Object Based Land Cover Classification with Orthophoto Data After Natural Disaster

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Key words: OBIA, Earthquakes, Building Damage Detection, Orthophotos

SUMMARY

Earthquakes are the most destructive natural hazards, which result in massive loss of life, highly infrastructure damages, extensive destruction of the built environment and great financial losses. More than a million earthquakes occur around the worldwide which is equal to two earthquakes per minute according to the statistics about the earthquakes. Natural disasters have brought more than 780.000 deaths approximately % 60 of all mortality is due to the earthquakes after 2001. After the earthquake, earthquake-induced building damage detection is very significant step. On October 23th, 2011, at 10:41 UTC (13:41 local time), a great earthquake took place at 38.75 N 43.36 E in the eastern part of Turkey in Van Province. 604 people died and about 4000 buildings seriously damaged and collapsed after this earthquake. In recent years, the development of remote sensing technique make it possible to detect and monitor things on the Earth's surface fast, cheap and accurate by using satellite and aerial images. Image classification is one of the most significant analysis in order to create thematic maps with satellite and aerial images.

The motivation of this study is to detect the collapsed residential buildings and debris areas after the earthquake by using orthophotos with the object based image analysis and also see how well remote sensing technology was carried out in determining the collapsed buildings. In this study, conventional pixel-based classification algorithm was not used in classifying orthophotos due to aerial images were ineffective to create land use/land cover map especially in complicated urban areas. Orthophotos are the aerial photograph which is generally applied in geospatial data establishment and update. In this study, two different land surfaces were selected as case study areas. In the first phase, segmentation was applied with optimum scale and then two different classification approaches, namely "supervised" and "unsupervised" approaches were applied and their classification performances were compared. Object-based Image Analysis (OBIA) was performed using e-Cognition software.

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1. INTRODUCTION

Among the natural hazards, earthquakes are the most destructive disasters and cause huge loss of lives, heavily infrastructure damages and great financial loses every year all around the world. More than a million earthquakes take place around the world which is equal to two earthquakes per minute according to the statistics. The research is stated that, natural disasters have resulted in 780.000 deaths approximately % 60 of all mortality was due to the earthquakes between 2001-2011 (Bartels and Van Rooyen, 2011). After natural hazards, earthquake-induced building damage detection is a very important step as it is one of the most critical threats to cities and countries in terms of the area of damage, rate of collapsed buildings, the damage grade near the epicenters and also building damage types for all constructions. In the last two decades, object extraction in urban environments has been an important topic in the study field of remote sensing, photogrametry and computer imaging. The automatic or manual extraction of objects such as buildings, roads, vegetation, shadows and other fields have also been popular in many scientific studies in recent years.

The motivation of this study is to evaluate the remote sensing technology performance in detecting collapsed buildings after natural disaster using orthophotos. In the processing, an Object-Based Image Analysis (OBIA) was performed with e-Cognition software.

2. STUDY AREA & DATA SETS

In general, most of the earthquakes originate along the boundaries between plates. Turkey is one of the most seismically active country due to the junction of three important plates. In Turkey, every 2-3 years, great and damaging earthquake takes place according to the statistical data. General Directorate of Mineral Research and Exploration revised and published new active fault map of Turkey in 2012. The number of faults and fault segments have reached to 485 which have potential of generating earthquakes M> 5.5 in this map (Duman et al 2013). In this study, the region which is situated in the Eastern part of Turkey is examined. The study area is located at 38^{o} 29’ 57” Northern latitude and 43^{o} 20’ 55” Eastern longitude (Figure 1). The case study area is situated about 60 km at the northern part of Van city center.

