

# A Novel Machine Learning Automated Change Detection Tool for Monitoring Disturbances and Threats to Archaeological Sites

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# EAMENA

Endangered Archaeology in the Middle East & North Africa



- Create a **baseline inventory and database of sites** for the MENA region – from Mauritania to Iran, from the Palaeolithic to the Second World War
- Record and **track condition, disturbances, and threats** to heritage sites
- Development and improvement of **remote sensing methodologies and workflows** for heritage recording
- **Share data and methodologies** to aid those responsible for cultural heritage in the MENA region to **protect and maintain** these sites







<https://database.eamena.org>

**EAMENA** Endangered Archaeology in the Middle East & North Africa

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ARCADIA

**MarEA** Maritime Endangered Archaeology

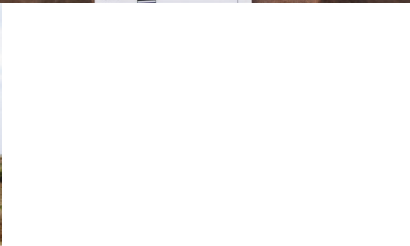
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EAMENA Database v4.0  
 Endangered Archaeology in  
 The Middle East & North Africa



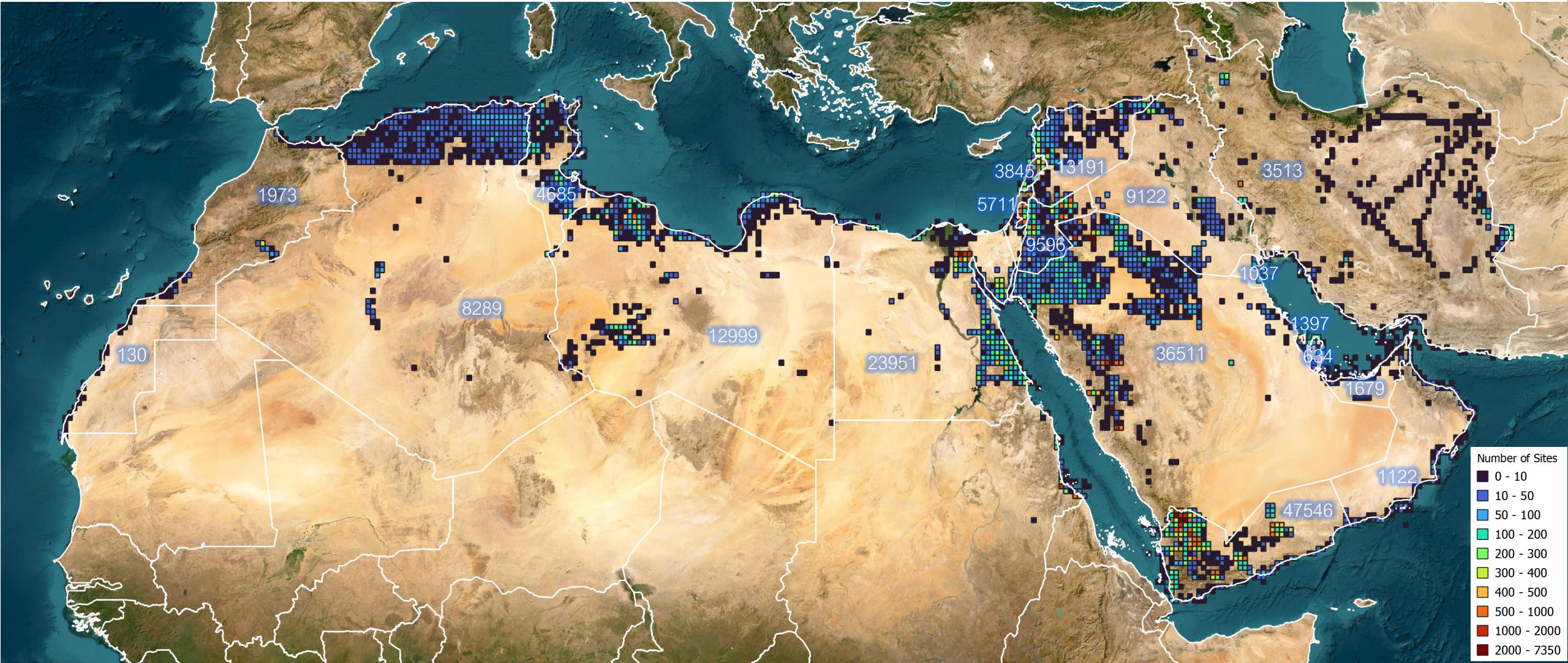
A View of Petra, Jordan © Andrea Zer...



archesproject.org



# Distribution of heritage site records recorded in the EAMENA database (as of 23 August 2024): 217,117



<https://database.eamena.org>

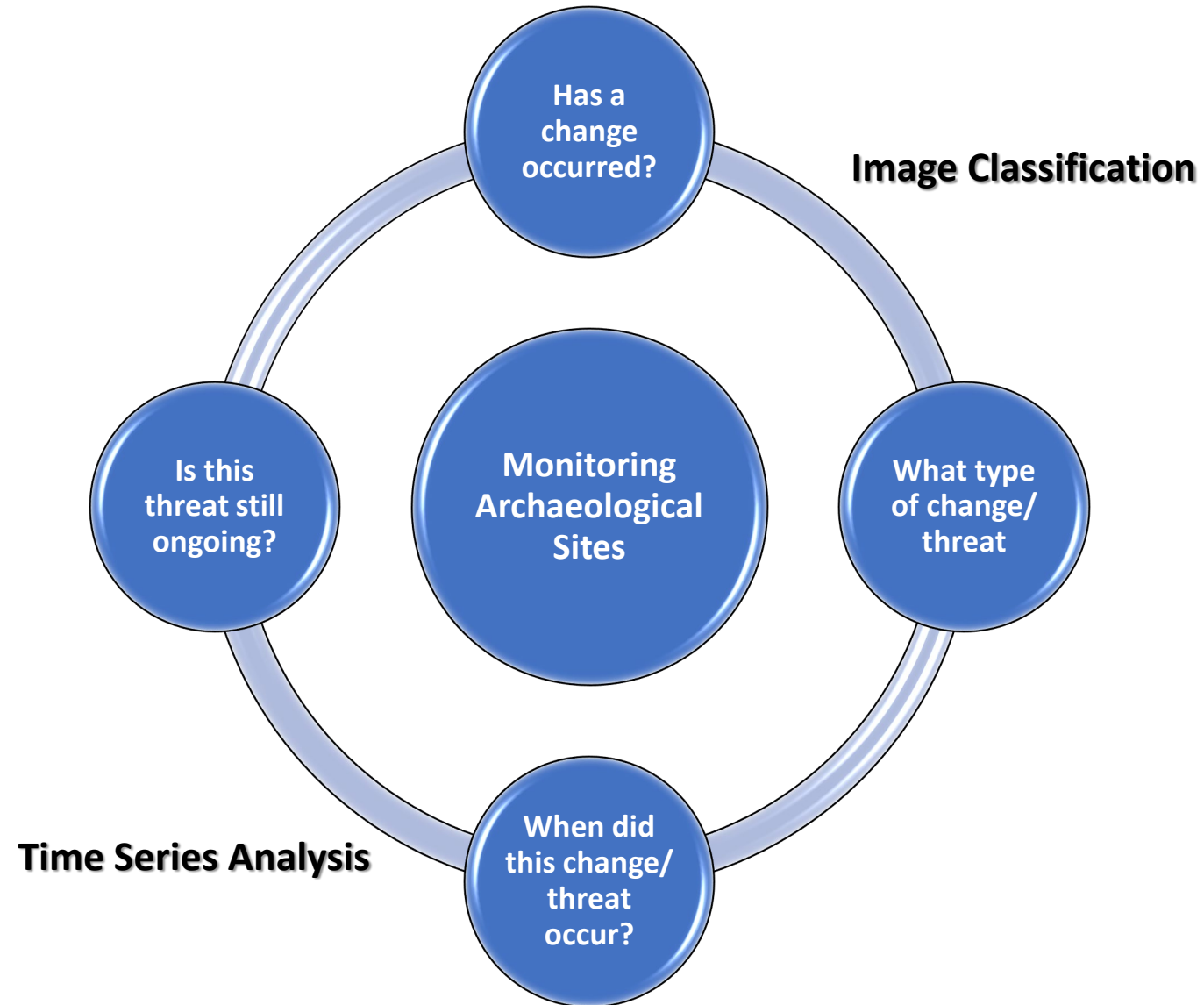




# Monitoring Archaeological Sites

There are four main questions that need to be answered to accurately monitor endangered archaeological sites:

