AIP Conference Proceedings

pubs.aip.org/aip/acp

Volume 2601

Proceeding of the 7th International Conference of Science, Technology, and Interdisciplinary Research (IC-STAR 2021)

Bandar Lampung, Indonesia • 26–27 October 2021

Editors • Misfa Susanto, Fethma M Nor and Ahmad Kafrawi Nasution

AIP Publishing

RESEARCH ARTICLE | JUNE 02 2023

A combined of electrical resistivity tomography and structure from motion method for landside-prone zone analysis in East Kota Agung Region FREE

Rahmat Catur Wibowo ✉; Muh Sarkowi; Ahmad Zaenudin

AIP Conference Proceedings 2601, 020001 (2023)
https://doi.org/10.1063/5.0129571

A Combined of Electrical Resistivity Tomography and Structure from Motion Method for Landside-Prone Zone Analysis in East Kota Agung Region

Rahmat Catur Wibowo[a)], Muh Sarkowi, and Ahmad Zaenudin

Geophysical Engineering, Engineering Faculty, Universitas Lampung Jl. Prof. Soemantri Brojonegoro No.1 Bandar Lampung City, Lampung, 35145, Indonesia

[a)] *Corresponding author: rahmat.caturwibowo@eng.unila.ac.id*

Abstract. Indonesia's territory has a high level of risk of landslides. One of them is Batu Keramat Village, Tanggamus district with steep topographical undulation, making it a landslide-prone area. This research aims to analyze landslide-prone zones based on Structure from Motion (SfM) and the method of electrical resistivity tomography (ERT). The research location has very potential for landslides, supported by signs on the surface and clarified with a subsurface image. From the SfM analysis, the research location has a steep slope (> 600) with a slope height of about 30 m. Young volcanic rocks dominate in the study area in breccias, lava, and tuff with andesite-basalt composition. There are several Tertiary-aged andesite rocks exposed which are thought to be bedrock at this location. Based on the ERT model, the resistivity distribution value is in the range of 70-2100 ohm.m. The subsurface model has three layers divided into topsoil in the upper part, which is indicated by a resistivity value of 350 - 500 ohm.m. The clay layer is indicated by a resistivity value of 70 - 120 ohm.m, and bedrock (andesite) is indicated by 1000 - 2100 ohm.m. The clay layer can become a slip surface and cause the study area to be prone to landslides.
Keywords: electrical resistivity tomography, structure from motion, Kota Agung, landslide, hazard.

INTRODUCTION

Landslides are the most frequent geological disasters in Indonesia. The Indonesian landslide inventory developed by the Indonesian Geological Agency reports about 49 landslides per year [1]. Many of the landslides affected residence [2]. One of them is Sumatra Island, which is marked by the highest number of landslide victims, followed by Lampung. Most of the landslide victims in Lampung caused by geomorphological, geological and climatic conditions were recorded in several areas, namely Tanggamus, West Coast, North Lampung, and West Lampung [3]. Among these areas, Tanggamus showed the highest landslide density, especially in Batu Keramat Village. It is related to clay material, duration of intense rainfall, deforestation, massive urbanization, and geomorphological conditions. Landslide is a reactivation of the old movement which is characterized by a high level of difficulty and variability in both time and space dimensions. Because of this, integration of different methodologies is needed to obtain surface data, and UAV is one method that can provide useful information for geological disaster mitigation, especially landslides [4-6].

This article uses a multi-disciplinary method based on the integration of aerial photography (structure from motion) and ground-based methods for landslide investigations in Batu Keramat Village, Kota Agung Timur District, Tanggamus Regency, Lampung. To get more information about landslides studied, integration through Structure from Motion (SfM) analysis and 2D Electrical Resistivity Tomography (ERT).

The SfM method is used to determine the characteristics of the soil surface conditions that have the potential for landslides [7]. Elevation model images (DEMs) with the detailed resolution are produced by aerial photography techniques with the aim of estimating the movement of landslide mass volumes. Finally, the ERT method, which has the characteristics of high spatial resolution, low-cost field data acquisition process, and relatively fast process, was

Proceeding of the 7th International Conference of Science, Technology, and Interdisciplinary Research (IC-STAR 2021)
AIP Conf. Proc. 2601, 020001-1–020001-8; https://doi.org/10.1063/5.0129571
Published by AIP Publishing. 978-0-7354-4465-2/$30.00

used to predict the investigated landslide geometry (e.g., slip surface depth and the geometry of the material involved) [8-9].