2.1 Van-Ercis Earthquake

An enormous earthquake (Mw=7.1) struck Van city center and its vicinity towns in the eastern part of Turkey on October 23^{th} 2011 at 13:41 local time (10:41 GMT). The epicentre coordinates of Van-Ercis earthquake was at 38° 37′ 40.8″ N, 43° 29′ 9.6″ E near Tabanlı village, 16 km far away from the northern part of Van city centre (Kalafat et al. 2014). The main shock was occurred at 26 km depth and its duration was 50 seconds. After the earthquake, 11 aftershocks above M>5 were occurred (Erdik et al 2012). It was recorded that, Van-Ercis earthquake caused 604 loss of life and 2608 wounded according to the information provided by Prime Ministry Disaster and Emergency Management Presidency (Url: 1). In Van city center and Ercis town, approximately 4000 buildings seriously damaged or totally collapsed due to the earthquake. Besides, a majority of the casualities and building damages occurred due to the irregular urbanization (Turan 2012, Utkucu 2013, Korkmaz 2015) (Figure 1).

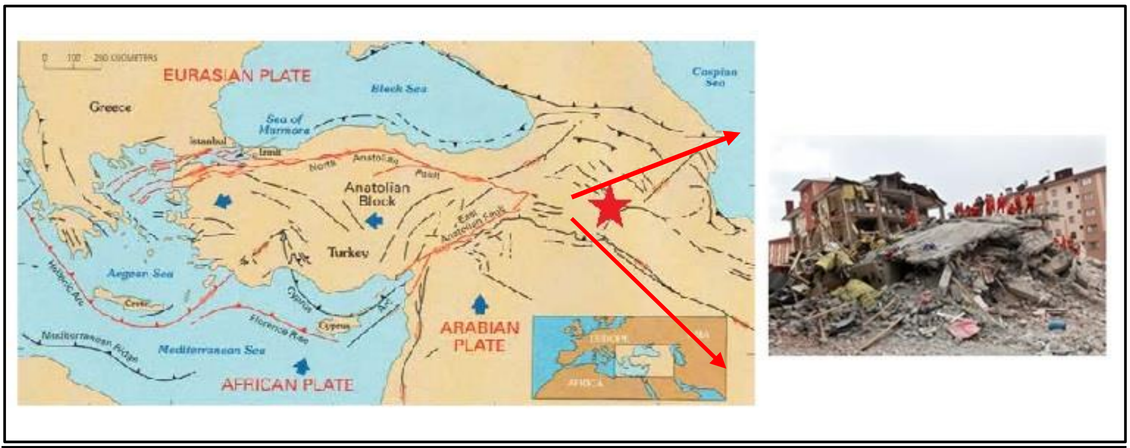

Figure 1: The map of the study area with streetview data taken after the earthquake (Url 2)

2.2 Data sets

In this study, two different data sets were used. The initial data type used was the orthophotos of the case study area. The aerial photos of the case study area were obtained one day later after the earthquake and produced orthophotos by General Command of Mapping (GCM) which is the national mapping agency of Turkey (Kayı et al. 2014). The orthophotos had 3 bands (RGB) and the spatial resolution was 45 centimeter. 152 aerial photos were taken with Microsoft Ultra CAM-X digital air camera. The pixel size of the camera was 7.2 and focal length of it 100 mm. The second data type used was streetviews of the disaster areas of the Van city center and Ercis town. These images were obtained by Earthmine Inc. on 9th November 2011. The maps used in this software is supported by Nokia Maps. Table 1 displays the specifications of the data used in this study.

Table 1: Specifications of used two types data in this study

Data type	Acquisition date	Spatial resolution
Ortophoto	24 October 2011	0.45m
Street view	9 November 2011	32 megapixel

3. METHOD & APPLICATION

With the advent of very high resolution multispectral imagery, aerial photos, computer programming and digital image processing; the efficiency of image classification is uncertain. Object based image analysis started at 1970s however, it was not used due to the limitation of satellite images and aerial photos spatial resolution and digital image processing (Platt and Rapoza 2008). OBIA uses not only the spectral information but also the shape, contextual and semantic information is being used. In this study, object based image analysis was used.

3.1 Segmentation

Segmentation is the initial step in the object based analysis. The motivation of the segmentation is to create meaningful objects from the target images by dividing images into different domains in terms of a homogeneity criterion. The segmentation success depends on the classification success (Baatz and Schape 2000, Baatz et al. 2005). Segmentation can be classified into two basic types: Top-down and Bottom-Up. Multiresolution segmentation and classification-based segmentation are the examples of bottom-up segmentation (Definiens 2012).

