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Geothermal Surface Manifestation Mapping using unmanned aerial vehicle (UAV) in Tropical Forest of Indonesia

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ABSTRACT

Indonesia is a geothermal country whit tropical forest area covering most of the geothermal prospects. The surface thermal manifestation is one of the essential keys for geothermal exploration, resource confirmation, geochemistry monitoring during the exploitation phase, and geothermal development, and supposed to be touristic place. Images data with spatial reference can be obtained from the unmanned aerial vehicle during field survey. The images form field data acquisition is processed using Agisoft Methasape software to build orthophoto data with spatial reference. The data can be processed using GIS software to make 2D and 3D maps/terrain maps. This method was useful for manifestation identification, area measurement for natural heatloss calculation, identification of hazardous area during geochemistry sampling, and resource evaluation for exploration and development of geothermal field in tropical forest area in Indonesia.

1. INTRODUCTION

Indonesia is a country with the largest geothermal potential in the world. Geographically, Indonesia's climate conditions are located in the tropical climate. In addition, location of potential geothermal energy resources in Indonesia is located in mountainous areas overgrown with dense vegetation and most of them are in tropical forest areas. The geothermal conceptual model in Indonesia is dominated by high terrain model and is located in the highlands associated with volcanic mountains (Nicholson, 1993; Hochstein and Sudarman, 2015). Pertamina Geothermal Energy (PGE) is an Indonesian geothermal energy company taking many geothermal working areas permits from the government of Indonesia. Currently, PGE holds 13 geothermal work areas, and most of the prospects are located in the mountains in tropical forest areas of Java island, Sumatra island, and northern Sulawesi. Continues exploration and development carried out to increase the business portfolio and geothermal energy electricity generation. One of the stages in geothermal exploration is geoscience data acquisition through geological, geochemical, and geophysical studies. Geothermal manifestations on the surface can be an important key in managing geothermal prospects and become a reference for building a conceptual model of exploration and development of the geothermal prospect. The challenge in the identification of the surface manifestations can be solved with remote sensing methods from satellite imagery, but satellite imagery often has limitations and interference from the presence of thick cloud cover in the tropical forest area. To figure out geothermal manifestations on the surface, unmanned aerial vehicle (UAV) technology was developed to be able to acquire high-resolution aerial photographs and can be further processed to become a 2D map and even a 3-dimensional map model in the form of a digital terrain model (DTM). These technologies and methods are applied in geothermal exploration, especially in remote areas that are difficult to reach and are in tropical forests with high vegetation cover. The UAV, also known as a drone, have been developed for mapping or know also as photogrammetry in many countries for geothermal and volcanic studies, such as New Zealand (Harvey et al., 2016; Nishar et al., 2016), Costa Rica (Granados-Bolaños et al., 2020), Italy (De Beni et al., 2019), Spain (Sedano-Cibrián et al., 2022), Taiwan (Liu et al., 2016), and Indonesia (Idroes et al., 2021). The UAV/drone used in this study is the DJI Mavic Pro 2 which has high flexibility because it is small in size, can be folded and put in a backpack, and is lightweight to carry to areas that are difficult to reach by vehicle.

2. METHODS

To conduct a geothermal manifestation mapping and identification in geothermal exploration and development area, the steps taken are starting from the initial stages covering reconnaissance & satellite images identification and then continuing to make a design for mapping operation in the survey planning stage. Furthermore, after all equipment and personnel are prepared in the field, the UAV flight operations & data acquisition stage is carried out. Then, the stages are continued at the office/studio workstation to carry out data processing (orthophoto & DTM), and then at the final stage is map layouting & building 3D models.

2.1 Reconnaissance & Sattelite Images Identification

Reconnaissance is a preliminary survey for identifying thermal manifestations. This stage is carried out in the exploration or development of geothermal prospects that have not been reached or have not been studied in detail due to accessibility which is located in remote areas or tropical forests. The method is used to identify the characteristics of geothermal manifestations on the surface such as volcanic craters with the presence of hydrothermal alteration, hot pools, or hot mud pools. It may be also found as volcanic lakes associated with other manifestations such as fumaroles, mud pools, and hot springs. The remote sensing method is applied using satellite imagery analysis which may have limited resolution to see geothermal manifestations that are small in size and not extensive, but this method can be used for initial identification and planning points of interest for field surveys. Recommended satellite images are high-resolution satellite images such as GeoEye, Maxar, IKONOS, Worldview, Quickbird, and Pléiades. The remote sensing method applied is the same as land cover and vegetation analysis. This is very applicable in geothermal prospect areas in tropical forests such as Indonesia. Other satellite images with thermal or infrared sensors such as ASTER can also be applied to identify zones with thermal anomalies on the surface.