Although the method used has often been applied to several landslide cases, the integration of several methods carried out in this study can be considered as one direct example [10]. Combining different techniques is expected to collect all information about landslide characteristics both on the surface and below the surface. Besides that, it can also help in increasing knowledge and solving problems related to the weaknesses of each method [11,12]. In addition, an elaborate study of the characteristics of landslides can support more appropriate mitigation measures.

RESEARCH LOCATION

Batu Keramat Village is one of the areas most prone to landslides in Tanggamus. This is related to the existing clay material, the morphology of the slopes, and the occurrence of extreme rainfall. Historically, many landslide events have occurred due to extreme rainfall. The research location (Fig. 1) is located in the East Kota Agung and on the southern Tanggamus. The zone is characterized by a landslide influencing the topography of the Qhv (Young Quaternary Volcanics) and Tomh (Hulusimpang Formation) with lithological formations such as breccia lava, tuff with andesite-basal intercalated layering. The debris at the hill (lower part), characterizes the topographical conditions in the study area. Observations made in March 2018, show the results of erosion caused by heavy rain and involving the Hulusimpang formation. The geometry of landslide is 200 x 30 m with an elevation range varying between 500 - 600 m m.s.l. These landslides are categorized as complex retrogressive landslides and represent reactivation of an ancient mass movements. Landslides rolled down the road near several residents' houses, which had to be evacuated immediately

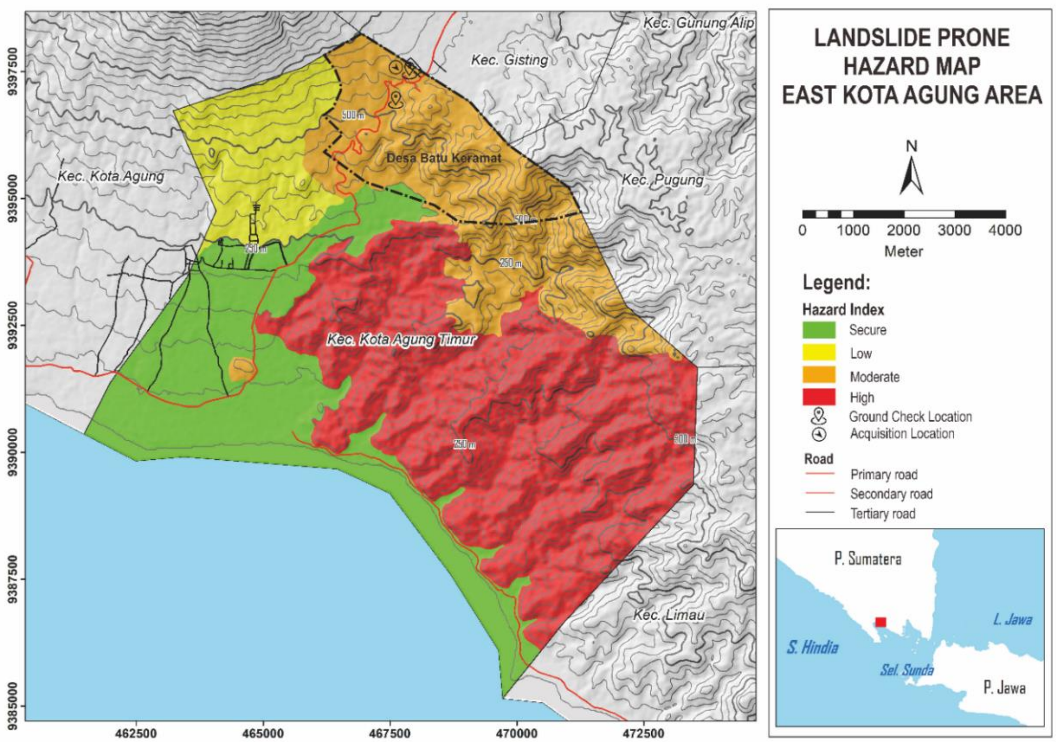

FIGURE 1. Landslide hazard map based on AHP method [4][10-12] in East Kota Agung area and study area is located on the northern part with dash line border with acquisition location symbol (both of SfM and ERT). The research area is included in the moderate category, and it is proven that landslides occur in several areas.

