Relief evolution monitoring using airphotos time series and gis. A case study from western Greece

Katerina Kavoura[1], Konstantinos Nikolakopoulos[1] and Nikolaos Sabatakakis[1]
1. University of Patras, Department of Geology, Laboratory of Engineering Geology, Rio, Greece; kavoura@upatras.gr, knikolakop@upatras.gr, sabatak@upatras.gr

Abstract. Western Greece is suffering by landslides. The term landslide includes a wide range of ground movement, such as slides, falls, flows etc. mainly based on gravity with the aid of many conditioning and triggering factors. Landslides provoke enormous changes to the natural and artificial relief. The annual cost of repairing the damage amounts to millions of euros. In this paper a combined use of airphotos time series, high resolution remote sensing data and GIS for the relief evolution monitoring is presented. Analog and digital air-photos used covered a period of almost 70 years from 1945 until 2012. Classical analog airphotos covered the period from 1945 to 2000, while digital airphotos and satellite images covered the 2008-2012 period. The air photos have been orthorectified using the Leica Photogrammetry Suite. Ground control points and a high accuracy DSM were used for the orthorectification of the air photos. The 2008 digital air photo mosaic from the Greek Cadastral with a spatial resolution of 25 cm and the respective DSM was used as the base map for all the others data sets. The rms error was less than 0.5 pixel. Changes to the relief and to the artificial constructions were digitized and then implemented in an ARCGIS database. The results are presented in this paper.

Keywords. Landslides, airphotos, relief monitoring, photogrammetry, GIS, Engineering geology.

1. Introduction

Landslides are particularly common in Greece and specially at Western Greece. These phenomena considered a major geologic hazard that can be included in the frame of natural disasters. Western Greece is suffering by landslides. Long time investigation around the Greece, presents a detailed description about this hazard. At the Achaia Prefecture has developed a landslide database which contains historical landslide records but also newest inventories until today. A special case is the Karya landsliding zone which located near the Patras city. Three large landslide events had been triggered in the past, the first one in 1962, the second in 1999 and the third in 2001. Today, the in-situ monitoring with inclinometer instrument, in the framework of "Landslide Vulnerability Model – LAVMO" project which aims to create a persistently updated electronic platform assessing risks related with landslides, the phenomenon is calmed.

Digital image analysis techniques for mapping landslides and monitoring related elevation changes from repeated DEMs are comparably often applied [1], [2], [3], [4] in contrast to respective horizontal displacement measurements [5], [6],[7].

Despite of the great advances in remote sensing technology and the existence of satellite data with a spatial resolution of 0,5m, the first fundamental phase to evaluating landslide hazard for land use planning and development [8], is routinely performed by means of aerial photo interpretation and fieldwork.

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In this paper a combined use of airphotos time series, high resolution remote sensing data and GIS for the relief evolution monitoring of Karya landsliding zone is presented. Analog and digital air-photos used covered a period of almost 70 years from 1945 until 2012. Classical analog air-photos covered the period from 1945 to 2000, while digital airphotos and satellite images covered the 2008-2012 period. Changes to the relief and to the artificial constructions were digitized and then implemented in an ARCGIS database. The results are presented in this paper.

2. About landslides

The term landslide includes a wide range of ground movement, such as slides, falls, flows etc. mainly based on gravity with the aid of many preparatory and triggering factors. Landslides cause enormous changes to the natural and artificial relief. The annual cost of repairing the damage amounts to millions of euros. According to [9] landslides can be classified into different types as shown in Table 1 and Figure 1.

Table 1. Landslide types (Varnes 1978)

<table>
<tr><th colspan="2" rowspan="3">TYPE OF MOVEMENT</th><th colspan="3">TYPE OF MATERIAL</th></tr>
<tr><th rowspan="2">BEDROCK</th><th colspan="2">ENGINEERING SOILS</th></tr>
<tr><th>Predominantly coarse</th><th>Predominantly fine</th></tr>
<tr><td colspan="2">FALLS</td><td>Rock fall</td><td>Debris flow</td><td>Earth fall</td></tr>
<tr><td colspan="2">TOPPLES</td><td>Rock topple</td><td>Debris topple</td><td>Earth topple</td></tr>
<tr><td rowspan="2">SLIDES</td><td>ROTATIONAL</td><td rowspan="2">Rock slide</td><td rowspan="2">Debris slide</td><td rowspan="2">Earth slide</td></tr>
<tr><td>TRANSLATIONAL</td></tr>
<tr><td colspan="2">LATERAL SPREADS</td><td>Rock spread</td><td>Debris spread</td><td>Earth spread</td></tr>
<tr><td colspan="2" rowspan="2">FLOWS</td><td rowspan="2">Rock flow
(deep creep)</td><td>Debris flow</td><td>Earth flow</td></tr>
<tr><td colspan="2">(soil creep)</td></tr>
<tr><td colspan="2">COMPLEX</td><td colspan="3">Combination of two or more principal types of movement</td></tr>
</table>