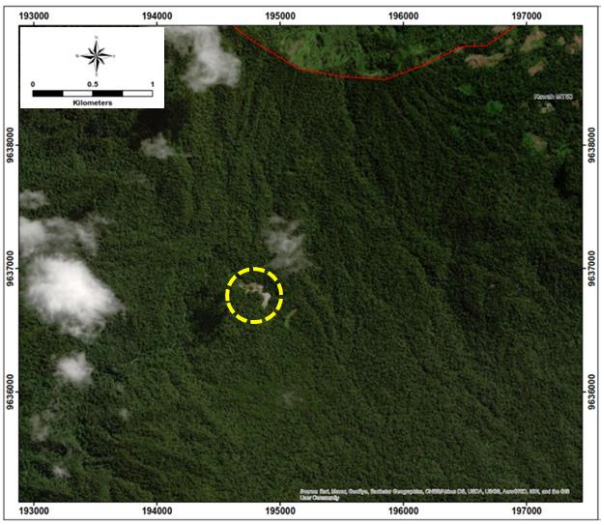

Figure 1: Map of geothermal manifestations identification obtained from satellite image analysis. For example, above, the yellow dotted line circle indicates areas identified as geothermal manifestations that will be surveyed in more detail in the field and taken as a target for aerial photographs acquisition using UAV.

2.2 Survey Planning

The next stage is preparing for survey activities by designing a plan for the point where aerial photography data will be acquired. It might require a specific strategy to reach the target location. In some cases, the targeted locations are far from people's housing and located in tropical forests. This causes the need for preparation regarding vehicle access options and tracking routes, the number of support team personnel, equipment, and logistics. To be able to carry out good survey activities, the survey team for mapping and study of geothermal manifestations can design on a survey planning map the flying camp planning location points as shown in the example in Figure 2.

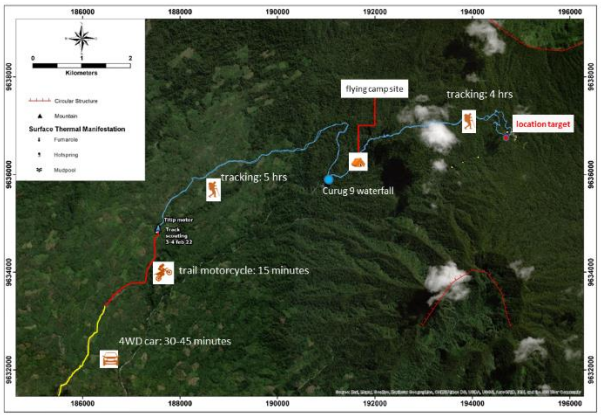

Figure 2: Survey planning map to reach the targeted manifestation in tropical forest area.

This will be of more concern if the targeted location must be reached within a few days and requires the survey team to carry out a flying camp strategy. The planning survey phase is also urgently needed for medical team support in emergencies, communication media in remote areas, environmental permits, and logistics that must be prepared. The team leader in the survey must discuss and prepare careful planning to be able to reach the target location with a UAV that can be carried in a backpack if the target location cannot be reached by vehicles. In this stage, the reference used is a geothermal manifestation identification map based on the analysis of satellite image data and the application of GIS software to estimate the distance traveled and the terrain to be traversed. In this stage, it is also possible to plan the area of the area to be mapped using the UAV, the altitude of the aircraft, and the number of aerial photographs to be acquired so that they can be processed into a map. Planning measurement points and UAV flight routes can be assisted using applications available from manufacturers such as DJI Pilot, and DJI GO 4, as well as applications such as Pix4Dcapture.

2.3 UAV flight operation & data acquisition

When all the team personnel and equipments have been prepared in the field, UAV flight operations & data acquisition can be carried out. The UAV can be carried in a backpack to the target location to determine a safe point and it is possible to carry out the UAV flight following the planned flight route. Determination of flight location points, flight paths, flight duration, and other technical aspects can refer to the manufacturer's specifications of the UAV or drone used. The important thing to do is ensure that the UAV take off and landing locations are in a safe location, which can be in open land so that the UAV is not disturbed by the presence of trees or existing morphology such as cliffs or hills. UAV flight operations can be controlled using a remote control that can be controlled by the UAV pilot and displayed or set using an application installed on the UAV pilot's smartphone/tablet as shown in Figure 3.

