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Assessment of the impact of the Syrian conflict on archaeological sites in the Daraa region

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To date, the attention of both local and global cultural heritage preservation initiatives in Daraa Province, southern Syria, have focused on the well-known Bosra World Heritage site. A comprehensive investigation of damage to Daraa's many other archaeological sites, poorly studied in comparison to other parts of Syria, has until now, not been undertaken. This study, for the first time, attempts to remedy this, by detailing 1632 instances of damage across 196 archaeological sites surveyed using freely available high-resolution satellite images captured between 2004 and 2022. A key element of this dataset is that it indicates that while the types of damage to heritage sites identified are similar to those that have been documented elsewhere in Syria, the temporal and spatial patterning of this damage can be related to specific local conditions and events. This underscores the need for large-scale studies undertaken using remote sensing, to be grounded within an understanding of local circumstances, to maximize their information value.

Keywords satellite imagery, remote sensing, Syrian conflict, endangered archaeology, looting, military damage, Daraa

Introduction

Satellites that regularly capture images of the surface of the Earth can be a reliable source for assessing the condition of archaeological sites that are under threat (Cunliffe *et al.* 2014). High- and medium-resolution satellite data from publicly available platforms like Google Earth, Copernicus Sentinel-2 and Landsat-8 have, in recent years, been recognized for their value in evaluating the state of Syrian archaeological monuments (Agapiou 2020; Casana 2015; Cunliffe 2014; Danti *et al.* 2014; 2017; El Hajj 2021; Mamo *et al.* 2022; Rayne *et al.* 2017; Tapete and Cigna 2018; 2019; 2020).

Syrian cultural heritage sites have endured considerable impacts from various human activities, including agriculture, urban expansion, as well as other factors, over the years. The Syrian War has, however, exacerbated certain forms of damage and resulted in a heightened level of neglect towards Syrian heritage. The absence of authorities capable of implementing heritage protection measures, driven by the escalation of armed violence and the influence of extremist organizations, has further compounded these challenges (Al-Jabbai 2014; Mamo *et al.* 2022). The armed conflict in Syria has manifested in destructive actions, such as the bombing of museums and archaeological sites, the establishment of military installations on these sites, and the looting of archaeological sites followed by illicit trafficking of artefacts (Cunliffe et al. 2014). In the face of these threats, Syrian archaeologists, as well as

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non-archaeologists and the broader community, bear a profound responsibility to safeguard and rescue their heritage. This commitment is grounded in the understanding that heritage serves as the bedrock of identity. Thus, the preservation of Syria's cultural heritage is synonymous with preserving the nation's identity and collective memory.

Daraa Governorate, situated in south-western Syria, has been significantly impacted by the ongoing conflict (Fig. 1). It has a rich archaeological heritage, despite being less well-explored than other parts of the country. A mere 5% of the known archaeological sites in the region have been the subject of archaeological investigations, revealing only a fraction of its historical significance. Despite limited exploration, the area has provided valuable insights into some of the oldest human occupation of the region in the Palaeolithic and Natufian periods (Al Kassem 2013; Al Kassem *et al.* submitted; Cauvin 1974), and hosts important evidence for settlement and land use from Bronze Age through the early Islamic periods (e.g., Tell Ashtara, Nabi Ayoub Bath, Al Omary Mosque) (Abu Assaf 1968; 1969; Meinecke 1992). Furthermore, traversing the study area is the Al Hijaz Railway, which connects Bosra in the east with Acre/Akko, Haifa and Nablus, on the Mediterranean, in the west. This railway intersects with the line from Damascus to Al Madina al Munawara in Saudi Arabia, adding another layer to the historical and cultural significance of the region.

Previous research in the Daraa region

Al Omary Mosque, situated in Daraa city and having the distinction of being the first mosque built in the region, was the first cultural heritage site in Syria for which damage was reported in the current conflict. It was subjected to mortar attacks between 2011 and 2013 (AAAS 2014; Al Kassem 2016; BBC 2011). Subsequently, examples of damage were extensively shared on social media platforms. In 2014, both the Directorate General of Antiquities and Museums (DGAM) and UNESCO released a report detailing the conditions of archaeological sites affected in Syria (dgam.gov.sy). The list included only a few sites in Daraa. Aiming for increased accessibility and awareness, the DGAM launched an interactive map in 2015, showcasing the same damaged sites highlighted in the previous report, including Bosra city, a UNESCO World Heritage site (dgam.gov.sy). In 2015, supported by the DGAM, the primary author conducted an extensive documentation project on archaeological sites in the eastern sector of the Daraa Governorate. The assessment encompassed 15 sites that had been previously recorded, and 12 sites that had not been previously documented (Al Kassem 2016). The findings indicated substantial damage resulting from heavy weaponry. Notably, the documentation revealed that looting was the most prevalent form of damage, and that this was most apparent on previously unrecorded archaeological sites. In the same year, Al Omary Mosque in Daraa city, the Islamic Mozerib Castle and other sites in the western sector of Daraa province were evaluated by DGAM (Nasrullah and Al Doss 2016). Both reports concentrated on recording and listing observed damages. Lastly, a team from the DGAM also assessed the UNESCO site of Bosra. Their primary objective was to evaluate and document the damages incurred by the site. In their findings, the team concluded that looting emerged as the most substantial threat to the city's cultural heritage (DGAM 2018).

Satellite remote sensing studies have also focused on specific sites in the Daraa region. One study compared a Bing Maps image from August 2011 and a WorldView-1 image of Tell Ashtara captured on August 27, 2013, to highlight significant damage to the top and northern sides of the site, characterized by substantial holes (Casana and Panahipour 2014). Cunliffe *et al.* (2014) also utilized satellite imagery to illustrate the diverse damages resulting from conflict in the historic district of Bosra city. They assert that a predominant share of the damages appears to have resulted from military operations or shelling, with a significant portion of these impacts potentially confined to the internal structures, rendering them indiscernible in satellite images. While providing valuable insights, it is crucial to note that their observations primarily focused on the losses incurred within the city's historic district. Finally, an evaluation of the duration, extent and severity of natural events — specifically, floods — at the Bosra UNESCO site was carried out by Tapete and Cigna (2020). They used radar satellite images from the Italian Space Agency's COSMO-SkyMed constellation and the European Commission's Copernicus Sentinel satellites. The investigation found that rain caused flooding of several important sites, including the Roman Theatre. It took a few days to many weeks for these places to be completely dried out and evacuated.

Looting, and site destruction, has been widespread across Daraa province, but previous research conducted by both local and global organizations has been predominantly focused on the Bosra World Heritage, and a handful of other sites. While this is

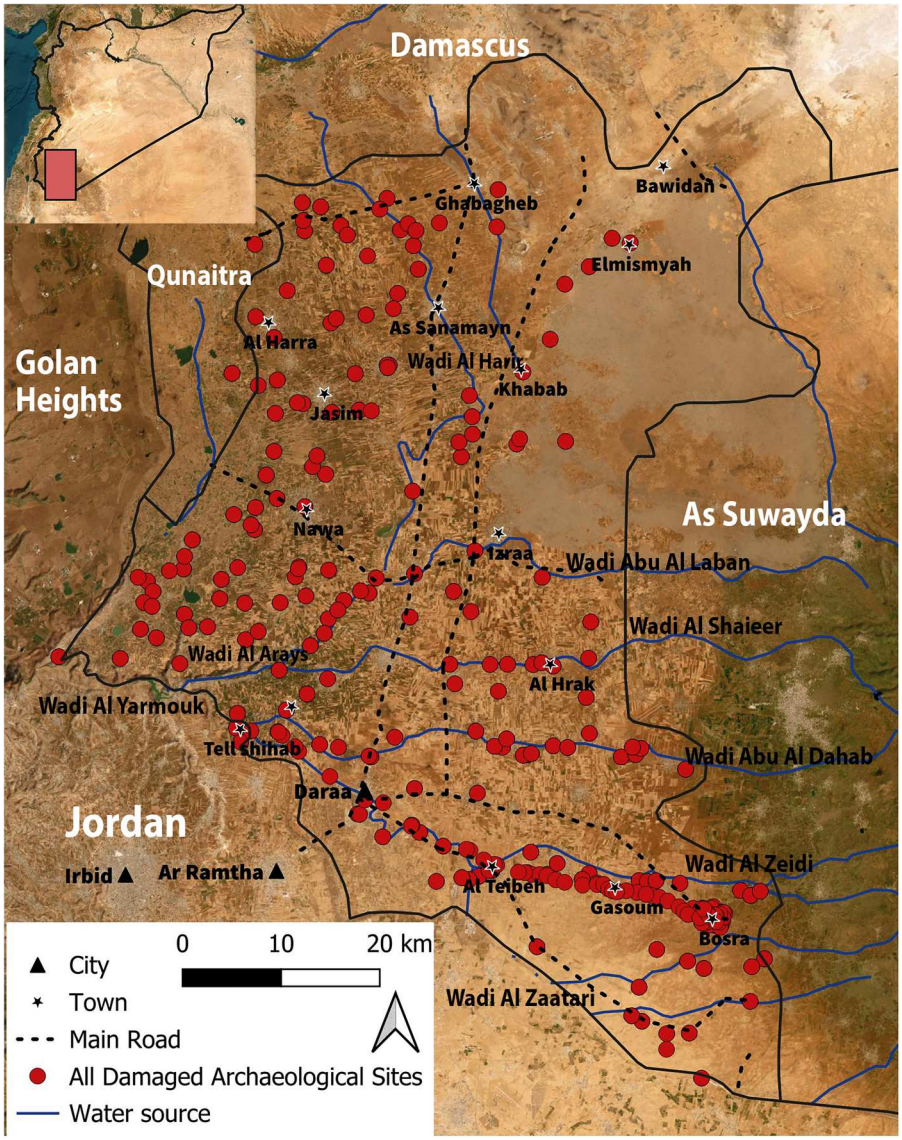

Figure 1 **A map depicting the locations of the damaged archaeological sites studied within the region of Daraa, Syria. Employed in compliance with the terms of service of Google Maps/Earth for research purposes.**

crucial, it has not generated a wider body of data that can help us understand the spatial and temporal impacts of the conflict over the entire province. In addition, a lack of data on a wider sample of sites may focus any succeeding documentation, building and restoration efforts, only on sites deemed important through international recognition. The aim of this study is to use satellite imagery to assess the condition of a much larger sample of sites in Daraa province than has been previously attempted, and thereby present a more comprehensive evaluation of the impact of the Syrian conflict on the cultural heritage of the region. This data will be made available via the EAMENA Syria database to civil society and community heritage organizations to aid in developing local strategies for future protection efforts.

Daraa Governate during the armed conflict

Daraa province was the location of the first demonstrations of the Syrian conflict, and by the end of 2011, these demonstrations had transformed into armed clashes (BBC 2016). By early 2012, these had evolved into large-scale confrontations, with heavy weapons, between government and opposition forces, including the so-called Free Syrian Army (FSA). This eventually led to a situation where almost the entire governorate, except for half of Daraa city and the highway connecting Daraa to Damascus, was beyond the control of the Syrian government (Bakkour 2022). The Islamic faction Al Nusrah Front made its appearance in Syria towards the end of 2011 and started asserting its influence in Daraa (represented by the Muthana

Movement) over the following few years (Bakkour 2022).

In 2013, the armed opposition and the Al-Nusra Front launched an offensive, gaining control over some villages and military bases along the border with Jordan, west of Daraa city. A few days later, the Syrian army managed to reassert control over some of them. Although, in this instance, the armed opposition and the Al-Nusra Front, were working toward the same outcome, their relationships were not stable and there was constant tension between the two factions.

