# VERIFYING THE DETECTABILITY OF SMALL-SCALE LOOTING IN SAR IMAGES

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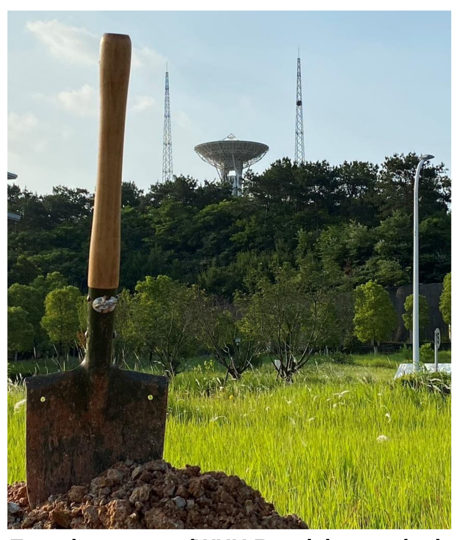
## Abstract

Looting is an ongoing global threat to cultural heritage. Detecting looting activities is therefore of the utmost importance. Cultural heritage authorities can more successfully advocate for funding and action if they can rapidly and correctly count and quantify the number of looting pits and their locations [1]. In archaeology, the term "looting" means illegal excavations in historical places [2]. Remote sensing offers a possibility to detect looting in remote and inaccessible areas. The all-weather and continuous observation capabilities of SAR is extremely beneficial for any practical implementation. However, SAR data is difficult to interpret and suffers from speckle noise, making the detection of small changes challenging. Therefore, the detectability of small-scale looting is analyzed in this work. Based on an experimental setup with two different sized artificial looting holes which we dug in Wuhan University Receiving Station, we analyze the detectability of these holes in SAR images of different resolution, polarization, looking angle, orbit, etc.



Experiment area (WHU Receiving station)

Team deciding on the location of the hole

Excavation of first hole (1x1)

Second hole, first stage (2x1)

## Introduction

The detectability of large-scale looting activity in high-resolution SAR images, for example in the context of the Syrian civil war, has been shown before [3]. Many other looting activities are rather small scale and do not reach the almost industrialized looting activities witnessed in this conflict. In this work, we dug 2 artificial looting hole in different sizes and tried to detect them with TerraSAR-X images by using different parameters.

UAV Images of first and second hole

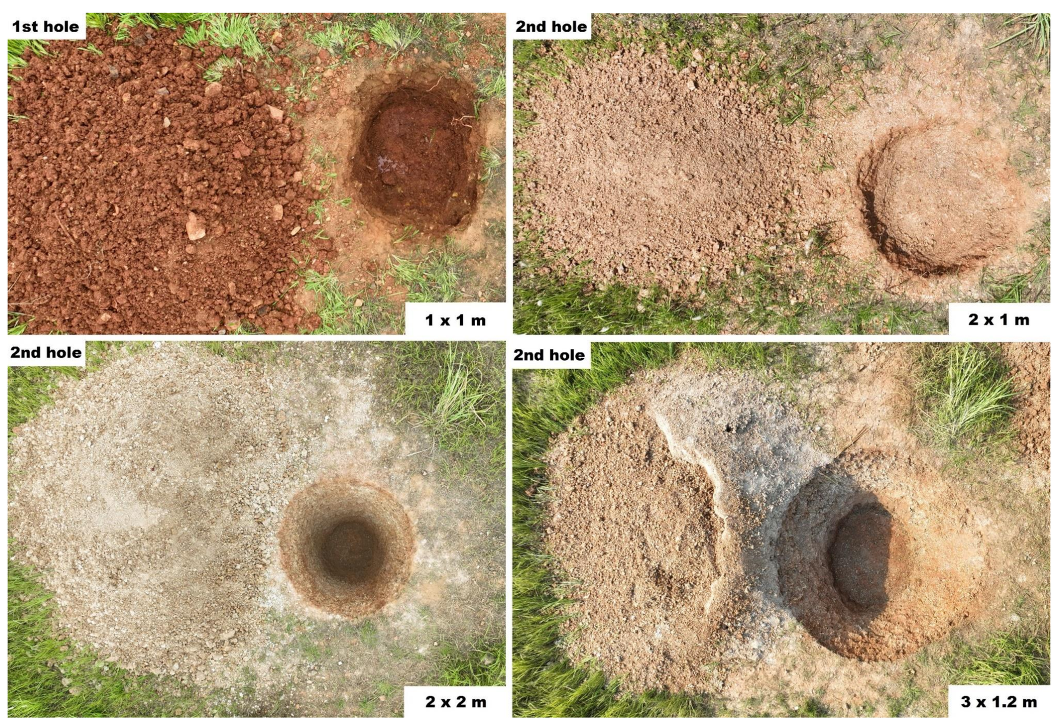
## Objectives

- Creating different sizes of looting holes in Wuhan University Receiving Station (Experiment area) to identify the smallest-scale we can detect.
- Detecting simulated looting holes with high resolution TerraSAR-X images.
- Identifying best acquisition parameters to detect small-scale looting holes to use in future studies.

