CHANGE DETECTION TECHNIQUES FOR URBAN AREA DISASTER ASSESSMENT USING HIGH RESOLUTION SATELLITE DATA

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ABSTRACT

Unfortunately, the year 2023 began with a devastating earthquakes unprecedented in recent years, spreading over the territories of two neighboring countries (Turkey and Syria) located on the same tectonic plate. On the night of February 6, 2023, Turkey and Syria were hit by a powerful 7.8 magnitude earthquake. The earthquake was one of the strongest in the region in more than a century. Even more devastation was caused by aftershocks that hit both countries hours later. A few days later, weaker earthquakes were reported in two other countries (Romania and Croatia) located on different with respect to first one, but neighboring, tectonic plate.

This paper represents an approach for using change detection techniques based on free access high resolution Earth observation satellite data (Sentinel, Landsat) for assessment of the consequences caused by earthquakes in an urban area. Known change detection techniques have been investigated such as: image differencing, image rationing, change detection based on indexes calculation and comparison, etc.

As a result, a comparative analysis of the investigated change detection techniques with respect to an urban area adequacy is presented.

Keywords: change detection, Earth observation, Sentinel, earthquakes, disaster, MATLAB

1. INTRODUCTION

Today we are witnessing of crises caused by natural disasters covering significant territories, and in some cases they even extend to the territories of neighboring countries, as was the case with the earthquakes of February 6, 2023 in the territories of Turkey and Syria. Most of these crises cause huge destructions, involve human, financial and material resources, continued with days. Daily map of the events of the earthquakes is shown on figure 1.

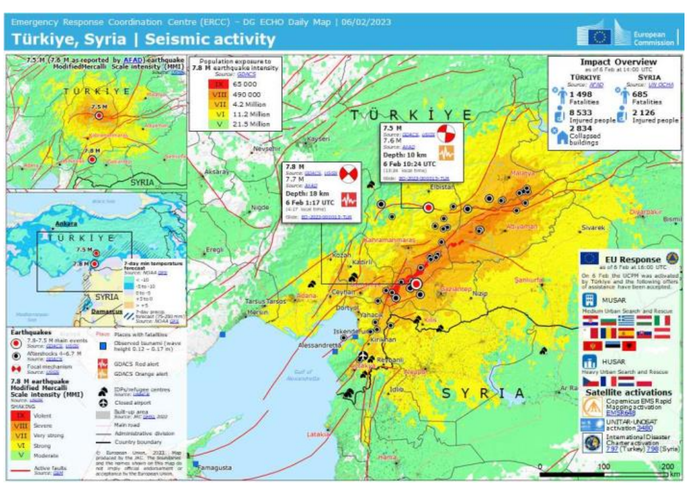

Figure 1. Daily map of the M7.8 and M7.5 earthquakes in Türkiye and Syria [1]

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The figure 1 shows the scale and huge territory that the two strong consecutive earthquakes struck. Thanks to the rapid development of technologies and to the open access satellite Earth observation data, it is possible to assess the destruction in urban areas on big scale. The approach which is tested in this survey is usage of change detection (CD) techniques using open access high resolution multispectral data from Sentinel SCI Hub repository.

2. METHODOLOGY

2.1 Satellite data

For the disaster assessment [7, 9, 11, 13, 15, 17, 19] in the area of the Türkiye – Syria border Sentinel-2 images with close to zero percentage cloud coverage was selected. Two products covered plate T36SYF in accordance of European Space Agency (ESA) naming nomenclature from dates 2022.10.27 and 2023.03.01 was used for the survey presentation in the paper.

Table 1. ESA Sentinel-2 products used.

№	ESA Product
1	S2A_MSIL2A_20230301T081851_N0509_R121_T36SYF_20230301T113239
2	S2B_MSIL2A_20221027T082009_N0400_R121_T36SYF_20221027T100936

For reference map was used map of Antakya, Turkiye (Figure 2), showing number, location and statistics of destroyed buildings per building block determined using data from the Humanitarian Open Street Map Team (HOTOSM) (downloaded on 15 February, 11:12, GMT+1) [2].