The western region of Daraa witnessed the most violent battles. These were often for control of strategically important elevations, mostly small or large archaeological mounds (henceforth tells). In 2014, the conflict in Daraa province intensified between the opposition and Islamic factions against the Syrian army to both the east and west of Daraa city (Hourani and Ward 2014). Over four months from February to May, the opposition, including the Al-Nusra Front, gained control of various strategic locations and checkpoints, such as Tell al Jabyia (The Carter Center 2014; Sands and Maayeh 2014), Tell Om Horan, Tell Braq, and Tell al Ahmar Sharqy, Tell Matouq al-Kabir and Tell Matouq al-Saqhir (Syrian Observatory for Human Rights 2014a; 2014b). By June 14th, armed opposition secured Tell al Joumoa, followed by the control of three military bases in Al Sheikh Saad on July 15th and Zamreen town on August 26th. In October 2014, the opposition, aided by Al-Nusra Front, launched another successful offensive targeting Tell al Harra and al Sanamain. They aimed for the Umm al-Mayathen checkpoint near the Syrian-Jordanian border on October 23rd (Khaled 2014).

In 2015, the armed opposition with its allies controlled Bosra city in the east (Al Jazeera 2015) and Sheikh Miskin city in the west of Daraa, aiming to disrupt the Syrian army's supply routes via the Damascus highway to Daraa city. The situation deteriorated in 2016, especially in the 'Triangle of Death', which connected the Daraa countryside, Damascus and Quneitra (Einav 2015; The Syrian Observer 2017). Numerous battles erupted between Islamic factions (two groups linked to Islamic State of Iraq and Syria (ISIS), the Yarmouk Martyrs Brigade and the Islamic Muthanna) and the armed opposition on one side, and between the armed opposition and the Syrian army on the other (Enab Baladi 2016; Mohamad 2016; Orient 2015).

In 2017, fierce battles erupted in the western outskirts of Daraa city as ISIS sought to regain control over the Talirmouk Basin. Simultaneously, clashes between the Syrian army and armed opposition forces intensified in other parts of Daraa city. In June and July 2018, Syrian-Russian forces launched an offensive on the governorate to regain control. Following several days of intense conflict and gaining control of approximately 58% of the governorate's territory, a ceasefire was brokered with Russia's support. Subsequently, the Syrian Army consolidated its control over the entire Daraa border with Jordan and the Golan Heights frontier through extensive reconciliation efforts among all parties involved. Despite these efforts, however, incidents such as assassinations, explosions and general chaos continued unabated until recently (Tokmajyan 2020).

Methodology

Our investigation commenced with a thorough examination of previously recorded sites identifiable on available satellite imagery. The first author gratefully received a list from the DGAM in Daraa, which provided co-ordinates of 90 archaeological sites that were known to the directorate. Subsequently, and after inspection of all mentioned sites in the list, we systematically scrutinized the broader study area, actively searching for previously unrecorded archaeological sites. All the previously unrecorded sites located on the satellite imagery had visible damage. The sites identified on satellite imagery were primarily tells, though we also identified some built architecture, such as the Hijaz Railway and historic buildings within historic Bosra. Given the compact size of the study area, and our familiarity with its terrain, we remotely surveyed the region twice, with slightly different methodologies, thereby increasing the accuracy of identification. The first pass consisted of a visual inspection of the entire region using high-resolution satellite imagery available on Google Earth Pro (GE). Following this, we conducted a second pass of the imagery, concentrating on tells situated around water resources (e.g., wadi/valley, lake or well), which, from previous experience, were often the focus of anthropogenic damage due to their accessibility and proximity to towns and villages. In total, we identified 1632 instances of damage across 196 archaeological sites (80 of which had been previously recorded by the DGAM), on images captured between 2004 and 2022. Our survey has therefore recorded, and added condition information, for more than double the number of sites that were previously known to the DGAM.

Imagery coverage of the study area is both geographically and temporally variable because our core

approach utilizes freely available imagery on Google Earth (GE). For one site, there may be sporadic coverage between 1984 and 2021/2022 at various spatial resolutions, while another may have consistent high-resolution coverage between 2004 to 2019. Most of the images taken between 1985 and 2004 were of limited use in our study because of their low spatial resolution. Therefore, for most sites, our record of damages dates to between 2004 and 2022 when high resolution imagery is generally available. The next stage of the project intends to incorporate other imagery sources and methodologies (e.g., Sentinel 1 cf. Tapete and Cigna 2019).

This means that isolating damage to a specific date is nearly impossible. However, following the methodology developed by the EAMENA project (Bewley *et al.* 2016), we can record instances of damage as having occurred on a specific date, between two dates, or before a certain date. Most frequently, with the available dataset, we can say that damage occurred between two dates, often years apart. This can make it complicated to identify specific periods during which there are increases or decreases in damage types across a large sample of data and, in particular, to quantify incidents of damage along a temporal axis; we deal with this by using a simple aoristic model (e.g., Palmisano *et al.* 2021) that was also employed by Mamo *et al.* (2022) in an investigation of conflict damage in Hasaka Province. In short, we have calculated a probability weight for each year of an event by assigning a value of 1 to each 'event', then divided this by the number of calendar years within the potential duration of a specific event. The results are not absolute, but are relative values that suggest periods during which there is an apparent increase or decrease in damage. While this model enables us to approximate a broad understanding of the potential timeframe for the occurrence of certain types of damage, it is not without limitations. For example, our assessment does not include severity of the damage (c.f. Casana and Laugier 2017). Furthermore, we acknowledge that the variability in the number of images available, and the dates that these images cover are not the same for every site in the analysis, which can introduce some uncertainties (Mamo *et al.* 2022). Nevertheless, this method does highlight the relative magnitude of change between years and is highly beneficial because it leverages our understanding of social, political and military developments, enabling us to correlate our data with events on the ground. While we have included the over 140 instances of damage that were recorded in the city of Bosra and along the Al Hijaz Railway in our assessment of types of damage, we have not included these in our temporal assessment, as this may skew the overall picture. We will deal with these in a separate article.

A further limitation inherent in all satellite-based approaches is that looting is not always easily detectable. This is because looting holes can be very small, or present in areas of a site that are not visible to the satellite, obscured by accumulated sediment, within structures and buildings (as observed in Bosra), or excavated as tunnels and holes along slopes (Cunliffe 2014; Vella *et al.* 2015). Therefore, satellite data may not capture all forms of looting, as emphasized by Tapete and Cigna (2019). The geography and geology of the Daraa region also played a role in our ability to identify and define damage types. In many cases, differences in the reflectance of the soil/rock in or near looting pits, allowed us to distinguish these features easily from the surrounding environment. However, within the basalt plateaus in the north-eastern part of Daraa (where the maximum extension of Jebel Al Arab/Jabal ad Druze Volcano in Swuyda is located), which are characterized by dark stone, it was very difficult to confidently attribute certain disturbances to looting (see Fig. 1). This is because it was nearly impossible to recognize shadows created by looting pits from pits naturally formed in the black volcanic rocks. Looting on archaeological sites with walls composed mainly of basalt was specifically hard to distinguish. Nevertheless, observed changes in the soil colour on the periphery of looting pits were used to boost our certainty between looting pits and other types of shadows. Lastly, since many historical towns are located within modern towns in Daraa province, our assessments were sometimes hampered by modern structures, under which we could not assess with imagery.

Results

Figure 2 shows the number of instances that fall under each type of damage category over the entire sample, along with the number of sites that have been affected by that type of damage. The most frequent type of damage impacting the archaeological sites in this sample is damage caused by looting (603 instances). Following this is damage caused by agriculture/pastoral activities (597 instances). Across the MENA region, the most frequent damage category is often agricultural/pastoral activity (Rayne *et al.* 2017; 2020), and the leading cause within this category is often ploughing or other activities associated with cultivation (e.g., irrigation). In Al Hasaka, for example,

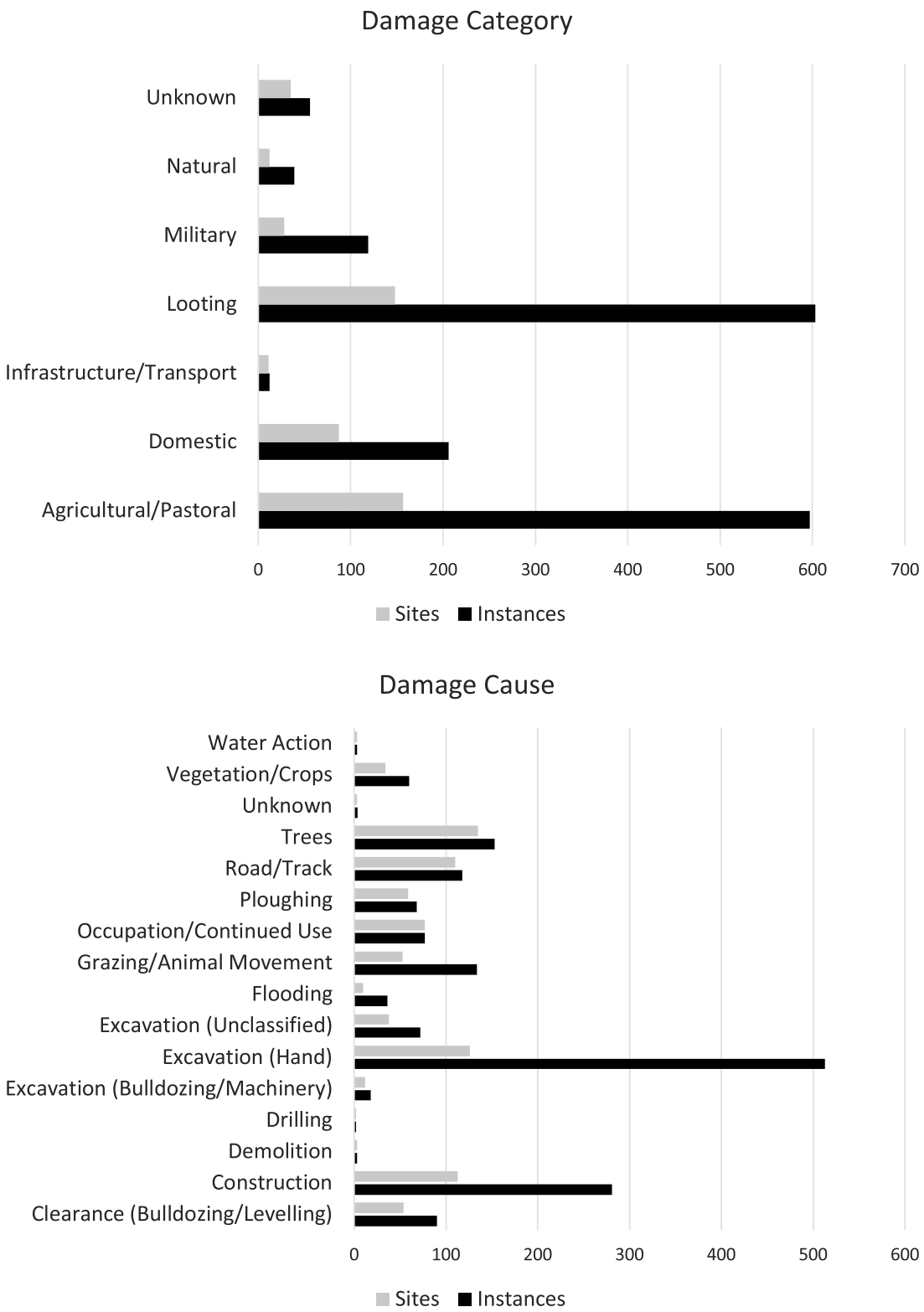

Figure 2 **Number of sites vs. number of individually recorded instances of damage by 'damage category' (top) and 'damage cause' (bottom). Damage category is overarching category of activity that the damage belongs to (e.g., agricultural/pastoral activity), while damage cause, is the specific mechanism of damage (e.g., ploughing).**

ploughing is one of the most common sources of damage, even during conflict (Mamo *et al.* 2022: 3). By contrast, in Daraa, more instances of damage can be attributed to grazing activities (pastoral) since the start of the conflict. Interestingly, damage attributed to both agricultural/pastoral and looting

activities frequently appear on the same sites (though not exclusively), and the possible relationship between these two damage types will be explored further below.