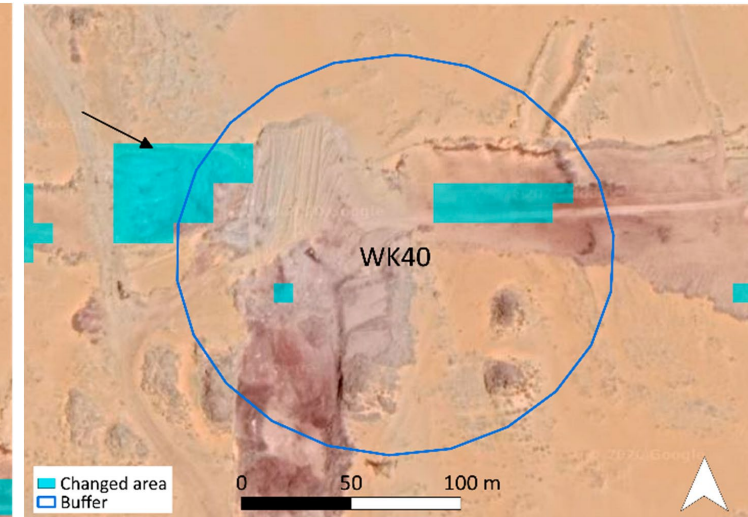
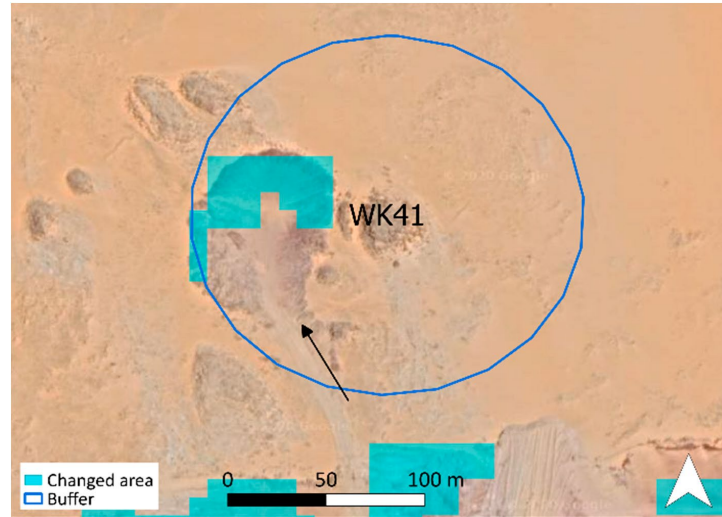
1. Has a change or a potential threat been observed in the vicinity of the site?
2. What type of change or threat has been observed?
3. When did this change or threat occur?
4. Is the change or threat still ongoing?





# EAMENA Automated Change Detection (ACD) Version 1

- First version of the EAMENA ACD used image differencing to identify areas with changes and areas with no change.
- Instances where areas of detected change fall within defined buffer zones around known sites are highlighted for validation
- Advantages of this method that it is fast, simple to apply and easy to adapt as it relies only on the two images to detect the changes between them.



Construction of a new track and piles of spoil damaged two sites WK40 and WK41 in Aswan, Egypt



Article  
**Detecting Change at Archaeological Sites in North Africa Using Open-Source Satellite Imagery**

Louise Rayne <sup>1,\*</sup>, Maria Carmela Gatto <sup>2</sup>, Lamin Abdulaati <sup>3</sup>, Muftah Al-Haddad <sup>4</sup>, Martin Sterry <sup>2</sup>, Nichole Sheldrick <sup>2</sup> and David Mattingly <sup>2</sup>

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<sup>2</sup> School of Archaeology and Ancient History, University of Leicester, Leicester LE1 7RH, UK; mcg25@leicester.ac.uk (M.C.G.); mjs66@leicester.ac.uk (M.S.); ens4@leicester.ac.uk (N.S.); djm7@leicester.ac.uk (D.M.)

<sup>3</sup> Department of Antiquities, Hun, Libya; lamin2751969m@yahoo.com

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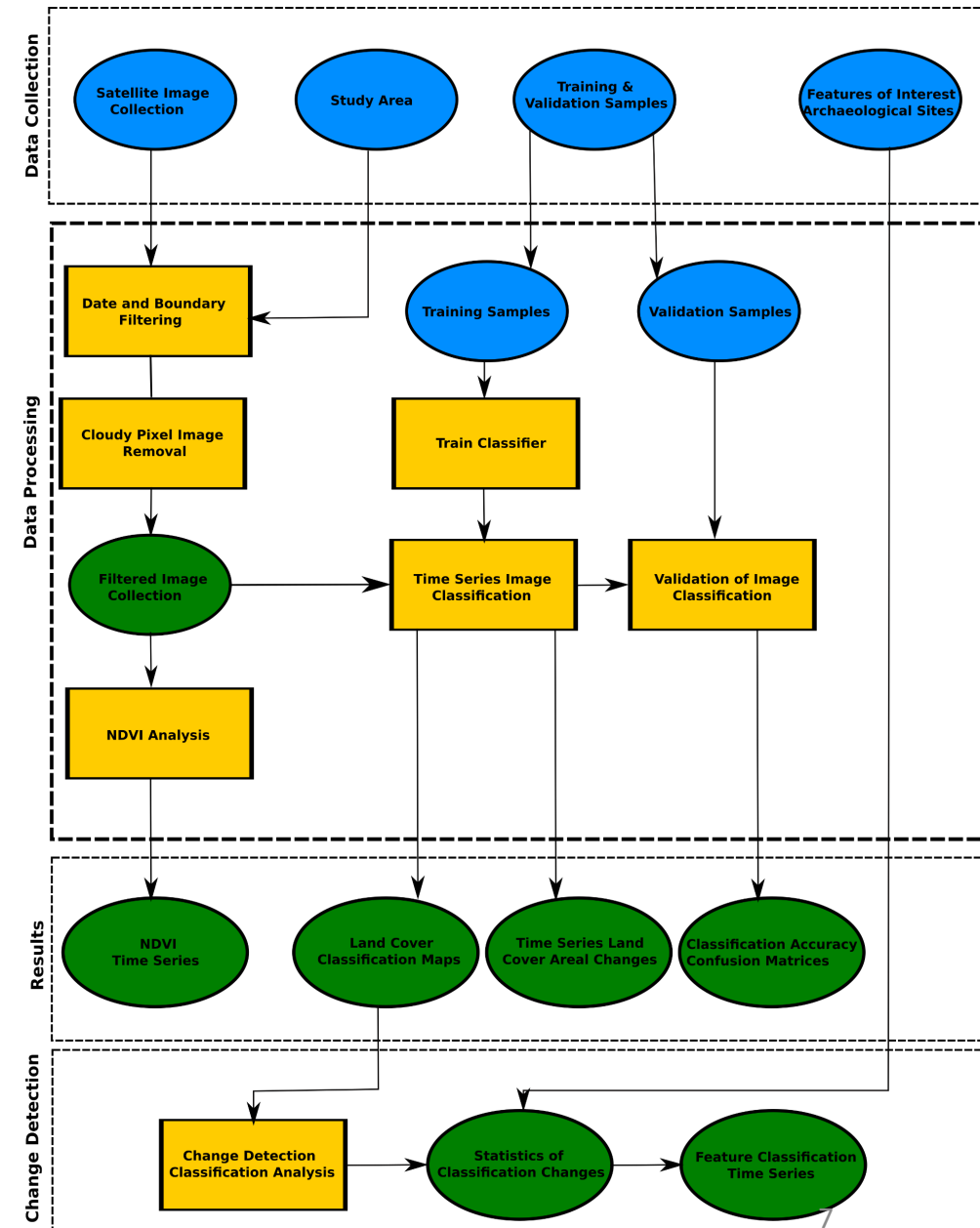






# EAMENA Machine Learning Automated Change Detection (Version 2)

- **Platform:** Google Earth Engine.
- **Data:** Harmonized Sentinel-2 MSI Level-2A optical imagery (10m spatial resolution); **Heritage sites; Study Area; Classification sample datasets** collected from high resolution archived images (Google Earth, PlanetScope, etc) or ground surveys.
- **Concept:** It applies machine learning algorithms (i.e., **Random Forest**) to process time series of images and generate land classification maps.
- **Processing:** Filter images based (**AOI, dates, cloud coverage**), train classification model for **image classification, supervised classification and change detection analysis**.
- **Results:** land classification maps, **change detection maps, time series change detection charts, statistics** on archaeological sites under threat and changes.



