ASSESSING THE IMPACT OF THE TURKISH EARTHQUAKE ON CULTURAL HERITAGE

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Abstract

Earthquake occurrence is a natural phenomenon we have no control over, often times the cost of this disaster usually out-weighs monetary valuation because human lives and various important pieces of history are torched by it and calculating the complete economic and social impact can be a daunting task. This study used high resolution TerraSAR-X images taken after the earthquake and open access sentinel 1 data to assess it's impact on selected cultural heritage sites leveraging on different orbit and incidence angles of image acquisition of the high resolution Image and archived pre-event data of sentinel 1 for coherence change detection as well as fore-knowledge of each site to delineate structural damages to varying degrees. To mitigate the damages and impacts of earthquakes, quick disaster reaction is required [1]

Figure 1: City center after the earthquake

Introduction

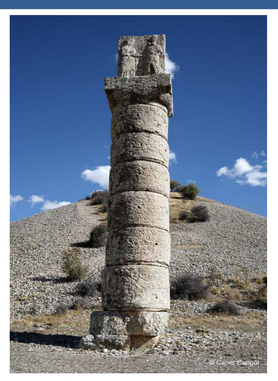

Figure 2: Karakuş Tumulus also known as the black-bird is the tomb of the women of the Commagene Kingdom Family which dates back to 20 BC.[3]

Figure 3 : İskenderun Latin Catholic Church in Hatay is a 152yrs old church, first built in 1871 was heavily damaged by the earthquake.[4]

Figure 4: Habib-I Neccar Mosque named after a religious man Habib-i Neccar worked to spread Christianity in Antakya during the Roman era (64 BC–396 AD). The precise date are unknown. There are rumors that the mosque was originally a chapel, which the Syrian Mamluks had destroyed and replaced with a mosque.

Figure 5: Ulu Mosque in Hatay city has its exact date of construction as unknown. However, the oldest data that can be traced back to it goes as far back as 1271 in the chess-shaped Kufic inscription on the minaret, and it belongs to the period when the Mamluk Sultan I. Baybars dominated the city[5]

Objectives

- The aim of this study is to detect damaged cultural heritage sites in the earthquake zone of Adiyaman and Hatay in Turkey
- Assess the magnitude of structural damage to these important piece of history

Figure 6. Google earth outline of the 3 most hit cities

Methods and Materials

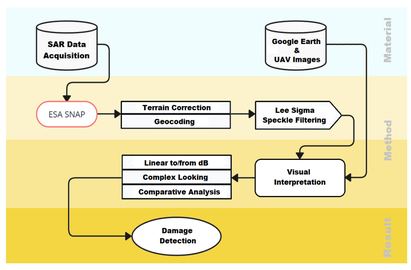

Figure 7: Workflow for TerraSAR-X

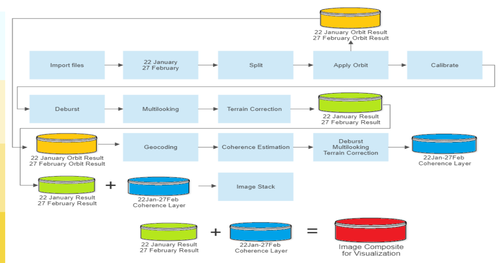

Figure 8: Workflow for Sentinel 1 coherence change detection

Table 1. Properties.

Image	Satellite	Acquisition Mode	Polarization	Pass	Incident Angle Center	Relative Orbit	Date of Acquisition
Hatay city Center	TDX1	High Resolution Spotlight	HH, VV	ASCENDING	51.54	115	23 Mar 2023
Karakus Tumulus 1	TDX1	Staring Spotlight	HH	DESCENDING	44.26	107	12 Mar 2023
Karakus Tumulus 2	TDX1	Staring Spotlight	HH	ASCENDING	27.49	54	21 Apr 2023
Karakus Tumulus 3	TDX1	Staring Spotlight	HH	ASCENDING	43.16	130	26 Apr 2023
Karakus Tumulus 4	TDX1	Staring Spotlight	HH	ASCENDING	43.16	130	07 Apr 2023
Hatay - İskenderun	TDX1	Staring Spotlight	HH	ASCENDING	39.70	39	20 Apr 2023

Results

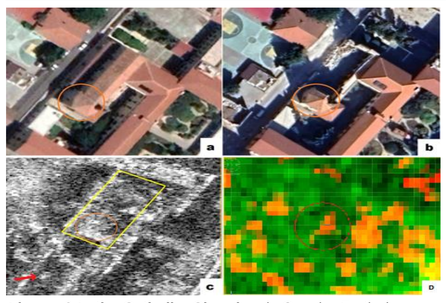

Figure 9:Latin Catholic Church. **a**) Google Earth image before earthquake, **b**) Google Earth image after earthquake, **c**) SAR image, orange circle indicates the abscissa where the roof is still standing **d**) Coherence change detection with Sentinel 1 image. Red circle indicates the damaged Church. (TerraSAR-X Acquisition date : 20 Apr 2023)