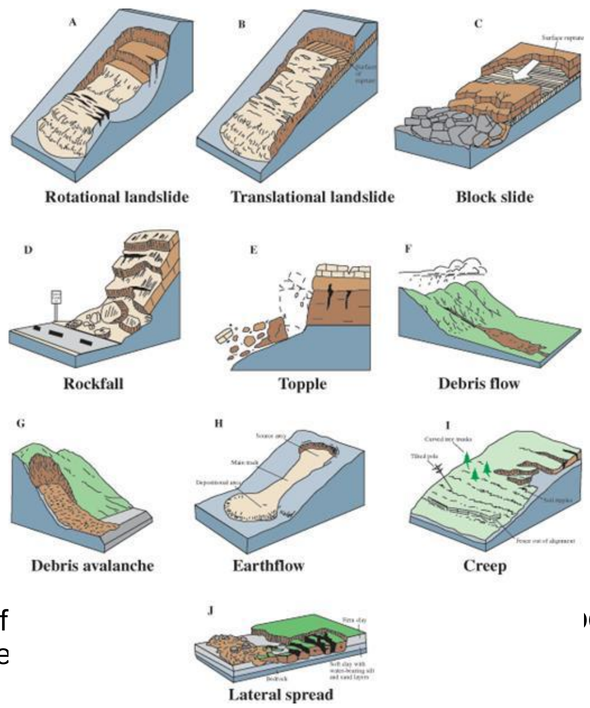

Figure1. Schematic illustration of the basic landslide types (USGS)

The characteristics that will be describe a landslide completely can be:

· the type movement,
· the landslide-forming materials
· the velocity of landslide
· the activity of landslide
· the dimensions of landslide
· the site of landslide (geomorphology, distance from a residential area, the distance from a hydrographic network ect.)

3. Study area - Karya Landslide

The study area is located about 12 km away from the center of Patras city and close to Panachaikon mountain (Figure 2). The general morphology of the area depends strongly on the lithological and structural characteristics of bedrock formations. Local geology composes a complex of Olonos - Pindos alpine basement features and Pleistocene - Holocene deposits. Where the alpine basement appears the rock-mass quality was characterized as poor, because of the intense tectonicm of the zone. The normal sedimentary sequence includes schists, cherts and limestones were unconformity overlying from clastic deposits (Figure 3).