EAMENA MLACD Framework

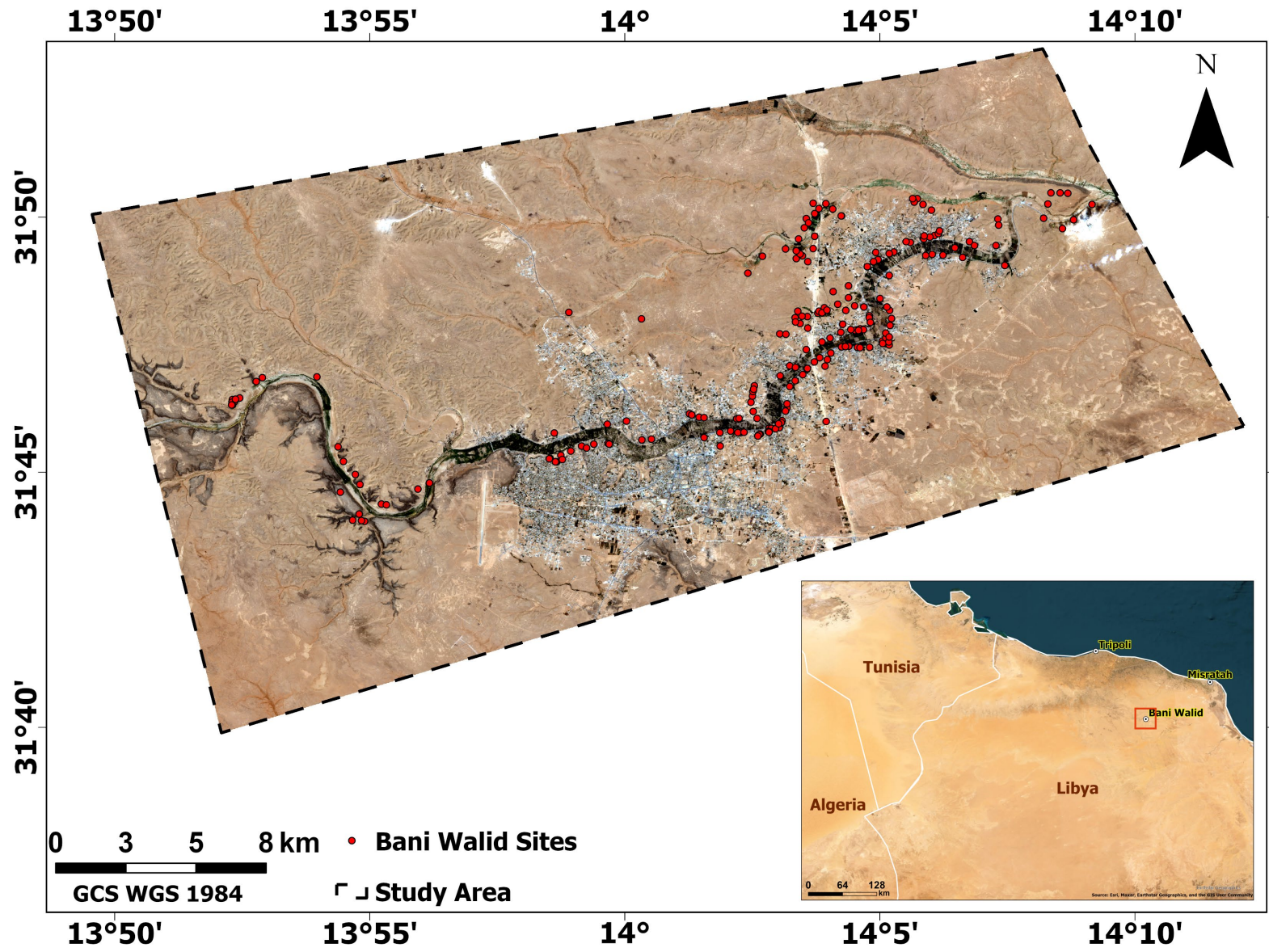








# Bani Walid (Libya)



Sites found within and around the city, are from Roman and Late Antique farm sites, to medieval villages

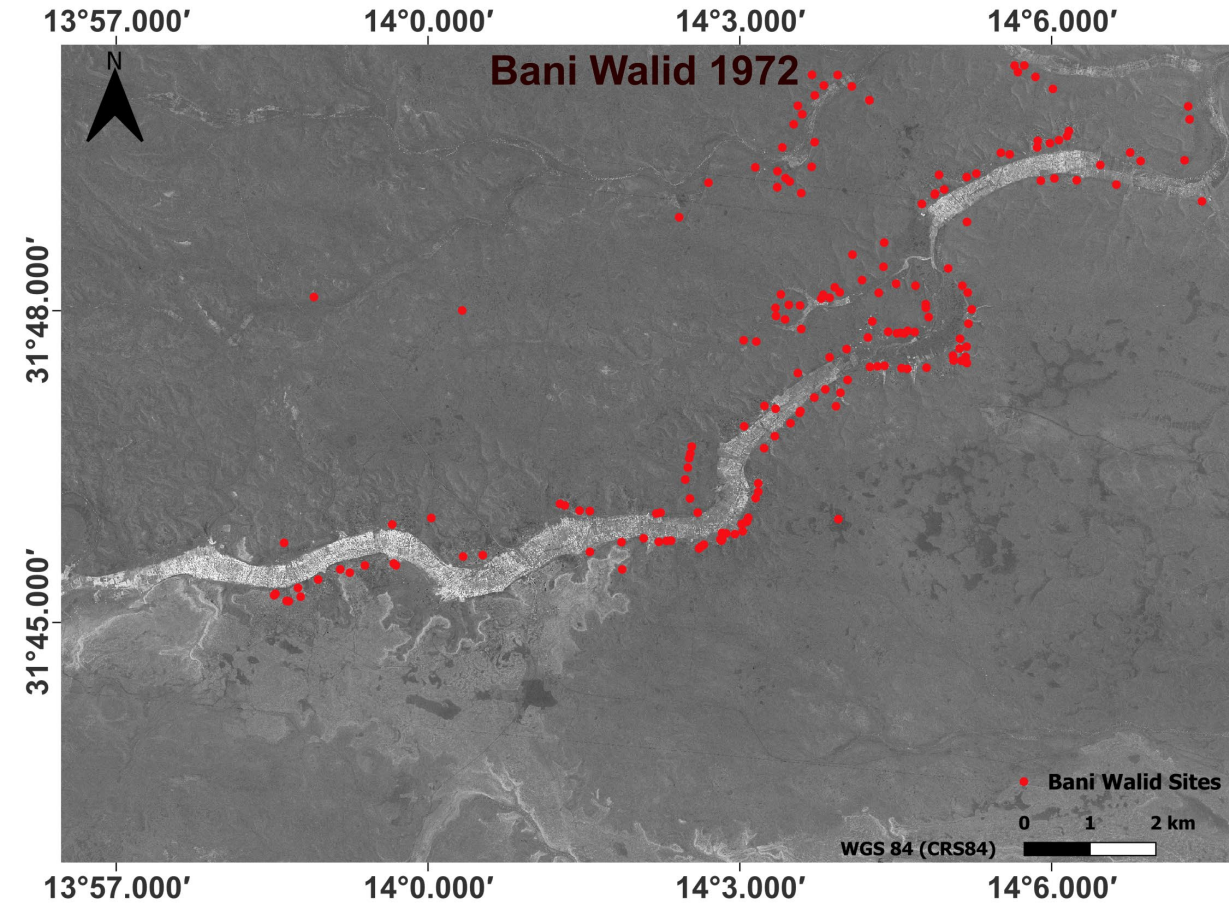


UNESCO Libyan Valleys Survey Archive, British Institute for Libyan and Northern African Studies Archive

