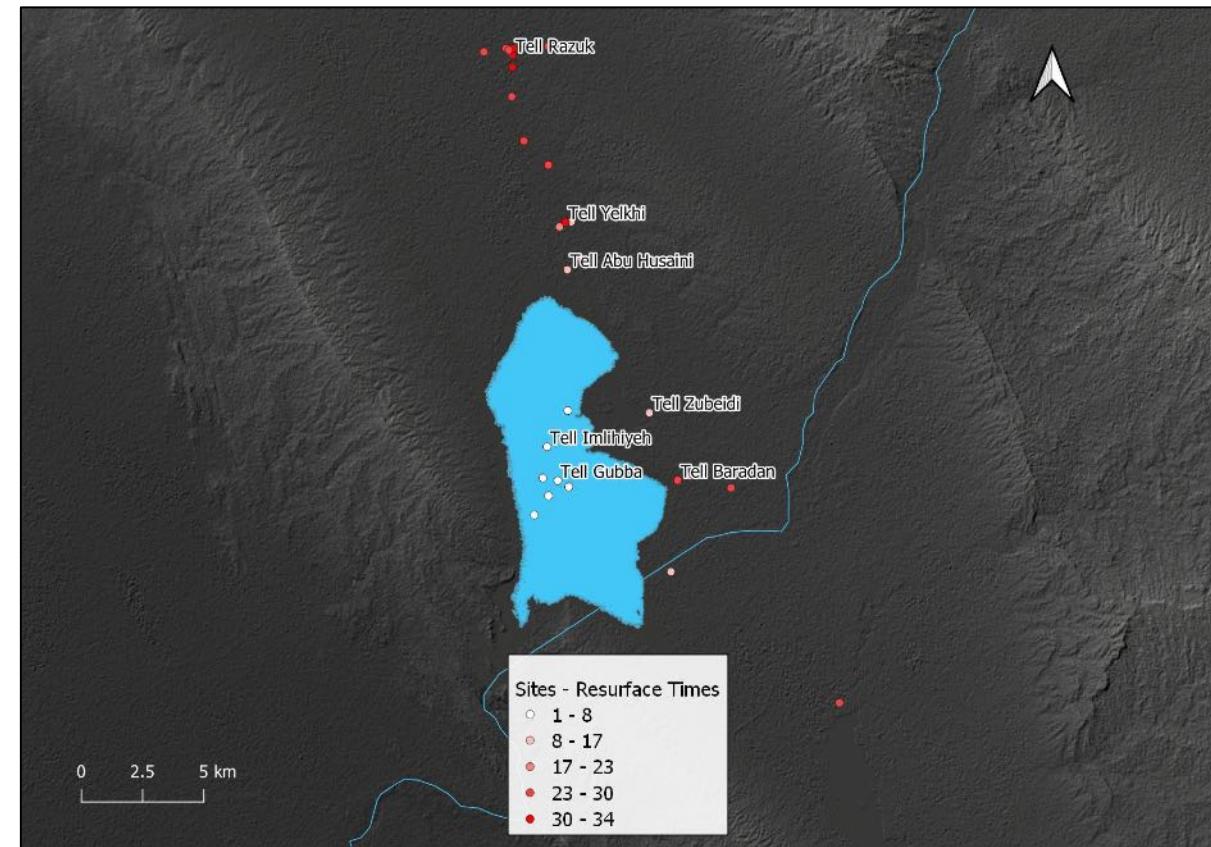
Years	No. Sites Resurfaced
2000	23
2008	30
2015	22
2017	14