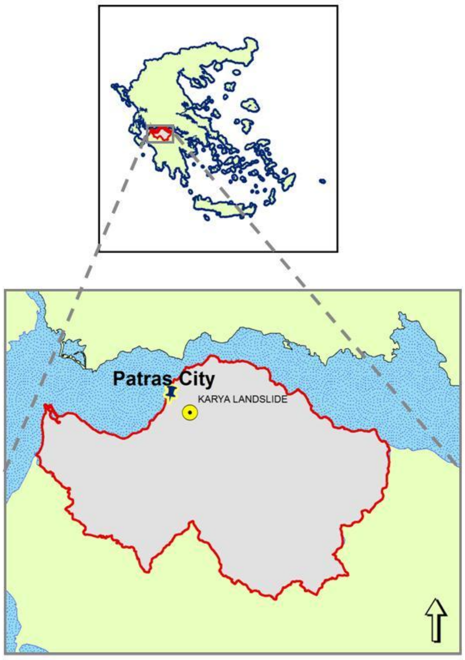

Figure2. The site of study area

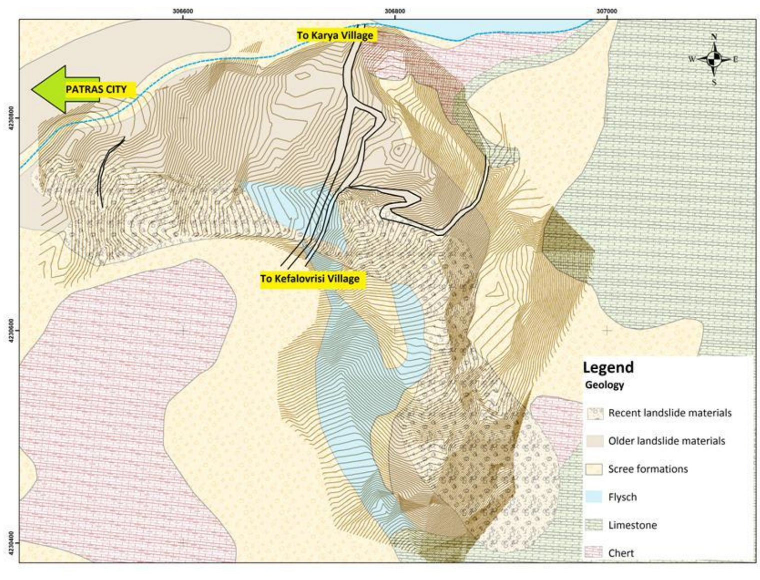

Figure3. Geology map of landslide area

The instability phenomena were started 50 years ago. The first failure was recorded in 1962 and the result was the destruction of old Karya village which sited on the head of landslide. The

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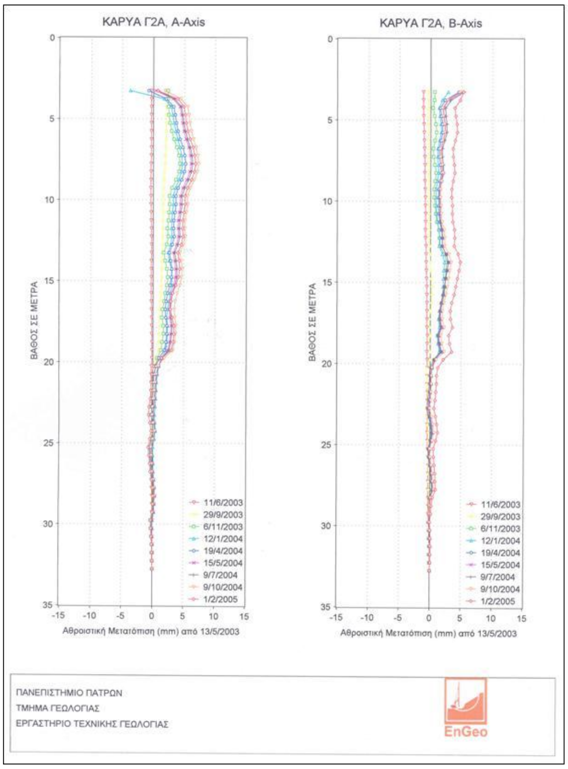
next, episode was activated in February 1999 when a sudden mass movement occurred during an intense and prolonged rainfall [10]. At the end, in December 2001, another intense rainfall event triggered the landsliding zone. A large volume of debris materials flowed rapidly on the slope. A house was destroyed and the local road destroyed too.

After these activations a monitoring program of landsliding zone was started with the installation of inclinometer boreholes. A displacement of 3.6mm to 7.5mm at depths of 7 and 19m of the period June 2003 till March 2005 (Figure 4) [11]. In the frame work of "Landslide Vulnerability Model – LAVMO" project a new inclinometer borehole was installed and for period March 2013 till May 2014 a displacement of 2mm at 21m depth was detected (Figure 5). According to Cruden and Varnes 1996 [12] the landslide can be classified as extremely slow.