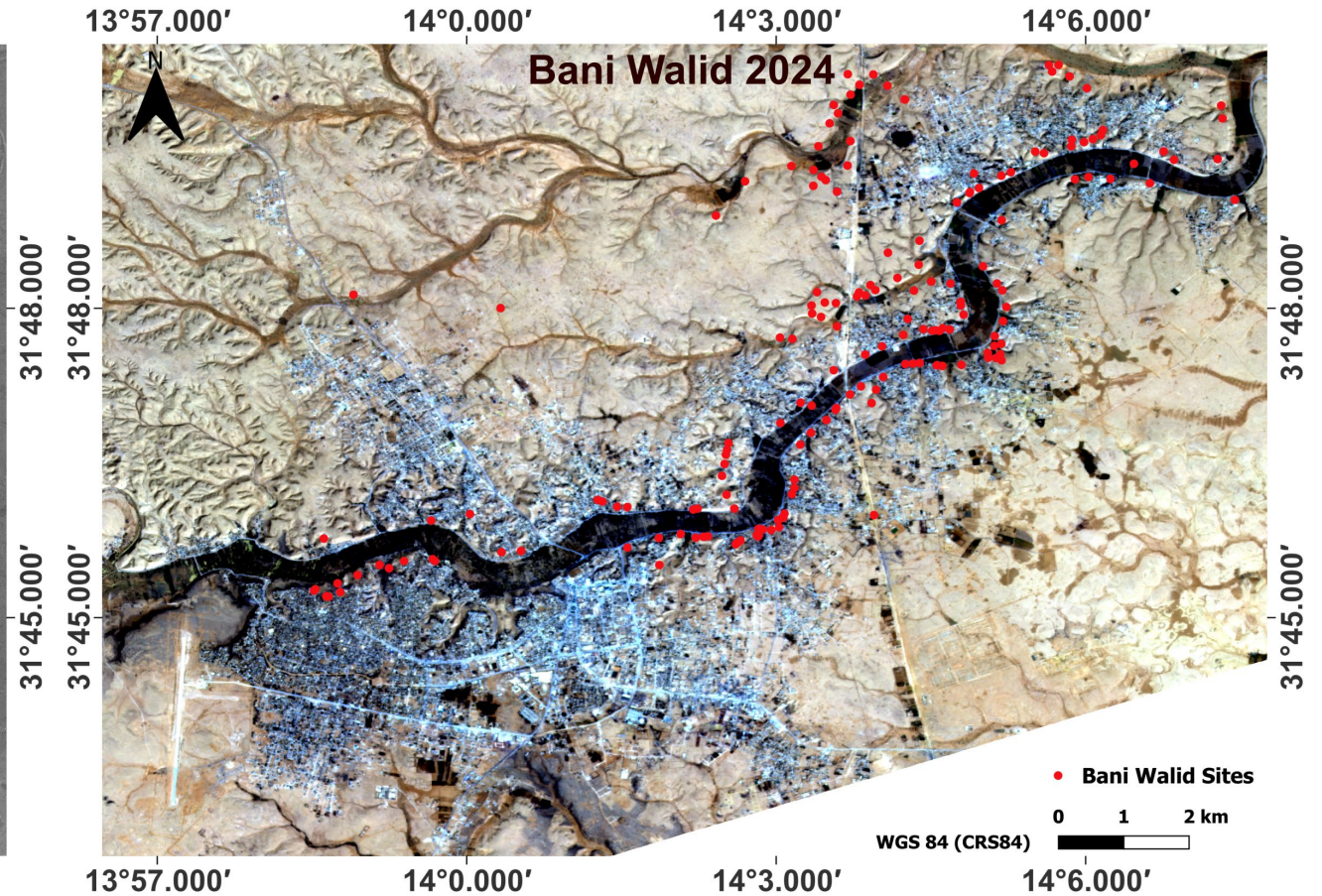




# Threat of Urban Expansion



**KH-9 Corona satellite imagery of Bani Walid acquired on the 08 July 1972 © USGS D3C1203-100014A008;**



**PlanetScope imagery of Bani Walid acquired on 23 February 2024 Image © 2024 Planet Labs PBC**

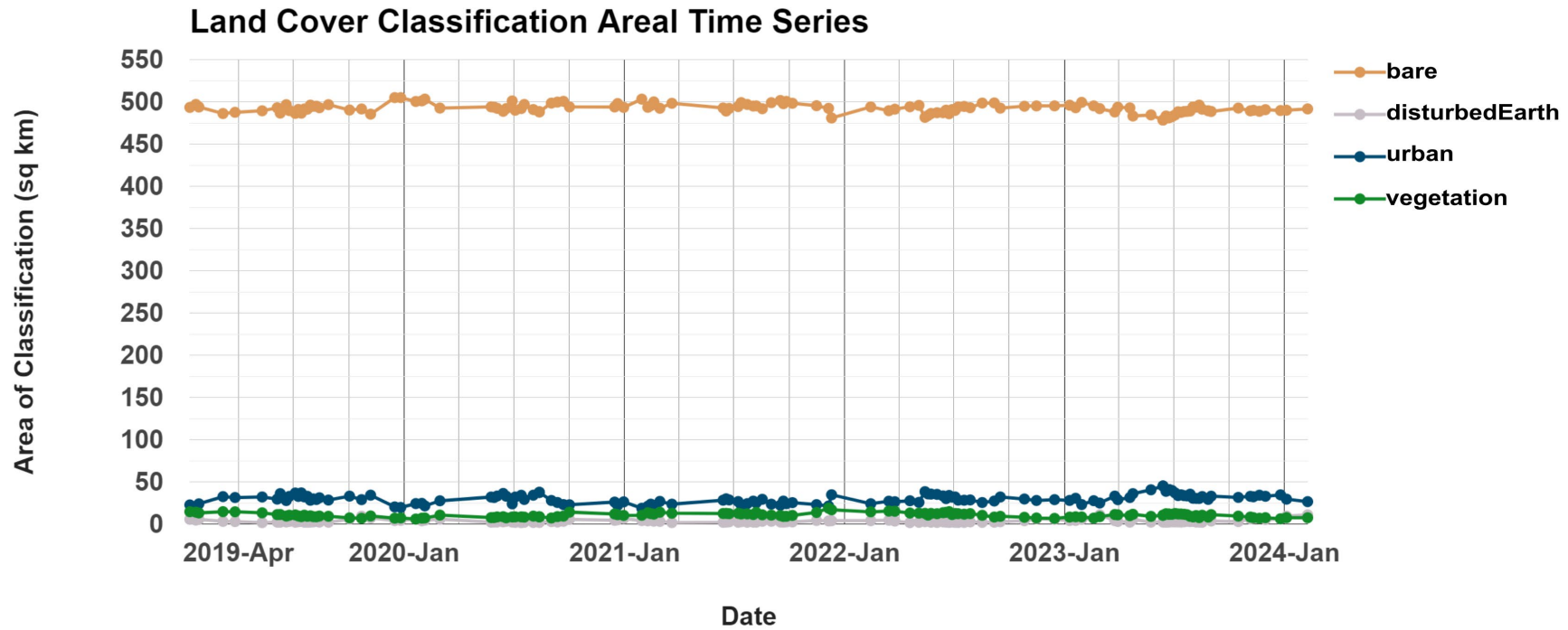




# EAMENA MLACD Results



| Class Value | Class Name      | Description  |
|-------------|-----------------|--|
| C1          | Bare            | Bare and rocky soil  |
| C2          | Disturbed Earth | Areas of recently disturbed earth, exposing sub-surface soils and geology, due to activities such as bulldozing, quarrying and looting |
| C3          | Urban           | Buildings and roads  |
| C4          | Vegetation      | Areas of natural or agricultural vegetation  |