Figure 3: Screenshot display on the smartphone applications: PiX4D (left) and DJI Pilot/DJI GO4 (right). Those applications was useful for planning UAV flight routes, monitoring flight missions, the number of photos taken, and display of photo capture from UAV.

After carrying out operations in the field, team personnel in the field must ensure that all areas of geothermal manifestations have been covered from the UAV flight route that has been carried out. This is to ensure that the results of processing photo data into orthophoto and DTM can cover all areas of interest.

2.4 Data Processing (Orthophoto & DTM)

After carrying out data acquisition in the field, the next step is to perform data processing from UAV aerial photographs that already have geospatial reference values to be processed using the Agisoft Methasape software (see Figure 4). The use of Agisoft Methasape software to create orthophoto and digital terrain models can be an effective method for processing aerial photographs into maps such as those applied in various locations (Kabiri et al., 2020; Ahmed et al., 2021). The process of processing photos into orthophoto includes the following processes: align photos, build dense clouds, build mesh, build textures, build tiled models, build digital elevation models (DEM), build orthomosaic, and export data to files with the extension .tiff and .pdf or files. other image extensions.

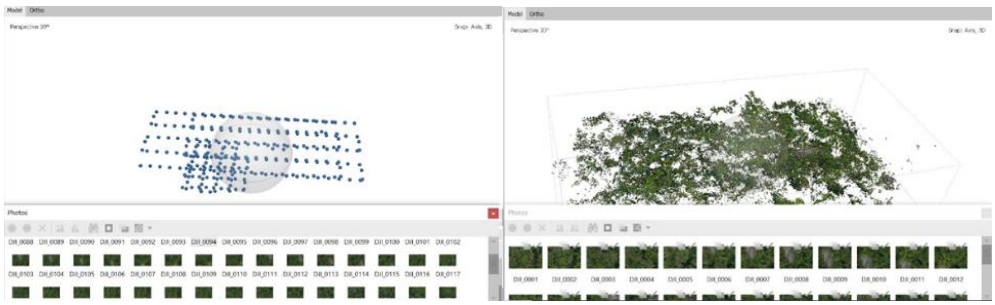

Figure 4: The processing of aerial photos from UAV into orthophoto and DTM using Agisoft Methashape software

2.4 Map Layouting & Building 3D model

At this final stage, the orthophoto and 3D model results can be adjusted to the appearance and layout of the map using ArcGIS software or other GIS software. This stage is carried out by processing orthophoto files with the .tiff extension into a map that has been equipped with elements on the base map that contains geographic information. In addition, processing with GIS software can help identify the extent of the manifestation area, determine the distribution points of manifestations based on the type of manifestation, and can even map the danger zones on manifestations which can assist in planning a safe tracking path when conducting geochemistry surveys on manifestations. Information about this area is currently useful for calculating the dimensions of the manifestation area and in more advanced applications, temperature distribution measurements can be carried out if the UAV used is equipped with a thermal infrared sensor.

3. RESULT AND DISCUSSION

The results of the stages of mapping geothermal manifestations using the UAV described in the previous chapter can show results as in the following example (Figure 5).

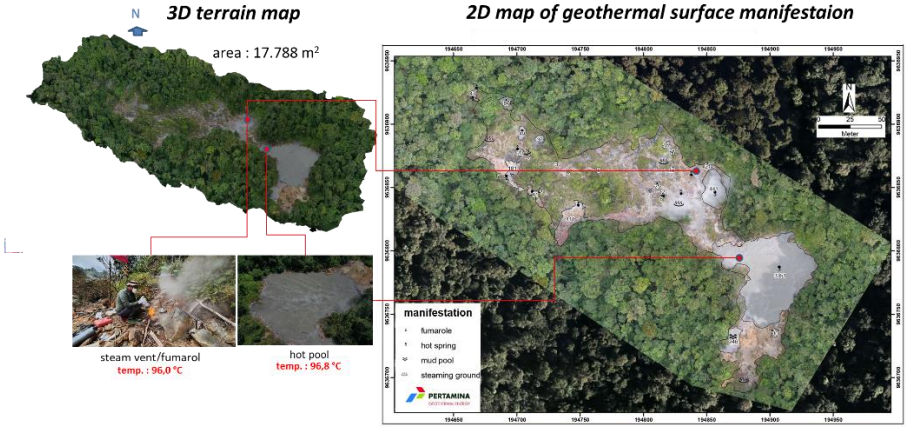

Figure 5: Examples of the results of mapping geothermal manifestations using UAV which can be in the form of 2D maps and 3D maps/terrain models. In the map above it can be seen that manifestations are found among vegetation and trees in one of the tropical forest locations in Indonesia.