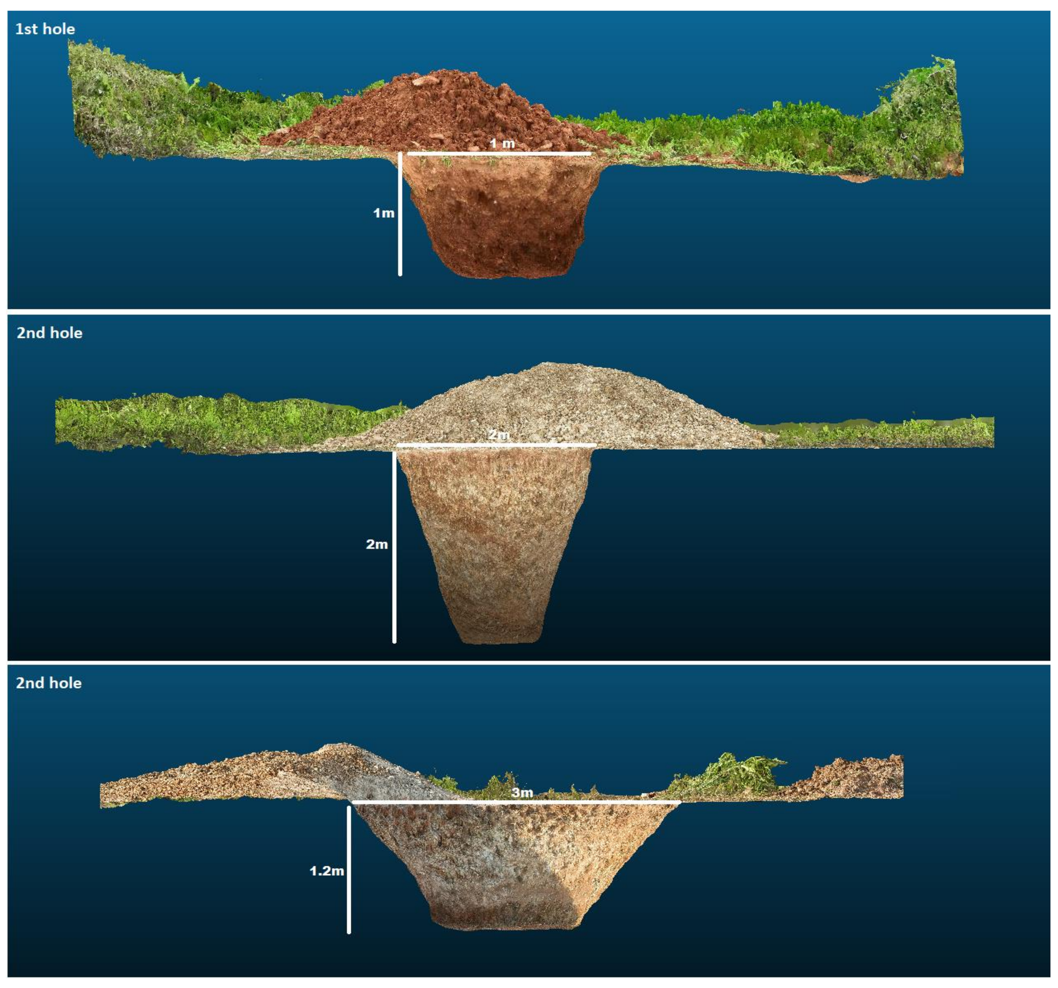
## Materials and Methods

Untill this point, we have collected 32 TerraSAR-X images from the study area, 22 before and 13 after the digging. More images will be collected depending on the future direction of the studies/results. UAV images were also taken after every digging activity to archive optical images and to create 3D photogrammetric models.

We have visually interpreted the images and used band math in ESA SNAP software to highlight the holes. Experiment is still ongoing and different type of CCD algorithms will be implemented.




