Utilization of unmanned aerial vehicles in geothermal exploration: A review

Marwan1, T R Noviandy2, A Maulana2, R Suhendra2, M Yusuf3, A Lala3, G M Idroes4, Muslem5, Mahmudi6, R Idroes3,7,*

1Department of Geophysical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Kopelma Darussalam, Banda Aceh 23111, Indonesia
2Department of Informatics, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Kopelma Darussalam, Banda Aceh 23111, Indonesia
3Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Kopelma Darussalam, Banda Aceh 23111, Indonesia
4Department of Chemical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Kopelma Darussalam, Banda Aceh 23111, Indonesia
5Department of Chemistry, Faculty of Science and Technology, Universitas Islam Negeri Ar-Raniry, Banda Aceh 23111, Indonesia
6Sekolah Tinggi Ilmu Kesehatan Assyifa Aceh, Banda Aceh 23242, Indonesia
7Department of Pharmacy, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Kopelma Darussalam, Banda Aceh 23111, Indonesia

*E-mail: rinaldi.idroes@unsyiah.ac.id

Abstract. Geothermal is a source of heat energy from the earth and is a renewable energy source. Geothermal exploitation as an energy source is still ongoing. Recently there has been an increase in the use of an unmanned aerial vehicle (UAV) technology as an alternative option in aerial surveys and observations in geothermal areas. The use of UAVs in geothermal exploration is an alternative option. This is because the unmanned aerial vehicle has many advantages and features that can be utilized. Various studies that have been conducted have shown that the use of UAVs has become a method that brings changes in the exploration process of geothermal areas. UAVs are proven to assist in the geothermal exploration process and produce fast, reliable, and cost-effective solutions. UAVs also help explore geothermal areas that were previously difficult to study, namely areas with extreme environmental conditions and rugged access terrain. UAVs can also be used to search for potential sources as new manifestations in geothermal areas so that the points of manifestation in geothermal areas can be identified. This is very helpful in increasing the efficiency and less risk for the researcher.

1. Introduction
Geothermal is a source of heat energy from the earth and is a renewable energy source [1]. Indonesia is the largest geothermal producer in the world. This is indicated by 13% of the total number of volcanoes in the world in Indonesia, and 80% of which is estimated to have the potential for geothermal energy production. [2]. The potential of geothermal energy in Indonesia is estimated at 28,617, about 40% of the world's geothermal potential [3]. Geothermal can be said as an alternative energy resource for the
world with high and renewable development prospects. This geothermal energy source can be a more environmentally friendly and prospective alternative to fossil energy sources [4].

Geothermal exploitation as an energy source is still being carried out. In Indonesia, geothermal exploitation is still centered on the island of Java, although seen from the geography and mapping of volcanic areas in Indonesia, almost half of Indonesia's geothermal potential is on the island of Sumatra [5]. Aceh is a province located in Sumatra that has nearly 20 potential geothermal energy sources. The three areas that are very potential as geothermal energy are Mount Seulawah Agam, Jaboi, and Geuredong [6], [7]. Several studies have been carried out to explore geothermal energy at Seulawah Agam Volcano [8]. Geophysical research from the Seulawah Agam Volcano has reported deep and shallow data of the subsurface structures of the geothermal system [9]. In addition to this, research has been carried out to identify geochemistry in the southern zone, namely Ie Jue[10], Ie Brouk [11], Ie Seu’um [12], and Van Heutz Crater [7].

The resources in the geothermal film are highly varied. Not only the manifestations like hot spring and fumarole but also the geology sites [13] and the biodiversity [14], [15]. Therefore, an advanced technology that can process images [16] is needed to cover that all interests. Recently there has been increasing use of unmanned aerial vehicle (UAV) technology as an alternative option in aerial surveys and observations in geothermal areas [17]. UAV is a platform that can carry several different measuring devices and can be controlled manually by a trained person on the ground or controlled automatically using a programmed flight plan [18].

Figure 1. DJI drone modified with ICI thermal camera and UAV module [19]

The use of UAVs in geothermal exploration is an alternative option. Because the UAV has many features, namely equipped with a video recorder/camera, GPS, temperature sensor, and other components that can be used to support field research. The thermal sensors in the UAV can provide a choice for a high-resolution generation, as seen in Figure 1. This technology is promising to allow quick and safe surveys in geothermal areas with dangerous and difficult access to terrains [19].

