Mapping damage and destruction to archaeological sites in the Middle East and North Africa

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Endangered Archaeology

The Endangered Archaeology of the Middle East and North Africa (EAMENA) Project is documenting archaeological sites and their condition in an online database that spans 20 countries (Fig. 1; see Bewley et al 2016; Rayne et al 2017a and b). Increasingly, sites are at risk from deliberate damage and land use change. The project is working with heritage professionals in each country to promote the recording and protection of cultural heritage at risk using accessible and open-source remote sensing tools. This poster describes EAMENA's methodology of using high-resolution data to record sites, and lower-resolution multispectral data to monitor changes which put sites at risk.

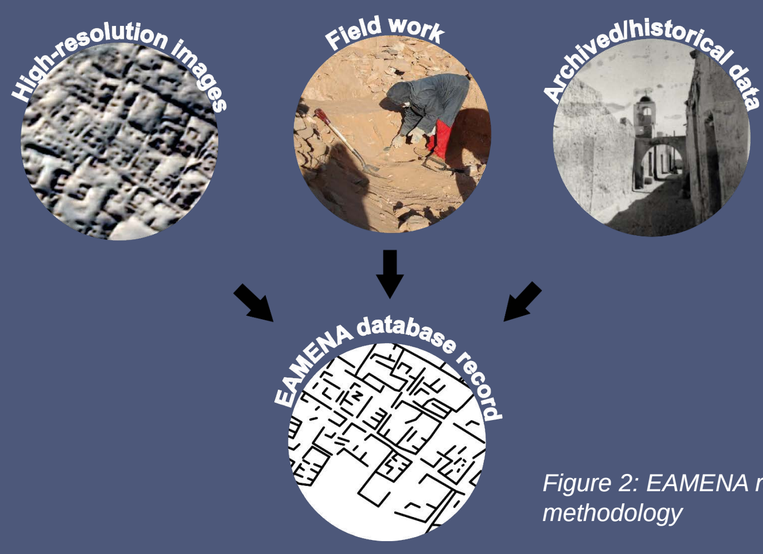

Figure 2: EAMENA recording methodology

Monitoring

EAMENA is utilising classification algorithms to monitor the main threats posed by modern land use (Rayne et al 2017a and b). We are using Google Earth Engine (a cloud-based platform harnessing high performance computing power- see Gorelick et al 2017) to map previous and ongoing change across the MENA region in order to identify the most significant land-use impacts affecting each area. In this example we mapped change using NDVI (Normalised Difference Vegetation Index) in the extent of the cultivated area over time in Al-Jufra oases in the Libyan Sahara (Fig.4). In Al-Jufra we have recorded 90 archaeological sites of all periods including tombs, settlements and ancient irrigation channels (see Rayne et al 2017b). Our workflow can be seen at http://bit.ly/Jufrachange and comprised;

- Production of composite images using least cloudy, median pixel values from Landsat 5 and 8 collections (calibrated for TOA) representing 2 year periods of interest
- Application of cloud and water masks
- NDVI for each composite and selection of appropriate threshold value
- Cultivated area represented by NDVI calculated (in km^2)

In Al-Jufra the vegetation indices revealed that the oasis expanded from 26 km^2 in the 1985-86 composite to 121 km^2 in the 2017-18 composite. Of the 90 sites, 47 have been destroyed or damaged by this modern agricultural activity, with the remains of ancient water management particularly affected.