Although the area was host to one of the most brutal areas of conflict in Syria, military activity (primarily clearance bulldozing/levelling, construction, demolition and road/track building) caused only 119 instances of damage recorded here (7% of the total). A similar percentage of damage instances was attributed to military causes in Al Hasakah (8% of the total) (Mamo *et al.* 2022), a study using the same methodology as ours. While a wide range of damage types were identified on the satellite imagery, it is important to bear in mind that there are likely further examples that were not visible. For example, field evaluation of damaged archaeological sites in Daraa undertaken in 2015 (Al Kassem 2016) highlighted wall damage caused by Gunfire/Light Weaponry and looting inside archaeological sites/buildings that was not visible on satellite imagery. For instance, the Temple of Al Moutayia was damaged by shelling in 2014, but this was not visible in satellite images. This may suggest that instances of military damage may be under-reported on satellite imagery only assessments.

Interestingly, the ASOR CHI documentation project, assessing sites across Syria and Northern Iraq between July 2014–June 2017 data suggested that types of military damage (explosives, air strikes, intentional destruction, gun-fire/light weaponry) were the most common cause of damage followed by illegal excavation (Danti *et al.* 2017: fig. 2). Their results, however, focus specifically on conflict related damage (as opposed to all damage), use a larger sample size (all of Syria and Northern Iraq), cover a shorter time span and incorporate vital on-the-ground reporting (more likely to pick up things like gun-fire damage).

Further broad comparisons can be made with Casana and Laugier's (2017: 12) study. They reported that that nearly 11% of the sites in their sample (Syria and Iraq) showed looting having taken place during the period of the conflict (2011–2016). Taking into account just Syria they report that 13.4% of sites were looted during the period of the conflict they assessed. In our much smaller scale dataset, 76% of sites we recorded had looting damage. Direct comparisons are, however, somewhat misleading as our sample was restricted to Daraa and covers a much wider timespan (2004 and 2022).

We would argue that overall, the results of these various studies are not entirely at odds but show the variability that can be produced depending on sample size, time range and project focus, and that there is significant value in supplementing large-scale remote sensing studies with smaller regional datasets to understand geographical variations in these patterns. Regional-level studies that take into consideration local social and political factors (e.g., local community attitudes, geography) and use this information to understand types and locations of damages will undoubtedly improve the datasets available for larger scale studies.

Looting damage

Satellite imagery can be a useful tool for documenting looting on archaeological sites (Casana and Laugier 2017; Mamo *et al.* 2022; Tapete and Cigna 2019). In recent years there have also been significant advances in using processing techniques that incorporate some automation to identify and assess looting (Tapete and Cigna 2019).

Satellite imagery enabled us to record 603 instances of looting damage on 148 archaeological sites (Fig. 3; see Fig. 4 for an example of looting damage). Distinguishing the mechanisms of looting, (e.g., whether looting was carried out using machinery or manual labour) is, however, a problem which has been noted in other studies (e.g., Mamo *et al.* 2022). Despite this difficulty, we can say that illegal excavation using hand-held tools (as opposed to machinery) is the most frequent mechanism of looting we recorded. This is suggested by the scale of the activity, with most of the looting instances being visible as small pits. This was followed by examples where the mechanism was unclear and thereby labelled as unclassified. This corresponds with the evidence gathered from the ground-based evaluations carried out in the region in 2015 (Al Kassem 2016). Despite knowing that looting had occurred within modern settlements, between buildings, or within archaeological sites, as noted in the earlier field documentation (Al Kassem 2016), these instances were not distinguishable on the satellite imagery, except for a few rare examples that were well known. Understanding the mechanisms of looting is interesting as it suggests local political conditions have an important impact on the types of looting activity that may occur. For example, in parts of north-west Syria, large-scale looting programmes using machinery were frequent and often linked to Islamic State control (Almohamad 2021).

Our analysis indicates some geographical patterns in looting activity. During the remote survey, we also observed that some sites (mostly tells) located

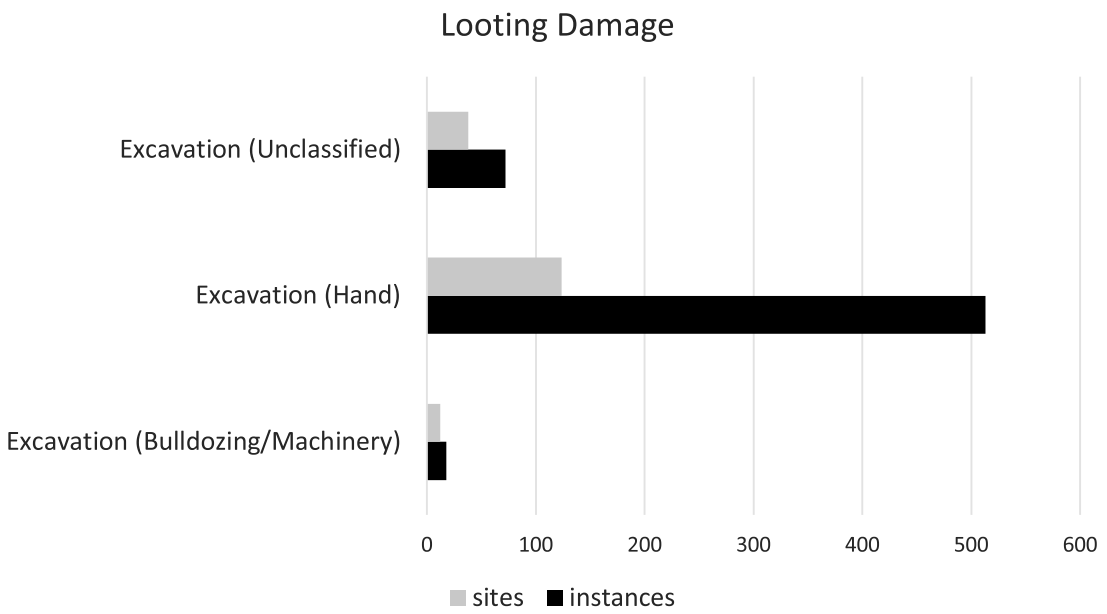

Figure 3 **Looting damage plotted by number of instances (black), and by number of sites at which that type of damage was observed (grey).**

away from villages, on basalt plateaus along watercourse banks in the south-east, south-west and north-west of the study area hosted an abundance of structures, likely comprised of vehicles and tents. Over the course of the available satellite images (e.g., through seasons and years), the tents, along with sheep pens of black rock, and water tanks, change configuration suggesting seasonal or temporary use of these locations for grazing/pastoral activities. There appears to be a correlation between the appearance of looting pits and the settlement at the sites. Of interest to our study is that on these sites

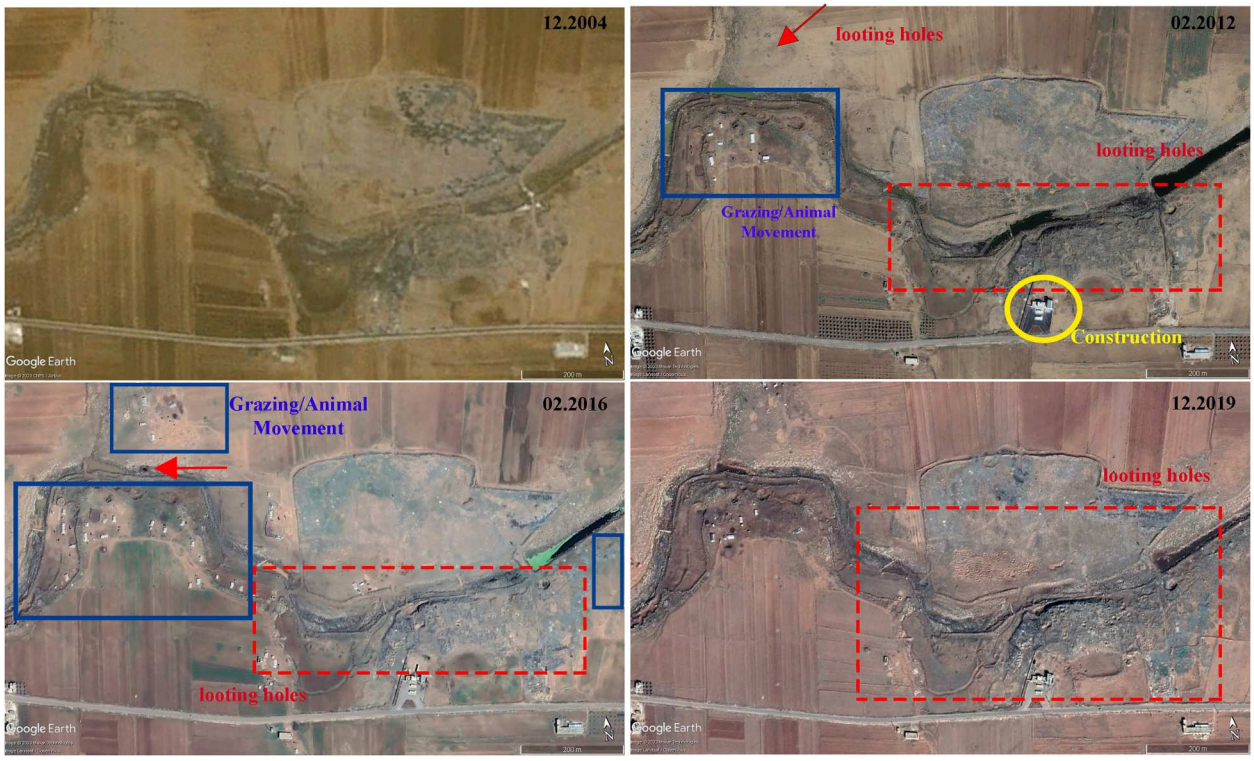

Figure 4 **A time-series of images of site D1 that has been looted frequently between 2013 and 2022. Image © 2023 Maxar Technologies. Used in accordance with the Google Maps/Earth terms of service for research purposes.**

where we have noticed instances of pastoral activities, we have also observed instances of looting (51 of the 148 sites with looting damage also have pastoral activity) (see Figs 4 and 5). This was also observed by the first author during field visits in 2015 (Al Kassem 2016) to Al Qnaia, which is located on the bank of Wadi Al Dahab, and where both looting and grazing/pastoral activities were evidenced (Fig. 6).

This presents the possibility that looting and pasture usage may be connected in some cases, especially where we can see evidence of the same locations being utilized for pasture annually (e.g., Fig. 4). However, some sites are abandoned after a single season and show no pattern of return, and/or looting appears to occur before sites are occupied (Fig. 7). It is also possible that the same conditions that have increased the use of these areas for grazing (e.g., lack of local regulations or essentially, power vacuums) have also made it easier for these sites to have been looted by a potentially broader number of parties. Figure 8 illustrates the correlation between the temporal fluctuations in damages caused by several damage categories. It shows that the trend line for pastoral activities and looting appear to rise and fall in-step, despite variations in the frequency of instances.