METHODS

The method used is an integration of rock electrical survey techniques and aerial photography. The SfM method is a combination of advanced computer programming and conventional photogrammetry that can be used for topographic survey techniques. While the ERT method provides useful information about the geometry and geological structure of the subsurface landslide area.

Structure from Motion

Geomorphological features (slopes, terraces, and ditches), erosion, and depositional zones can be determined by interpretation of aerial photography analysis at a maximum scale of 1:5000. The main procedures in digital photogrammetry for automatic image orientation are interior and relative orientation, point transfer in aerial triangulation (align point), reference system registration, and point extraction [13]. Interior orientation is carried out using parameters found in the camera, such as calibrated focal length, main point position, and radial lens distortion. The same nine binding points in both images are used to obtain the relative orientation of each stereo pair. The stereoscopic model generated with the WGS84 reference frame is absolute orientation by determining the position of the ground control points (GCP), which consist of 10 points. GCP is a natural element representing a geological condition in a certain area that is easily identified in the photo. These points are located in a stable area at certain time intervals.

The aero-triangulation process resulted in a small accumulation error (0.08), which means that the process was successful. So, it can produce reliable high-resolution DEM. The accuracy of the orientation step depends on several things, such as camera-object distance, image quality, and the quality when taking GPS measurements (especially in GCP determination).

Electrical Resistivity Tomography

Subsurface electrical imaging with 2D models is one of the methods used in subsurface modeling with moderate to complex geological conditions [14]. This is a great advantage associated with measuring the variation in resistivity values in vertical and horizontal directions. This is different from the 1-D resistivity method which only reviews the resistivity value vertically [15]. A 1D resistivity measurement generally consists of 10-20 measurements, whereas a 2D resistivity imaging survey involves approximately 100-1000 measurements.

Figure 2 shows a possible sequence of measurements on the Wenner electrode configuration for a 20 electrodes system. The "a" is the distance between the electrodes. On the first measurement, all possible measurements with electrode distance "1a" are taken automatically. Electrodes 1, 2, 3, and 4 were used for the first measurement, where electrodes 1 and 4 were used as current electrodes (C1, C2), and electrodes 2 and 3 were used as potential electrodes (P1 P2). While in the second measurement, electrodes 2, 3, 4, and 5 were used as C1, P1, P2, and C2, respectively. Furthermore, measurements were made up to electrodes 17, 18, 19, and 20. After completing the measurement with a distance of "1a", the first measurement used electrodes 1, 3, 5, 7 using a distance of "2a". Measurement continues until electrodes 14, 16, 18, and 20 are used for the final measurement. The process is repeated on measurements with a distance of "3a, 4a, 5a, and 6a" [16].

Field data processed with the RES2DINV computer program produces a profile 2-D resistivity model of the subsurface. The inversion program generates a 2-D resistivity model consisting of several rectangular blocks. The distribution of data points in the pseudo-part is loosely tied to the arrangement of several blocks. The program generates the distribution and blocks size automatically where the number of data points is more than the model block (Fig. 3). The depth of the lower row of beams is set to approximately equal the depth of the probe datum point, which is equivalent to the distance of the most significant electrode [17].

This program is operated to solve the resistivity of a rectangular block which will produce a pseudo-section of resistivity that corresponds to the actual measurement. Forward modeling is used to calculate the apparent resistivity value, while at the backward modeling stage, a non-linear least-squares optimization technique is used. The technique tries to find the value of the difference between the calculated and measured apparent resistivity values to a minimum while still aligning the resistivity block model. The measurable differences that occur are generally reflected by the root-mean-square (RMS) parameter. When the RMS value decreases and does not change significantly, the last model is selected after several iterations.

