Monitoring of Landslide at Tuncbilek Open Pit Stripping Area with Terrestrial Laser Scanner and Optical Images

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Monitoring of Landslide at Tuncbilek Open Pit Stripping Area with Terrestrial Laser Scanner and Optical Images

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Abstract. Remote sensing techniques used for providing data on earth sciences have rapidly developed in recent years. Usage of remote sensing for monitoring of slopes have made a lot of progress in the last decade. The most important benefit of remote sensing applications on slope monitoring is safe working conditions with high accurate results. Terrestrial laser scanners are one of the ground-based remote sensing equipment which provide detailed and highly accurate 3D data. In this study terrestrial laser scanner method was carried out for monitoring the landslide at Tuncbilek Open pit stripping area and also optical images were evaluated for determining the development of landslide. The head part of landslide was measured with terrestrial laser scanner at three various dates and the point cloud of head part of landslide were created. Then the three-point cloud were compared. Also six optical satellite image with resolution 1m and below were examined for determining the development of landslide between 2001 and 2013

1. Introduction

Open-pits are big excavation areas. Geotechnical parameters of these areas are constraints for the slope angles. On the one hand the slope angels have to be low enough to ensure the stability of slope and on the other hand it has to be steep enough to excavate the mine economically. This situation is an optimization problem between profit and safety.

Landslides are movements of rock, debris or earth down a slope under the influence of gravity. Monitoring landslide movement over huge areas has high importance for landslide hazard and risk assessment. The key element in landslide monitoring is to determine the ground displacement and rate of displacement in lateral direction. Many techniques are available today for monitoring the landslide and they are classified as remote sensing, geophysical, geotechnical and other methods according to acquiring of data by Michoud 2012 [1].

Geotechnical methods have been the most preferred methods until recent years. Although geotechnical measurement techniques provide information about the mechanism of landslide, they require labour force and intensive in-situ measurements. Remote sensing techniques are fast growing study area today. The impressive progress of remote sensing techniques has contributed greatly to research on landslides during the last two decades. Applications of remote sensing can be grouped into three main categories: recognition and mapping, monitoring, spatial analysis and hazard prediction [2]. In this paper a big landslide occurred at Tuncbilek open-pit mine stripping site was monitored. The stripping mass has moved along the valley towards Yorguc village and now the distance between the head of the landslide and nearest house of village is about 80 meters.
The landslide threatens the houses in Yorguc village. This movement developed for about 15 years and the engineers and the villagers are not sure if the movement has ended.

2. Study Site
Tuncbilek lignite district is located in the north-east Aegean region of Turkey and it is about 60 km far from Kutahya. Turkish Coal Enterprise (TKI) is the owner of the lignite licenses in the region and produces 7.5% of the all lignite production of Turkey from this license area. According to data taken in 2014 80% of lignite production has been produced from open pit mining. The other 20% of lignite production have been produced from underground mines [3]. The waste rock excavated from open pits were dumped to stripping site at the north west of mine that is not used at present. The dumped rocks at the stripping site have been moving down over slope with the influence of gravity and the sliding mass has moved through along the valley towards Yorguc village (Figure 1).

3. Methodology of Landslide Monitoring
Two different methods were carried out for monitoring the landslide to determine previous and current movements. These are comparison of satellite images taken at various years for characterizing the previous movements and measurement of the head of the landslide by terrestrial laser scanner for determining the current situation.

3.1. Satellite Images
Most of the geotechnical field techniques used for measuring the displacement on landslides provides data about recent displacements of the landslides, they do not give information on the past movement episodes. However, with help of optical satellite systems development of the landslide can be examined and the characteristic of the moving mass can be determined. Using sequential optical imagery to map ground surface changes due to landslide requires geometrically comparable image on a pixel by pixel basis. Remotely sensed image data gathered by a satellite or aircraft are representations of the irregular surface of the Earth. Even images of seemingly flat areas are distorted by both the curvature of the Earth and the sensor being used [4]. Therefore, geometric correction has to be applied to raw sensor data to correct errors of perspective due to the Earth’s curvature and sensor motion.

Orthorectification is a form of rectification that corrects for terrain displacement and can be used if there is a DEM (Digital Elevation Model) of the study area. It is based on collinearity equations,
which can be derived by using 3D Ground Control Points (GCPs). In relatively flat areas, orthorectification is not necessary, but in mountainous areas (or on aerial photographs of buildings), where a high degree of accuracy is required, orthorectification is recommended [4].

