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Remote sensing and map quantitative data in an armed conflict zone.

Case study: Quantitative monitoring and mapping of the damage in Syria archeological site Afamia (Apamea).

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Abstract: The destruction of cultural and natural heritage resulting from armed conflicts threatens the whole of humanity. Despite that, their conservation in conflict areas is deficient, one of the causes of this is the difficulties in accessing information.

Today, evolve strategies and tools for monitoring and actively protecting world heritage is very important, which requires the collection and analysis of large amounts of data obtained from various sources. In this context, the objective of this study is to present data of a spatio-chronological analysis methods for the quantitative monitoring of the damage caused by the looting of archaeological sites in conflict zones using spatial images.

Key words: Remote sensing, Mapping data, conflict, Syria, Apamea

1. Introduction

In areas of armed conflict, access to field data is impossible. In this context, the strategies and tools for monitoring and active protection of archaeological sites need to be developed. Geographic information, remote sensing and spatial mapping technologies currently offer new potential for observations related to the impacts of armed conflicts on these areas and better preparing for the post-war period conflict. These tools can also be used to document controlling violations in real time (Mobaied, 2022).

Syria is considered one of the richest regions in the world in terms of historical sites and archaeological heritage. Conflicts have caused considerable damage to the Syrian heritage park (Bouvier, 2019).

In this context, this study presents results and data of a quantitative monitoring and mapping of the damage in Syria archeological site Apamea, named Afamia in Arabic, on the Orontes River in western Syria. (Figure 1)

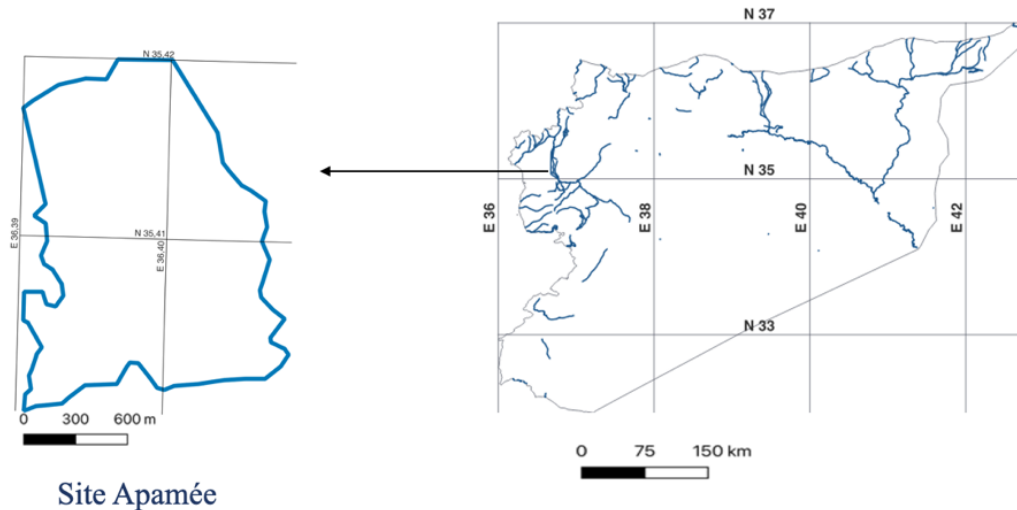


Figure 1 Location of the Apamea site in Syria SCR: WGS 84

2. Archeological site Afamia

The site of Afamia is located on a limestone plateau in western Syria, near the Orontes River (Al Assi). It is considered to be the seat of a Greco-Roman acropolis, then a medieval citadel (CReA-Patrimoine¹). The city of Apamea is one of the most important cities built in northern Syria during this period. The decade-long conflict in Syria has had serious consequences for Apamea and its medieval citadel. This site is among the Syrian sites most affected by war damage.

These can be direct consequences such as the bombings, or indirect consequences such as the clandestine excavations in Apamea which is located in a border area between the areas controlled by the government and the areas controlled by the opposition. Despite

¹ Research Centre in Archaeology and Heritage of the Université libre de Bruxelles

this, the site remained under government control during this period, in particular the high-altitude sectors which were used as military observation posts.