1st and 2nd hole with different stages of second hole




3D models of the holes and stages (Side look).

## Results

After creating artificial looting holes and collecting SAR images before and after the activity, we visually interpret the images first. Depending on the outcome, we have changed the size of the hole to use different looting measurements. In 3 out of 11 'after' images, we detected the second hole clearly. First hole was clearly visible only in one image out of those 3 images (Figure 1). In some images, the second hole was barely visible (Figure 2). After the June 19 rainfall, the second hole was filled with water, and this had negative effect as we couldn't detect the hole in the image taken shortly after the rain due to a lack of backscatter (Figure 3). We also noted that the holes were mostly visible in descending passes (Table 1). We also used change detection and highlighted the holes (Figure 4,5).

Table 1. Parameters of data taken after digging artificial holes

| Date | Orbit | Polarization | Incident Angle | Hole Size (m) 1st | Hole Size (m) 2nd | Visibility 1st | Visibility 2nd |
|---|---|---|---|---|---|---|---|
| 4.06.2023 | Ascending | HH | 50.15 | 1x1 | | Not visible | Not Visible |
| 8.06.2023 | Descending | VV | 29.12 | 1x1 | 2x1 | Not visible | Barely V. |
| 14.06.2023 | Descending | HH | 45.52 | 1x1 | 2x1.7 | Not visible | Barely V. |
| 15.06.2023 | Ascending | VV | 50.15 | 1x1 | 2x1.7 | Not visible | Not Visible |
| 19.06.2023 | Descending | VV | 29.14 | 1x1 | 2x2 | Not visible | Not Visible |
| 6.07.2023 | Descending | HH | 45.5 | 1x1 | 2x1.6 | Not visible | Visible |
| 7.07.2023 | Ascending | VV | 50.16 | 1x1 | 2x1.6 | Not visible | Not Visible |
| 11.07.2023 | Descending | HH | 29.16 | 1x1 | 2x1.6 | Visible | Visible |
| 18.07.2023 | Ascending | HH | 50.16 | 1x1 | 2x1.6 | Not visible | Barely V. |
| 22.07.2023 | Descending | VV | 29.14 | 1x1 | 2x1.6 | Not visible | Visible |
| 28.07.2023 | Descending | HH | 45.49 | 1x1 | 2x1.6 | Not visible | Barely V. |
| 19.08.2023 | Descending | HH | 45.49 | 1x1 | 3x1.20 | Not visible | Barely V. |
| 20.08.2023 | Ascending | HH | 50.16 | 1x1 | 3x1.20 | Not visible | Not Visible |

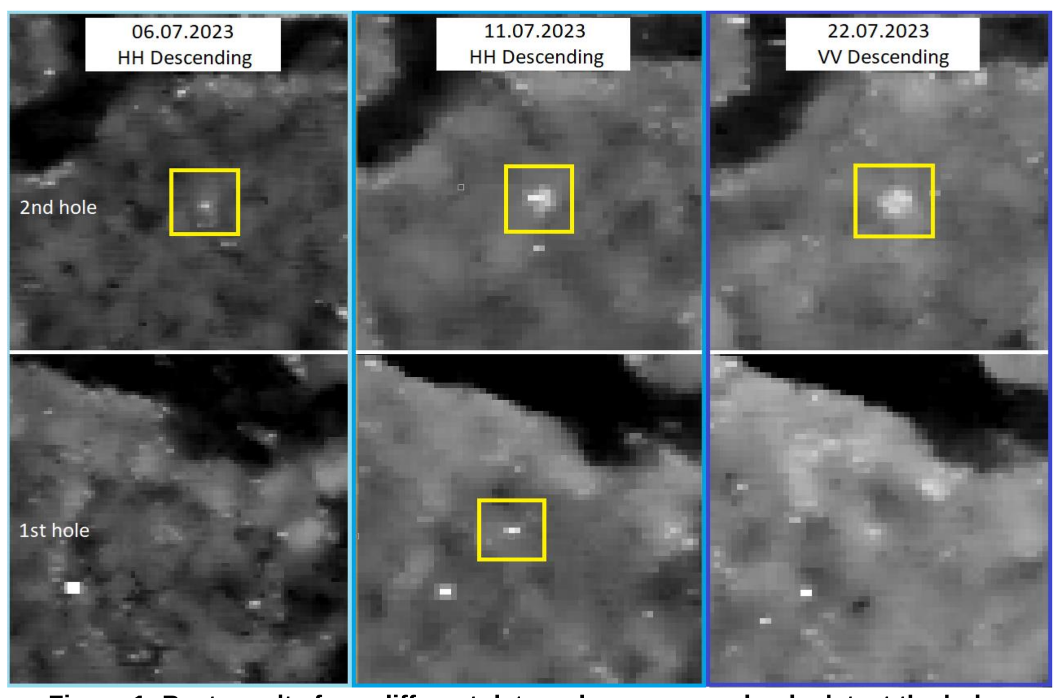



Figure 1: Best results from different dates where we can clearly detect the holes.