In this paper, we will demonstrate the results of research conducted by various researchers related to the use of UAVs in the exploration process of geothermal areas. We will show the research results: the location, objectives, equipment used for exploration, and the output.
2. Recent Studies
Researchers have carried out various studies related to the use of UAVs in exploring geothermal areas. Research has been carried out in various geothermal manifestations worldwide, with various research objectives and different equipment uses. Table 1 presents the research results that have been carried out, covering the year, location, objectives, equipment, and the output.

| Year | Location | Objective | Equipment | Output | Ref. |
|------|----------|-----------|-----------|--------|------|
| 2015 | Tauhara thermal area, New Zealand | Demonstrating that drones have the potential to become a major tool in geothermal exploration | Using the DJI Phantom 2 Vision + quadcopter equipped with an ICI 640x480 uncooled thermal sensor with automated image capture (ICI UAV module) | RGB orthomosaic, thermal orthomosaic, DEM, and thermal 3D model | [20] |
| 2015 | Wairakei – Tauhara, New Zealand | Demonstrate the use of a small (<2kg) and cost-effective quadcopter to map the physical and biological characteristics of geothermal areas safely and accurately | Using the Blade 350 QX2 Quadcopter with a Spectrum DX5e DSMX 5-Channel transmitter equipped with a Sony HDR-AS100V, FLIR Tau 320 camera, and sensors for capturing infrared thermal video | RGB orthophoto and thermal orthophoto | [21] |
| 2016 | Karapiti thermal area, New Zealand | Shows the utility and economy of drones to produce accurate aerial photographs, DEM, and thermal imagery | Using the DJI Phantom 2 Vision + quadcopter equipped with an ICI 640x480 uncooled thermal sensor with automated image capture (ICI UAV module) | Thermal infrared orthophoto, RGB orthophoto, and DEM | [22] |
| 2016 | Waikite geothermal area, New Zealand | To assess the benefits of drone technology for finding hot tubs and other thermal features in difficult terrain such as wetlands and dense scrubs, and providing an estimate of the surface heat loss from thermal water in the survey area | Using the DJI Phantom 2 Vision + quadcopter equipped with an ICI 640x480 uncooled thermal sensor with automated image capture (ICI UAV module) | RGB orthophoto, thermal orthophoto, and DEM | [19] |
| 2017 | Hsiaoyukeng, Taiwan | Quadcopter design to collect thermal imagery that will be used for monitoring volcanic geothermal as a solution to dealing with difficult terrain, very | Using the AI-RIDER YJ-1000-QC Quadcopter that has been installed with GPS, compass, air pressure sensor, inertial measurement units | DSM and thermal orthoimages | [23] |
| Year | Location | Objective | Equipment | Output | Ref. |
|------|----------|-----------|-----------|--------|------|
| 2018 | Geysir Geothermal Field | The use of UAVs to understand the relationship between deep and surface expressions in the Geysir geothermal field. | Using the DJI Matrice 100, which is equipped with a DJI Zenmuse X5R optical camera and a FLIR Tau 2 thermal camera | DEM, infrared mosaic, and thermal 3D model | [24] |
| 2019 | Various locations. Iceland | Proving that the use of an integrated drone system of optical and thermal cameras produces a fast, reliable, and cost-effective solution | Using the DJI Matrice 210 Drone, which is equipped with optical and thermal cameras | Thermal orthomosaic, DSM, and surface temperature map | [25] |
| 2018 | Khankala, Chechen Republic, Russia | Evaluating the use of UAVs for monitoring the geothermal plant environment | Using a Geoscan 201 UAV equipped with a Thermoframe-MX-TTX thermal imager and a Sony DSX-RX1 digital camera | RGB orthophoto and Thermal orthophoto | [26] |
| 2020 | Parco delle Biancane, Italy | Analyze surface temperature and distribution of thermal signatures in Tuscany’s geothermal districts using data obtained through three separate surveys via satellite, the UAV | Using a FlyBit octocopter equipped with a FLIR VUE PRO thermal imaging camera | RGB orthomosaic, thermal orthomosaic, and surface temperature maps | [27] |

From Table 1, it can be seen that researchers have successfully utilized UAV technology for the exploration and monitoring of geothermal areas. In general, it can be seen that the main equipment needed to explore geothermal areas is a UAV equipped with optical and thermal cameras. UAV battery life must also be following the coverage area to be explored. Therefore it is advisable to bring additional chargers and batteries.

Before operating the UAV, it is very important to make a flight plan. One thing to note is the weather conditions in geothermal areas because unpredictable weather conditions can hinder the UAV operation. Temperature, fog, rain, and strong winds can all impact UAV performance [28]. Operating the UAV during strong winds and opposing wind direction also causes the UAV to consume more battery power, resulting in reduced flight time [21].

UAVs are used to collect RGB and thermal images of the geothermal area. Furthermore, the image that has been collected is analyzed to look for errors that may occur in the image retrieval process, such as images that are out of focus, blurry, and bouncy. These two-dimensional RGB and thermal images will later be converted to a three-dimensional point cloud using the software. The results obtained later can be a variety of map layouts. The layout maps that have been made by several researchers include the RGB orthophoto, thermal orthophoto, RGB orthomosaic, thermal orthomosaic, surface temperature map, digital elevation model (DEM), digital surface model (DSM), and thermal 3D model.
3. Conclusion
Various studies that have been conducted have shown that the use of UAVs has become a method that brings changes in the exploration process of geothermal areas. UAVs are proven to assist in the exploration process of geothermal areas and produce fast, reliable, and cost-effective solutions. UAVs also assist in exploring geothermal areas that were previously difficult to study, namely areas with extreme environmental conditions and difficult to access terrain. The utilization of UAVs can also be used to search for potential sources as new manifestations in geothermal areas so that the points of manifestation in geothermal areas can be identified. UAVs allow researchers to obtain images of the location of geothermal environments, such as cliffs, forests, and others, making it easier for researchers to reach points of manifestation. This allows mapping of areas using unmanned aerial vehicles in geothermal fields to be efficient for researchers’ safety, especially for new areas where the situation is unknown.