We also recognised a pattern of looting pits along the historical Al Hijaz railway. Local rumours suggest that depressions along the length of the railway are signs of buried treasure from the Ottoman period. This has led to digging along the railway line to loot this supposed treasure. The pits may destabilize the railway, threatening its structural integrity. Moreover, looting has led to the loss of critical components, such as hardware, further compromising the railway's integrity. Thirty-eight cases were recorded on the satellite imagery, though more may be present but not visible. In addition, the imagery shows that the railway has been cut to facilitate vehicle crossings (probably for military purposes) (Fig. 9), while in other places, the railway has been buried using asphalt, which may be for the same reason.

Military damage

Specific damages associated with military activities, as documented in incidents at the Moutayah temple, Ma'araba and al Omary mosques (Al Kassem 2016), could not be identified on satellite imagery. We could, however, recognize other types of damage related to military activities, such as clearance (bulldozering/levelling), the construction of roads/tracks, the construction of military structures or emplacements on tells, shelling of buildings (causing visible structural damage) and the demolition of monuments, as happened at the World Heritage Site of Bosra (Cunliffe *et al.* 2014).

Clearance (by bulldozing or levelling) is the most common damage type attributed to military activity in Daraa province (Fig. 2; Fig. 10). All the sites on which this damage type occurred were tells that were used to establish a military base by one or another of the conflicting forces on the ground (e.g., Fig. 10). Moreover, some of the fiercest battles that were waged in Daraa were to gain control of tell sites (Bakkour 2022). Given the flat terrain of the province and the scarcity of prominent elevations, it was crucial to occupy elevated points to effectively monitor the surrounding area. Many of these tells were used as military points before the war, but the deliberate clearance of these sites for military purposes increased after 2012.

Agricultural/pastoral damage

Inhabitants of Daraa province rely on various sources for their livelihoods. Many among them operate their own businesses in Gulf countries and remit money to their families, while a significant portion are engaged in farming or trading. It is noteworthy that agricultural activities decreased with the onset of the Syrian war (Baladi 2023), though still impacted archaeological sites through the conflict (Fig. 2). The conflict triggered significant waves of displacement towards Jordan, consequently leading to a decline in agricultural pursuits (further details below). Notably, there is a surge in tree felling in the area (Fig. 11). This may be related to water shortages, caused by an increase in unauthorized well digging due to the absence of governmental authority following the conflict. The entire area, due to the scarcity of perennial water sources for irrigation, relies on artesian wells. Without ample irrigation, and a lack of labour to care for them, using the trees for fuel during the winter would have been of greater value than leaving them planted, especially as no alternative heating sources were available (Al Nofal 2024).

Figure 12 illustrates the primary causes of damage within the agricultural/pastoral category, highlighting grazing/animal movement and construction (i.e., vehicles, tents and other equipment used in the site) as the most significant contributors.

Domestic damage

In Daraa province, a distinctive feature of the countryside is the presence of old towns (i.e., historic settlements) in each modern village/town. These old towns

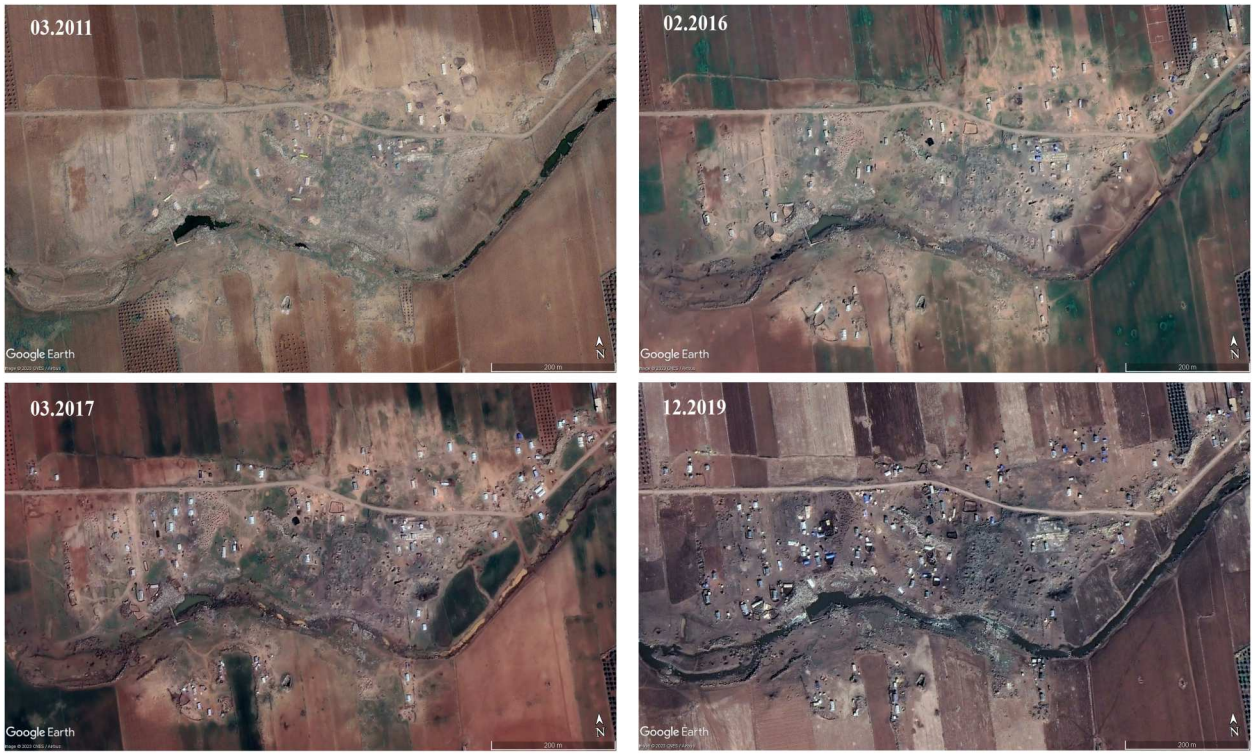

Figure 5 A time-series of images of site D43 shows the simultaneous grazing/pastoral and looting activities. Image@ 2023 CNES/Airbus. Used in accordance with the Google Maps/Earth terms of service for research purposes.

have served as cores from which modern towns have grown and evolved. These ancient settlements bear witness to various periods of occupation and, intriguingly, have often been abandoned over time, despite their central locations within the contemporary towns. Nevertheless, continued occupation in their vicinity, and the associated roads/tracks and construction activities, are the drivers of damage in the domestic category (Fig. 13). In addition, looting pits were often visible on the satellite imagery outside

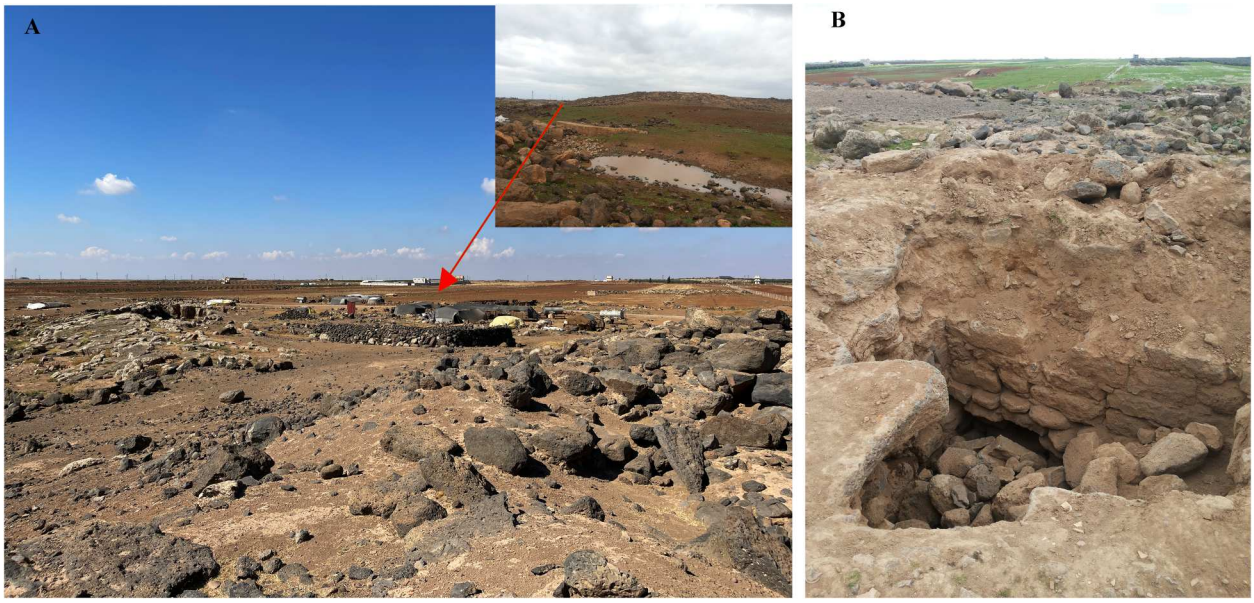

Figure 6 (A) Vehicles and tents on Al Qnaia plateau and on the bank of Al Dahab valley. (B) one of the documented looting pits (Al Kassem 2016).

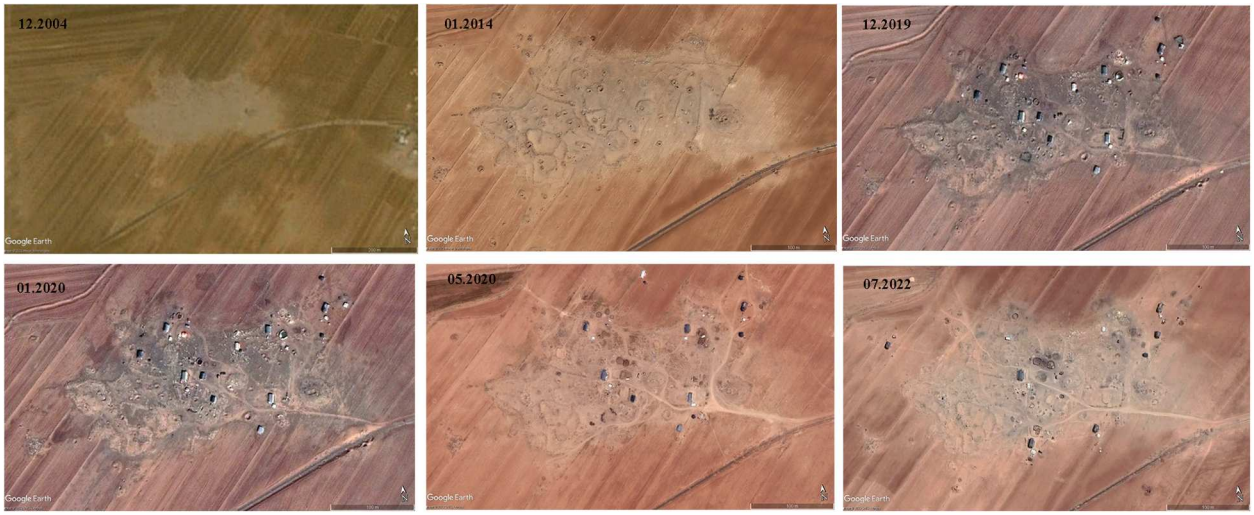

Figure 7 **A time-series of images of site D2 showing the temporal relationship between the settlement of the site and looting activity. Image © 2023 Maxar Technologies. Used in accordance with the Google Maps/Earth terms of service for research purposes.**

the buildings of these abandoned old towns. Similar pits were recorded inside buildings during field visits (Al Kassem 2016) but are not visible on satellite imagery.