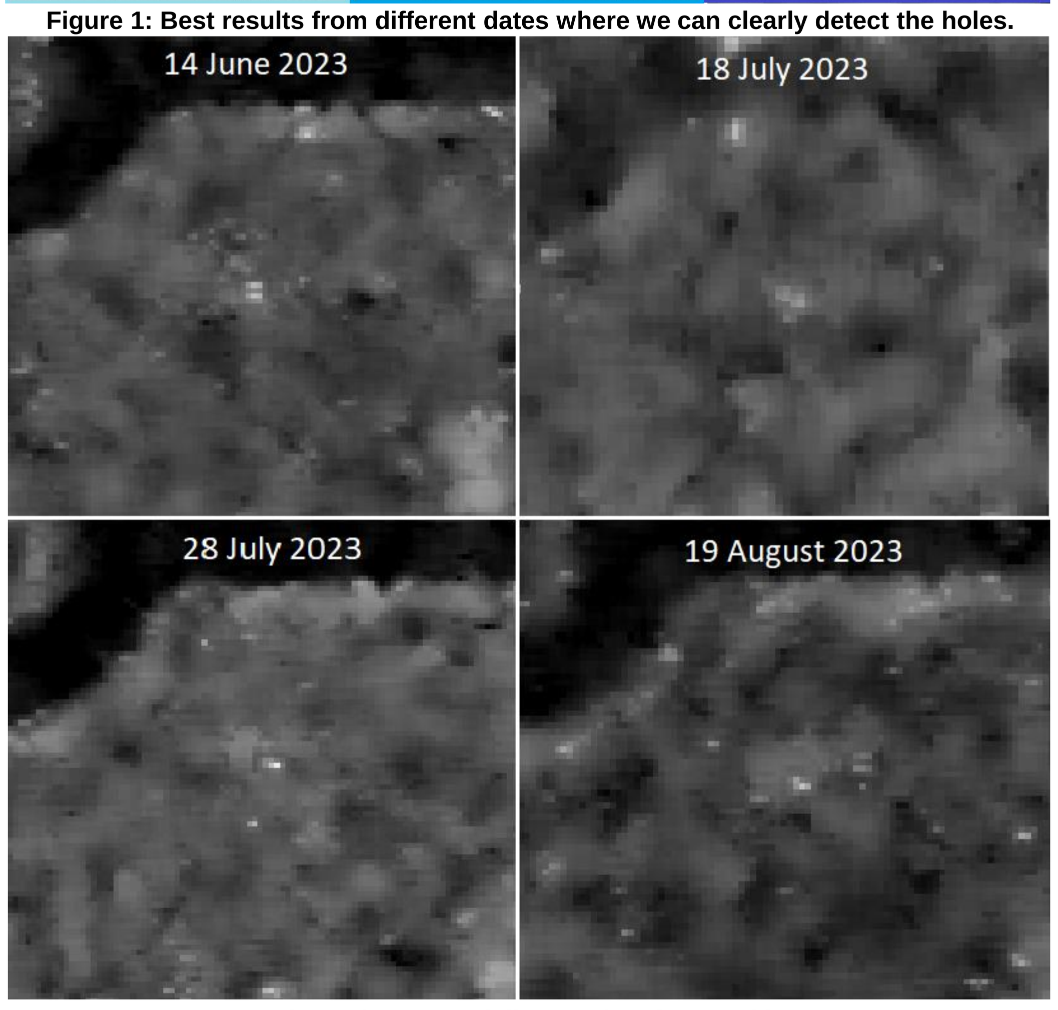



Figure 2: Barely visible marks of second hole

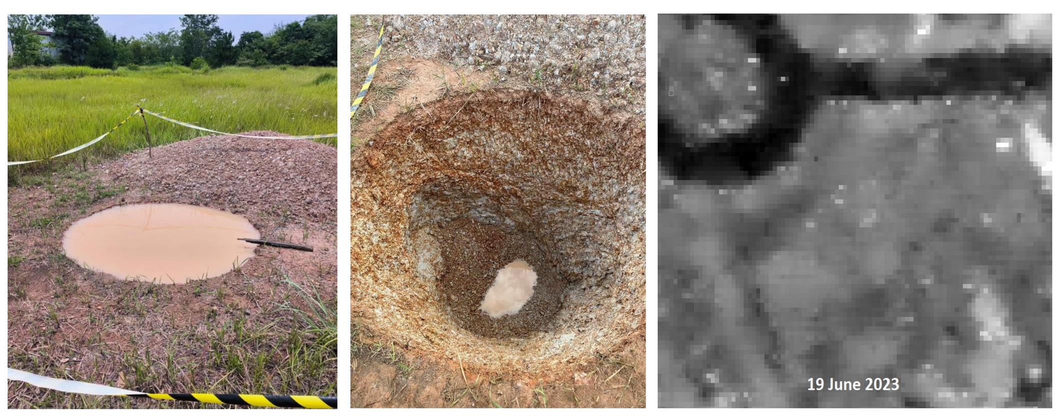



Figure 3: Image taken after the rainfall. Soil slide after rain changed the measures of the hole.