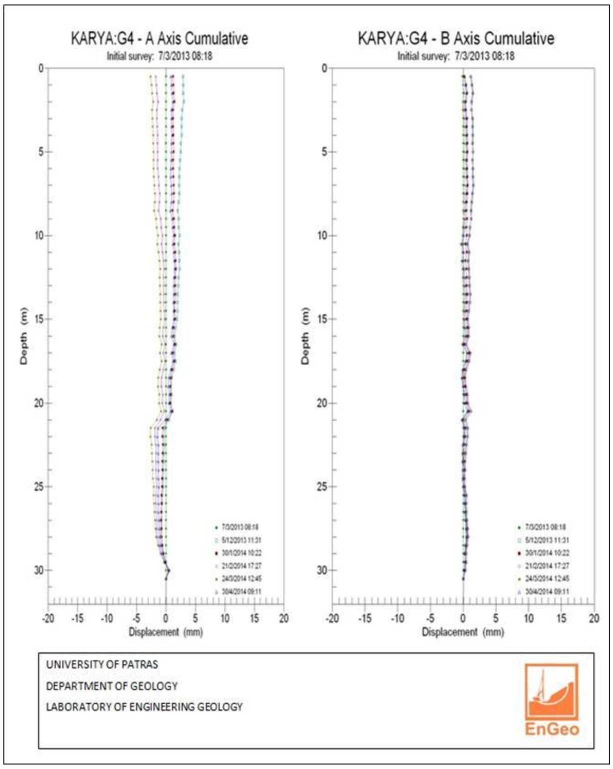


Figure 4. Cumulative displacement inclinometer graph (2003-2005)

Figure 5. Cumulative displacement inclinometer graph (2013-2014)

4. Relief evolution monitoring with airphotos and GIS

Despite the in-situ monitoring engineering geological – geotechnical method, the changes of relief morphology were caused due to repeated activation of landslide can be determined in aerial photographs.

Analogue airphotos of 1945, 1960, 1967, 1971, 1988, 1994 and 2007 were used. All the air photos have been orthorectified using the Leica Photogrammetry Suite. Ground control points and a high accuracy DSM were used for the orthorectification of the air photos. The 2008 digital air photo mosaic the Greek Cadastral with a spatial resolution of 25 cm and the respective DSM was used as the base map for all the others data sets. The rms error was less than 0.05 pixel. The high accuracy of the orthorectification is presented in Figures 6 and 7. The orthorectified airphoto of 1967 is overlapped to the respective airphoto of 1960 and in the ERDAS viewer is upper panel is scrolled slowly to the left. In Figure 8 the landslide area (from the in situ mapping) is presented on the orthophoto of 1967.

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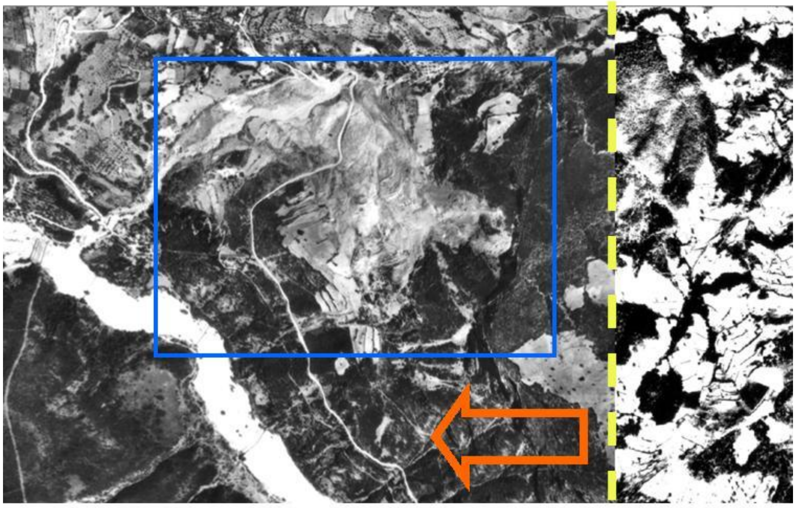

Figure 6. From 1960's to 1967's orthophoto

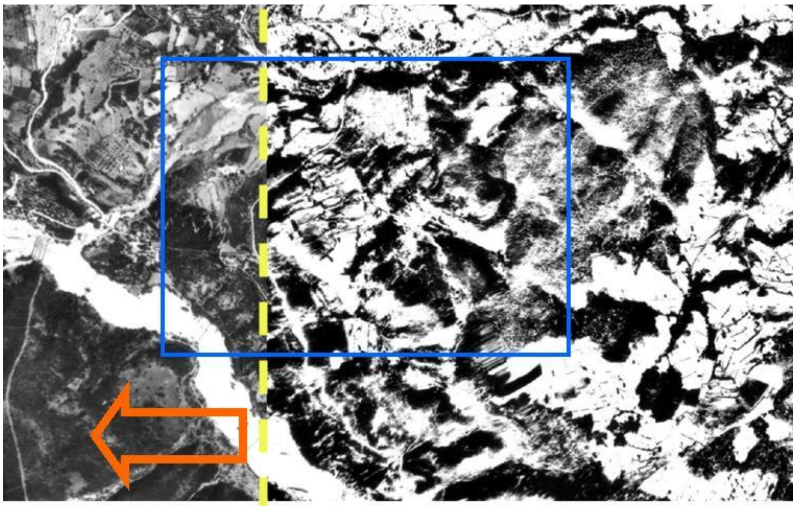

Figure 7. From 1960's to 1967's orthophoto the area in the box has been modified after the landsliding event of 1962

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Figure 8. The landslide area in 1962

Changes to the relief and to the artificial constructions (roads, cultivated planes, houses) were digitized and then implemented in an ARCGIS database. Some results are presented in Figure 9.