Land cover classification changes time series of Bani Walid between Jan 2019-Feb 2024

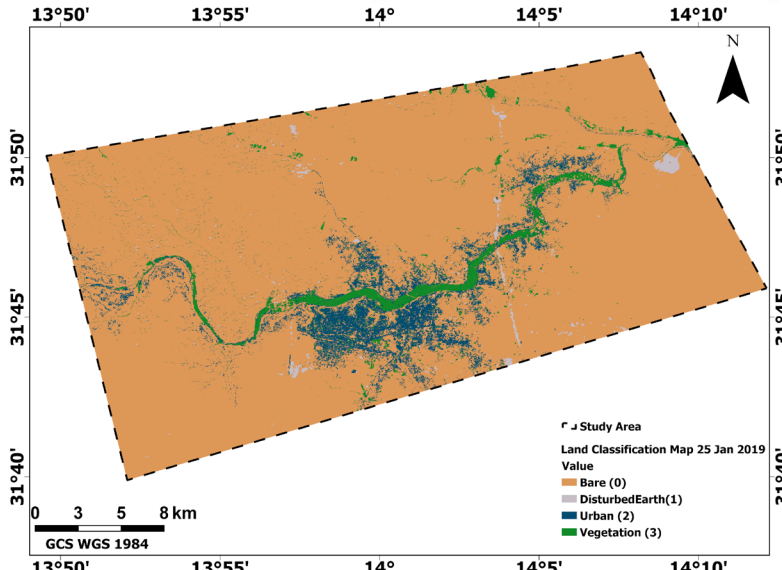




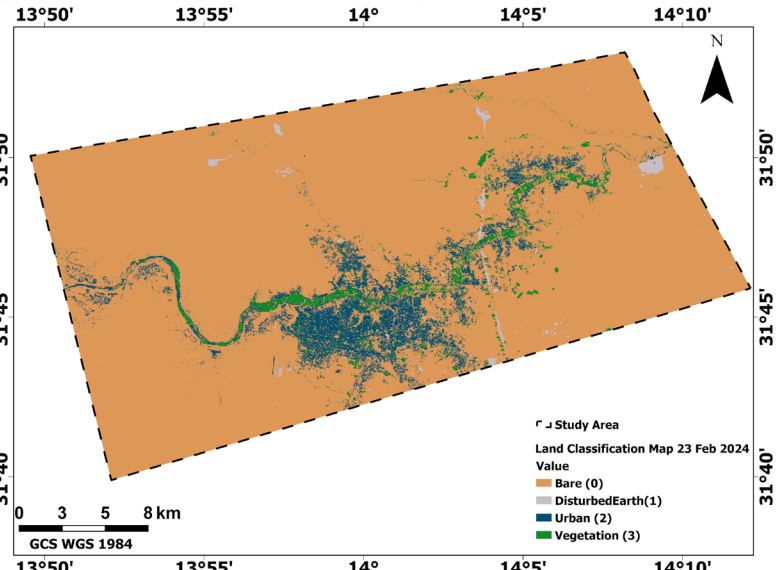
# Change Detection between Jan 2019 and Feb 2024

Select First Image

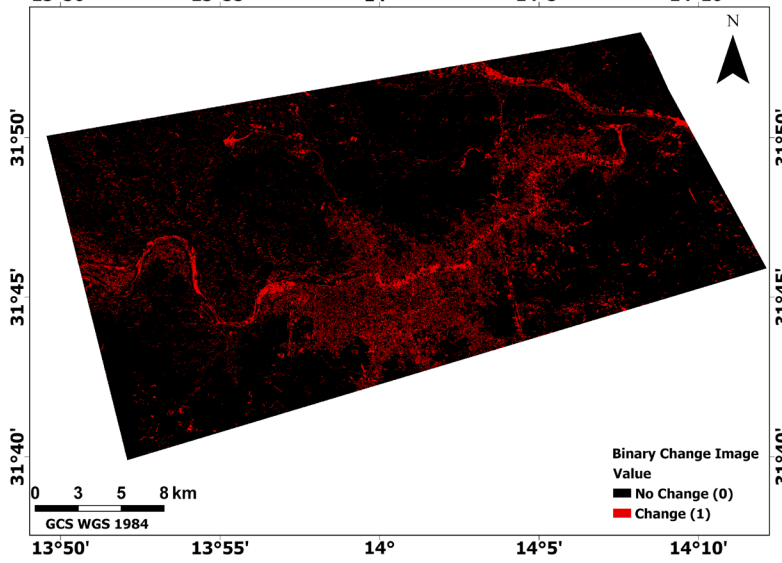
Select Second Image



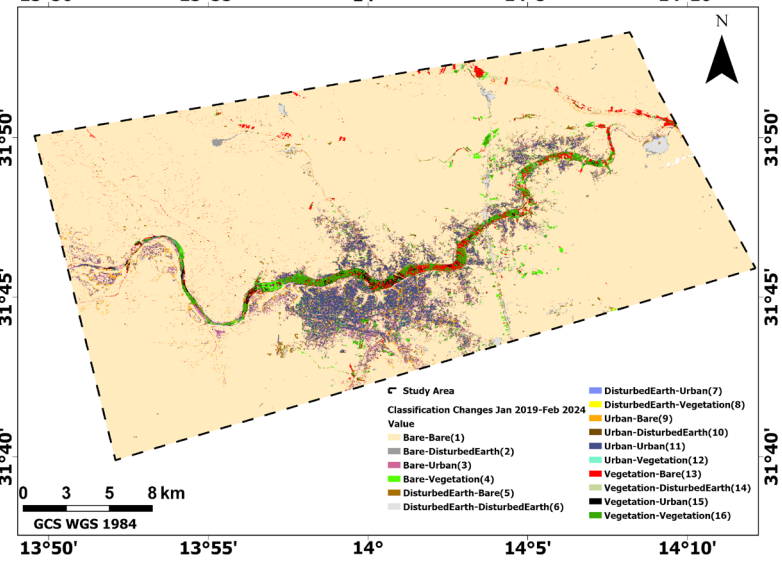
Bani Walid land-use classification map Jan 2019



