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Temperature Profile at Shallow Subsurface Depth of Warm Ground Geothermal Manifestations in Bukit Kasih Minahasa, North Sulawesi: Implications for SDG 7

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ABSTRACT

Objective: *To investigate the shallow subsurface temperature profile of warm ground geothermal manifestations in the Bukit Kasih area, Minahasa, North Sulawesi, Indonesia. Specifically, this study examined the relationship between temperature variation and subsurface depth to develop a preliminary thermal model of geothermal manifestations. The study contributes to geothermal resource assessment and supports sustainable renewable energy development in line with Sustainable Development Goal 7 (Affordable and Clean Energy).* ***Method:*** *The study employed a field-based quantitative approach through direct temperature measurements at warm ground geothermal manifestation sites. Temperature data were collected from several randomly selected measurement points at shallow subsurface depths ranging from 0 to 200 cm. The research was conducted over six months, consisting of field surveys, preparation of measurement equipment, geothermal manifestation observations, temperature data acquisition, laboratory analysis, and data processing. The temperature gradient and depth-temperature relationship were analyzed to determine the subsurface thermal characteristics and develop temperature distribution models.* ***Results:*** *The results showed that the shallow subsurface temperature gradient of warm ground manifestations in the Bukit Kasih geothermal area varied from 13.61 to 71 °C/m. The temperature-depth relationship demonstrated a linear pattern at shallow subsurface depths, indicating a consistent increase in temperature with increasing depth. Meanwhile, the temperature model at greater depths followed a logarithmic function pattern, reflecting changes in heat transfer behavior within the subsurface environment. These findings provide important information regarding shallow geothermal characteristics and potential indicators for further geothermal exploration.* ***Novelty:*** *The study provides new insights into the shallow subsurface thermal characteristics of warm ground geothermal manifestations in Bukit Kasih, Minahasa, North Sulawesi, by developing a temperature-depth model based on direct field measurements. The findings contribute to geothermal exploration strategies and the advancement of renewable energy utilization in accordance with SDG 7 (Affordable and Clean Energy).*

INTRODUCTION

The prospect of utilizing geothermal energy in Indonesia is quite promising, considering that geothermal energy as a renewable electricity source provides a sustainable alternative with low environmental impact compared to conventional fossil-based energy resources. The development of geothermal energy aligns with global efforts to achieve Sustainable Development Goal 7 (SDG 7), which emphasizes access to affordable, reliable, sustainable, and clean energy. Geothermal resources have significant potential to support the energy transition by reducing greenhouse gas emissions and promoting the utilization of environmentally friendly energy technologies (Alhamid et al., 2016; Suryani et al., 2025; Yudha et al., 2022). Therefore, comprehensive geological, geophysical, and geochemical investigations are required to improve the understanding of geothermal systems and support sustainable geothermal resource development.

North Sulawesi has abundant geothermal resources marked by the emergence of geothermal manifestations in several locations, including the Minahasa region (Mukti et al., 2022; Rauf et al., 2023). The occurrence of geothermal manifestations is commonly associated