In this study, multiresolution image segmentation was used. 3 important parameters should be determined as accurate as possible in this segmentation. These parameters are; scale, color/shape and compactness/smoothness. Among these parameters scale is the most significant one that determines the size of image objects. If the scale is high, image objects are relatively large. As displayed in Figure 2, the segmentation is carried out by weighting of all bands and by using the parameters given in Table 2.

Table 2: Criteria used in segmentation for both case study areas.

	Used Parameters & Criteria				
Study Area	**Scale**	**Color**	**Shape**	**Smoothness**	**Compactness**
Orthophoto - Homogenous	100	0.4	0.6	0.3	0.7
Orthophoto-Heterogeneous	120	0.6	0.4	0.3	0.7

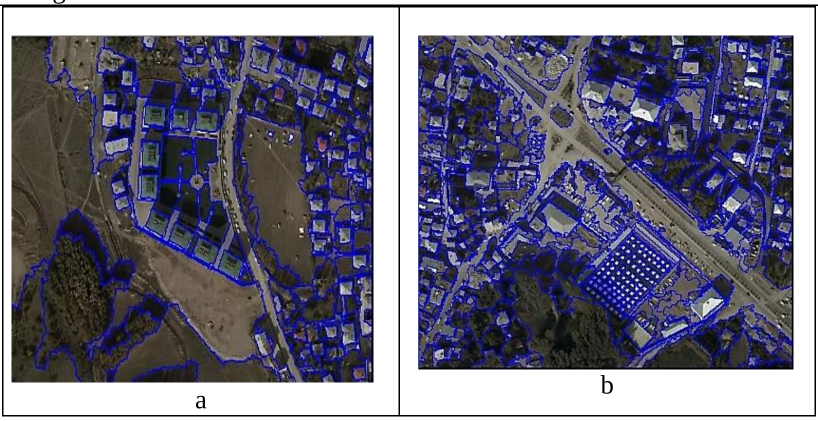

Figure 2: Segmentation of (a) Homogenous area (b) Heterogeneous area

3.2 Unsupervised Classification

The image objects are allocated to the most suitable class which are described by conditions in unsupervised classification. Conditions are outlined the criteria of the collection in terms of textural, spectral and contextual properties. The unsupervised classification images carried out in both regions are given in Figure 3. At total, 10 main classes were defined in the both case study areas.

The used classes are; agricultural area, vegetation, buildings, tent city, collapsed buildings, debris areas, open land, shadow, mixed areas and road. The classes and the descriptions used for the two case study areas are given in Table 3. When the results of unsupervised classification performed in the homogeneous region were analysed, not much mixing among the classes were observed due to the texture of the region but, open land, shadow and mixed areas classes were mixed partly. In order to extract the collapsed buildings, optimum criteria was selected. Quite the reverse, in the heterogenous region the unsupervised classification results indicated that the number of classes much more mixed. For the most part, mixed areas and debris class were mixed.

Table 3: Selected criteria and classes during the process in e-cognition software for both area.

Classes	Homogoneous region	Heterogenous region
Agricultural area	Aritmetic mean	-
Vegetation	Area + Aritmetic mean	Area + Area
Buildings	Rectangular fit + Elliptic fit	Rectangular fit +Elliptic fit
Tentcity	-	Area+Shape index
Collapsed buildings	Based on skeloton	Brigthness + Based on skeloton
Debris area	-	Texture after Haralick
Open land	Unclassified segments	Brightness
Shadow	Brightness	Brightness
Mixed areas	-	Unclassified segments
Road	Length/width	Length