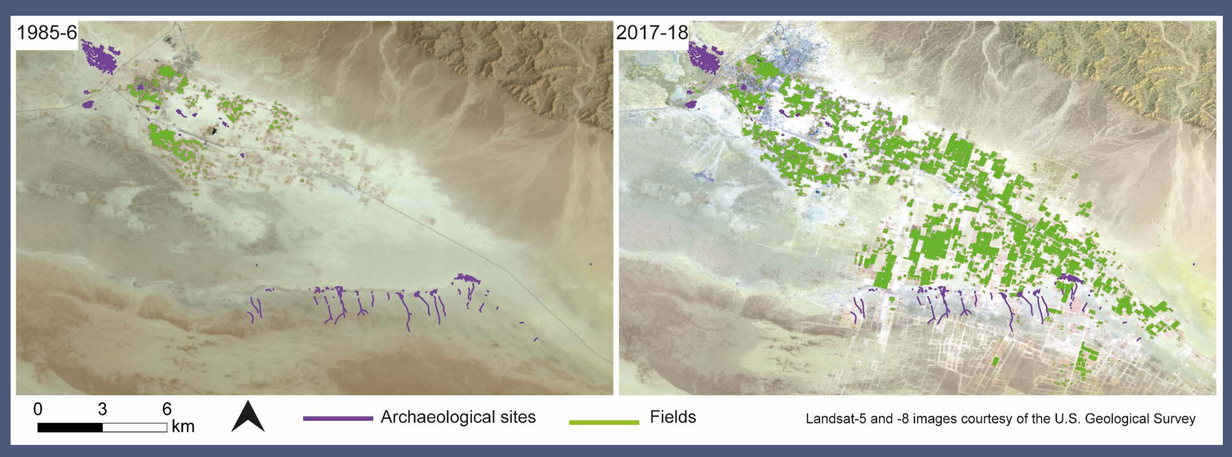

Figure 4: Landsat images show the Increase in cultivation in Al-Jufra between 1985-2018.

We made confusion matrices to test the accuracy of the classification (e.g. see Congalton 1991). This allows the proportion of correct pixels in the classification to be quantified. In this example (table 1) we tested the Landsat 8 NDVI pixels against the original Landsat images and images available in Google Earth of the same date. The overall accuracy was high at 97%, although the producer's accuracy of 79% reflects some pixels on the edge of newly planted palm fields which were missed by the classifier.

		Reference (Landsat composite and Google Earth images)		Total
		Vegetation	Other	
SAVI classification	Vegetation	30	1	31
	Other	8	261	269
Total		38	262	300

Table 1: Error matrix

User's accuracy: 30/31 = 97%

Producer's accuracy: 30/38 = 79%

Overall accuracy: 291/300 = 97%

To facilitate monitoring of surviving sites in the MENA region we are now developing a methodology using Google Earth Engine which automates agricultural change detection in the vicinity of each of our sites: http://bit.ly/fieldsmonitor. This takes advantage of the multispectral properties and short revisit interval of the Sentinel-2 sensor:

- AOI defined by user
- Sites feature collection loaded in by user
- Dates of two 12-month periods defined by user
- Production of (masked) composite images using least cloudy, median pixel reducer
- NDVI calculated and threshold value selected by user
- Comparison between NDVI composites to calculate change
- User selects buffer value to generate aoi around each site
- Result of change detection within each buffer appended to site table

This workflow highlights sites where new fields are beginning to encroach. For example in Al-Jufra we found that cultivation increased within 300 metre buffers of 12 sites between 2016-2018. Across Libya as a whole, so far we have recorded 5638 sites. Our monitoring script highlighted 1035 of these as having undergone changes in vegetation extent in their buffered vicinity in the last 3 years (Fig.5).

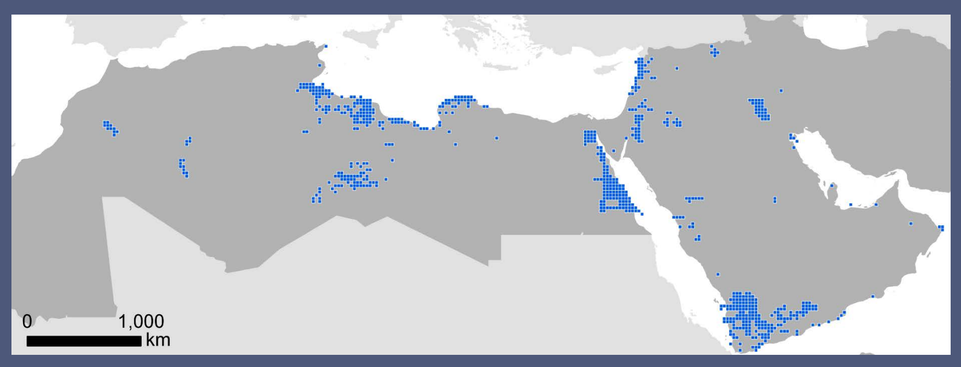

Figure 1: EAMENA study area and locations where sites are recorded in our database so far.

Recording

Our image interpretation methodology, which primarily relies on Google Earth and Bing maps, feeds directly into user-friendly and standardised data entry in our Arches database.

- Satellite and aerial imagery is first examined systematically by analysts and digitized in Google Earth/GIS.
- Available field-based survey and excavation data is checked
- Archived/historical data is examined
- The site's morphology is described
- An interpretation including form and function is made
- Condition, damage and threat are recorded

EAMENA's use of a range of datasets (Fig. 2 and 3) increases the possibility of recording a site, even where ground survey data is lacking. Through comparison with existing digitised datasets, analysts are able to make interpretations about what the features observed via imagery might represent. Recording is done by trained analysts, including a team of post-doctoral researchers with significant experience of remote sensing and archaeological survey and by heritage professionals in the region who have been trained during specific courses delivered by EAMENA (2017-2019).