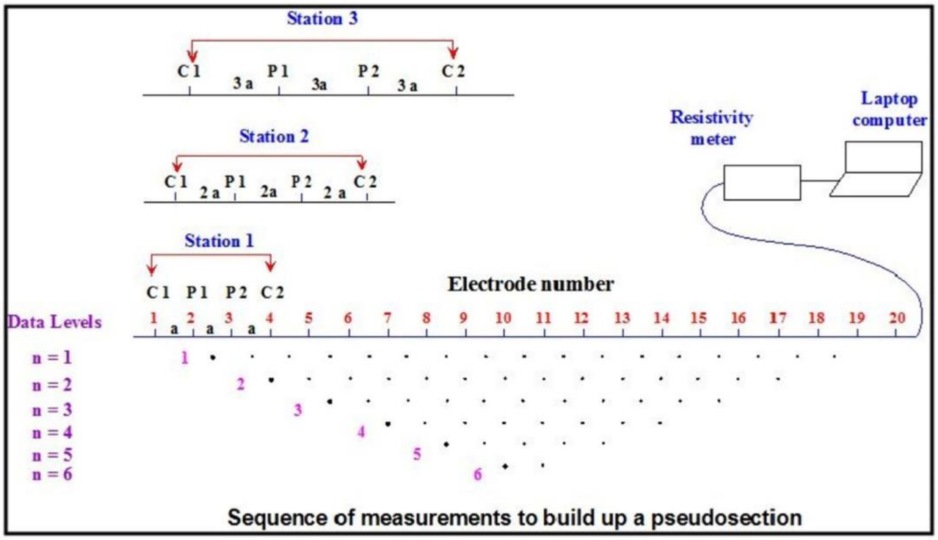

FIGURE 2. The electrodes arrangement for a mapping ERT survey [16]

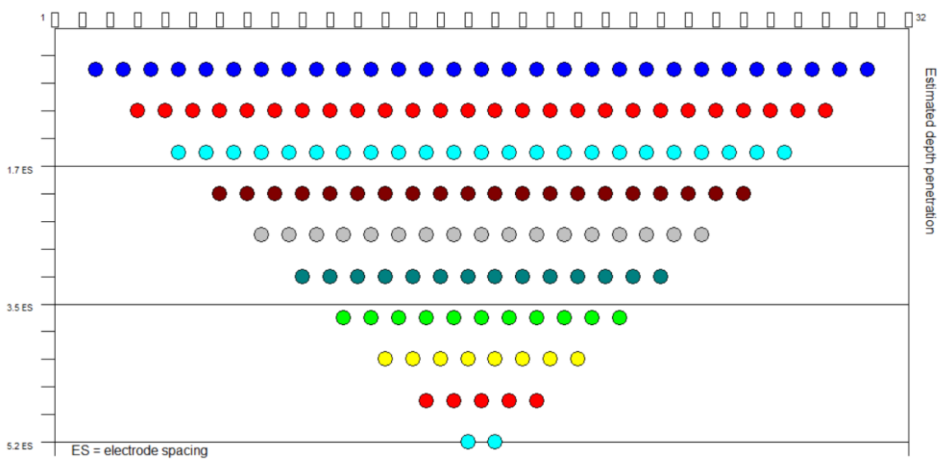

FIGURE 3. Resistivity measurement scheme with Electrical Resistivity Tomography (ERT) method, Wenner-Schlumberger configuration

Inversion calculations can support both advanced finite difference modeling and finite element techniques. These calculations can be used for surveys that use several configurations such as pole-pole, Wenner, dipole-dipole, Wenner-Schlumberger, and Schlumberger.

RESULTS AND DISCUSSION

Structure from Motion Results

A computer with the characteristics of an Intel Core i7 9750H 2.6Ghz processor with 16 Gb RAM, a 6 Gb GTX1650 GPU with 64-bit Windows10 is used to run the Photoscan program. The processing time for SfM data in one acquisition is: (1) matching and detecting image features for 150 minutes; (2) creation of solid 3D geometry in about 130 minutes; (3) GCP identification approximately 4 hours; (4) recreating a solid 3D model in about 130 minutes; and (5) making orthophoto and DEM about 60 minutes. In an area of 1 ha, the resulting 3D model contains 1 million vertices corresponding to 100 points per m^2. The displacement of the landslide area can be mapped by interpreting the results of orthomosaic aerial maps (Fig. 4). The movement of material in landslides is uneven, significantly different from one location to another. In less than four months, the main slope (A) retreated by about

5.5 m. The left main slope (B) is the most vulnerable and spreads over an area of 3-4 m at the end of the slope in several directions. An active chunk most likely triggered the main scarp's failure and the toe's extension in the main part (middle part). The moving area results in loss of support on the main steep slope, resulting in further collapse and may trigger cliff extension (bottom part).