In this study six sequential optical images were used for determining the development of landslide. The acquisition date and resolutions of images are given at Table 1.

Table 1. Acquisition date and resolution of optical images

| Satellite       | Acquiring Date          | Resolution       |
|-----------------|-------------------------|------------------|
| Ikonos          | 09 September 2001       | Multispectral - 1.00 m |
| Quickbird       | 04 July 2004            | Multispectral - 0.60 m |
| Worldview-1     | 18 July 2008            | Panchromatic - 1.00 m |
| Worldview-2     | 8 August 2010           | Multispectral - 0.50 m |
| Worldview-1     | 11 October 2011         | Panchromatic - 1.00 m |
| Worldview-2     | 20 May 2013             | Multispectral - 0.50 m |

3.2. Terrestrial Laser Scanning (TLS)

3D laser scanning also known as LiDAR (Light Detection and Ranging), is a system that scans real objects to produce three dimensional discretely sampled surfaces which represent the scanned objects. The spatial information data are stored as is or can be transformed to be stored as a group of x, y and z coordinates. The data of spatial information can be exported to computer-aided design applications for additional modelling such as a mesh or a solid model [5].

Extensive applications in the geotechnical and geological fields have been implemented; these include volume estimation, detailed 3D rockfall geometric modelling, extraction of structural and geometric information on landslides from terrestrial laser scanning (TLS) data, and optimization of LiDAR for the automatic structural evaluation of discontinuities [6]. There are two types of platforms from which LiDAR data is collected, airborne (ALS) and terrestrial (TLS). In this study terrestrial laser scanning system was used for monitoring the head of the landslide. The head of the landslide was scanned on three different date with LeicaScan Station II terrestrial laser scanner. The scanning resolution at scans was 5cm x 5cm for 300 m range.

4. Results and Discussion

4.1. Satellite Image Study

The six optical images which given in table 1 were orthorectified with Rational Polynomial Coefficients (RPCs) and Digital Elevation Model files for determining the development of the landslide. After orthorectification step, image to image rectification was performed. The rubber sheeting method with linear transformation was used for image to image rectification. In this method the reference points on the first image were matched with the second image (reference point can be a rock, edge of a house or other constant places) and linear transformation process was applied. Sixty matching points were chosen for image to image rectification. The six optical images were sequentially matched two by two and the development of the landslide was determined for every image pair. After all rectification steps the border of landslide was drawn for each year and the differences between overlaid image pairs were measured. All rectification and measurement steps were performed with ERDAS Desktop 2011. The results for satellite image measurements are given in Figure 2a-2e.
The satellite image study shows that a huge movement occurred between 2001 and 2004 then the movement of mass slowed until 2010 and after that no significant movement especially at the head of landslide wasn’t observed from satellite images (Figure 3). But regional instabilities were also observed after 2010.

4.2. Terrestrial Laser Scanning (TLS)

The laser scanner study was carried out on 22 January 2014, 12 February 2014 and 13 June 2014. After every field study the point cloud of landslide head was created by using Cyclone V. 8.0. Then at the end of the study all point clouds were overlaid. The point clouds which derived from the scans are given in Figure 4 (up). After the superposing process transverse and longitudinal cross sections were taken from the superposed point cloud and sections were analyzed for any displacement.
Figure 3. Development of landslide between 2001-2013

The line of cross section for the superposed point cloud and the section views are given in Figure 4 (down). All 3 sections indicate almost identical polyline and they don’t indicate any significant displacement.

Figure 4. Cross sections on superposed point cloud
5. Conclusion
Sliding of Tuncbilek open pit stripping material threatens Yorguc village. The recent and possible situations that may occur were evaluated with optical satellite imagery and TLS.

Six optical satellite images were examined between 2001-2013. Optical image study shows that the development of landslide has continued until 2010 then it reached stability. However regional small movements can be observed from optical images.

The head of the landslide was studied on three different dates with terrestrial laser scanner. The point clouds and the cross sections which taken from superposed point clouds don’t indicate any significant displacement at the head of landslide.

In the view of such information the landslide doesn’t pose a risk for the village at present, however this doesn’t mean no future threat. Landslide area must be monitored periodically and it must be evaluated with the past studies.

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