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Preliminary Study on Land Cover Mapping in Village on Transitional Volcanic Landscape Using Deep Learning with UAV Orthophoto

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ABSTRACT

This preliminary study explores the use of DEEPNESS, a deep learning tool via QGIS, for land cover mapping in the Tubansari Sub-Village - Bompon Watershed, a transitional volcanic landscape with complex human and environmental dynamics. The region faces challenges such as rapid land cover changes, landslides, erosion, and unsustainable land use driven by population growth and agricultural expansion. DEEPNESS efficiently processed 85.1 hectares of 10 cm resolution UAV orthophoto in about 5 seconds. However, its segmentation accuracy was unsatisfactory for village areas, mainly due to the model's training on datasets from regions like Poland, which differ in key features like building types and roof structures. Despite this, the study highlights the potential of deep learning for large-scale land cover mapping. Future work should focus on fine-tuning the model with localized data, exploring urban areas, and using higher-resolution or multi-spectral imagery to improve accuracy. This research lays the foundation for advancing land cover mapping to support sustainable land management, disaster mitigation, and environmental conservation in similar volcanic landscapes.

Keywords: *deep learning, land cover mapping, DEEPNESS, UAV orthophoto*

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1. INTRODUCTION

Central Java Province is one of the regions in Indonesia that has a high risk of landslides. This occurs especially in varied areas such as highlands and hills (Isnaini, 2019; Marfai et al., 2008; Trimasukmana, 2019). One area in Central Java Province, such as the Sumbing Quaternary volcanic system and Menoreh Tertiary structural-volcanic system, has a high threat of landslides (Aliyyah et al, 2022; Noviyanto et al, 2020). Therefore, it is necessary to carry out research on disaster management in this area, such as hazard mapping, vulnerability assessment, and adaptation strategies to reduce risks and losses from landslides (Maes et al., 2017; Pradhita et al, 2022). One of the main assets for these studies is detailed land cover data. However, detailed land cover data is very difficult to obtain.

Detailed scale land cover mapping is generally done using the visual interpretation method. This interpretation relies on several keys such as shape, size, tone, shadow, pattern, texture, site, association, and resolution (Fariz et al., 2023). This method is very accurate in mapping land cover, but is not efficient in terms of data processing time. One of the latest approaches in land cover mapping is to use Deep learning. Deep learning is a type of machine learning that uses artificial neural networks, which have been widely used in detailed scale land cover mapping such as Karra et al (2021) and Alhassan et al (2020).

One of the areas of the Sumbing Quaternary volcanic system and Menoreh Tertiary structural-volcanic system is the Bompon Watershed. This area is characterized by thick volcanic soils, which offer excellent potential for diverse land uses, including agriculture, supporting high land productivity (Sartohadi et al, 2024). However, the rough relief and thick soil layers also make the region highly susceptible to environmental hazards such as landslides, erosion, and drought (Fariz et al, 2023; Nhindyasari et al., 2024; Rahmi et al., 2019). Rapid land cover changes, driven by human activities such as extensive development, monoculture farming, and settlement expansion, have further exacerbated these issues. Land cover in the Bompon sub-Watershed has undergone significant transformations, marked by the construction of concrete roads, increased building density, and the conversion of natural landscapes into monoculture gardens (Purwaningsih et al, 2020; Sartohadi et al., 2024). These changes have altered land surface characteristics, accelerating erosion and landslide processes (Adzima et al, 2020; Sambodo et al, 2018). Population growth and limited land availability have also led to the establishment of settlements in unsuitable areas, further increasing the region's vulnerability.

Given these pressing environmental challenges, there is an urgent need for detailed and accurate land cover mapping to support sustainable land management and disaster mitigation efforts. This study serves as a preliminary exploration into the application of deep learning techniques for land cover mapping in the Bompon Watershed using UAV orthophoto. As an initial step in a broader research initiative, this work aims to evaluate the feasibility and potential of deep learning in addressing the complexities of land cover classification in transitional volcanic landscapes. By focusing on this watershed, the study seeks to lay the groundwork for future, more comprehensive research that can inform land use planning, environmental conservation, and disaster risk reduction strategies in similar regions.

2. METHODS

The study location is in Bompon Watershed in Magelang, Central Java, Indonesia (Figure 1). This area is located in a transitional volcanic landscape between Mount Sumbing and the Kulonprogo Mountain Range, which is very prone to erosion and landslides (Sambodo & Arpornthip, 2021). Bompon Watershed consists of several villages, namely Kuaderan, Wonogiri and Margoyoso. However, the key areas in this study are focused on Tubansari Sub-Village, Margoyoso Village.