FIGURE 4. 3D model of orthomosaic result from SfM method

2D Profiles of Electrical Resistivity Tomography

Variations in resistivity values indicate differences in soil and rock layers in the study area. In line-1, there are several shallow zones with medium resistivity values (350-500 ohm.m). At points 45–90 m (bottom of the slope) and points 135-140 m (top of the slope area) with a depth range of 5–40 m, including high resistivity zones (1000-2100 ohm.m). Meanwhile, the area that stretches from the first to the last electrodes is grouped in a low resistivity zone with a resistivity value of 70–120 ohm.m, with an average depth of 1.0–30 m (Fig. 5).

In the area between the point 15–45 m (the bottom of the slope area) and the point 80–100 m (the top of the slope area) in the line-2 profiles with an average depth of 1-5 m, there are several shallow zones with medium resistivity (value resistivity ranges from 350–500 ohm.m). At a depth range of 0.5–20 m, the zone with a high resistivity value (1000-2100 ohm.m) is located at 45–90 m (bottom of the slope area). Meanwhile, the zone that has a low resistivity value is located along the measurement line, especially under the medium resistivity zone with a depth range of 1.0–35 m and a resistivity value of 70–120 ohm.m (Fig. 6).

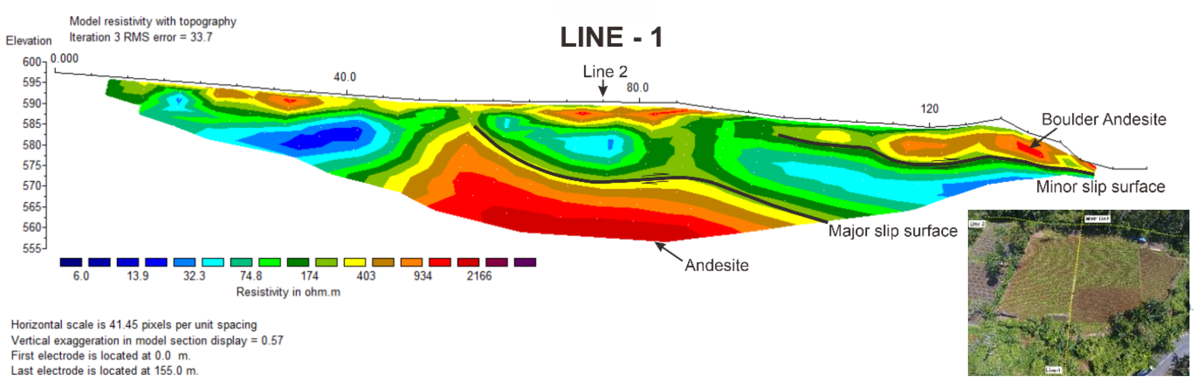

FIGURE 5. 2D ERT line-1 section of the research area using a Wenner–Schlumberger configuration.

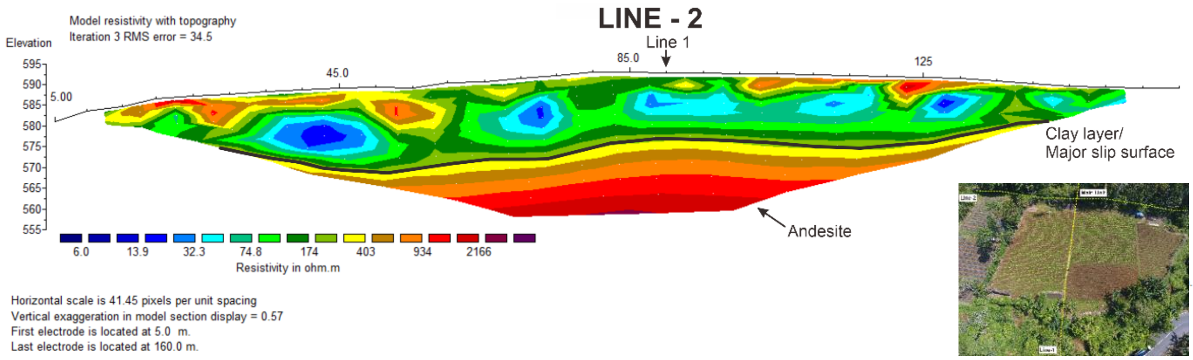

FIGURE 6. 2D ERT line-2 section of the research area using a Wenner–Schlumberger configuration

The study of surface and subsurface characteristics in Batu Keramat Village was carried out through integrated multidisciplinary techniques such as ERT and SfM investigations. The same technique has been used separately for landslide investigations, providing only limited information. Particularly, aerial photogrammetry is often used to monitor areas affected by deformation of soil [7], landslide activity [13], and morphological characterization [18] and can record information about quantities such as quantity to the rate of displacement [19,20]. Reconstruction of subsurface geological settings in 2D or 3D is carried out with more sophisticated techniques such as geophysics [21,22]. The characteristics of landslide geometry and temporal evolution can be obtained by combining several techniques in an integrated manner. This research is an integration of aerial photogrammetry techniques and electrical earth measurements to characterize landslides and calculate the mass volume.

