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Evaluation of Earthquake Damage in Hatay/Antakya City Center after the Turkey-Syria 6 February 2023 Earthquake by Examining the Spatial Change between 2000-2002†

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Abstract: Turkey is an high seismic hazard country where disasters occur frequently due to its geographical location. Earthquakes cause spatial changes in urban and rural areas, which can be monitored and analyzed fast and accurately with Remote Sensing and Geographical Information Technologies. The study aims to determine the spatial changes in the city center of Hatay, Antakya, which was heavily hit by two large earthquakes of magnitude 7.7 and 7.6 on 06.02.2023. It was accepted that the structures added to the building stock from 2000 to 2002 were built according to the earthquake regulation published in 1997, and the damaged structures after the earthquake have been evaluated in this context. During the period leading up to the publication of the new building inspection law, the structures built according to the earthquake regulation were identified, and it has been observed that changes are taking place in these areas. To fulfill this aim, 2000 and 2002 images of LANDSAT 7 were used to perform NBDI (Normalized Building Difference Index) analysis, and the image differencing was applied by subtracting the image of the year 2000 from the year 2002. The structural area changes were then determined by comparing them with the 2023 SENTINEL-2A satellite image created after the earthquake. LANDSAT 7 data within the scope of the study USGS.gov (United States Geological Survey (.gov)) from the website and SENTINEL-2A data were obtained from the SENTINELS COPERNICUS (Sentinel Online) website by selecting certain dates within the scope of the topic. Potential difficulties within the study's scope may arise from the possibility of satellite images and the geography data obtained from the website not providing accurate results at the expected rate due to weather conditions. The study indicates that the buildings constructed in adherence to the earthquake decrees of 2000-2002 have undergone alterations following the 2023 earthquake. It also highlights that the current regulations are insufficient in terms of earthquake preparedness. In this context, earthquake regulations should be reviewed, their application should be done correctly during the construction of the structure and it should be ensured that the structures are not damaged. This study, which is based on the spatial change analysis after the earthquake, is an important and useful study in determining the points where the earthquake regulations in question are insufficient in the areas that need to be rebuilt in the city center of Antakya. In addition, it will be an important analysis example for the city planning studies expected to be carried out by local governments for the earthquake zone. Policy makers and practitioners can develop strategic planning methods by dividing land determination and urban planning studies into regions within the framework of these areas. By determining the damaged urban use areas located in the areas where change detection is observed within the study area, city planning intervention decisions related to this area can be developed.

Keywords: Remote Sensing; Geographical Information Systems; Change Detection

1. Introduction

The main reasons for the rapid development and change of cities in Turkey are uncontrolled population growth and economic-political factors. In recent years, the Eastern Mediterranean and Southeastern Anatolia regions have experienced demographic changes. The increasing population in urban areas has led to new housing demands and infrastructure needs. Therefore, there has been a change in the urban space with new construction activities. During these changes, earthquake regulations and building control laws have been published at certain periods. While construction activity continues to meet emerging needs, structures have continued to be prepared in accordance with the regulations as they have been published. The continuous changes and updates in earthquake regulations result in the emergence of building stock consisting of masses built according to different laws in the densely populated urban space. Consequently, structures that are built according to different Decrees and laws in urban centers and maintained to be used together (housing, commercial buildings, social infrastructure areas, etc.), the situations of receiving damage as a result of various earth tremors and disasters vary. In this study, satellite images were used to determine the changes in the position of the structures built after the earthquake according to the regulation published in 1997. It is seen that large-scale construction activities have been carried out in Turkey with the earthquake regulation developed in the year in question. For this reason, the data obtained from the selected study subject and the results will prove that the construction activity applied in the residential area is insufficient against disasters, while it will guide the construction activities to be carried out again in urban areas damaged after the earthquake. Romaniello, Piscini, Bignami, Anniballe, and Stramondo detail methodologies to evaluate the sensitivity of optical and synthetic aperture radar (SAR) variation features obtained from satellite imagery, towards the degree of damage inflicted by earthquakes. The authors utilised clear, unambiguous, and objective language, with a logical progression of information and technical terms explained where needed. They maintain a formal tone, use precise terminology, and adhere to consistent citation and formatting guidelines. The analysis centres on the 7.0 Mw earthquake that struck Haiti on 12 January 2010, 25 km west-south-west of Port-au-Prince. The text is grammatically accurate, and there is no evidence of bias or subjective evaluation. The study aims to estimate the derived features of objects and examine potential parameters that might impact the techniques outlined in existing literature, whilst focusing on object scale. A portion of the investigation area, located in Port-au-Prince, was segmented using a series of polygons. The obtained damage map indicates the rate of collapse, highlighting areas with a considerable quantity of buildings that have fallen due to the earthquake. The available satellite dataset included optical and SAR images captured prior to and after the seismic event. This comprised two optical images from GeoEye-1 (one before and one after) and three SAR images from TerraSAR-X (two before and one after). Various change detection features were examined from satellite imagery to evaluate their potential for assessing earthquake damage (Romaniello et al., 2017).