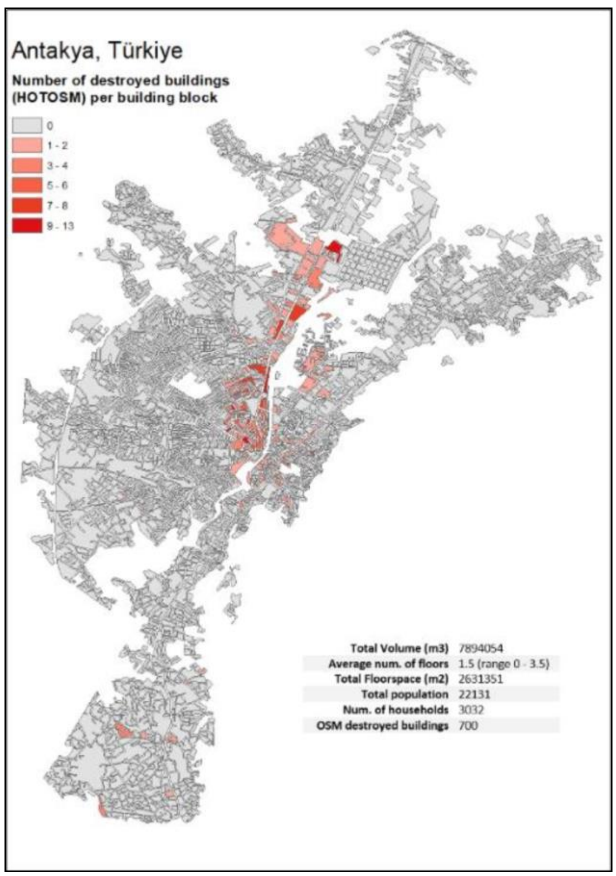


Figure 2. Map of Antakya, Turkiye (downloaded on 15 February, 11:12, GMT+1) [2]

2.2 Change detection techniques

The following pixel-based change detection (PBCD) techniques for urban area disaster assessment in high resolution satellite data was tested: image differencing (using Sentinel-2 bands 2 and 4 separately) [3], image rationing (using Sentinel-2 bands 2 and 4 separately) [3] and the disturbance index (DI) [4].

Bands No.	Central Wavelength (nm)	Band Width (nm)	Spatial Resolution (m)
1	443	20	60
2	490	65	10
3	560	35	10
4	665	30	10
5	705	15	20
6	740	15	20
7	785	20	20
8	842	115	10
8a	865	20	20
9	945	20	60
10	1380	30	60
11	1610	90	20
12	2190	180	20

Figure 3. Sentinel-2 bands defined by ESA

Mathematical expressions of the selected PBCD techniques are:

- Image differencing – $I_d(x,y) = I_1(x,y) – I_2(x,y)$, where I_1 and I_2 are images from time t_1 and t_2 and I_d is the difference image;
- Image rationing – $I_r = I_1(x,y) / I_2(x,y)$, where I_1 and I_2 are images from time t_1 and t_2 and I_r is the rationing image;
- Disturbance index (DI) – $DI = B_r – (G_r + W_r)$, where

  $B_r = (B - B_\mu)/B_\sigma$,

  $G_r = (G - G_\mu)/G_\sigma$,

  $W_r = (W - W_\mu)/W_\sigma$, where

  B_r , G_r , W_r – rescaled Brightness, Greenness and Wetness;

  B_μ , G_μ , W_μ – mean Brightness, Greenness and Wetness;

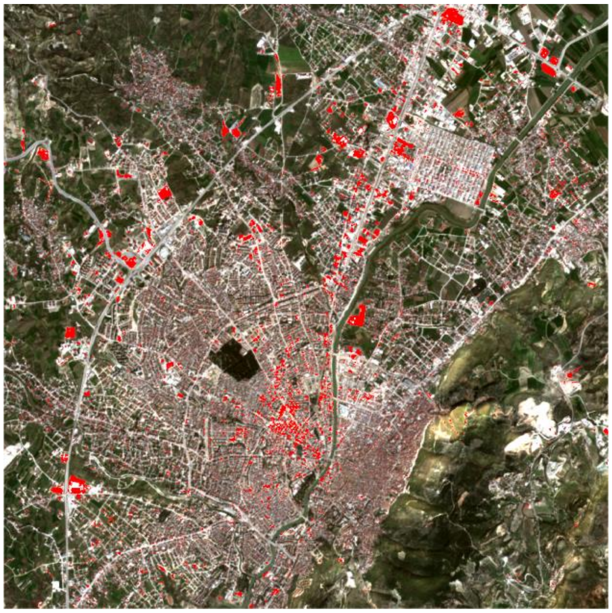
  B_σ , G_σ , W_σ – standard deviation of Brightness, Greenness and Wetness

Using the above-mentioned data (Table 1 and Figure 3) and mathematical expressions, a study was conducted to assess the adequacy of the selected PBCD techniques for urban area disaster consequences assessment. The study was executed using MATLAB by developing the GUI, algorithms and corresponding source code for reading, image processing and mixing the satellite image (as a background) and the PBCD index mask showing the locations and areas with changes detected [6, 8, 10, 12, 14, 16, 18].