The example results above show the findings of geothermal manifestations that have never been found in previous geoscience studies because they are located in locations that are difficult to reach and are in forest locations that are rarely traversed by human activity. The use of UAV can be applied to map manifestation locations with better image resolution than satellite and lidar images (see Figure 6). The use of UAV also assists the geothermal geoscience survey team in conducting exploration in tropical forest locations in Indonesia and reduces the risk of exposure to hazards in geothermal manifestations such as H_2S gas exposure, hot water eruption hazards, hot pools, mud pools, and locations with steep/steep terrain that can endanger the survey team personnel if they pass through the manifestation hazard location. In addition, by using aerial photographs using UAV at crater locations or geothermal manifestation complexs, the geothermal manifestation team can identify the distribution of other manifestations that are not detected by satellite or lidar imagery as shown in Figure 6. The PGE geoscientist team has experienced using this method in various geothermal fields in Indonesia such as: Sibayak, Lumut Balai, Hululais, Ulubelu, Karaha, Kamojang, Lahendong/Tompaso and PGE will try to do UAV data acquisition in other geothermal fields. As a note, from PGE experience in various fields that have been carried out, good orthophoto results are produced if the planning of the UAV flight path fulfills the overlapping requirements in the photogrammetry technique and between one photo/point and another can be aligned using software so that it can form a good photo mosaic. Another note, the results of the mapping above use a camera sensor that captures lighting from the sun, so that good photos are also influenced by weather conditions and cloud cover during the survey. At various other geothermal locations, several researchers such as Harvey et al. (2016) and Nishar et al. (2016) uses thermal infrared as an additional sensor in the UAV which is used to identify thermal zones on the surface.

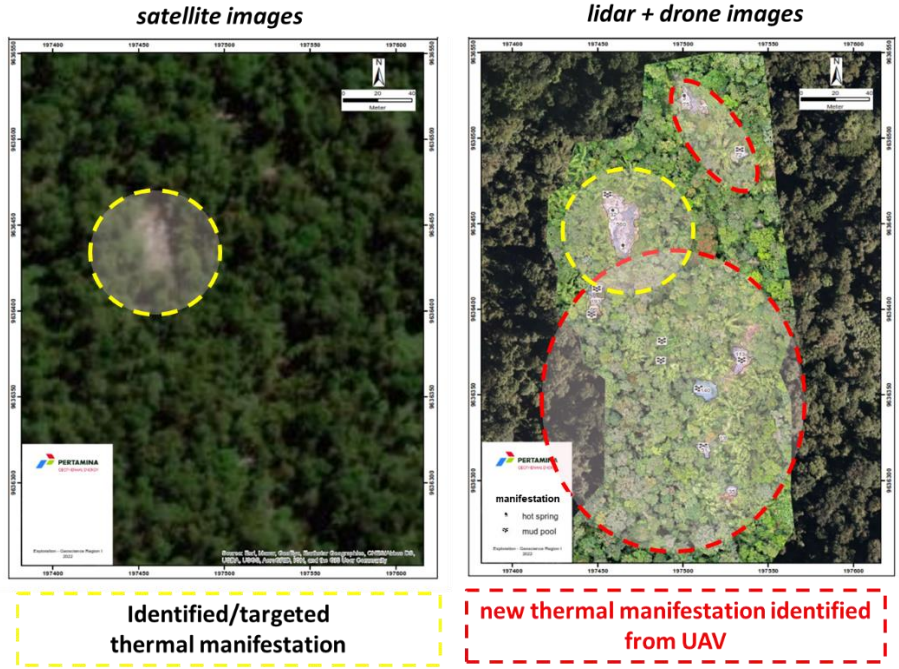

Figure 6: A comparison of geothermal manifestations from satellite imagery (left) and from UAV/drone mapping results (right). With a high image resolution from the UAV, other manifestation locations can be mapped such as hot pools, mud pools, and hydrothermal alteration at the location of the manifestation complex.

4. CONCLUSION

UAV technology is very useful to be applied in mapping geothermal manifestations, especially in tropical forest locations in Indonesia. To get good mapping results, a series of stages need to be carried out, including determining target points, planning surveys, planning UAV flight paths, executing in the field with safe UAV flights covering the manifestation area, then proceed with the processing stage to become a geothermal manifestation map that has high image resolution and has a spatial reference.

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