1.1. Study Area

The study area selected is Hatay/Antakya district, located in the southern part of Anatolia. It is situated between the east longitudes of 36° 05' 22.503-36°10'39.342" and the north latitudes of 36° 15' 42.553'' - 36° 10' 29.71'' (UTM Zone 37K - WGS84) (Figure 1). Antakya is the central district of Hatay province and covers a total area of 21.4 km2. The elevation of the city from sea level is 85 m. (Özşahi̇n & Kaymaz, 2015)

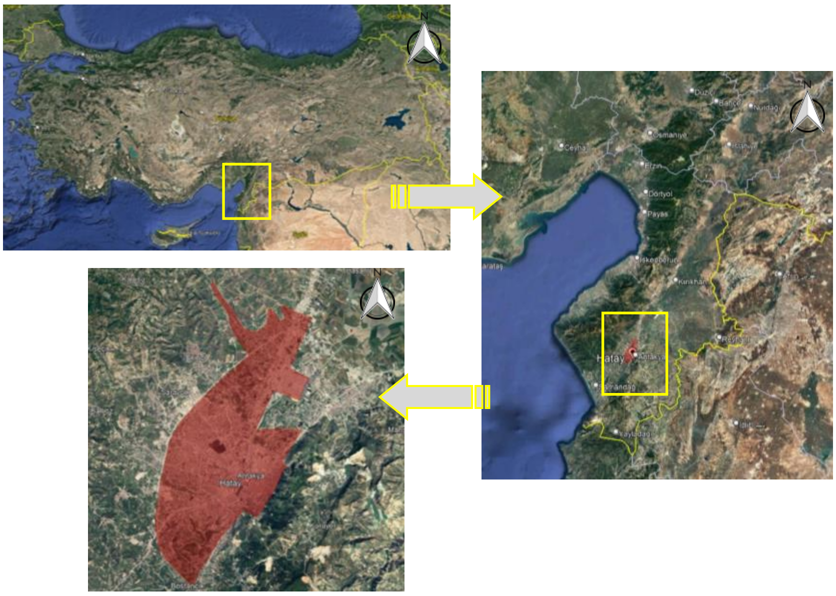

Figure 1. Location of study are (GOOGLE EARTH PRO, 2023)

In the study area, there are completed structures according to different regulations in the city center of Hatay/Antakya. In the study, structures built between 2000 and 2002 were identified. The structures built between 2000 and 2002 were constructed according to the earthquake regulations published in 1997. In addition to the earthquake regulations published in 1997, the "Building Inspection Law" was also published in Turkey in 2002. The rules in this law were included in the structures built after 2002. The aim of the study is to observe the damage status of structural areas constructed according to the earthquake regulations published in 1997, as a result of a major earthquake that occurred in 2023.

1.2. Satelitte Data

This article utilizes Landsat 7 imagery acquired on January 14, 2000, and November 19, 2002. The image preprocessing consists of a band composite. To detect post-earthquake changes, SENTINEL 2A imagery from July 19, 2023, was used. The LANDSAT 7 satellite images used in the study were obtained from the official website of the United States Geological Survey (USGS), and the SENTINEL 2A satellite images were obtained from the official Sentinel Copernicus website.