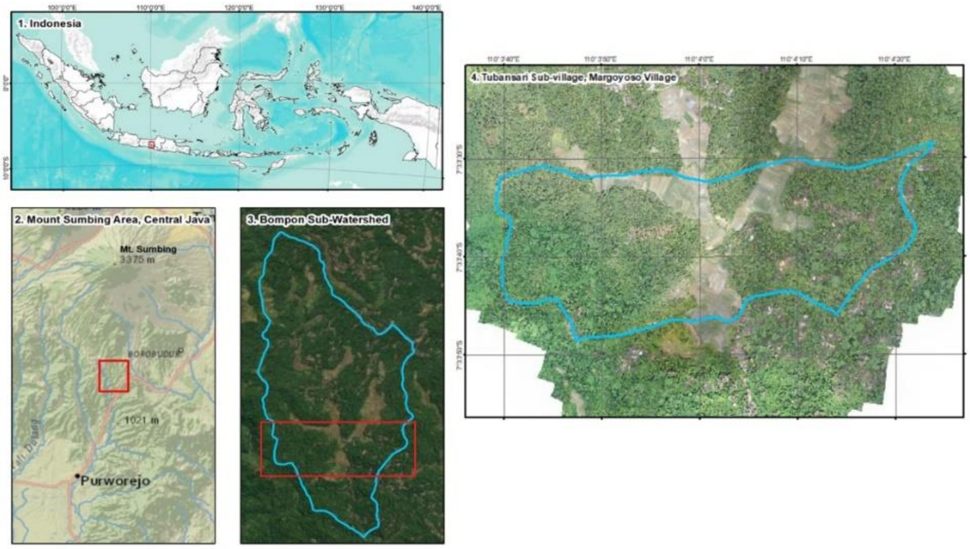

Figure 1. Study area

The primary data used in this study consists of orthophoto of the Bompon Watershed, captured using UAV technology. This orthophoto, with a high spatial resolution of 10 cm, were obtained from previous research from Fariz et al (2020). The core analytical approach in this study relies on remote sensing techniques enhanced by deep learning, specifically utilizing the DEEPNESS plugin. This study uses DEEPNESS as a plug-in in QGIS software, which is designed to facilitate the application of deep learning to tasks such as segmentation, detection, and regression on raster orthophoto. It leverages custom ONNX Neural Network models, making advanced deep learning accessible to both casual and expert users. Key features of the plugin include the ability to process any raster layer (such as custom orthophoto or online layers like Google Satellite), limit processing to predefined areas (using visible extents or vector polygons), and support for various model types, including segmentation, regression, and detection (Aszkowski, Ptak, Kraft, Pieczyński, & Drapikowski, 2023).

This study represents an initial exploration of DEEPNESS's potential for detailed land cover mapping in complex landscapes, such as the Bompon Watershed. The next analytical approach is a descriptive analysis that presents the mapping results using DEEPNESS. To enrich the discussion, this study compares parameters of tile overlaps set at 15% and 30%. The analysis of land cover mapping results from different tile overlaps is conducted visually, considering that this study is preliminary in nature.

3. RESULT AND DISCUSSION

The integration of deep learning into geospatial analysis has been significantly enhanced by tools like the Deepness plugin, which enables users to perform segmentation, detection, and regression tasks on raster orthophoto using custom ONNX Neural Network models. This plugin supports various raster layers, including custom orthophoto and online providers like Google Satellite, and allows users to limit processing to specific areas, such as visible regions or vector layer polygons. It supports common model types, including segmentation, regression, and detection, and integrates seamlessly with input and output layers, which can be saved as files. Land Cover Segmentation model, trained on the LandCover.ai dataset, which includes satellite images with resolutions of 25 cm/px and 50 cm/px. The model, based on DeepLabV3+ with a tu-semnasnet_100 backend and FocalDice loss function, is designed to classify land cover into four categories: buildings, woodland, water, and roads (Aszkowski & Ptak, 2022).