Several important parameters, such as erosion dimensions, changes in height due to shear and erosion, thickness, and changes in elevation, are used to estimate the required erosion volume. Only a fully integrated technique can provide all these parameters [14]. The results of the integration of the different techniques provide an accurate estimate of the volume of the moving material. The calculated mass transfer is 9.836×10^3 m^3.

The integration of techniques carried out can overcome each weakness. Although information about the volume of material moving, accumulation, and erosion is obtained from SfM, it does not provide information about the vertical thickness of the material. While the ERT method provides not only information on the thickness of the material but also about the subsurface geological structure. However, it is constrained by information related to elevation changes. The approach taken in this study is considered as an integrated technique integration in landslide investigations. This can significantly contribute both in terms of management and landslide risk mitigation.

CONCLUSION

The ERT method can be used in landslide investigations. The contrast of resistivity values in the study area reflects information on several lithological formations. The investigation carried out is related to detailed information about the subsurface conditions that exist on the hillside. A detailed subsurface geological model was developed based on the information from the ERT and SfM models. An integrated approach by considering subsurface and surface investigation methods produces landslide characteristics in the research area. From the SfM analysis, the research location has a steep slope (>60^0) with a slope height of about 30 m. Young volcanic rocks dominate in the study area in breccias, lava, and tuff with andesite-basalt composition. There are several Tertiary-aged andesite rocks exposed which are thought to be bedrock at this location. Based on the ERT model, the resistivity distribution value is in the range of 70-2100 ohm.m. The subsurface model has three layers divided into topsoil in the upper part, which is indicated by a resistivity value of 350 - 500 ohm.m. The clay layer is indicated by a resistivity value of 70 - 120 ohm.m and bedrock (andesite) is indicated by 1000 - 2100 ohm.m. The clay layer can become a slip surface and cause the study area to be prone to landslides. A key factor when designing a resistivity survey that must be considered, especially in the landslide risk analysis, is the interval electrode. It affects the resolution of the resulting image. The resistivity model must have high resolution and good quality to allow slip surface identification, which can be detected at high resolution, assuming closer electrode spacing.

ACKNOWLEDGMENTS

We would like to thank the Faculty of Engineering, University of Lampung and related parties who have assisted in conducting this research, especially in completing this article.