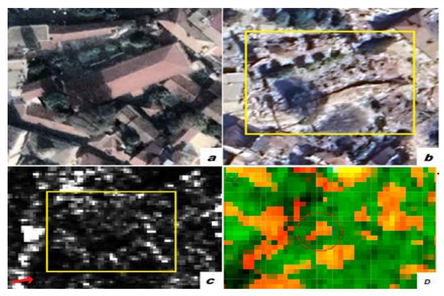

Figure 10. Hatay ulu mosque. a) Google Earth image before earthquake, b) Google Earth image after earthquake, c) SAR image, d) Coherence change detection with Sentinel 1 image. Red circle indicates the damaged Mosque. (TerraSAR-X Acquisition date : 23 Mar 2023)

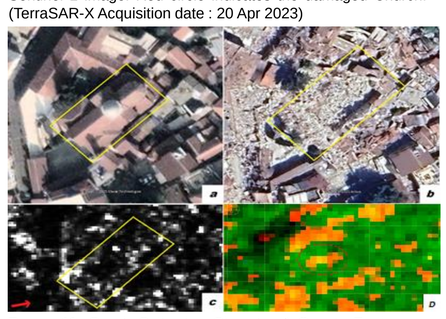

Figure 11. Greek Orthodox Church. a) Google Earth image before earthquake, b) Google Earth image after earthquake, c) SAR image, d) Coherence change detection with Sentinel 1 image. Red circle indicates the damaged Church. (TerraSAR-X Acquisition date: 23 Mar 2023)

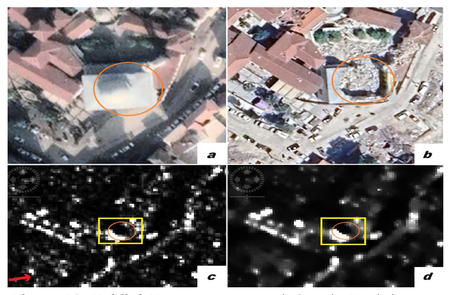

Figure 12. Habib-i Neccar mosque. a) Google Earth image before earthquake, b) Google Earth image after earthquake, c) SAR image, d) Filtered SAR image. Orange circle indicates the area where roof of the mosque is collapsed. (TerraSAR-X Acquisition date : 23 Mar 2023)

In this study, so many factors and parameters were combined to conclusively analyse the result, size of the damage, location of the structure, surrounding structures and coherence change detection played important roles. Because different size of damages backscatter differently and sometimes combining and comparing it with the backscatter from surrounding structures helps delineate the structures and identify damages (see Figure 9 & Figure 10). Also, we could see how the nature of the structural damage made a visible difference between Adıyaman Ulu mosque, Habib-i Neccar mosque and Hatay Ulu mosque where we could detect strong backscatter from the remaining north-west corner of the mosque roof of the Adıyaman Ulu mosque (see figure 18) and the collapsed circular dome of the Habib-i Neccar mosque (see figure 12). Parameters of acquired SAR images play a huge role. Specifically in the case of the Column in Karakus Tumulus, we have examined how different incident angles and orbits changes the view on the damage. Looking from the right direction is one of the major conditions to see damage in a single SAR image. For instance a thorough examination of the acquisition characteristics for Figures 15, 16, and 17 revealed that three of the four images (b, c, and d) shared the same pass (Ascending) and two of them (c, d) shared the same incidence angle center of 43.16° but had distinct first, last, near, and far longitudes and latitudes

Karakuş Tumulus

The Karakuş Tumulus (37°52'11.41"N, 38°35'14.26"E) is a great example to shows how different orbit and incidence angle makes a huge difference in SAR images, especially for visual interpretation. The tumulus has four columns, and it is easy to confuse shadow with the damage since their shadow fell westward in the same direction of the collapsed column. (See Figure 14). In the image, it took a keen eye to see that the angle of the collapsed column(Figure 14a) is slightly different from the shadow of the standing columns (Figure 14b)

Figure 13: Karakus Tumulus(a) and collapsed handshake relief (b)

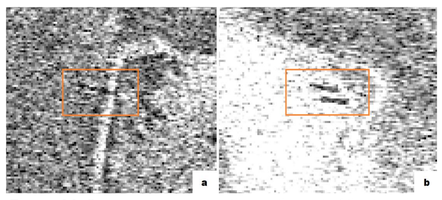

Figure 14: Collapsed column on the north-west of the tumulus, b) Shadow of standing columns on the north-east of the tumulus. (SAR Acquisition date : 12 Mar 2023)

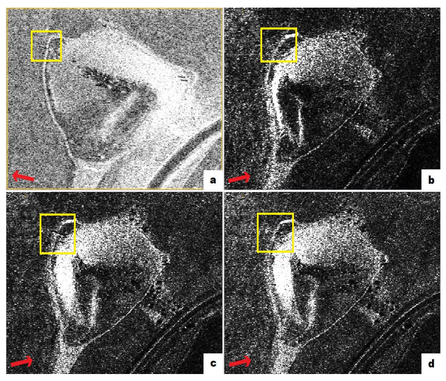

Figure 15: Acquired SAR images of Karakus Tumulus. Out of 4 images, only in image (c) we can clearly see the collapsed column. (SAR Acquisition dates; a: 12 Mar 2023, b: 21 Apr 2023, c: 26 Apr 2023, d: 07 Apr 2023)