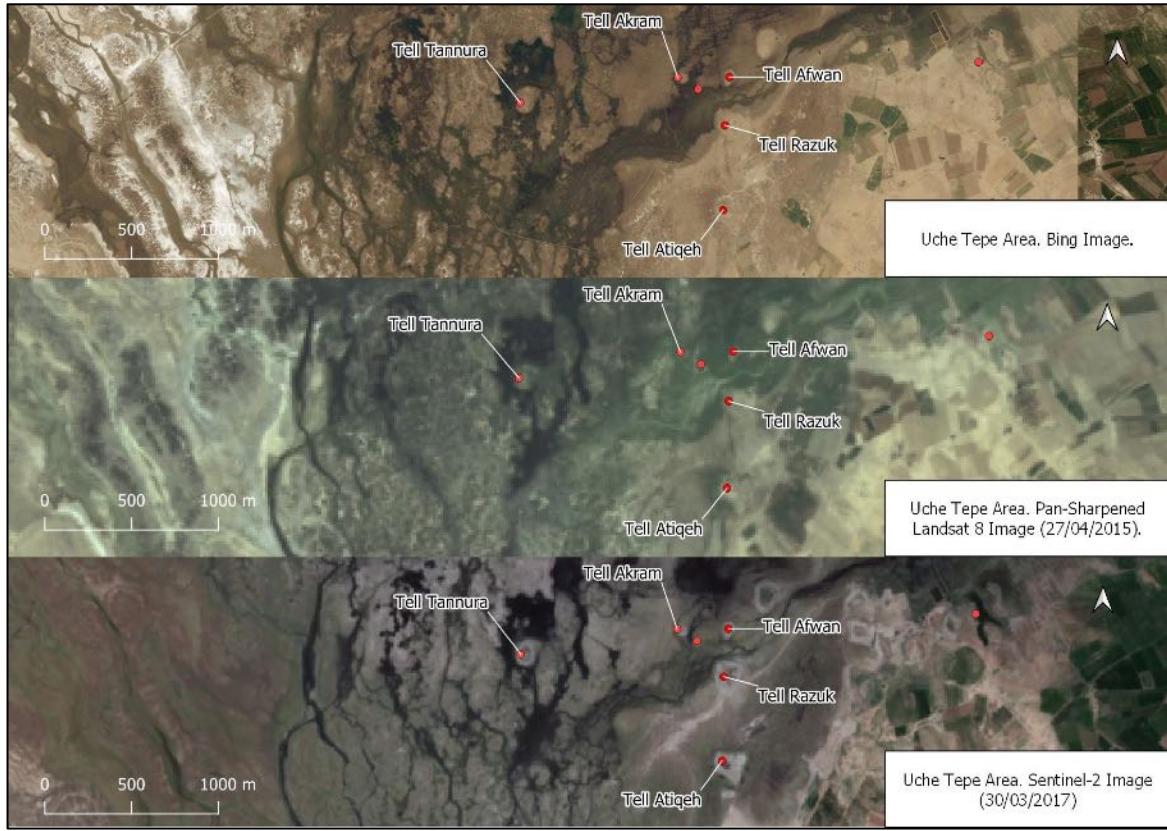
Results: Hamrin Dam – Sample Years



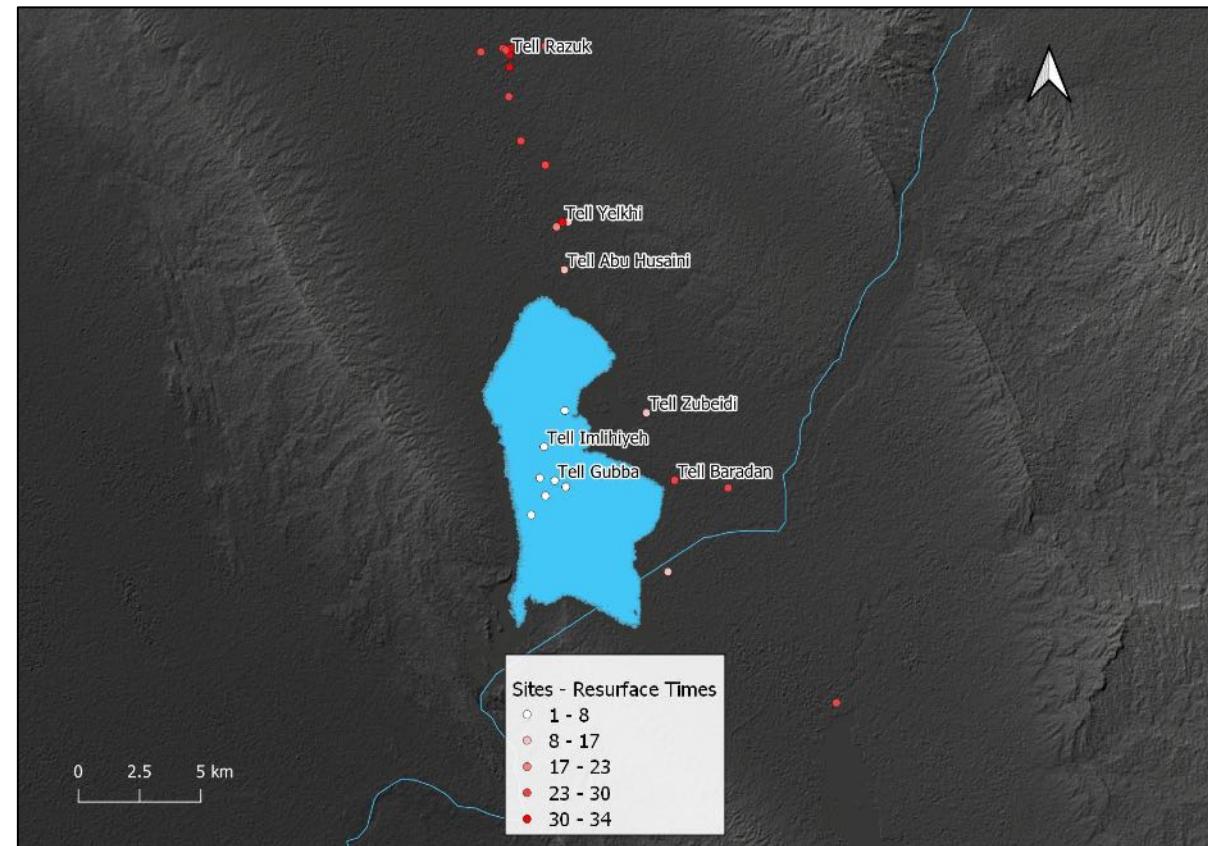
Year	Pixel Value (Tell Yelkhi)
1975	- 0.29
2011	- 0.25
2015	- 0.26
2017	- 0.20