REFERENCES

1. Zamroni A, Kurniati A C, Prasetya H N E. The assessment of landslides disaster mitigation in Java Island, Indonesia: a review. *J Geosci Eng Environ Technol*. 2020;5(3):139–44.
2. Samsul Arifin, Ita Carolina WC. Implementasi Penginderaan Jauh dan SIG untuk Inventarisasi Daerah Rawan Bencana Longsor. *J Penginderaan Jauh dan Pengolah data Citra Digit* [Internet]. 2006;3:77–86. Available from: http://www.jurnal.lapan.go.id/index.php/jurnal_inderaja
3. Kumoro Y, Anwar HZ, Comaluddin, Yunarto, Nur WH, Sukaca. *Potensi Kebencanaan Geologi dan Kerentanan Sosial sebagai dasar Penyusunan Tata Ruang di Kabupaten Tanggamus Propinsi Lampung*. Peran Puslit Geoteknologi dalam Optim Pemanfaat Sumberd Alam dan Mitigasi Kebencanaan di Indones. 2009;107–22.
4. de Bari C, Lapenna V, Perrone A, Puglisi C, Sdao F. Digital photogrammetric analysis and electrical resistivity tomography for investigating the Picerno landslide (Basilicata region, southern Italy). *Geomorphology* [Internet]. 2011;133(1–2):34–46. Available from: http://dx.doi.org/10.1016/j.geomorph.2011.06.013
5. Supper R, Römer A, Jochum B, Bieber G, Jaritz W. A complex geo-scientific strategy for landslide hazard mitigation - From airborne mapping to ground monitoring. *Adv Geosci*. 2008;14:195–200.
6. Merritt AJ, Chambers JE, Murphy W, Wilkinson PB, West LJ, Gunn DA, et al. 3D ground model development for an active landslide in Lias mudrocks using geophysical, remote sensing and geotechnical methods. *Landslides*. 2014;11(4):537–50.
7. Lucieer A, Jong SM d., Turner D. Mapping landslide displacements using Structure from Motion (SfM) and image correlation of multi-temporal UAV photography. *Prog Phys Geogr*. 2014;38(1):97–116.
8. Sigdel A, Adhikari RK. Application of Electrical Resistivity Tomography (ERT) survey for investigation of the landslide: a case study from Taprang landslide, Kaski district, west-central Nepal. *J Nepal Geol Soc*. 2020;60:103–15.
9. Falae PO, Kanungo DP, Chauhan PKS, Dash RK. Electrical resistivity tomography (ERT) based subsurface characterisation of Pakhi Landslide, Garhwal Himalayas, India. *Environ Earth Sci* [Internet]. 2019;78(14). Available from: https://doi.org/10.1007/s12665-019-8430-x
10. El Jazouli A, Barakat A, Khellouk R. GIS-multicriteria evaluation using AHP for landslide susceptibility mapping in Oum Er Rbia high basin (Morocco). *Geoenvironmental Disasters*. 2019;6(1).
11. Amir Yazdadi E, Ghanavati E. Landslide Hazard Zonation by using AHP (Analytical Hierarchy Process) model in GIS (Geographic Information System) Environment (Case study: Kordan Watershed). *Int J Progress Sci Technol (IJPSAT*) [Internet]. 2016;2(1):24–39. Available from: http://ijpsat.ijsht-journals.org
12. Wibowo RC, Sarkowi M, Setiawan AF, Yudamson A, Asrafil, Kurniawan M, et al. Flash flood hazard areas assessment in Bandar Negeri Suoh (BNS) region using an index based approaches and analytical hierarchy process. In: *Journal of Physics: Conference Series*. 2020.
13. Godone D, Allasia P, Borrelli L, Gullà G. UAV and structure from motion approach to monitor the maierato landslide evolution. *Remote Sens*. 2020;12(6).
14. Griffiths DH, Barker RD. Geophysical Exploration in Areas of Complex Geology, *I. J Appl Geophys*. 1993;29(3–4):179–358.
15. Loke MH, Barker RD. Rapid least-squares inversion of apparent resistivity pseudosections by a quasi-Newton method. *Geophys Prospect*. 1996;44(1):131–52.
16. Loke MH. *Electrical Imaging Surveys for Environmental and Engineering Studies*. A Practical Guide to 2-D and 3-D Surveys. RES2DINV Manual, IRIS Instruments [Internet]. 2001; Available from: www.iris-instruments.com
17. Loke MH. *Tutorial: 2-D and 3-D Electrical Imaging Surveys*, 2004 Revised Edition. Tutorial : 2-D and 3-D electrical imaging surveys. 2004.
18. Hafiz A, Setianto A. Application of structure from motion method to determine direction of slope failure. *Proc - 2019 5th Int Conf Sci Technol ICST 2019*. 2019;1–5.
19. Wibowo RC, Mulyatno BS, Romosi M, Zaenudin A. Determination of slip surface area using geoelectric, MASW, and soil mechanics data in cimuncang village, west Java. In: *EAGE-HAGI 1st Asia Pacific Meeting on*

Near Surface Geoscience and Engineering. Yogyakarta; 2018. p. 0–4.
20. Asriza, Supriyanto, Kristyanto TH., Indra TL, Syahputra R, Tempessy AS. Determination of the Landslide Slip Surface Using Electrical Resistivity Tomography (ERT) Technique. In: *4th World Landslide Forum*. Ljubljana; 2017.
21. Burazer M, Sad N, Urosevic M. Time-lapse Electrical Resistivity Tomography for Landslides Investigation. In: *SEG International Exposition and 87th Annual Meeting*. 2017. p. 5332–6.
22. Wibowo RC, Mulyatno BS, Dewanto O, Sarkowi M. Structure from Motion (SfM) method to characterize fluvial sedimentology in Way Semaka river in Lampung Province, Indonesia. In: *IOP Conference Series:Materials Science and Engineering*. 2021.