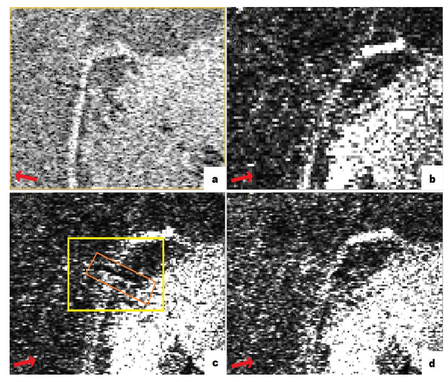

Figure 16: Zoomed SAR images into collapsed column. Yellow polygon in image (c) indicates the area where the column is. (SAR Acquisition dates; a: 12 Mar 2023, b: 21 Apr 2023, c: 26 Apr 2023, d: 07 Apr 2023)

Figure 17: Filtered SAR images of the collapsed column. Orange polygon shows the column on the ground. (SAR Acquisition dates; a: 12 Mar 2023, b: 21 Apr 2023, c: 26 Apr 2023, d: 07 Apr 2023)

Figure 18: Side view of the Karakus Tumulus with red arrow pointing to the affected column.

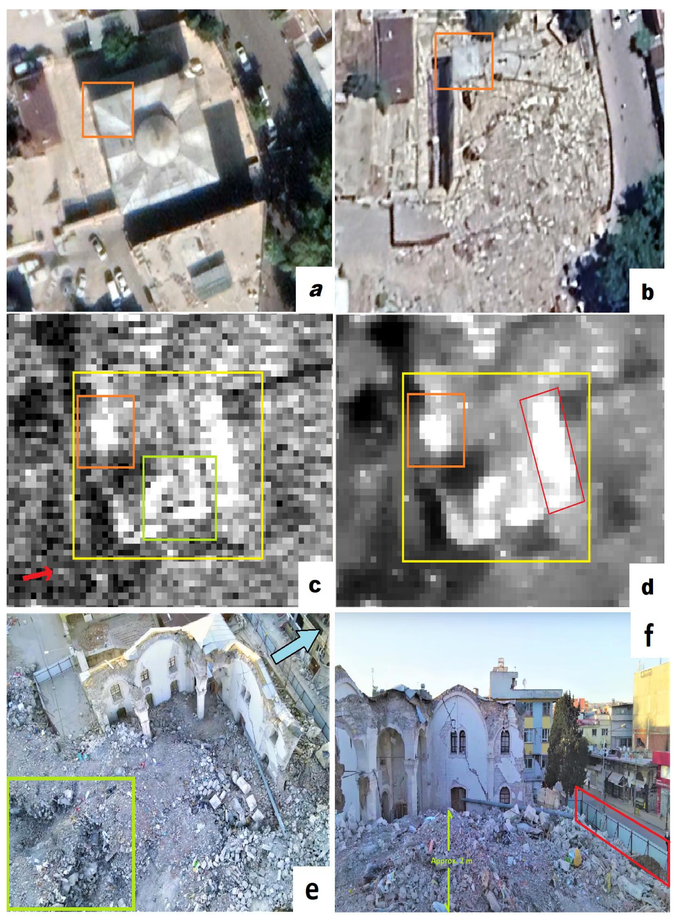

Figure 18. Adıyaman Ulu Mosque. a) Google Earth image before earthquake, b) Google Earth image after earthquake, c) SAR image with the green square indicating the 2m pile of rubble(see e & f), d) Filtered SAR image. Orange square indicate the area where standing part of the roof on north-west, red rectangle marks the brightly scattering makeshift aluminum fence (see f) (SAR Acquisition date: 30 Mar 2023)

Discussion

The combination of two techniques, different data and several parameters was helpful in the processing and interpretation of the result in this study

Even though the challenges of the two techniques combined in this study run parallel, they however complement each other. While open access sentinel 1 image was helpful, it had it own limitation because of it's low resolution, we could only detect change on a zonal level rather than structural. Detecting damages from single SAR high resolution (TerraSAR-X) post-disaster image on structures was to a large extent ambiguous.

Nevertheless, we observed that using different polarization, orbit and incident angle can help to achieve this task. We had different locations and structures to examine and visually interpret which showed us that the level of damages on buildings is also an effective parameter to understand the changes in pixel values in SAR images as was evidently seen in the partially collapsed Habib-i-Neccar mosque and totally collapsed Hatay Ulu mosque.

References

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Conclusions

When it comes to visual interpretation, location of the structure and size of the damage is very important. Different size and shape of damages backscatters differently and detecting it is often associated with the surrounding structures. In addition to the nature of the structural damage, parameters of acquired SAR images play a huge role. Specifically in the case of the Column in Karakus Tumulus, we have examined how different incident angles and orbits changes the view on the damage. Looking from the right direction/angle is one of the major conditions to see damage in a single SAR image.
Combining multiple resources and techniques that complement each other was key to achieving good result.