Results: Hamrin Dam – Sample Sites



Year	Pixel Value (Tell Razuk)	Pixel Value (Tell Tannura)
1975	- 0.19	- 0.25
2011	- 0.27	- 0.21
2015	- 0.29	- 0.25
2017	- 0.28	- 0.28

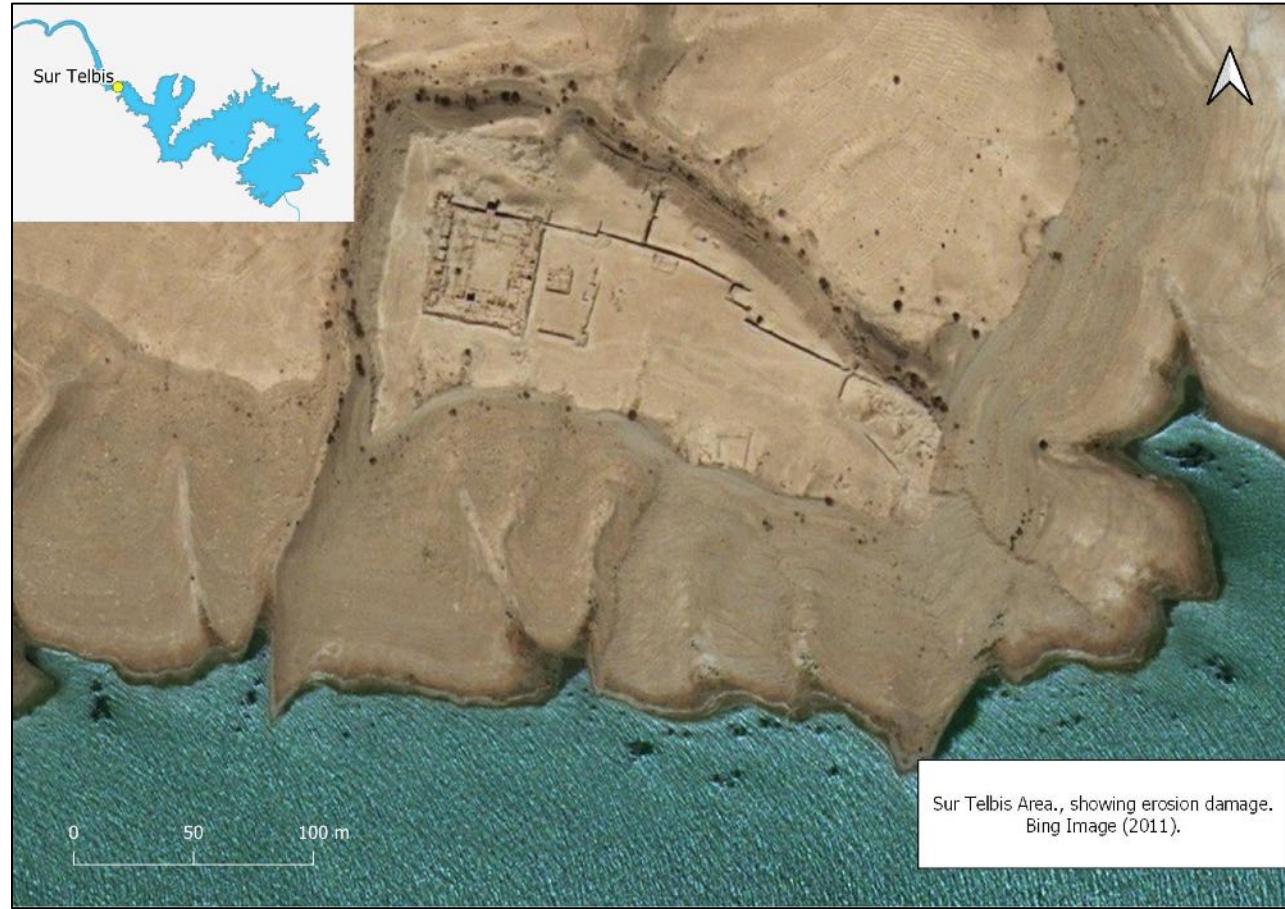




Year	Pixel Value (Tell Zubeidi)	Pixel Value (Tell Baradan)
1975	- 0.24	- 0.17
2015	- 0.21	- 0.25



Results: Hamrin Dam – Sample Sites



Results: Damage and Accessibility

Conclusions:

- Time-Series NDWI can confidently distinguish between land and water surfaces