3. Method

In this context, this study aims to show data result from a quantitative monitoring of the damage caused by looting in Afamia during the armed conflict in Syria, using remote sensing and spatial mapping technologies. (Figure 2)

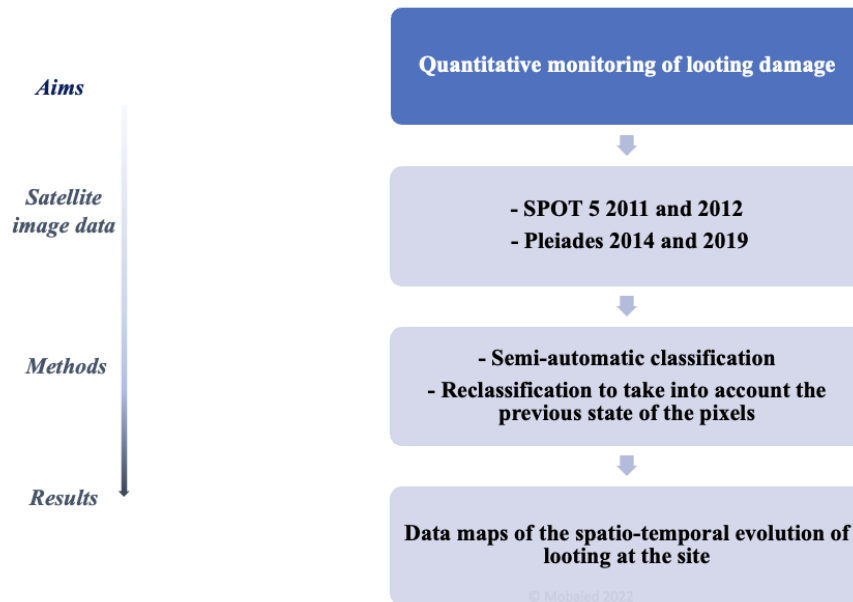


Figure 2: Methodological scheme

4. Spatial analysis

The spatial analysis of quantitative monitoring is based on an analysis grid covering the entire Apamea site (Balty, 2016) and a large part of the adjacent fields. The analysis grid is subdivided into basic units of 5 meter squares.

This dimension of 5m was used based on the dimensions of the holes used for clandestine excavations, dimensions varying between 0.5m and 3.5 meters (Tapete and al. 2016). This choice makes it possible to include and take into account the different sizes of the looting holes.

In this context, the database established and analyzed in this study contains 100,000 (exactly 98088) spatial record elements, over an area of approximately 2.5 km². The database is associated with this paper.

5. Temporal analysis

This method has been applied over 8 years, starting in 2011, the date of the beginning of the conflicts in Syria. We consider that this 8-year period allows us to study the changes that have taken place in this site and we propose a division into 3 successive periods.

2011 (T0), 2012 (T1), 2014 (T2), 2019 (T3) :

- T0 to T1 (1 year between 2011-2012): period marked by the beginning of the armed conflict and the most intensive looting in the area.
- T1 to T2 (2 years between 2012-2014): period marked by the continuity of looting, bombardments and artillery fire near the site.
- T2 to T3 (5 year between 2014-2019): period marked by the continuity of looting and fighting until May 2019

6. Sources of satellite images

Two sources of satellite images were used, images from the SPOT 5 and Pléiade satellites with respective pixel sizes of 10 m and 50 cm.

CNES AIRBUS, 2011-07, Apamea Syria, SPOT 5, Maxar Technologies Google Earth, historical imagery. Resolution 2.5 meters

- CNES AIRBUS, 2012-04, Apamea Syria, SPOT 5, Maxar Technologies Google Earth, historical imagery. Resolution 2.5 meters

The download was made at Google Earth

- Pleiades © CNES 2014, Distribution AIRBUS DS, Apamea Syria, Resolution 50 cm
DS_PHR1A_201403060825550_FR1_PX_E036N35_0411_01578

- Pleiades © CNES 2019, Distribution AIRBUS DS, Apamea Syria, Resolution 50 cm
DS_PHR1B_201905040827245_FR1_PX_E036N35_0509_01426

These two archive Pleiades images were obtained using Dinamis².

Concerning satellite images used in this monitoring study (Figure 3), the SPOT 5 image from 2011 before the start of the armed conflict in Syria, another SPOT 5 image from 2012 as well as two Pléiades images from 2014 and 2019 to show the evolution of clandestine excavations.