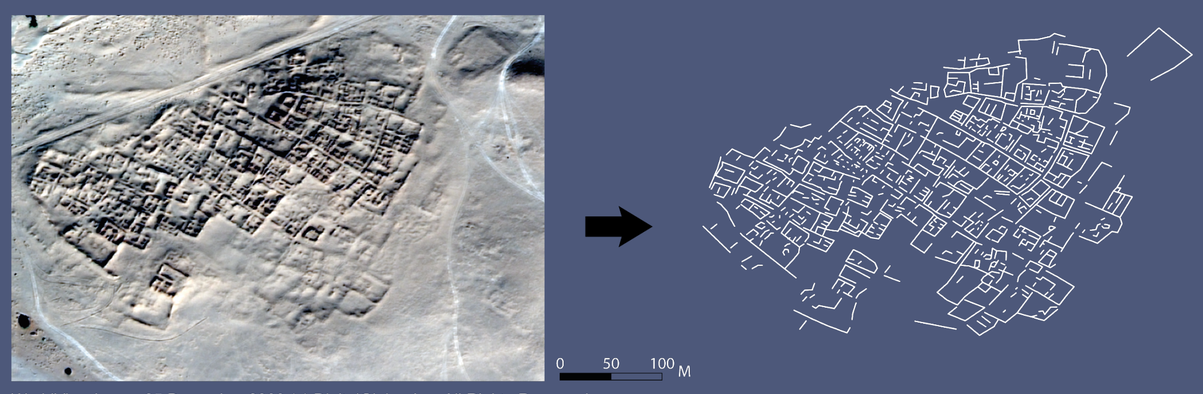

Figure 3: Digitised medieval town in Al-Jufra oasis, Libya

Conclusion

EAMENA is the only project specifically taking an open-source approach using trained interpreters (Fig. 6) to record the archaeology of the whole MENA region systematically. This leads to more accurate recording than automated methods of site identification and crowd-sourced data entry. Classification algorithms applied to multispectral satellite imagery then support this by allowing regular monitoring of changes to the recorded sites. Monitoring allows us to understand the kinds of modern activities that threaten archaeological sites.

Using our combined approach we have created over 120,000 site records. So far, we have found mundane human land-use activities such as agricultural and urban expansion to be the most widespread cause of damage to archaeological sites (Fig. 5), despite the high-profile attention given by media to conflict-related destruction and looting. These problems have been exacerbated by the reduction in both the ground-based monitoring of heritage sites and regulatory enforcement by governmental organisations, and the increased opportunities for unauthorised development that result from recent conflicts. Our database recording and satellite image monitoring methodologies are providing heritage agencies with tools that will enhance their protection of heritage assets. The next phases of this work will comprise integrating change assessment of urbanism and building a user interface for our monitoring workflow to integrate with our database.

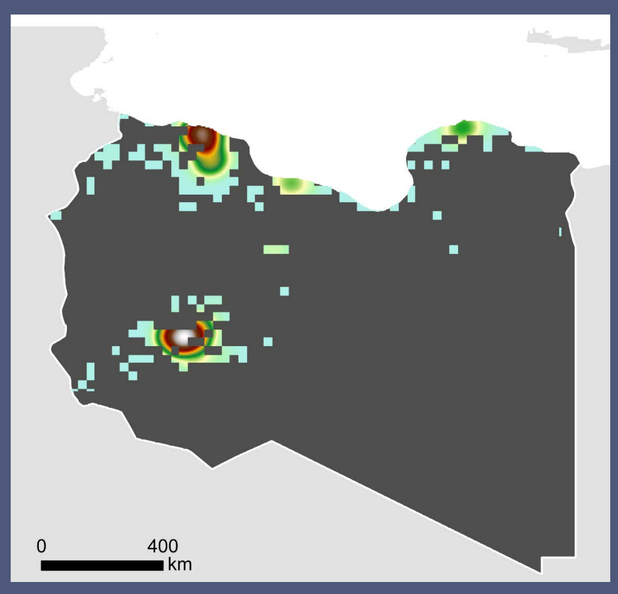

Figure 5: Kernel Density Estimate of sites in our digitised areas impacted by vegetation change 2016-18

Figure 6: Dr Mouna Hermassi and other participants of an EAMENA training course working with GIS

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