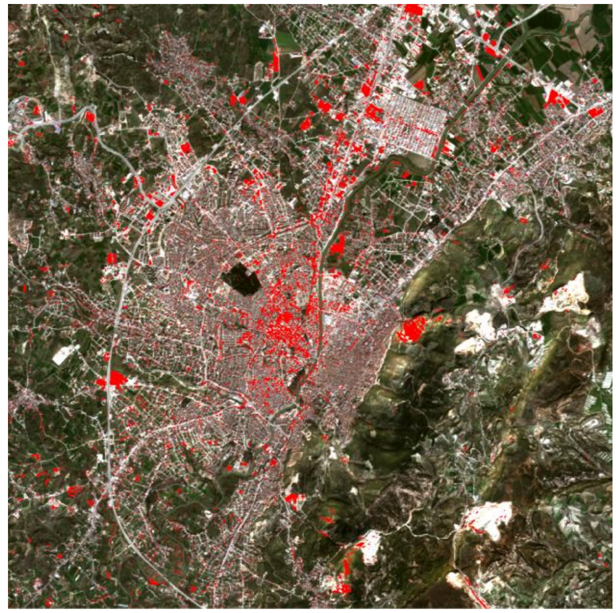
3. RESULTS

Figures 4 (from a to d) and Figure 5 shown the results of data processing. The pixels in which a change was detected depending of the PBCD technique are shown in red. It should be noted that the image used to assess the earthquakes consequences (Sentinel-2) is dated March 1, 2023, and the image used for reference (Figure 2) is dated February 15,

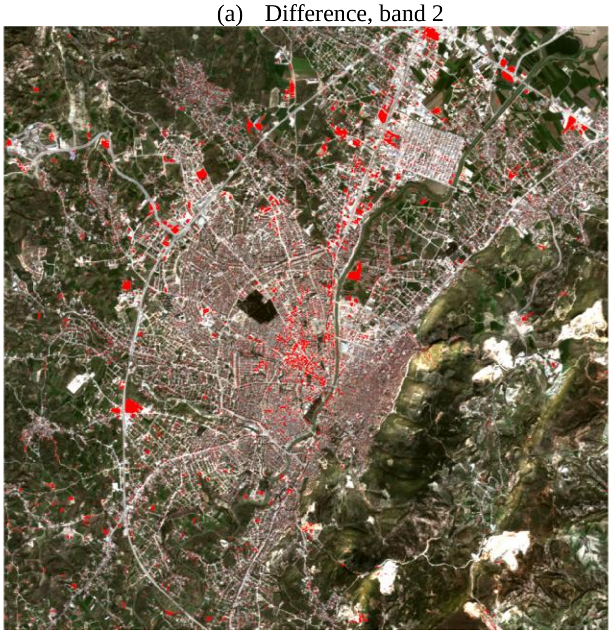
2023. It should be noted that during these almost two weeks clearing activities of the collapsed buildings were carried out.