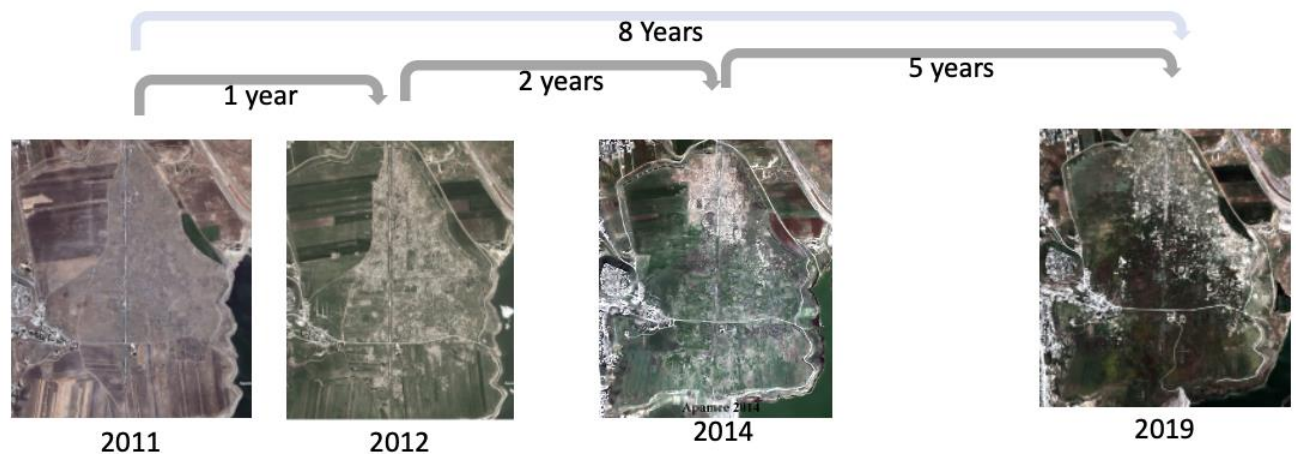


Figure 3: Satellite images used in this monitoring study: two SPOT 5 images for 2011 and 2012 as well as two Pléiades images for 2014 and 2019.

7. Spatio-chronological analysis

All data was integrated into a GIS project and processed using QGIS 3.20.3 software

A semi-automatic classification was applied to the satellite images based, in the first place, on the visual interpretation, in order to select the learning areas and then automatically classify the content of the SPOT-5 and Pleiades images using the tool Dzetsaka (Karasiak, 2019).

In a first step, four classes have been selected:

- Site
- Fields
- Other: urban areas
- Illegal excavations

² Dinamis : the French national facility for institutional procurement of VHR satellite imagery—is a platform that acquires and distributes satellite Earth imagery for French and foreign institutional users under specific subscription conditions. <https://dinamis.data-terra.org>

Then an additional classification of the images was applied to take into account the previous state of the pixels at (T-1).

The following classes have been added:

- Site without clandestine excavations in T1, T2 and T3
- Fields without clandestine excavations in T1, T2 and T3
- Previous clandestine excavations: Clandestine excavations in T-1
- Recent Clandestine excavations: in areas unexcavated in T-1
- Clandestine excavations erased: Areas already excavated in T-1 in which the excavations no longer appear.

At this stage, a total of 9 categories have been defined (Figure 4).