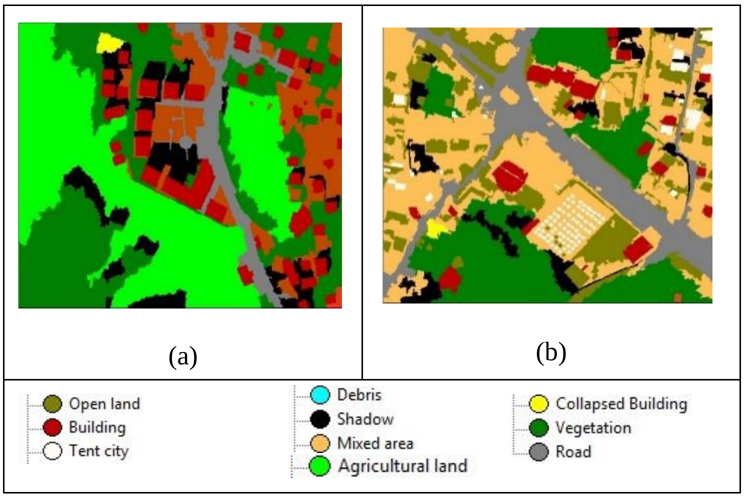

Figure 3: Unsupervised classification results (a) Homogenous area (b) Heterogeneous area and all classes.

3.3 Supervised Classification:

In supervised classification, in the first step, training objects for each land cover class should be selected. These training objects are used in order to describe each class in the following steps. After all, the analyst is used nearest neighbor classification procedure for classification (Definiens 2012).

In the supervised classification, again same 10 main classes were defined in the both case study areas. The training image objects used are displayed in Figure 4. The classified images obtained as a result of the supervised classification of homogenous and heterogenous regions are given in Figure 5. Supervised classification results were more accurate than unsupervised classification.

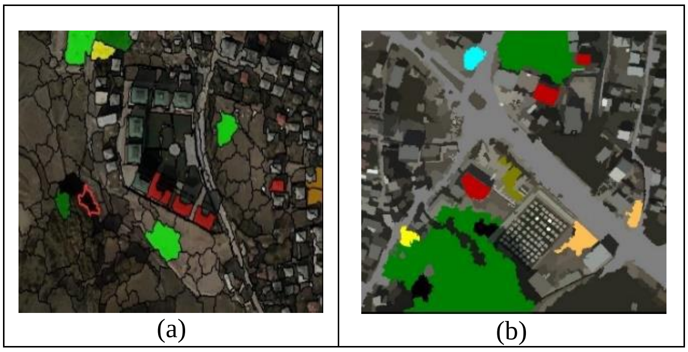

Figure 4. Training image objects selected for (a) Homogenous area. (b) Heterogeneous area.

Figure 5. Supervised classification results. (a) Homogenous area. (b) Heterogeneous area and all classes.

4. ACCURACY ASSESSMENT

In general, accuracy assessment is required to calculate the land cover classification quality. Error matrix is used for accuracy assessment (Foody 2002). In this study, error matrices and the Kappa index of agreement (KIA) were selected as measures for accuracy evaluation. In the first step of accuracy assessment, control segments were selected for two different case study areas. The overall accuracy for unsupervised classification was found as for homogenous region 81 % with Kappa Index as 0.77 and as 66 % for the heterogeneous area with Kappa Index as 0.61. The overall accuracy for the supervised classification was 92 % for the homogeneous area with Kappa Index as 0.90 and it was 71 % for the heterogeneous region with KIA as 0.66.

5. RESULTS & DISCUSSION

In this study, the condition-based and nearest neighborhood classification approaches were applied using total 10 main classes in the both case study areas. Some points to note are outlined as below:

- Van city centre and Ercis town have complex urban patterns. Regular settlement plan is not used in developed and developing countries in general. In the case study area, Ercis town also did not have a regular settlement plan so the classification results affected negatively. Besides, in Ercis, using different types of roof also have a negative effect in order to determine the buildings.
- The most common problem in extraction of building and distuighing between collapsed and uncollapsed buildings is that both class had a spectral similarity of reflectance. In order to overcome this issue, special parameters (elliptic fit and rectangular fit) were used to distinguish uncollapsed buildings.
- Another problem encountered in the study was to have only single objects for some classes, such as tent sites and debris fields. In this case, the objects selected for the training objects were also used as the control objects in the classification accuracy analysis (Sabuncu vd. 2016a; Sabuncu vd. 2016b).

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URL 1: www.afad.gov.tr

URL 2: www. usgs.gov

BIOGRAPHICAL NOTES

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