- Applying the Index over a long time-span help in understand and quantify dynamics of submersion and emersion of archaeological sites
- Identified sites will likely resurface in the future under similar circumstances

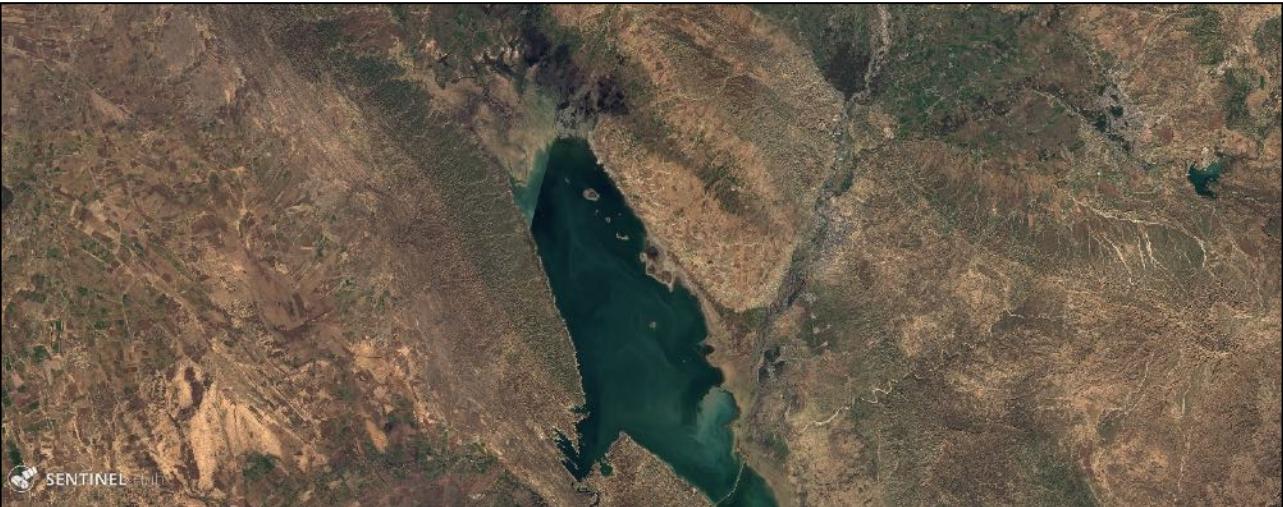


Further Improvements:

- Interannual variability analysis
- Estimate of resurfaced site extent
- High-resolution images

Advantages:

- Reproducible and (almost) free methodology
- If coupled with Sentinel-2, monitoring can be done on a very frequent basis at no cost



Thank you!

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