Natural damages

The impact of recurrent floods on archaeological sites includes artefact loss, structural collapse, alteration or gradual disappearance of stratigraphy, and, ultimately, the complete erosion of the site over time. All the natural damage we recorded was linked to flooding. Satellite images from multiple years confirms the rise and fall of water levels. Interestingly, all sites affected by these natural forces were subjected to looting (Fig. 14). This was also common in other studies (i.e., Al Hasakah province Mamo *et al.*

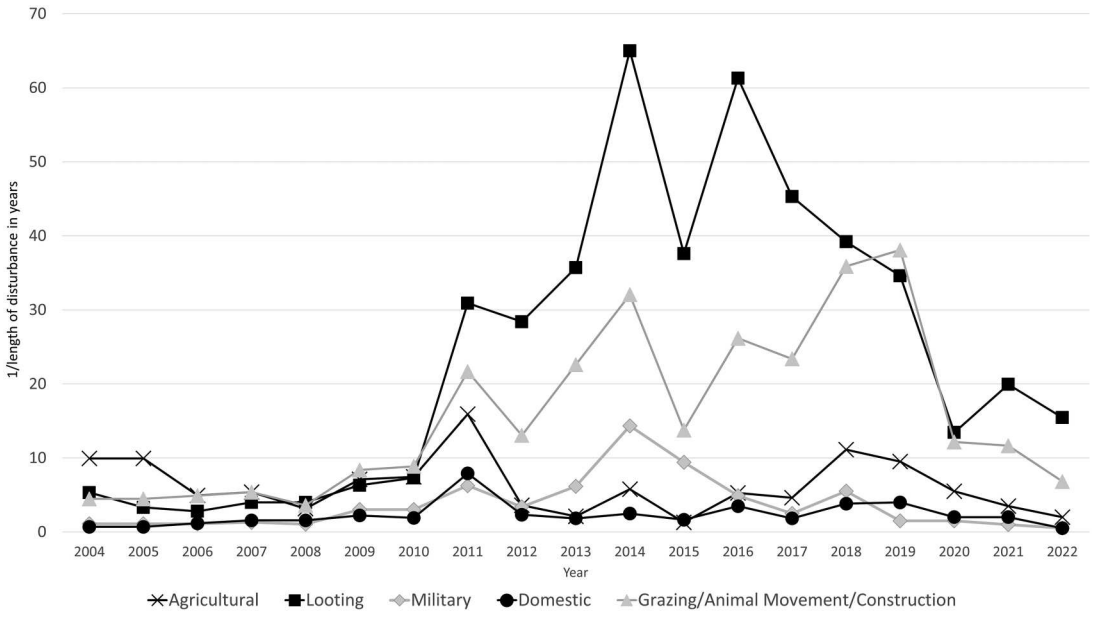

Figure 8 **Occurrences of damage attributed to looting, grazing/animal/construction (tents and vehicles), agriculture, military and domestic disturbances documented by year, taking into account all sites in the dataset except Bosra and the Al Hijaz Railway (which will be dealt with in a separate article). The y-axis denotes the probability weight of the event occurring in each year of its duration, calculated through aoristic methods.**

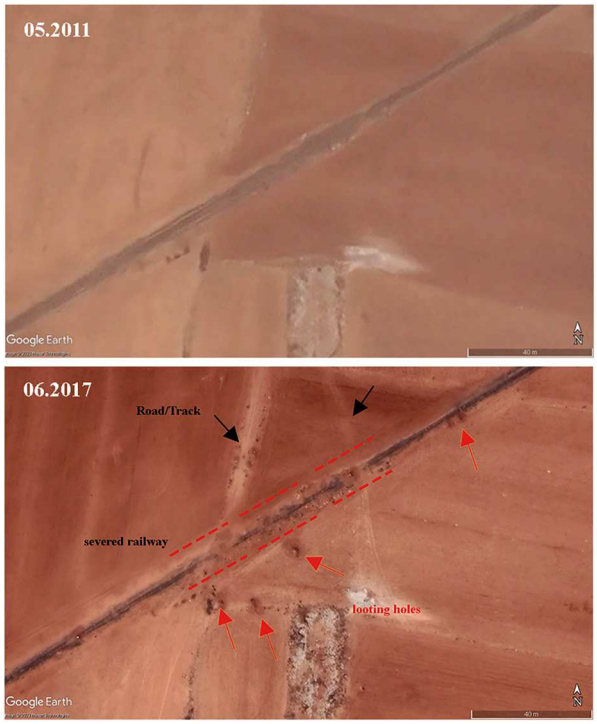

Figure 9 A section of the Al Hijaz railway in May 2011 and again in June 2017. Various disturbances are clearly visible.

2022). It is possible that sites more recently exposed would be seen as 'untouched' targets for looting. Equally, the erosion caused by flooding and subsequent exposure may have made archaeological strata more visible.

Geographical distribution of disturbance causes

The instances of looting damage we documented align with locations previously identified in reports using ground-based data (Al Kassem 2016; Nasrullah and Al Doss 2016) and satellite imagery analysis (Casana and Panahipour 2014; Cunliffe *et al.* 2014; Tapete and Cigna 2020). Our analysis, however, offers a more comprehensive perspective on the diverse types of damage caused by looting, covering sites that may not have been previously documented in publications, whether through ground-based data or satellite imagery.

Daraa province is characterized by its flat terrain, marked by basalt plateaus and intersected by water resources such as Wadi Al Zeidi, Wadi Al Dahab, Wadi Al-Raqqad, Wadi Al Yarmouk and Wadi Al-Arayes (Fig. 1). Our analysis suggests that looting happened on basalt plateaus, tells and surface structures (i.e., old towns and ruins), especially those situated either in valleys or within towns (Fig. 15). The line of the Hijaz railway and its Ottoman train stations have also not been immune to incidents of looting and vandalism. Consequently, pinpointing specific geographical areas that are more prone to being looted is challenging. Acts of vandalism and looting appear to affect both documented and undocumented archaeological features. It is worth noting, however, that in the Lejat area in north-eastern Daraa (Fig. 16), recognized as the largest lava field in southern Syria (Braemer and Taraqji 2016), we were not able to identify any visible signs of damage. As mentioned earlier, the dark colour of the basalt in this region poses a challenge in discerning pits commonly associated with looting. There may also be less looting in this area, simply due to its further proximity from population centres, its lack of accessibility and the fact that armed groups continue to settle there.

It is not surprising that damage caused by military activity is concentrated in the northern part of the western region of Daraa province (Figs 15 and 17). Firstly, tells are the most common site type here and are also the most likely to be used as military monitoring points. Secondly, it is here that intense battles between the Syrian army and various armed factions, as well as conflicts between these armed factions and ISIS occurred — all with the aim of gaining control over these strategic high points in the region.

Chronological variations in damage types

There is an obvious increase in the incidence of various forms of damage after the conflict (Fig. 18), except for those associated with ploughing and occupation. This could reflect the fact that Daraa, being the location of the earliest protests, quickly fell out of state control, but could also be, in part, due to the frequency of imagery available for 2011 for this region. After 2011, the Daraa region experienced noticeable and fluctuating rises in damages related to looting, military activities and grazing/animal movement/construction. This aligns not only with the period of heightened war between the conflicting forces on the ground, but also with the dispersal of chaos and absence of authority from the beginning. Figure 18 shows the relationship between all damage types over the study period.

The conflict between the armed opposition and the Syrian army peaked in 2014, when the former launched an offensive that lasted for four months. Numerous locations were targeted across the governorate. The outcome saw the opposition, including the Al-Nusra Front, taking control of areas and checkpoints in both eastern and western Daraa,

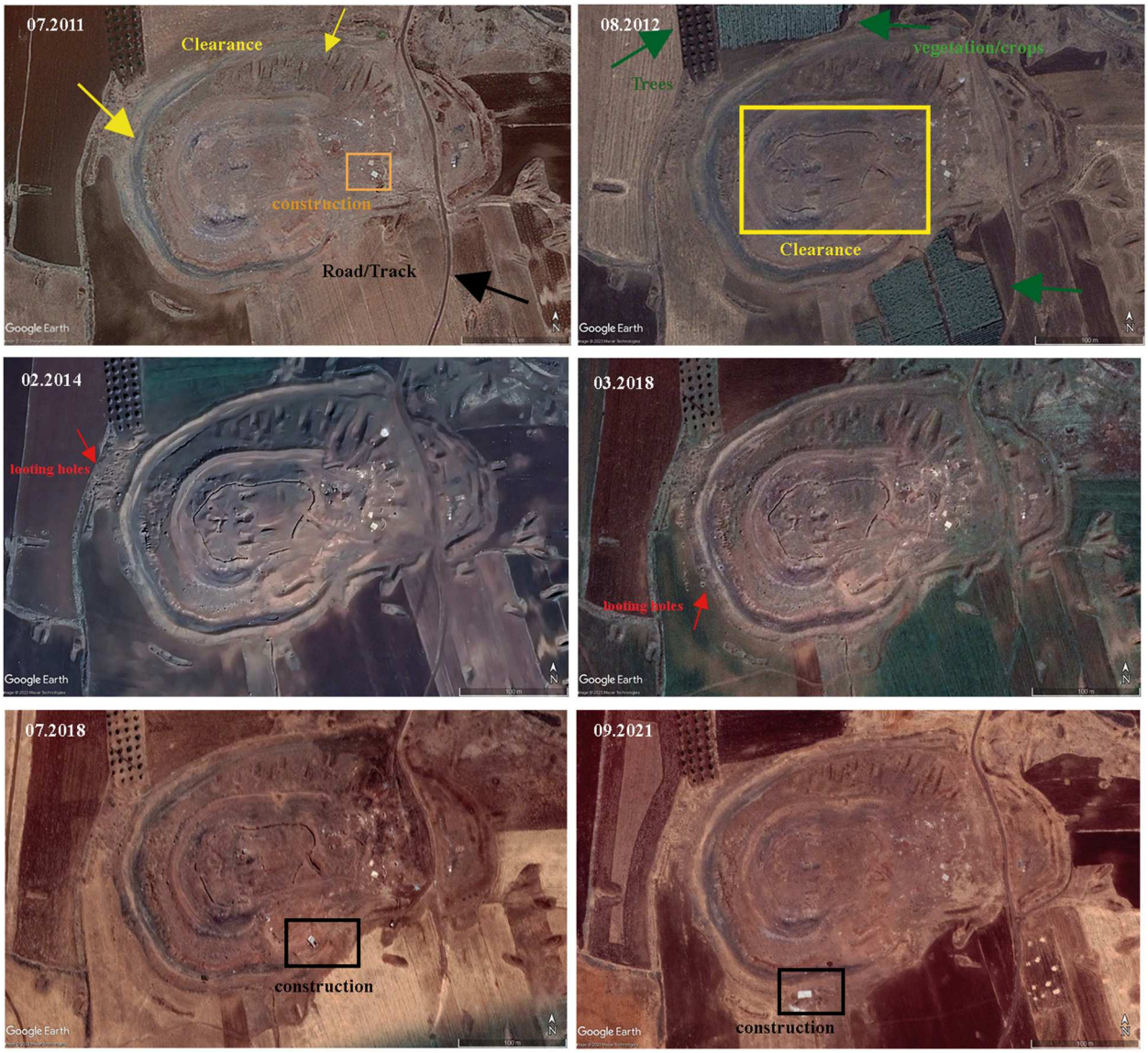

Figure 10 **A time-series of images of site D75 show a number of different types of damages including earth moving (bulldozing and levelling) and construction for military purposes. Image © 2023 Maxar Technologies. Used in accordance with the Google Maps/Earth terms of service for research purposes.**

including significant archaeological sites like Tell al Jabyia, Tell Om Horan, Tell Braq and Tell al Ahmar Sharqy. In 2016, Daraa province was subjected to a brutal attack from two groups affiliated with ISIS, who launched an offensive against Syrian opposition forces. Again, in February 2017, ISIS launched a large-scale offensive which resulted in re-controlling many areas of western Daraa in the Yarmouk basin.