References
[1] Mohammadzadeh Bina S, Jalilinasrabady S, Fujii H, Pambudi N A 2018 Renew. Sust. Energ. Rev. 93 499–506.
[2] Maryanto S, Dewi C N, Syahra V, Rachmansyah A, Foster J, Nadhir A, Santoso D R 2017 Geosciences 7 41.
[3] Nasruddin, Idrus Alhamid M, Daud Y, Surachman A, Sugiyono A, Aditya H B, Mahlia T M I 2016 Renew. Sust. Energ. Rev. 53 733–740.
[4] PT Geo Dipa Energi 2012 Tek. Pomits. I pp. 1–6. (in Bahasa Indonesia).
[5] Bertani R 2016 Geothermics 60 31–43.
[6] Putri D R, Nanda M, Rizal S, Idr esos, Ismail N 2019 IOP Conf. Ser. Earth Environ. Sci. 364 012003.
[7] Idr esos, Yusuf M, Saiful S, Alatas M, Subhan S, Lala A, Muslem M, Suhendra R, Idr esos G M, Marwan M, Mahlia T M I 2019 Energies 12 4442.
[8] Marwan, Yanis M, Idr esos R, Ismail N 2019 Int. J. GEOMATE. 17 173–180.
[9] Marwan, Syukri M, Idr esos R, Ismail N 2019 Int. J. GEOMATE. 16 141–147.
[10] Idr esos R, Yusuf M, Alatas M, Subhan, Lala A, Muhammad, Suhendra R, Idr esos G M 2019 IOP Conf. Ser. Mater. Sci. Eng. 523 012012.
[11] Idr esos R, Yusuf M, Alatas M, Subhan, Lala A, Muslem, Suhendra R, Idr esos G M, Suhendrayatna, Marwan, Riza M 2019 IOP Conf. Ser. Mater. Sci. Eng. 523 012010.
[12] Idr esos R, Yusuf M, Alatas M, Lala A, Suhendra R, Idr esos G M 2018 IOP Conf. Ser. Mater. Sci. Eng. 334 12002.
[13] Zhijie L, Guoying G 1986 Geothermics 15 339–345.
[14] Nuraskin C, Maralina, Idr esos R, Soraya C, Djufri 2020 Rasayan J. Chem. 13 18–23.
[15] Nuraskin C A, Maralina, Idr esos R, Soraya C, Djufri 2019 Res. J. Pharm. Technol. 12 5247.
[16] Suhendra R, Arnia F, Idr esos R, Earli a N, Suhartono E 2019 2019 IEEE Int. Conf. Cybern. Comput Intell. 35–39.
[17] Nishar A, Richards S, Breen D, Robertson J, Breen B 2016 J. Unmanned Veh. Syst. 4 136–145.
[18] van Blyenburgh P 1999 Air Sp. Eur. 1 43–47.
[19] Harvey M C, Rowland J V, Luketina K M 2016 J. Volcanol. Geotherm. Res. 325 61–69.
[20] Harvey M, Luketina K 2015 Proceedings of the 37th New Zealand Geothermal Workshop 2015. 20.
[21] Nishar A, Richards S, Breen D, Robertson J, Breen B 2016 Renew. Energ. 86 1256–64.
[22] Harvey M C 2016 GRC Transactions.
[23] Chio S H, Lin C H 2017 Sensors 17 1649.
[24] Walter T R, Jousset P, Allahbakhshi M, Witt T, Gudmundsson M T, Hersir G P 2020 J. Volcanol. Geotherm. Res. 391 106282.
[25] Bjomsson G, Grimsson G, Sigurdsson A, Laenen V 2019 Thermal Mapping of Icelandic Geothermal Surface Manifestations with a Drone.
[26] Cherkasov S V., Farkhutdinov A M, Rykovanov D P, Shaipov A A 2018 *J. Sustain. Dev. Energy Water Environ. Syst.* 6 351–362.

[27] Silvestri M, Marotta E, Buongiorno M F, Avvisati G, Belviso P, Bellucci Sessa E, Caputo T, Longo V, De Leo V, Teggi S 2020 *Remote Sens.* 12 2018.

[28] Sauter B. 2007. *Weather impacts on the aerostar unmanned aircraft system based on climatology over the US/Mexico border.* Army Research Lab White Sands Missile Range Nm Computational And Information.