2. Method

In this study, NBDI (Normalized Difference Built-up Index) analysis was conducted using LANDSAT 7 imagery from 2000 and 2002. In the first step, bands from each year's images were combined using a band composite process. This process involves merging bands to provide a comprehensive image of the study area. After band compositing for the years 2000 and 2002, the next step was to calculate NBDI values (Figure 2). The NBDI is a widely used index for analysing spatial changes caused by earthquakes and is calculated by comparing the infrared and red bands. (Kshetri, n.d., p. 8)

$$\textbf{NBDI} = (SWIR - NIR) / (SWIR + NIR)$$

$$\textbf{LANDSAT 7; NBDI} = (Band\ 5 - Band\ 4) / (Band\ 5 + Band\ 4)$$

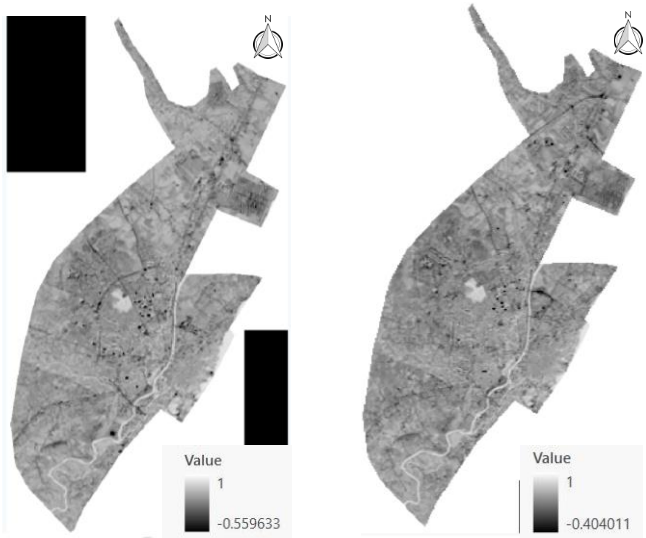

Figure 1. NBDI Analysis Hatay/Antakya City Center (Year: 2000 & 2002)

After calculating NBDI values for both years, a differencing operation was performed between the images from 2000 and 2002 (Figure 3). As a result of the differencing operation, structural areas constructed between 2000 and 2002 were identified.

The aim of the study is to compare the changes in structural areas between the years 2000-2002 with the post-earthquake period in 2023. To make this comparison, the NBDI values obtained from LANDSAT 7 imagery need to be compared with the corresponding areas in SENTINEL-2A imagery from 2023. The SENTINEL-2A imagery was transformed by applying a band composite process. NBDI analysis was then performed using the transformed imagery in ArcGIS Pro 2.9.1 software (Figure 3). The resulting LANDSAT 7 and SENTINEL-2A NBDI images were compared with each other.

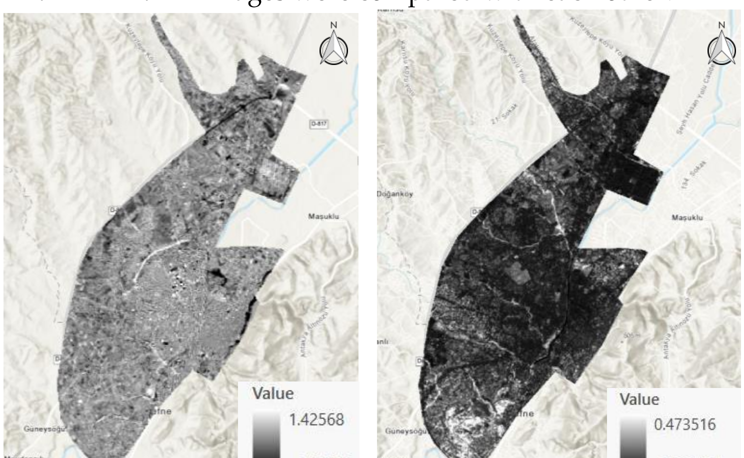

Figure 2. The NBDI Image (Extracted From 2002-2000 Each Other) and The NBDI Image (2023)

3. Results and Discussion

As a result, the differences in NBDI values have shown the changes in structural areas between the two time periods. The results of the analysis have demonstrated that the structural areas constructed according to earthquake regulations between 2000 and 2002 have undergone changes after the earthquake in 2023, indicating that the regulations were not sufficient in preventing damage. These findings highlight the need for the revision and update of earthquake regulations published in 1997, as well as the improvement of construction practices.