Analysis of the satellite imagery shows that the timing of damage caused by bulldozing related to military activity, increases in 2012, then fluctuates, reaching its peak in 2014, coinciding with the heightened battles on the ground, and then decreases notably from 2018, when the military situation in the region became somewhat more settled (Fig. 18).

The data suggests a peak in looting occurred in 2014 and 2016: the notable decline in between may be influenced by the availability of satellite imagery; however, a correlation between periods of increased armed conflict and looting is evident in the sample. This is likely a consequence of the absence of authorities meant to prevent looting, though, even in 2011, when the region was under government control, looting instances increased from previous years. Similarly, even after the Syrian government recaptured control of the region, looting activities have continued at levels higher than before the conflict started (e.g., another increase in 2021). These earlier and later peaks in looting damage are in contrast to both more extensive assessments covering

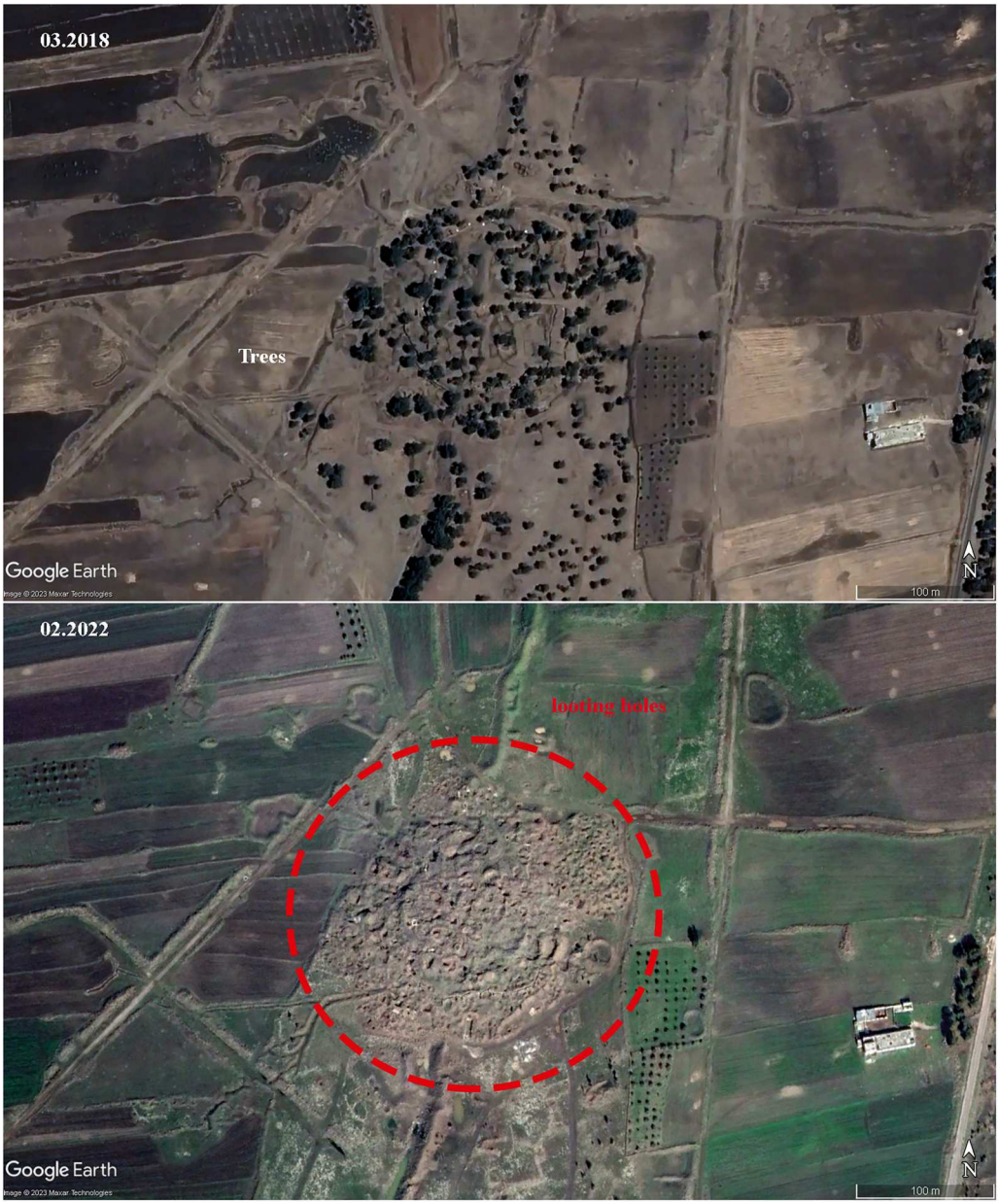

Figure 11 **A time-series of images of site D78 shows the removal of trees, and looting. Image © 2023 Maxar Technologies. Used in accordance with the Google Maps/Earth terms of service for research purposes.**

most of Syria (Casana and Laugier 2017) and more targeted studies in other regions (e.g., Al Hasakah) (Mamo *et al.* 2022). Both these studies indicate a decrease in instances of looting from late 2014. The results from Daraa may be influenced by several factors including the variable availability of satellite imagery mentioned previously, and regional variations in political events.

In addition, significant changes to the economic base/livelihoods of the region's inhabitants following the conflict may also have played a role. Daraa was known as a primarily agricultural region before the war. The acceleration of the conflict, however, caused the near complete suspension of crop cultivation, with inhabitants abandoning their livelihood because of insecurity, sanctions (which caused supply chain disruption) and power outages/shortages. We recorded a decrease in activities such as, ploughing, planting trees, road/track building and occupation/continued use of modern settlements associated with archaeological sites throughout the conflict. This is likely the result of the displacement of many of the regions inhabitants, primarily toward Jordan. UNESCO reported that Jordan welcomed more than 760,000 refugees, of which 49% (372,400 refugees) were from Daraa (Tiltnes *et al.* 2019). In

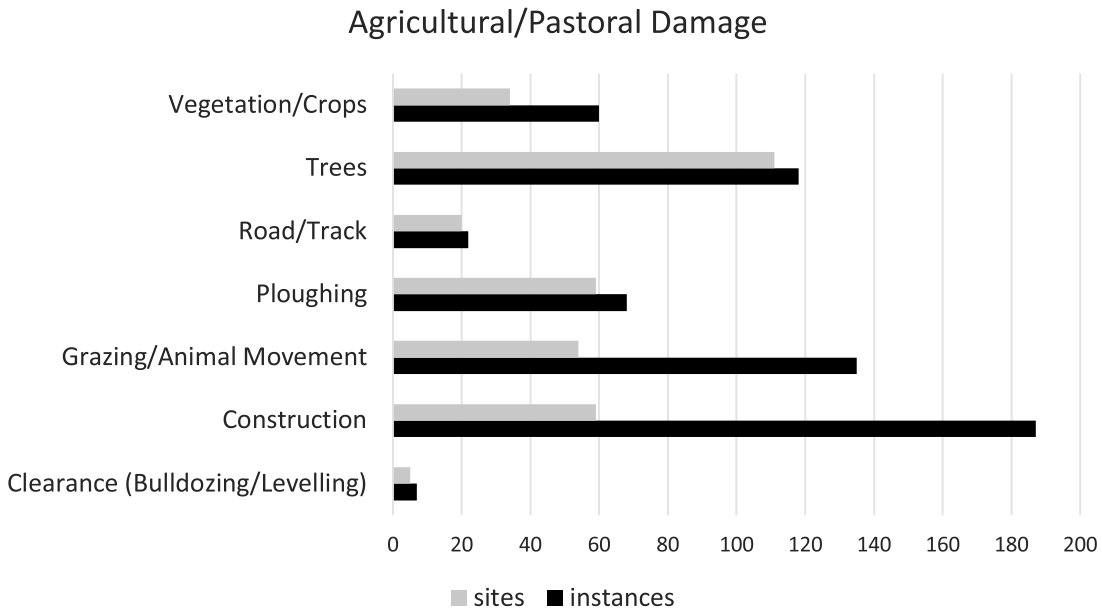

Figure 12 **Agricultural/pastoral damage plotted by number of instances (black), and by number of sites (grey) at which that type of damage was observed. Damage categorized as 'trees' include both the planting and felling of trees.**

2012, the Syrian Central Bureau of Statistics recorded that the population of Daraa was 998,000, suggesting that *c*. 37% of the region's population left following the conflict. This, of course, does not consider those who left and went to countries other than Jordan. Regardless, this is a staggering decrease in population and, by extension, will have had a significant impact on agricultural activities. Remarkably, however, damages associated with grazing/pastoral activities continued and increased. This may be related to the later surges in looting activity in Daraa, as discussed above, though agricultural activities attested an upturn when the Syrian army entered Daraa province in 2018.

Discussion

Analysis of satellite imagery in this study shows that looting activities increased from 2011 and the

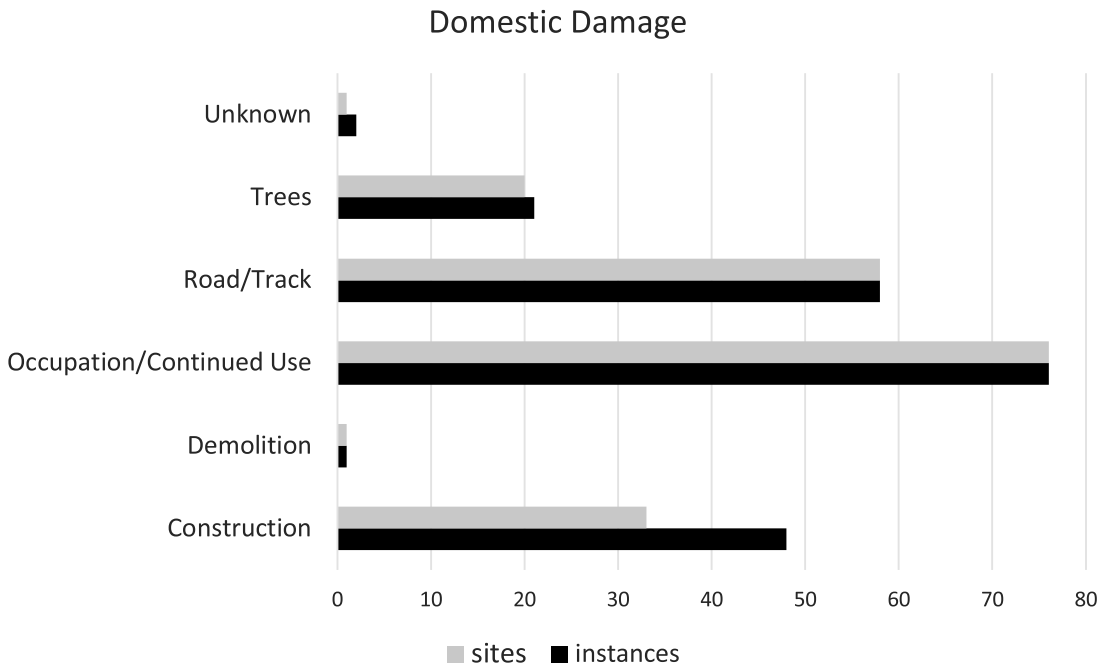

Figure 13 **Domestic damage plotted by number of instances (black), and by number of sites (grey) at which that type of damage was observed.**