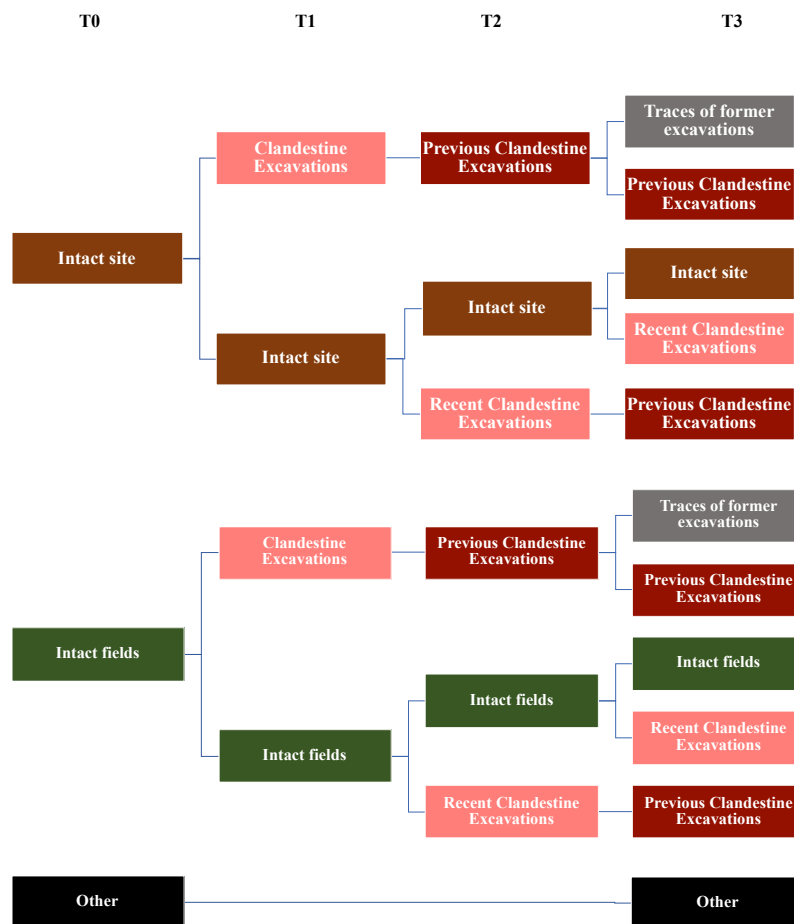


Figure 4: The categories of classification using in the mapping processes in T0, T1, T2, T3

8. Data maps and results

8-year phase (T0-T3): The results of the spatio-chronological analysis obtained using Pléiades and SPOT5 images made it possible to detect clandestine excavations extending over 95% of the Apamea site between 2011 and 2019 and over 60% of the adjacent fields, affected by the excavations during this same period (Figure 5 and 6) (Table 1).

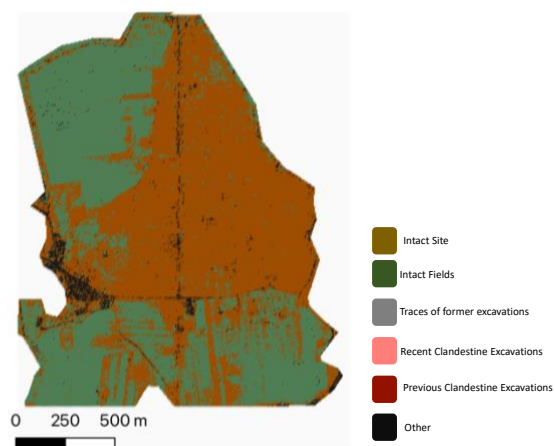


Figure 5 : Map T0 shows the Site Apamea in 2011 before the start of the armed conflict in Syria

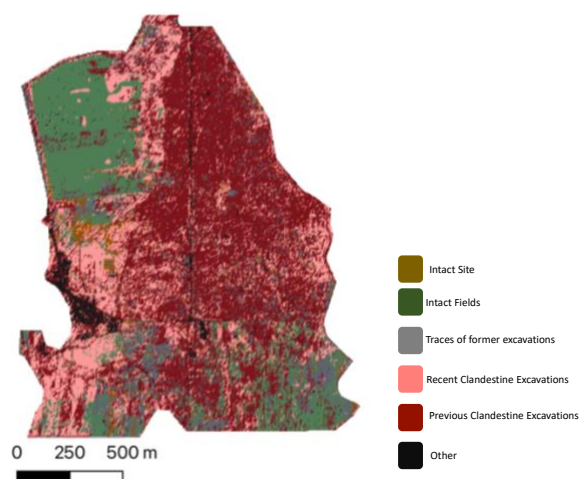


Figure 6 : Map T3 shows the clandestine excavations in the Site Apamea in 2019

Table 1: Changes of each category between (T0: 2011) (rows) and (T3: 2019) (columns) expressed as a percentage

Percentage	2019						
	Intact Site	Intact Fields	Traces of former excavations	Previous Clandestine Excavations	Recent Clandestine Excavations	Other	
2011	Intact Site	5%		10%	62%	23%	
	Intact Fields		40%	13%	26%	21%	
	Other						100%

To monitoring and mapping the damage in Syria archeological site Afamia over 8 years the dynamics of the changes were analyzed in three periods (T0/T1, T1/T2 and T2/T3)

Period T0-T1

Over the period T0-T1 (between 2011 and 2012), illegal excavations were detected on 59% of the Apamea site and on 17% of the fields adjacent to the excavated site. (Figure 7) (Table 2).