The results also demonstrate that technologies such as Remote Sensing and Geographic Information Technologies are effective tools for monitoring and analyzing post-earthquake spatial changes. In the discussion section, topics such as the reliability and accuracy of the analysis, the effectiveness and limitations of the methods used, can be addressed. Additionally, it is important to compare the results of the study with other similar studies and contextualize the findings in a broader context.

This study has been an important step in evaluating the effectiveness of earthquake regulations and the resilience of structures against earthquakes. Future studies can provide further information on reducing earthquake risk and ensuring the safety of structures.

Figure 4. The NBDI Image (Showing the Areas Where Changes Occurred After the Earthquake).

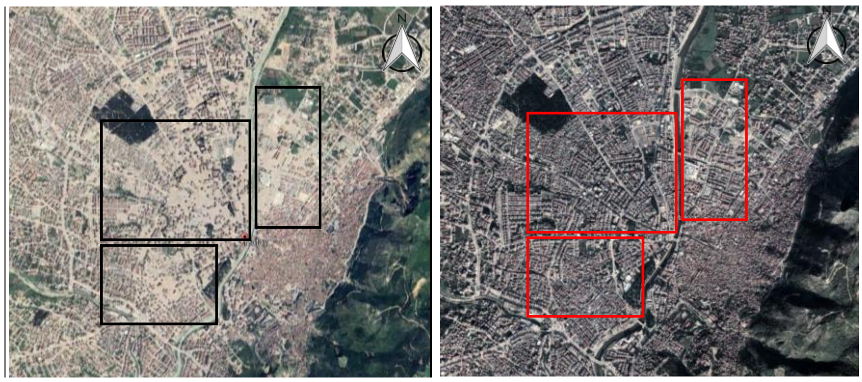

Figure 5. Satellite Image of The Date of 26.04.2023 (After The Earthquake) and Satellite Image of The Date of 01.12.2022 (Before The Earthquake) (GOOGLE EARTH PRO. (2023)).

As a result, in the resulting difference image (Figure 4), the areas where the change was observed are shown by zooming in. The result Nbdi image (Figure 5) contains negative (-) and positive (+) values. Pixel colors that are close to the "-" value in these values qualify the change. Color changes that have a value of less than zero characterize the areas where structures that have been damaged after an earthquake are located. As a result of this analysis, satellite images dated 26.04.2023 after the earthquake were examined from the "Google Earth Pro" system to confirm the areas where the damaged structures were located (Figure 5). As an example, it was concluded that the structural areas damaged after the earthquake in the Hatay /Antakya city center in the image obtained from Google Earth Pro (Figure 5) and the areas where changes were observed in the result Nbdi image (Figure 4) are similar. By comparing the Nbdi analyses conducted for certain years for the Hatay/Antakya city center and satellite images after the earthquake, it can be confirmed by observing in which area the structures built between Dec 2000 and

2002 were extensively built and damaged. Using this technique, gradual intervention techniques can be developed in earthquake-affected cities in post-disaster damage detection studies. In addition to the technique used in this study, higher October resolution satellite images can be obtained from official institutions and structure-based analyses can be performed. With this analysis method, the areas that need to be given priority in disaster management phases and subsequent improvement studies can be graded. This analysis is important for the initiation of improvement studies after the identification of damaged areas and for policy makers and practitioners to develop the most appropriate urban planning model for preparing for future disasters for the city. In accordance with the reference of these analysis results, the regions that received damage after the disaster can be determined as main regions and subregions. The development of urban planning and strategic intervention decisions based on the needs for the designated main and subregions will be beneficial for the gradual improvement of the city. Among the Decayed regions, each designated subregion may have its own urban texture. For example, strategic planning and intervention decisions for areas that have the character of a historical city center and new urban development zones should differ. In addition to the old and new urban settlement structure, the sustainability of the use of buildings with minor and moderate damage after the earthquake should also be a subject of discussion by local government and controllers. In addition, in order for the planning stages to progress smoothly, the most up-to-date earthquake regulations, the urban transformation law and the building inspection law should be applied correctly under supervision by practitioners. In order to make cities resistant to disasters, Geographical Information Systems and Urban Planning disciplines should play an active role together, and solutions to problems should be found by producing the analyses needed by cities.

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