Figure 14 A time-series of images of site D17 illustrating recurrent flood damage combined with looting activities. Image © 2023 Maxar Technologies. Used in accordance with the Google Maps/Earth terms of service for research purposes.

outbreak of the conflict, peaking between 2014 and 2016, when the fiercest confrontations between armed factions (e.g., ISIS, FSA, Al Nusra Front, Al Mouthana faction) and Syrian army were occuring. Other regional level studies, such as the one from Al Hasakah (Mamo *et al.* 2022) which uses the same methodologies, suggested a peak in looting activities between 2013 and 2014, and again in 2016. This may reflect differences in regional and local political situations (timing and intensity of fighting, who was in control and when), as well as the timing and availability of imagery. Interestingly, Casana and Laugier's (2017) broader remote sensing study, spanning Syria, northern Iraq and southern Turkey, classified looting activities in certain southern Syrian sites as non-severe. While our study does not evaluate the severity of looting, our analysis of high-resolution satellite imagery and on-the-ground observation done by Al Kassem (2016), suggest that looting may be more widespread in southern Syria than previously suggested. In part, the difference may relate to the fact that our study takes into consideration a longer timespan (2004–2022) and focuses on a larger sample of sites within a smaller region. This highlights the importance of conducting rapid large-scale assessments while ensuring they are complemented by more localized investigations, which will be our focus in the future, if the situation allows.

Sadly, some of the archaeological sites, which were evaluated through field-based investigations in 2015, have been shown to have undergone continuous looting by our remote sensing assessment. Examples include Khirbet Terouth northern Nawa, Khirbet Souhob southern Gasoum, the Ottoman train stations and al Hijaz railway (Al Kassem 2016), and the Bosra World heritage sites (Nasrullah and Al Doss 2016) in the eastern part of Daraa province. However, satellite imagery could not evaluate structural damage or looting carried out inside archaeological sites, such as Saint George, Saint Elias Churches in Izraa town, and Moutayah Temple which was partially damaged by shelling (Al Kassem 2016).

In fact, many instances of looting are not discernible through satellite imagery alone (e.g., the utilization of explosives and underground digging), which underscores the need for a more comprehensive assessment that involves on-the-ground survey. Field evaluation would provide the most reliable understanding of the severity of looting by taking into consideration density and spacing of looting holes, depth of looting, what types of archaeology are being exposed, and how the looting has been undertaken (e.g., via explosives, machines, or hand).

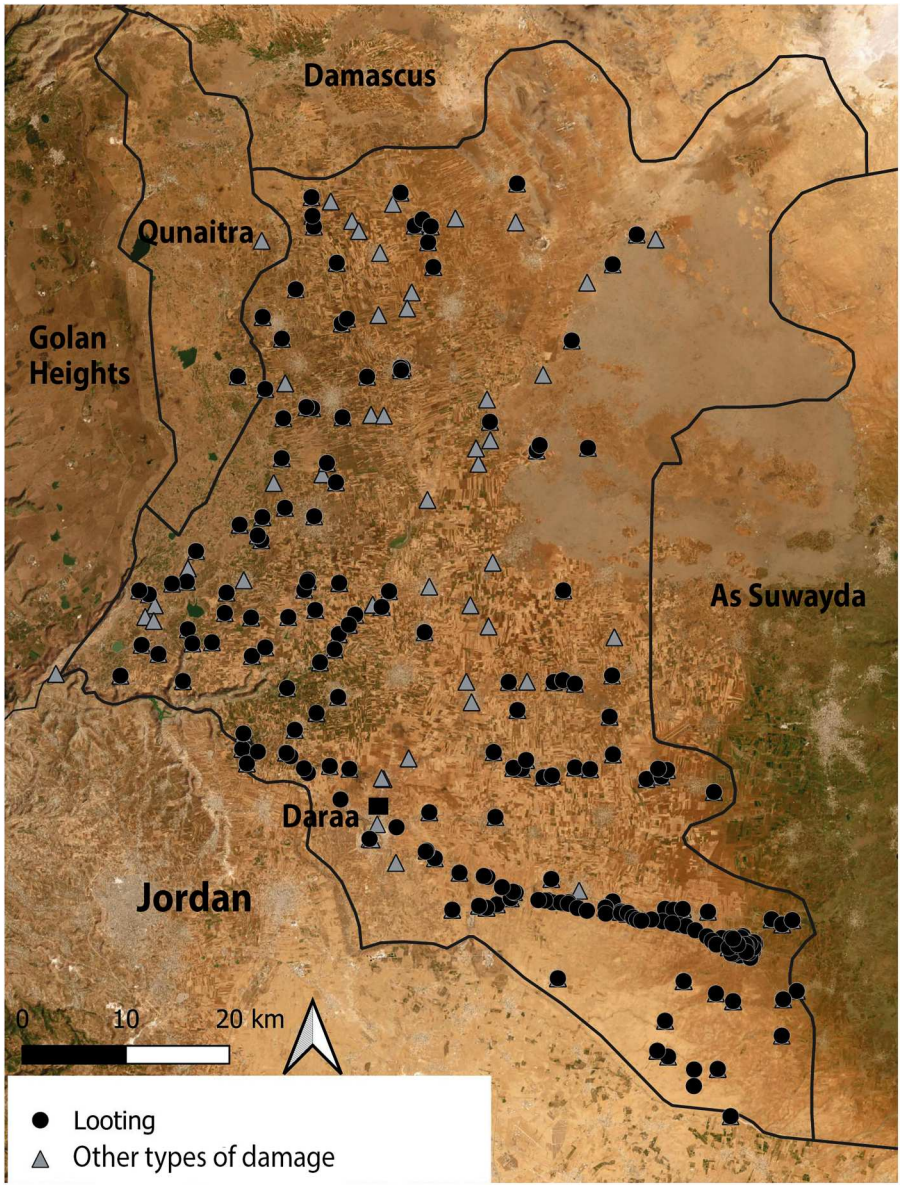

Figure 15 **A map illustrating the distribution of looting damage in relation to all documented archaeological sites affected within the study area. Employed in compliance with the terms of service of Google Maps/Earth for research purposes.**

Nevertheless, analysis of high-resolution, full-spectrum optical imagery does present some very promising opportunities for doing this remotely (Casana and Laugier 2017).

Several tells in Daraa appear to have been used as military bases and lookout points. While this was not unheard of before the conflict, the number increased following 2011. This has also been recorded in other areas of Syria (e.g., Al Hasakah), where it is perhaps even more common due to the frequency of tells; however, across the board, the most frequently documented type of damage related to military activity is clearance via bulldozing or levelling (Mamo *et al.* 2022). Danti (2015) argues, based on ground-based observations coupled with analyses of high-resolution satellite imagery, that damage to cultural heritage sites has been heaviest in the areas of Aleppo, Homs and Daraa. Moreover, he confirms that tells are often the targets as they make ideal locations for observation posts, tank and artillery emplacements and trenches. Less visible on satellite imagery, but observed on the ground, is the fact that many tell sites are also riddled with tunnels for military purposes. As mentioned above, the western part of Daraa has the most observed incidences of military damage (Fig. 16). This is because of where much of the fighting took place, but also because tells are more

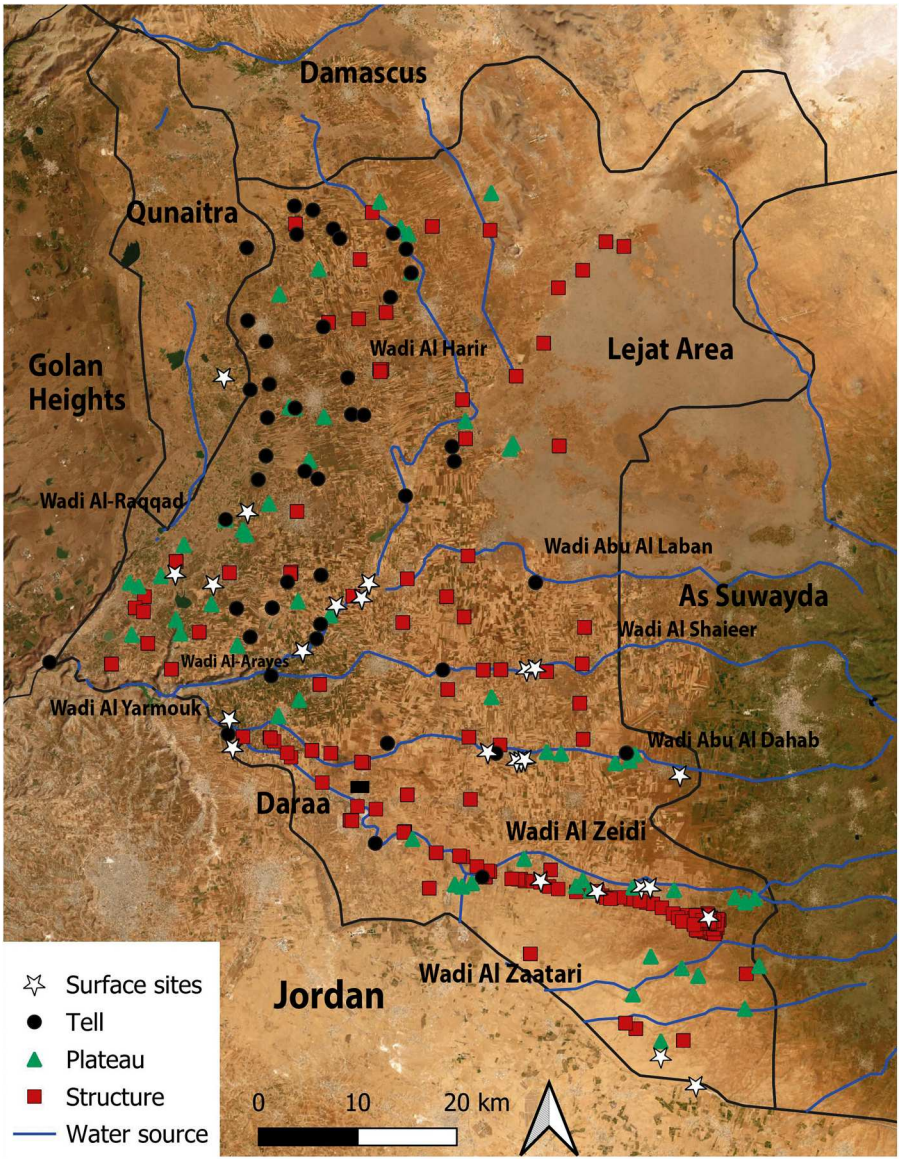

Figure 16 **A map illustrating damaged sites by type (tell, plateau, or structural features) and their location in relation to water sources. Employed in compliance with the terms of service of Google Maps/Earth for research purposes.**

prominent here than in the eastern part of Daraa. The peak of damages attributed to military activities (e.g., clearance, construction, road/track and felling trees) appears to have occurred in 2014, correlating with one of the most intense periods of the conflict, when for four months (February to May) fierce fighting between the Syrian Army and its allies, the opposition and various Islamic factions took place. Known sites such as Tell al Jabyia, Tell Om Horan, Tell Braq, Tell al Ahmar Sharqy, Tell al Harra and Tell al Joumoa were all impacted.