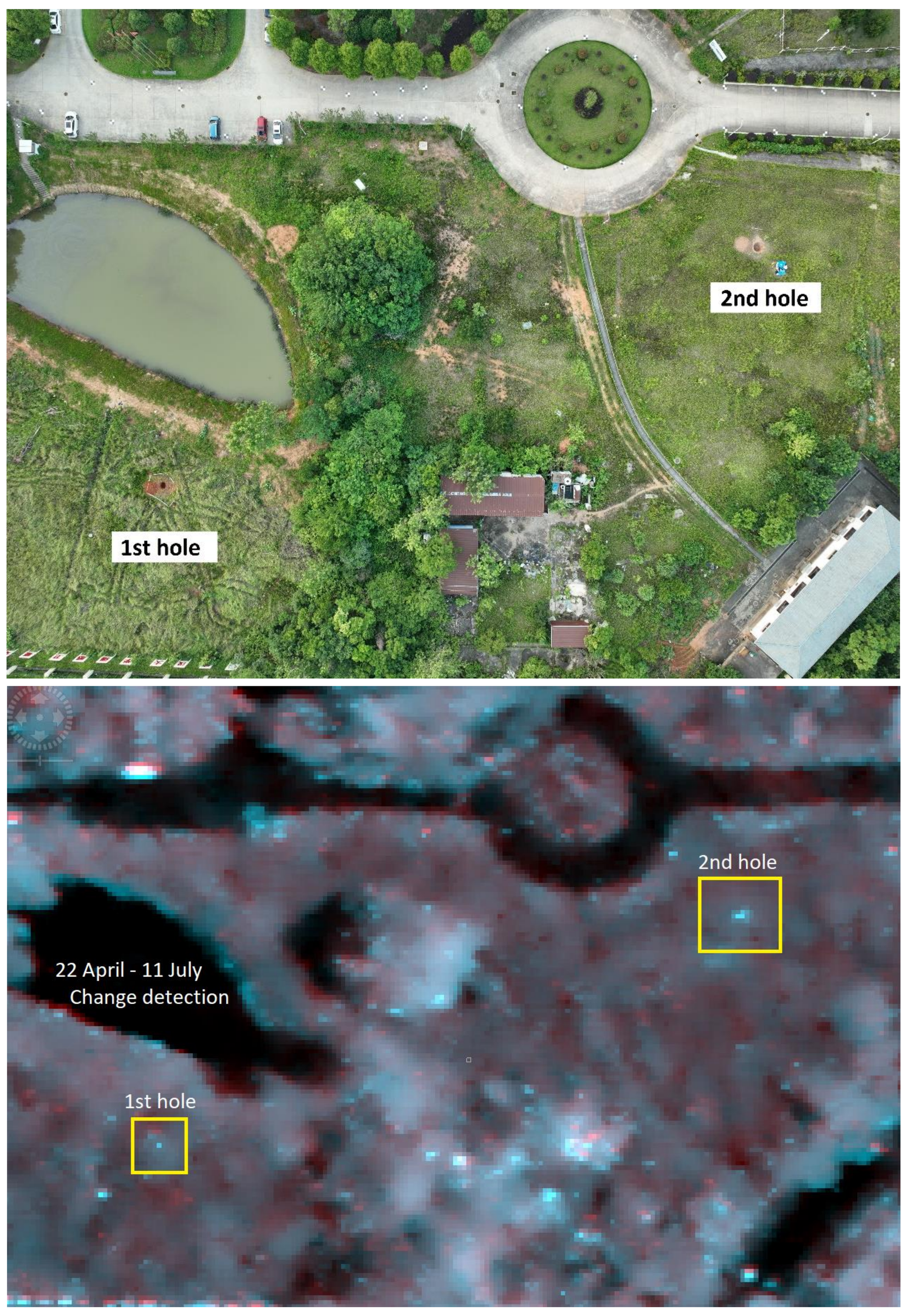



Figure 4: Figure 5: Coherence result of first and second hole between 2 dates

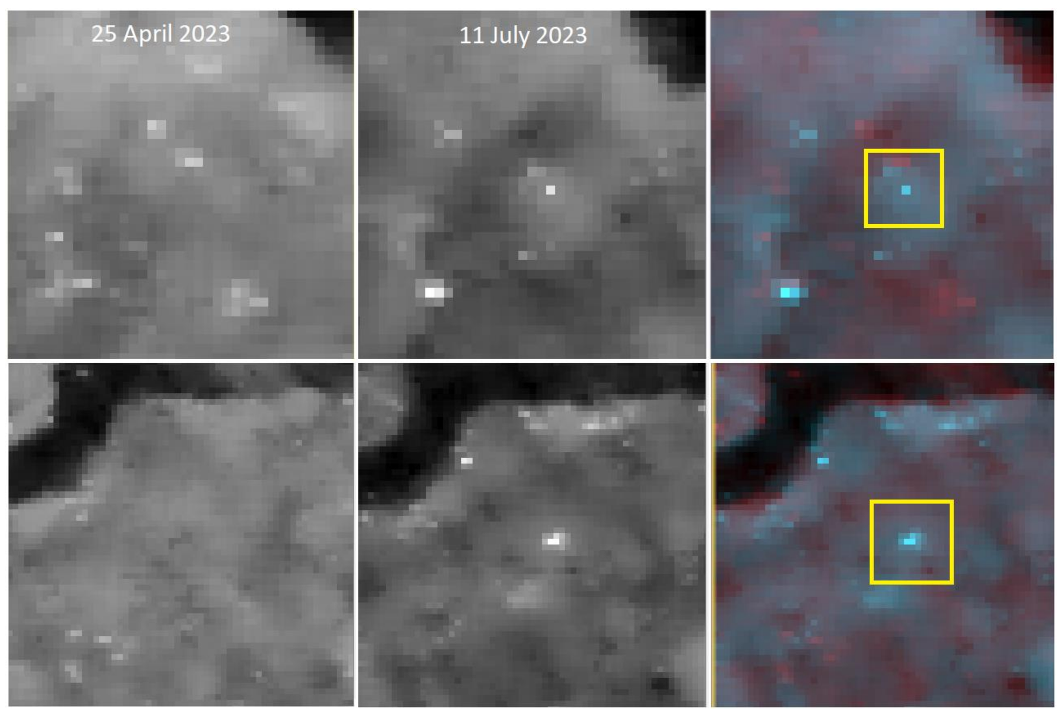



Figure 5: Coherence result of first and second hole between 2 dates

## Discussion

Detecting looting activities with SAR images is a challenging task. TerraSAR-X offers high resolution SAR images in Spotlight mode which gave us the opportunity to run this experiment. When it comes to detecting small-scale holes, especially inside archaeological fields that are full of complex looking ruins and sometimes with high volume of vegetation, it is hard to interpret/detect them. In this work, we have detected two holes we dug in the experiment area, which we gave different shapes in different dates to test different measurements. With the perfect condition where there is no vegetation, slope and location problem, it was not so hard to interpret small-scale holes in images. With all the results we had so far, we can say doing the same task in archaeological sites will be slightly harder but not impossible to achieve. Besides, archaeological fields have many natural factors like landslide, flood or high volume of vegetation and with that reason, a clear looting hole can lose its visibility in a short time. For the future studies, using optical images together with SAR images can increase the quality of the result.

## Conclusions

Experiment on detecting artificial looting holes with TerraSAR-X was partially succesfull. We wanted to determine the smallest scale of a hole we can detect and we were able to detect even 1m x 1m hole with high resolution SAR images. Detection of the small-scale looting holes practicable but to achieve a good results, applying new CCD algorithms or deep learning is necessary. The experiment is still in progress.

## References

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