Figure 7 : Map T1 shows the clandestine excavations in the Site Apamea in 2012

Table 2: Percentage change of each category between (T0: 2011) (rows) and (T1: 2012) (columns) expressed as a percentage

2011	Percentage	2012		
		Intact site	Intact fields	Clandestine Excavations
Fields			83%	17%
Site	41%			59%

Period T1-T2

Between 2012 and 2014, illegal excavations involved 42% of the previously unexcavated site as well as 34% of the adjacent fields in the field area that had not been previously excavated (Figure 8) (Table3).

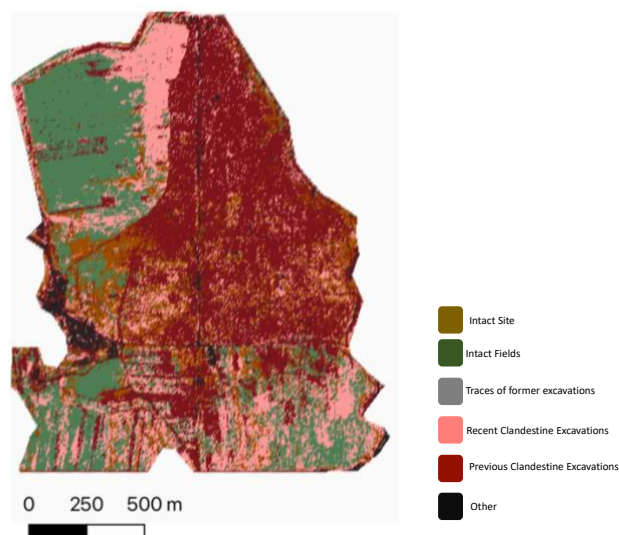


Figure 8 : Map T2 shows the clandestine excavations in the Site Apamea in 2014

Table 3: Percentage change of each category between (T0: 2012) (rows) and (T1: 2014) (columns) expressed as a percentage

	Percentage	2014			
		Intact Site	Intact Fields	Previous Clandestine Excavations	Recent Clandestine Excavations
2012	Intact Site	58%			42%
	Intact Fields		66%		34%
	Clandestine Excavations			100	

Period T2-T3

Between 2014 and 2019, illegal excavations were detected on 78% of the previously unexcavated site and 26% of the fields adjacent to the previously unexcavated area (Figure 9) (Table 4).



Figure 9 : Map T3 shows the clandestine excavations in the Site Apamea in 2019

Table 4: Percentage change of each category between (T2:2014) (rows) and (T3:2019) (columns), expressed as a percentage

	Percentage	2019				
		Intact Site	Intact Fields	Traces of former excavations	Previous Clandestine Excavations	Recent Clandestine Excavations
2014	Intact Site	22%				78%
	Intact Fields		73%			27%
	Previous Clandestine Excavations			13%	87%	
	Recent Clandestine Excavations			26%	50%	24%

9. Datasets

The data associated with our paper is arranged in CSV file.

The CSV files (Data-Afamia-MOBAIED) contains 143,426 rows and 9 columns that represent the 143,426 entities (points) which can be projected under an adapted GIS.

The ID for each entity is specified at the column (A), the spatial coordinates are determined under WGS 84 / UTM zone 37N at the columns (B, C, D, E).

The category of each entity is described for each of the years of observation at the columns (F, G, H, I) using the following code:

- (0) Outside of the archeological site Apamea
- (1) inside of the archeological site Apamea
- (2) Fields
- (3) Other
- (4) Intact Site
- (5) Intact Fields
- (7) Previous Clandestine Excavations

(8) Recent Clandestine Excavations

(9) Traces of former excavations

10.Data synthesis

The Apamea site was intensively excavated between 2011 and 2019. The use of high-resolution multi-source satellite images (SPOT 5 with a resolution of 2.5 m and Pleiades with a resolution of 70 cm) is proving to be very effective in detecting the appearance of clandestine excavations and in monitoring the damage caused by these excavations on archaeological sites. The results show that clandestine excavations extending over 95% of the Apamea site between 2011 and 2019, as well as over 60% of the adjacent fields affected by the excavations during the same period.

The data presented in this study can be used to continue monitoring the site concerned, as well as the method used, which can be a long-term monitoring method for this site and also other archaeological sites in the conflict zones.

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