Bani Walid land-use classification map Feb 2024



Binary change map between Jan 2019- Feb 2024



Change classification map between Jan 2019- Feb 2024

**Layers**

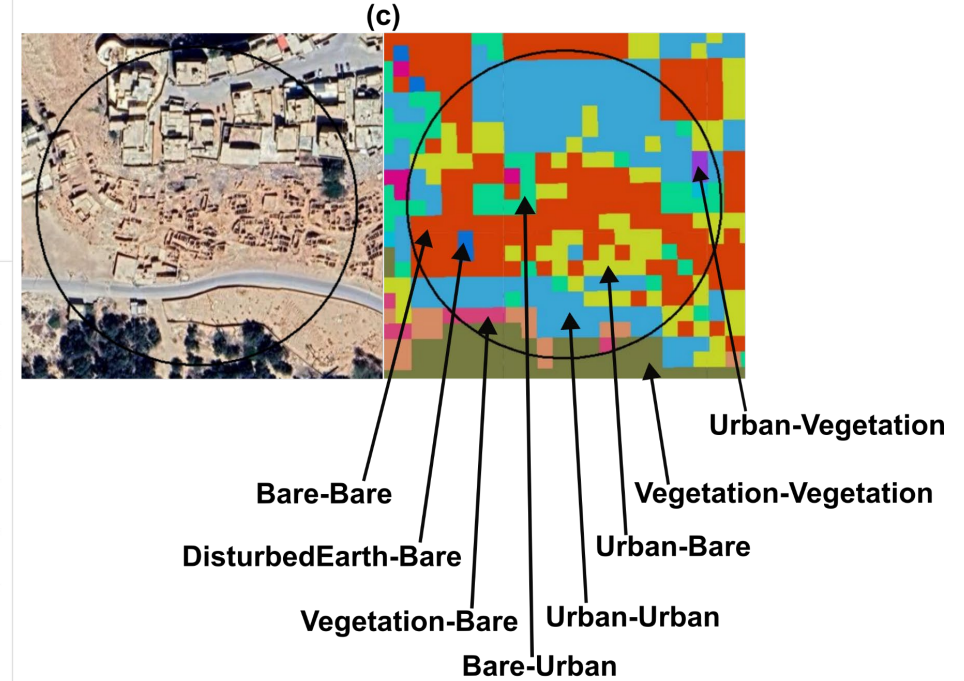
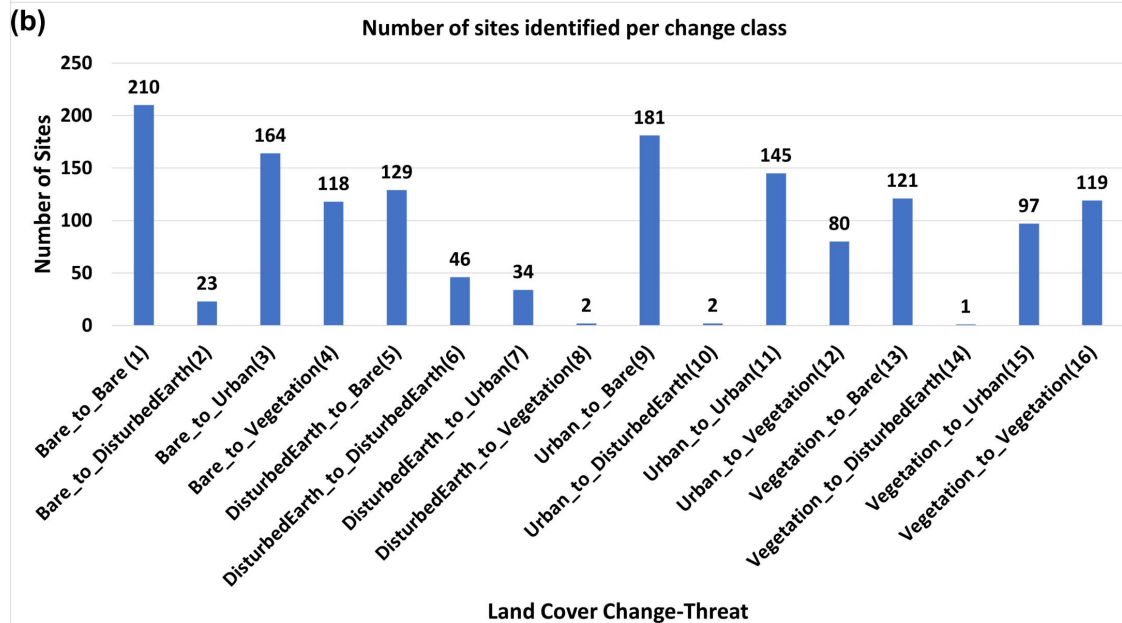
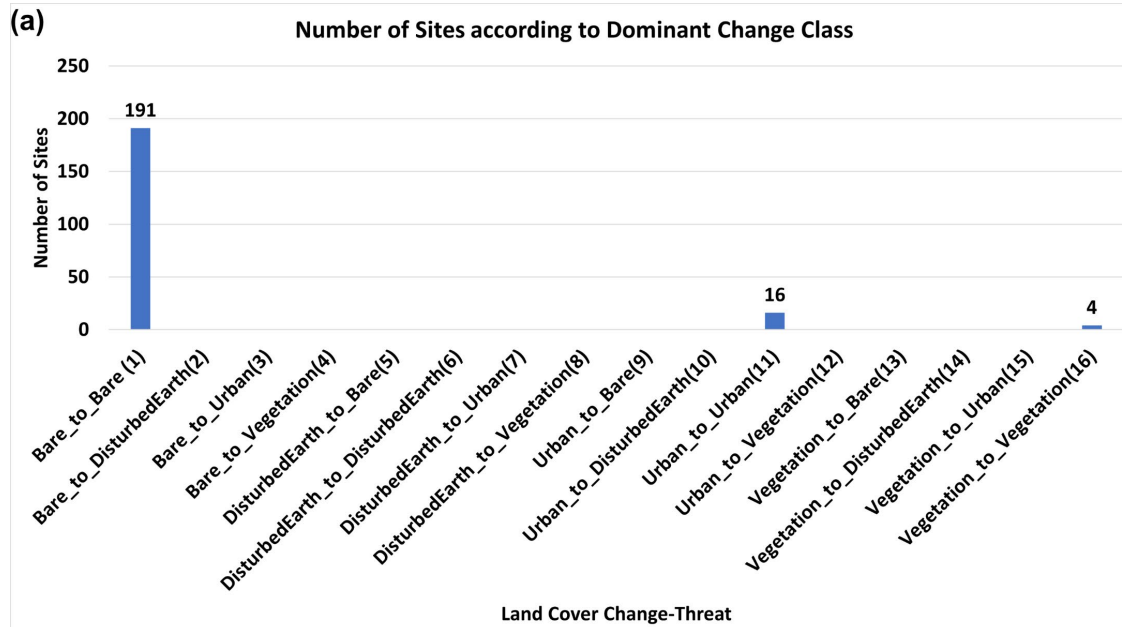
- Sites\_under\_Threat\_of\_Class\_Change
- bare\_To\_urban
- ClassificationChanges
- Binary Change
- Second\_classifiedImage
- First\_classifiedImage
- post\_imageNDVI
- prior\_imageNDVI
- Image\_Difference
- Second\_Image
- First\_Image
- Stratifiedtraining\_samples
- Sites
- Sites\_buffer
- Study\_Area

EAMENA MLCD Results in the Layers Tab





# Detected Change & Threat in Sites by EAMENA MLACD

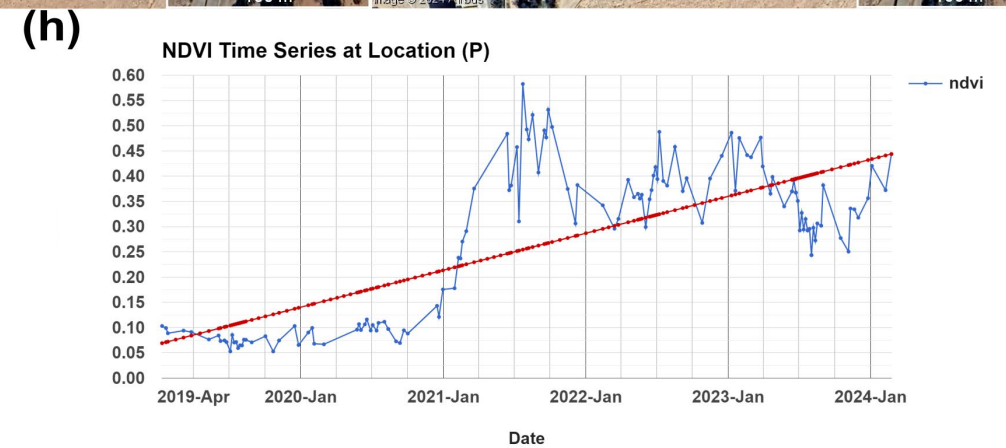
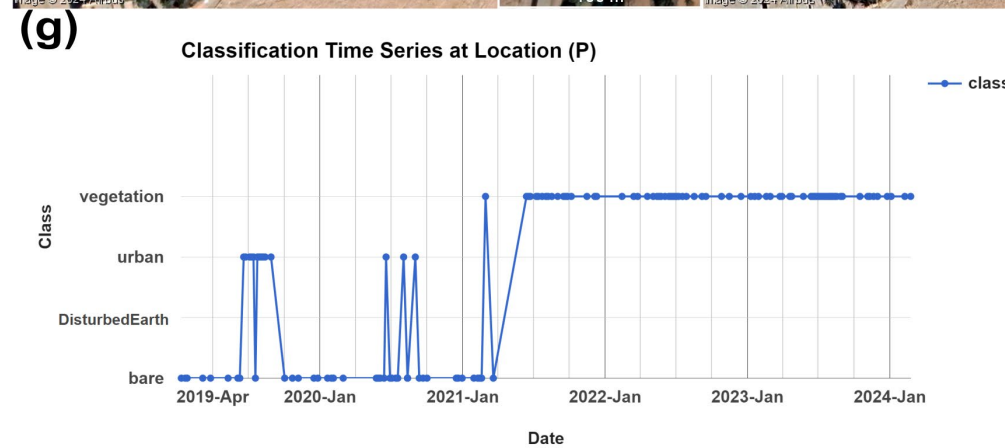


Example of classification change on a pixel level within the buffer zone of site EAMENA0189582.