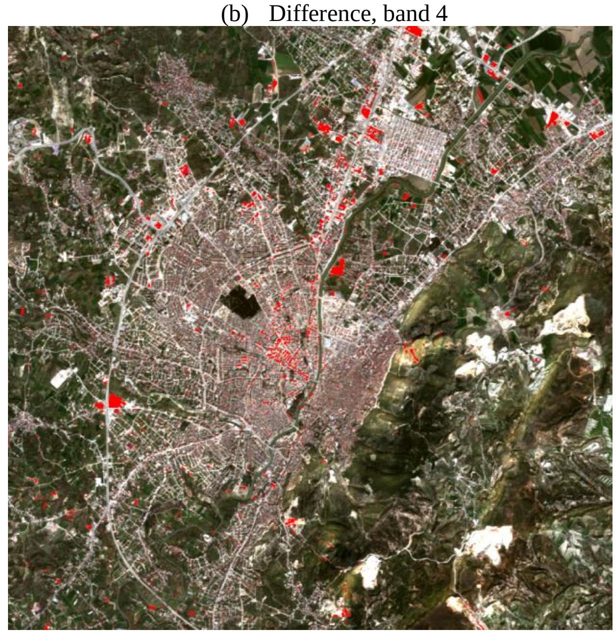
(a) Difference, band 2



(b) Difference, band 4



(c) Rationing, band 2



(d) Rationing, band 4

Figure 4. PBCD difference and rationing results for Antakya area

Table 2. Summary of PBCD index images and corresponding mask thresholds

	Fig. 4 (a)	Fig. 4 (b)	Fig. 4 (c)	Fig. 4 (d)	Fig. 5
Parameter/PBCD	Difference, B2	Difference, B4	Rationing, B2	Rationing, B4	DI
Index mean	-16	-72	1.0039	0.9580	0.014
Index std. dev.	560	583	0.6336	0.2865	0.77
Mask down-threshold	-5 x std.dev.	-5 x std.dev.	0	0	-5 x std.dev.
Mask up-threshold	-1 x std.dev.	-1 x std.dev.	1 x std.dev.	1 x std.dev.	-1 x std.dev.

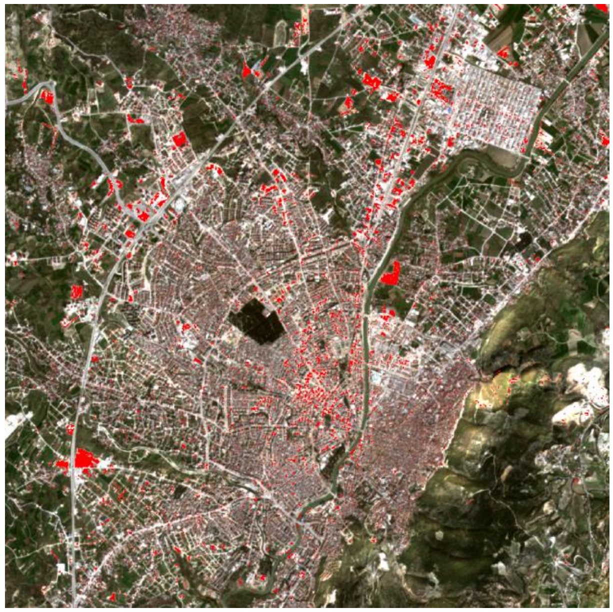


Figure 5. PBCD Disturbance Index (DI) results for Antakya area

The images of Figures 4 and 5 show a high degree of correlation with the reference image (Figure 2). However, the PBCD indices shows more destruction areas than depicted in Figure 2, which may be due to clean-up activities carried out during the two-week time interval between data sets (Sentinel-2 and HOTOSM) or to an incomplete reporting of destructions in all parts of the city by the HOTOSM.

Table 3. Summary of the survey final results

	Fig. 4 (a)	Fig. 4 (b)	Fig. 4 (c)	Fig. 4 (d)	Fig. 5
Parameter/PBCD	Difference, B2	Difference, B4	Rationing, B2	Rationing, B4	DI
Scene size [km2]	305.90	305.37	305.55	304.85	305.03
Damaged area size [km2]	8.04	7.23	3.73	2.50	8.12
Damaged area ratio [%]	2.63	2.37	1.22	0.82	2.66

Table 3 shows the summary of the survey final results expressed in square kilometers and ratio to gain a more realistic assessment of the performance of the tested techniques. For this purpose, one pixel of the scene is assumed to be 10 by 10 meters or 100 square meters. Through this approach, the area of the scene and the area formed by the number of red pixels, which represents the assessment of the consequences of successive earthquakes in the urban area were calculated.

The PBCD difference and disturbance index techniques show similar results in estimating the percentage of disaster assessment in an urban area, which gives us the right to rate them as more adequate than the rationing technique.

4. CONCLUSION

The conducted study of the possibilities of PBCD techniques for assessing the consequences of natural disasters, in particular earthquakes, shows that by using multispectral high resolution satellite data is realistic to visualize and calculate with sufficient accuracy the area of the affected urban areas.

Higher estimation accuracy and visualization precision can be achieved by using very high resolution multispectral satellite data. Such data are commercially available and have a resolution of 1.5 to 0.3 meters per pixel.

In addition, further research can be conducted to evaluate the adequacy of other change detection techniques or to develop new ones.

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