This study is of particular value in view of the insight it brings with regard to possible regional variations in the nature and timing of site damage and destruction during the Syrian conflict. Our sample suggests a slight increase in damages linked to both domestic and agricultural activities in 2011. This may be attributed to inhabitants taking advantage of the prevailing chaos to undertake construction where there was no governing authority: construction activities, such as those observed in the Tell Al Khtaybahin Khirbet Gazahla between 2011 and 2012, are such an example; however, a noticeable decline in both damage categories followed. This is likely linked to the displacement of a significant portion of Daraa's inhabitants to neighbouring countries. This decline was further exacerbated by economic sanctions imposed on agriculture. This appears to be somewhat different to the situation in Al Hasakah, for example, where the number of

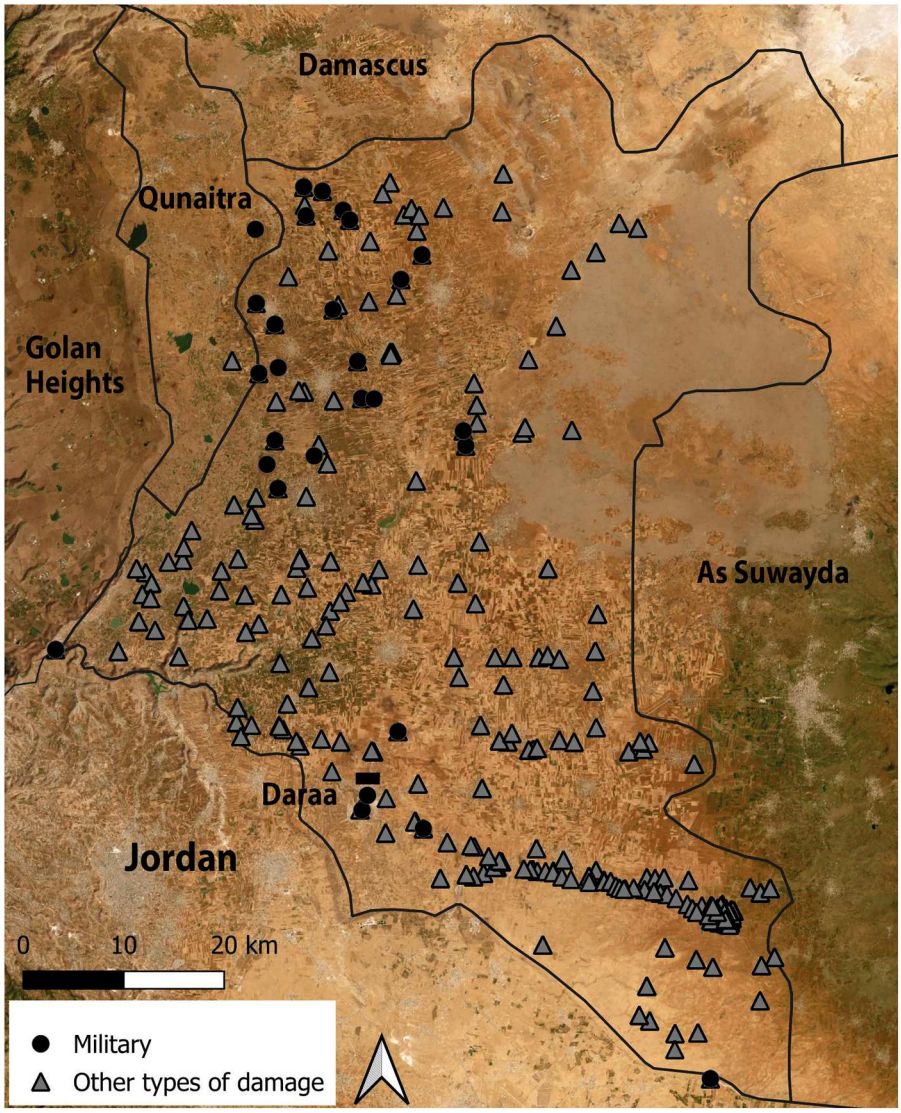

Figure 17 **A map depicting the distribution of military damage in correlation with all documented archaeological sites affected within the study area. Employed in compliance with the terms of service of Google Maps/Earth for research purposes.**

damages related to agricultural activities remained consistent and was the most prevalent form of damage both prior to and during the conflict (Mamo *et al.* 2022). Linked to the decrease in agricultural activity is a subsequent increase in pasturing and grazing on archaeological sites, along with an increase in looting. The potential link between these two causes of damage requires further investigation, but it seems likely that locations that would have previously been used for agriculture were, in the absence of authorities as the conflict intensified, more likely to be used for pasture, temporary settlements and/or more likely to be looted. The fact that at most of the sites where we recorded damage due to pastoralism/grazing, we also recorded looting, does seem to suggest some degree of planning in this activity, aided by a detailed knowledge of the local landscape.

Although there was a significant decline in looting between 2016 and 2020 due to the Syrian Army reasserting control over the region, it did not come to a complete halt. Consequently, looting has persisted since 2011 and continues to this day, albeit with varying levels of intensity.

To date, almost all national and international documentation efforts have been focused on evaluating damage to the UNESCO World Heritage site of Bosra (AAAS 2014; Cunliffe 2014; Danti *et al.* 2014; DGAM 2016; Muqdad 2018) and we intend to dedicate a separate article to the site to highlight the more than 104 damages that were documented through our analysis of the satellite imagery.

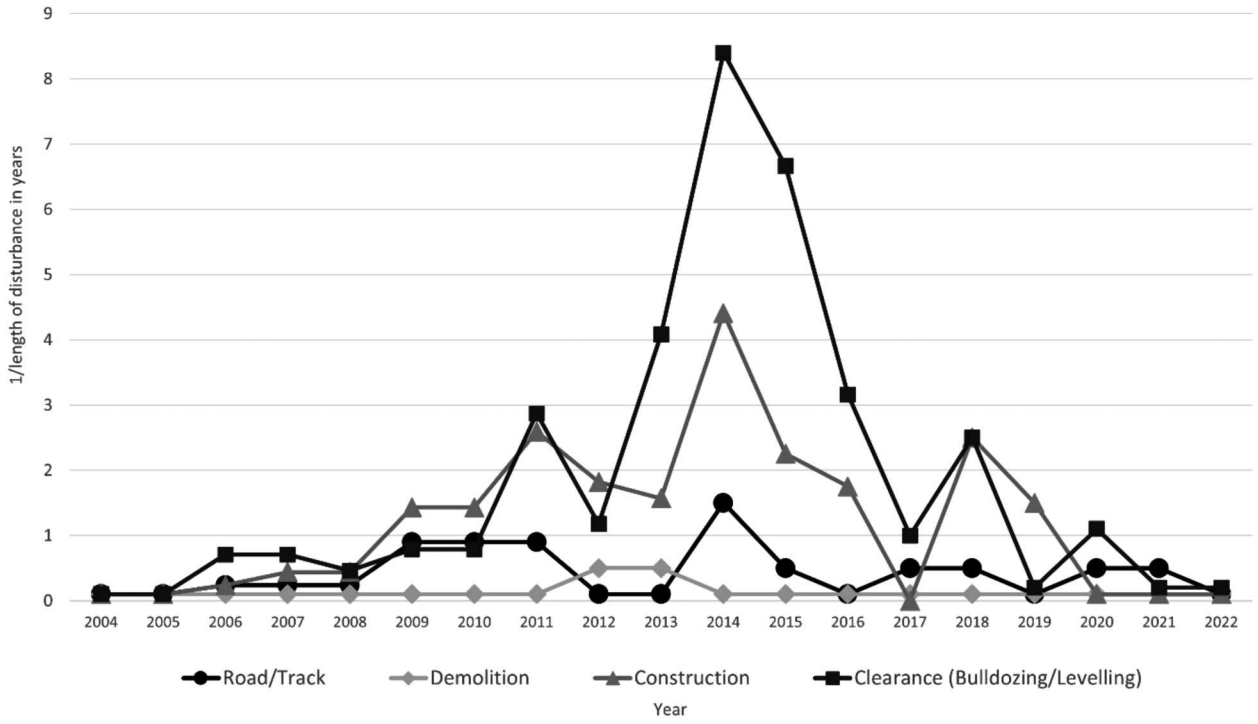

Figure 18 **Instance of damage attributed to military activity presented by damage cause. The y-axis denotes the probability weight of the event occurring in each year of its duration, calculated through aoristic methods. This does not include disturbances in Bosra or along the Al Hijaz railway, which will be dealt with in a separate article.**

However, as Tapete and Cigna (2020) have pointed out via their investigation of the extent and severity of damage caused by natural events, particularly floods at the Roman Theatre at Bosra, a number of other important sites were also impacted. An additional value of our current study is, therefore, the assessment of over 100 previously unrecorded archaeological sites, contributing to a much wider picture.

Conclusions

Remote sensing is a highly useful tool for assessing damage to archaeological sites, particularly in regions that are physically difficult to access. It can improve the effectiveness of conservation efforts, archaeological monitoring and overall understanding of cultural heritage. Using imagery for time-series analysis is particularly valuable, though it does not eliminate the requirement to evaluate damage on the ground. The resources and access needed to undertake comprehensive field visits is still beyond the scope of many projects.

In this case, satellite imagery analysis has exposed the scale of the catastrophe that has impacted archaeological sites in the Daraa region, recognized as archaeologically rich, but woefully understudied. The absence of effective authority from 2011 until today has allowed for unprecedented levels of looting that have affected both well-known and previously unexcavated sites. It has also highlighted the impact of different types of geology and terrain on the likely identification of looting, and the ways in which these activities were undertaken. For example, no looting has been identified in the Lejat area, likely because of the dark colour of its volcanic rocks, though it is visible in other basalt regions. Interestingly, the most common mechanism for looting in the study area is excavation by hand. Heavy machines and even explosives have been used in other regions, specifically, in the looting of basalt plateaus. This does not seem, however, to be the case in the rugged terrain of the Lejat, as despite visibility issues, this would potentially be visible on the imagery; it is likely that its distance from population centres make it difficult to reach.

The available time-series of images has also identified a possible link between areas used for grazing and looting activities, something particularly evident in non-urban areas, where basalt plateaus are located along valleys. This, as well as the observations linking the decline in agricultural activity (and therefore damage caused by it) with the displacement of a large number of the province's inhabitants, economic obstacles represented by the global sanctions

and the sieging of the area highlight the need for further regional level studies. Understanding the varied local impact of the conflict, along with making the data available, will benefit civil society initiatives. They are on the front line of heritage preservation and leading many of the initiatives focused on engaging communities in sustainable heritage protection (e.g., https://ansch.heritageforpeace.org/.).

The next stage of the first author's project is to carry out ground-based observations to verify the analyses of high-resolution satellite imagery, and aims to test theories regarding links between various damage activity categories (e.g., looting and pastoral activity), to better understand the types and locations of damages that are not visible on satellite imagery. In addition, we aim to broaden our imagery analysis to incorporate data from multiple open-source satellites and explore the possibility of implementing a machine-learning model for identifying locations of possible damage for ground investigation. We expect that the results of this study will prove valuable for future protection initiatives that could involve both national and local governments. Lastly, studies such as this one can inform educational strategies, designed and implemented by local civil society organizations, to promote the protection of these sites and deter looting.

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Data availability — Google Earth images (credits: 2023 Maxar Technologies) can be consulted through Google Earth Pro. The condition assessments of the sites will be deposited in the EAMENA Syria database and access can be applied for by Syrian researchers and civil society organizations.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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