# Threat of Vegetation Expansion

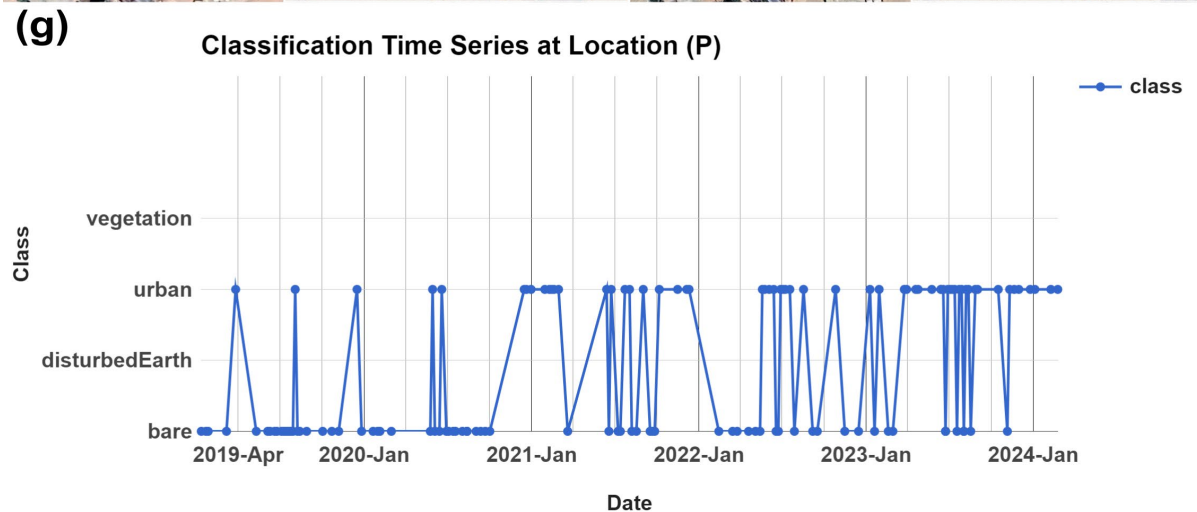
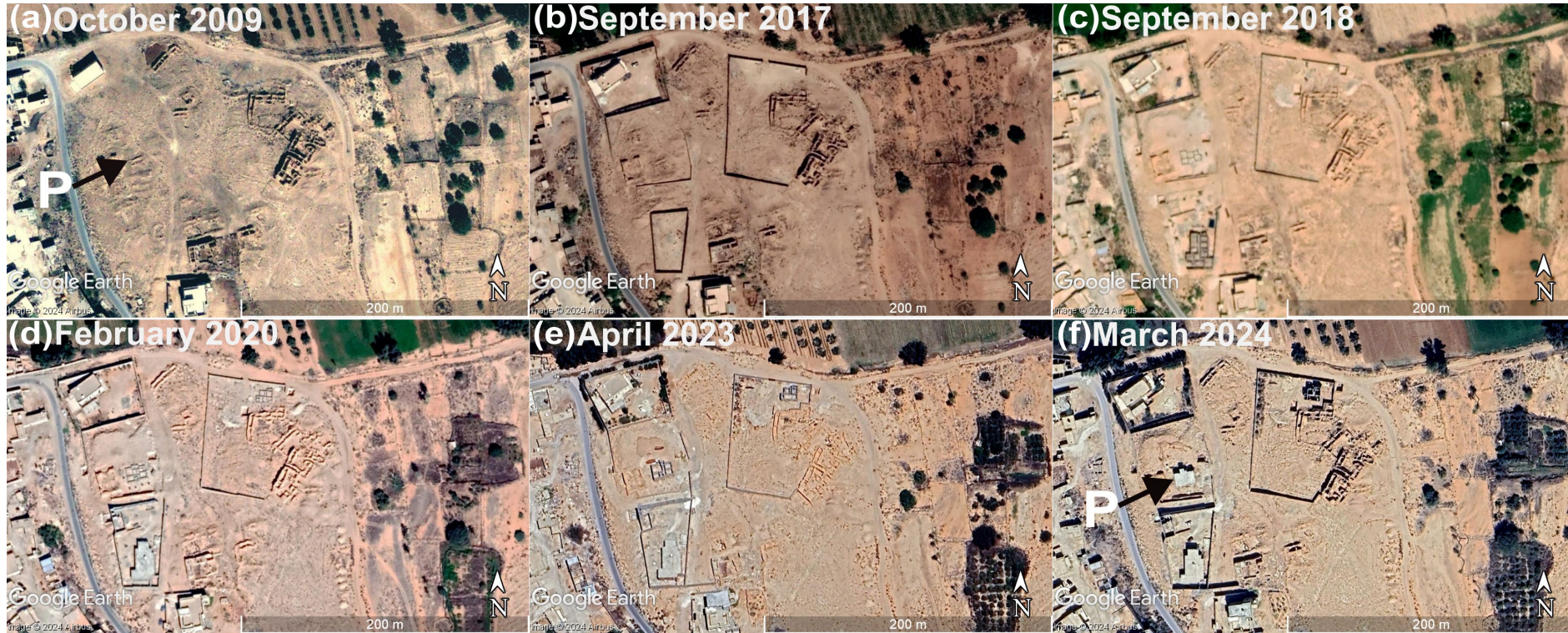


Results of MLACD analysis at location (P) on site EAMENA-0189408, indicating vegetation growth originating from the modern farm