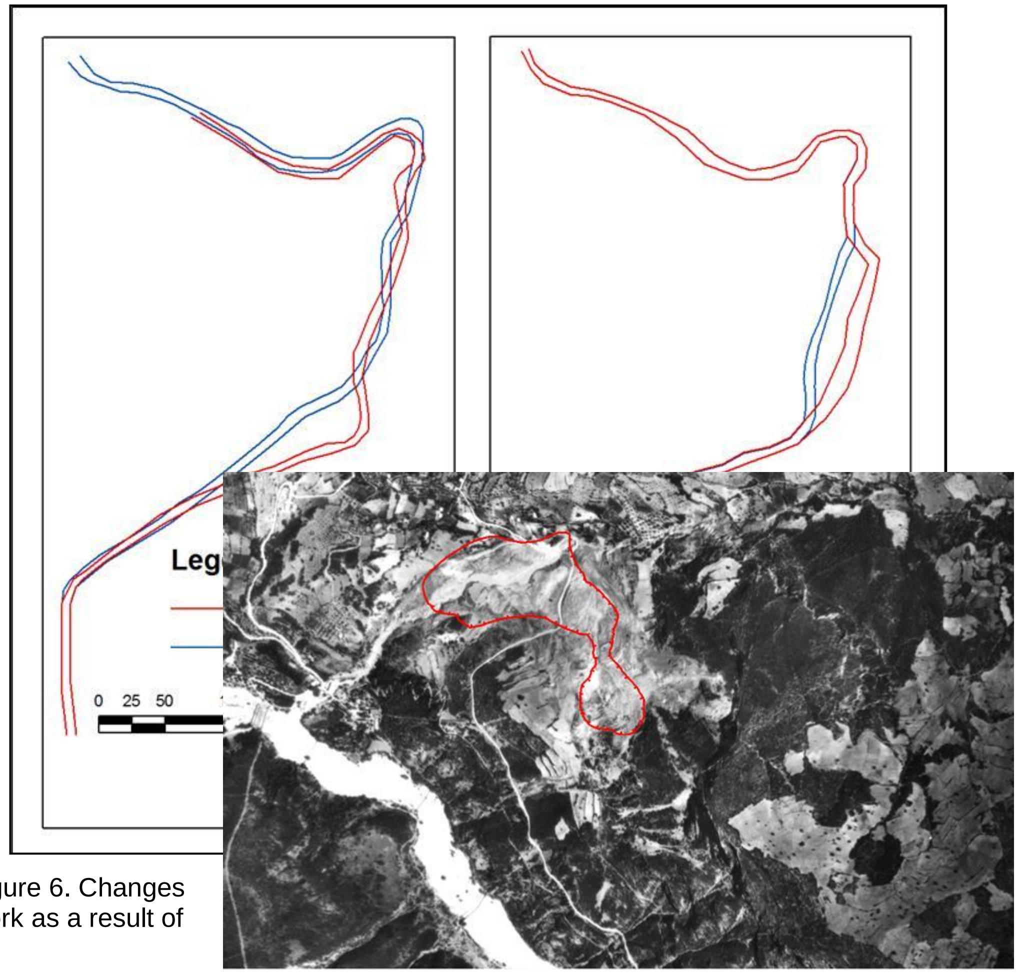

Figure 6. Changes to the road net-
work as a result of the landslides.

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5. Conclusions

The presented case study on landsliding shows that digital processing of airphotos are highly suitable and efficient for monitoring high-mountain relief deformation. Digital analysis of repeated optical imagery is able to contribute to the locating of landslides and to related hazards. The archive of analogue airphotos in Greece goes back in 40's and it is a valuable source of information for relief monitoring. Hazards, on roads cultivated planes and buildings can easily be detected and mapped. GIS technology is an essential tool in reaching these goals as it allows collection, management, analysis and dissemination of a large amount of data.

Acknowledgements

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