# Threat of Urbanization

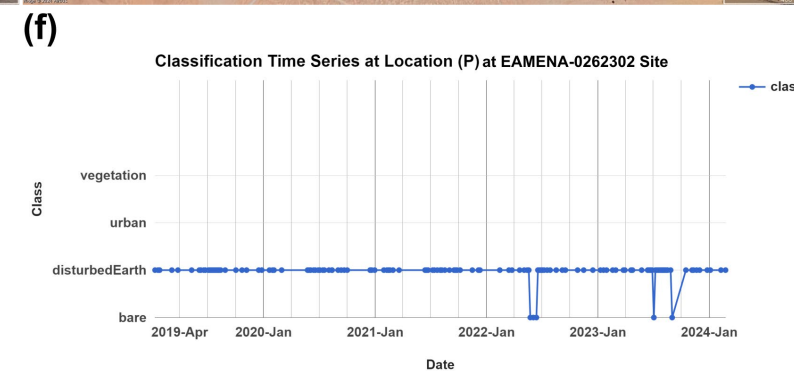
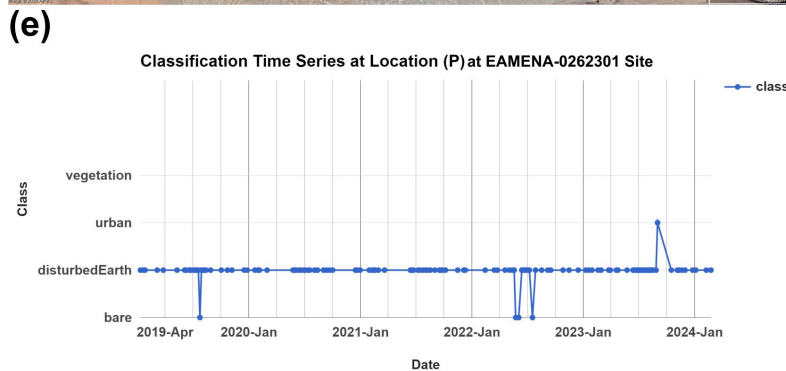
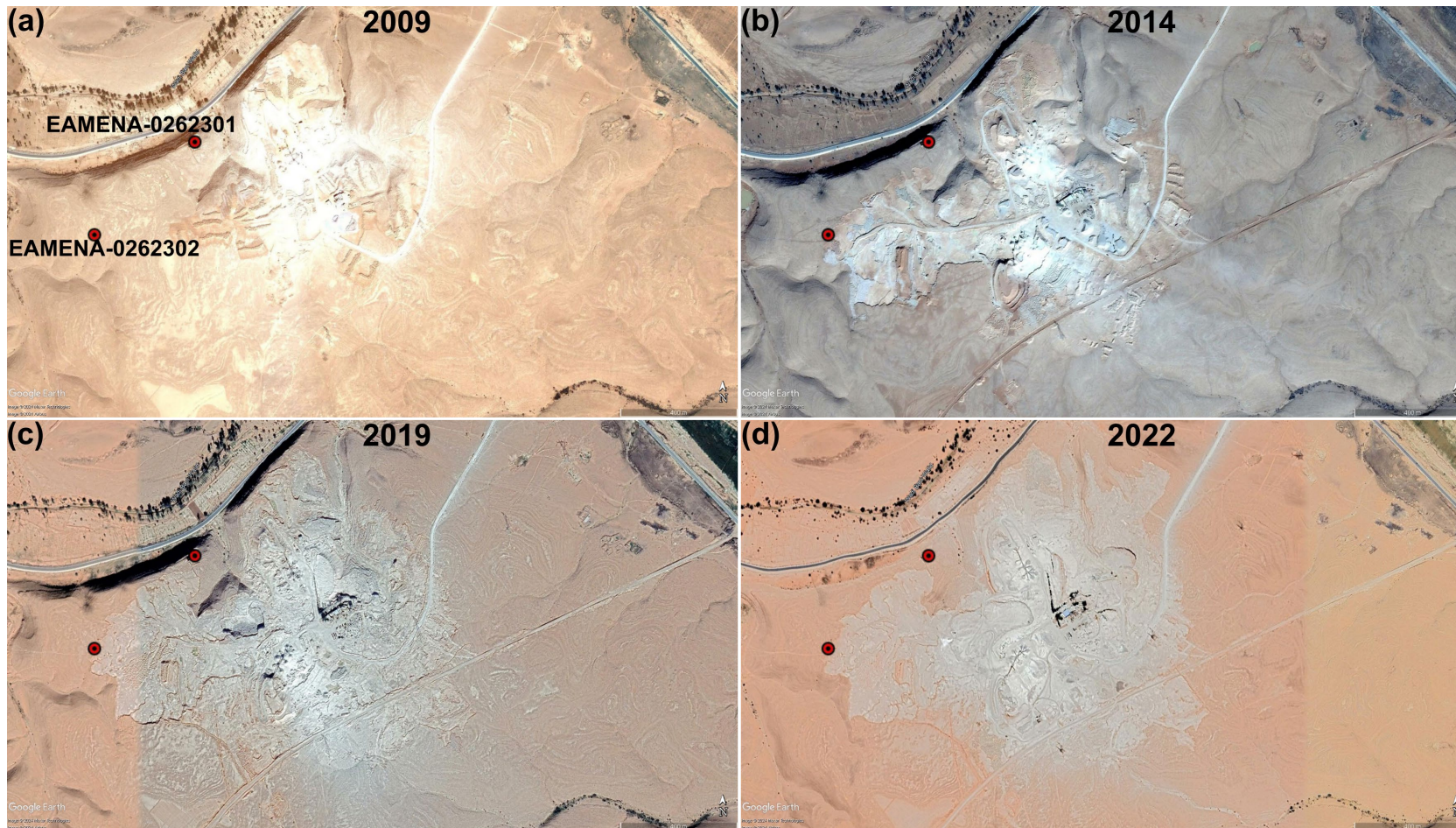


Identified urban expansion activity at site EAMENA-0087052





# Threat of Disturbed Earth-Quarrying Activities







# Fieldwork Survey for EAMENA MLACD Validation

(a) Vegetation growth



(b) Construction



(c) bulldozing



(d) Garbage dumping



(e) Looting pit



Documented threats on the ground

| Disturbances recorded        | Fieldwork Survey | MLACD – 50 m Buffer Zone |
|------------------------------|------------------|--------------------------|
| Urbanization                 | 63               | 136                      |
| Vegetation                   | 35               | 34                       |
| Bulldozing (Disturbed Earth) | 34               | 32                       |
| Garbage dump                 | 32               | N/A                      |
| Looting                      | 13               | N/A                      |
| Destroyed                    | 15               | N/A                      |

Comparison between threats detected using EAMENA MLACD & Fieldwork survey





# EAMENA

Endangered Archaeology in the Middle East & North Africa



Department for Digital, Culture Media & Sport

## Outreach, Training, and Capacity Building

- Training in remote sensing, GIS, change detection and database recording.
- More than **20 workshops** since 2017, funded by the British Council's Cultural Protection Fund.
- Training for over **200 heritage professionals** from Libya, Algeria, Tunisia, Egypt, Jordan, Palestine, Lebanon, Syria, Iraq, Yemen, and Iran.
- Focused on using **open-source data** and software





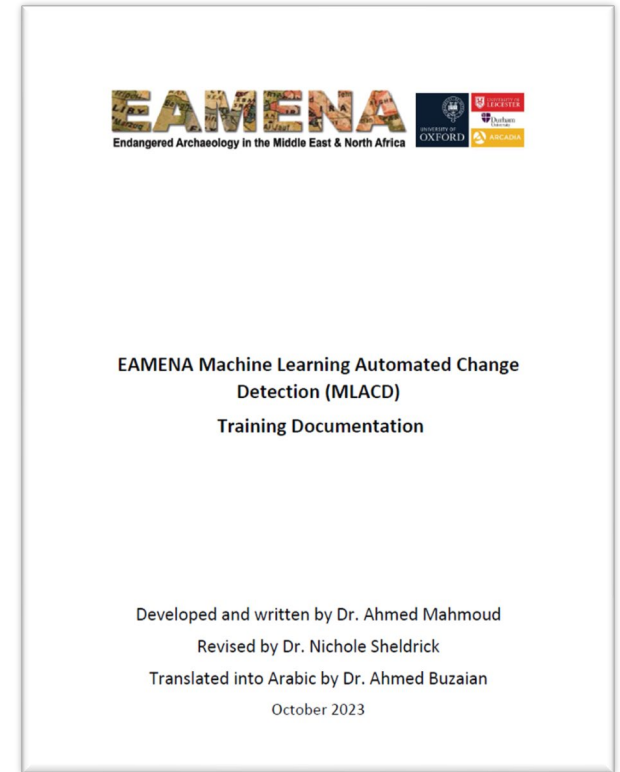


# Key Take Aways

- The EAMENA MLACD allows heritage professionals to **rapidly identify changes and threats** to heritage sites.
- It is provided with a simple **user interface**.
- The EAMENA MLACD can also **analyse individually imported images** from other sensors (e.g., LandSat, Planetscope, SkySat...).
- Further development includes the **integration of LandSat for longer time series**.
- The EAMENA MLACD is a powerful tool that has **various applications** in Earth Observation and Environmental Monitoring such as Deforestation, Mining...etc.
- EAMENA MLACD training documentation and APP can be found on the **EAMENA GitHub repository**.

<https://github.com/eamena-project/EAMENA-MachineLearning-ACD>

- Mahmoud, A. M. A., Sheldrick, N. & Ahmed, M. 2024. **A Novel Machine Learning Automated Change Detection Tool for Monitoring Disturbances and Threats to Archaeological Sites**. Available at SSRN 4914336 (Under Review).







EAMENA MLACD - EAMENA GitHub Repository

Thank-you!  
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Endangered Archaeology in the Middle East & North Africa



Centre for Endangered Archaeology and Heritage