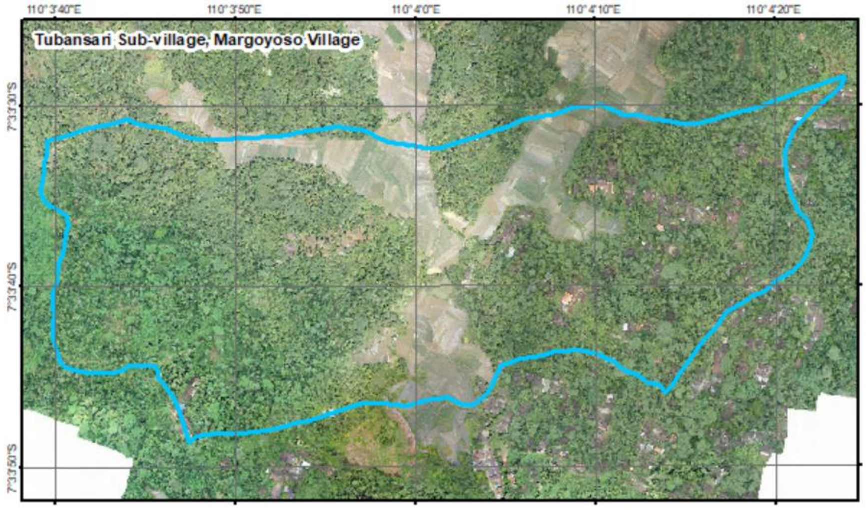

Figure 2. Orthophoto of the Tubansari sub-village area

Tubansari Sub-village generally has several land cover classes such as rural settlement, paddy field and agroforestry garden. Rural settlement will be classified as buildings, while agroforestry garden will be classified as woodland. For paddy field, it will be classified as background area because in Land Cover Segmentation model there is no agricultural land class such as paddy field. The processing results are presented in Figure 3, where woodland is the most dominant land cover class in Tubansari Sub-village.

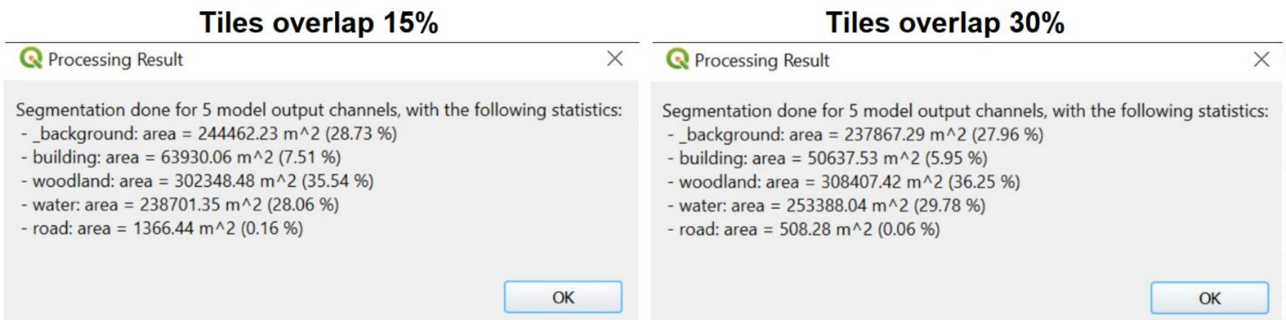

Figure 3. Processing result

The results of land cover mapping for the building class, as shown in Figure 4, are less than satisfactory for both the 15% and 30% tile overlaps. This is evident from the segmentation results, which fail to accurately capture the square shapes of the buildings visible in the orthophoto. Similarly, the mapping results for the woodland class, presented in Figure 5, are also imperfect, although the 30% tile overlap tends to yield slightly better segmentation compared to the 15% overlap. The poor segmentation performance for buildings can be attributed to the fact that the Land Cover Segmentation model was originally designed for land cover in Poland. According to Fariz et al (2023) and Setyawan et al (2016), buildings in the study area feature clay roofs and triangular structures (*pelana, limasan, srotongan* [Javanese traditional architectural terms]), which significantly differ from those in Poland, leading to suboptimal results.

Figure 4. Result of building object segmentation

UAV orthophoto is not only good for identifying building types, but also vegetation. In trees, UAV orthophoto should be able to visually distinguish tree species, including agricultural land which should be able to distinguish paddy field type and planting age. The results of land cover mapping for the paddy field class represented as the background area are presented in Figure 6. The segmentation results are quite good, although there are still blank areas. However, the segmentation results with 30% tiles overlap have better results than the results from 15% tiles overlap. This is indicated by the fewer blank areas in the results from 30% tiles overlap.

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Figure 5. Result of woodland object segmentation

The results of land cover mapping using DEEPNESS, a freely accessible deep learning tool via QGIS, generally yielded unsatisfactory segmentation accuracy for village areas. Despite this limitation, DEEPNESS demonstrated remarkable efficiency in data processing, completing the analysis for an area of 85.1 hectares with 10 cm spatial resolution orthophoto in approximately 5 seconds. This highlights its potential for rapid large-scale mapping applications. However, as this is a preliminary study, significant improvements and further development are needed to improve its performance in rural landscapes, especially Transitional Volcanic

Landscapes such as Tubansari Village. One of the key issues is the mismatch between the model, which was likely trained on datasets from regions like Poland, and the unique characteristics of village areas, such as buildings with clay roofs and triangular structures, as noted by Fariz et al (2023).

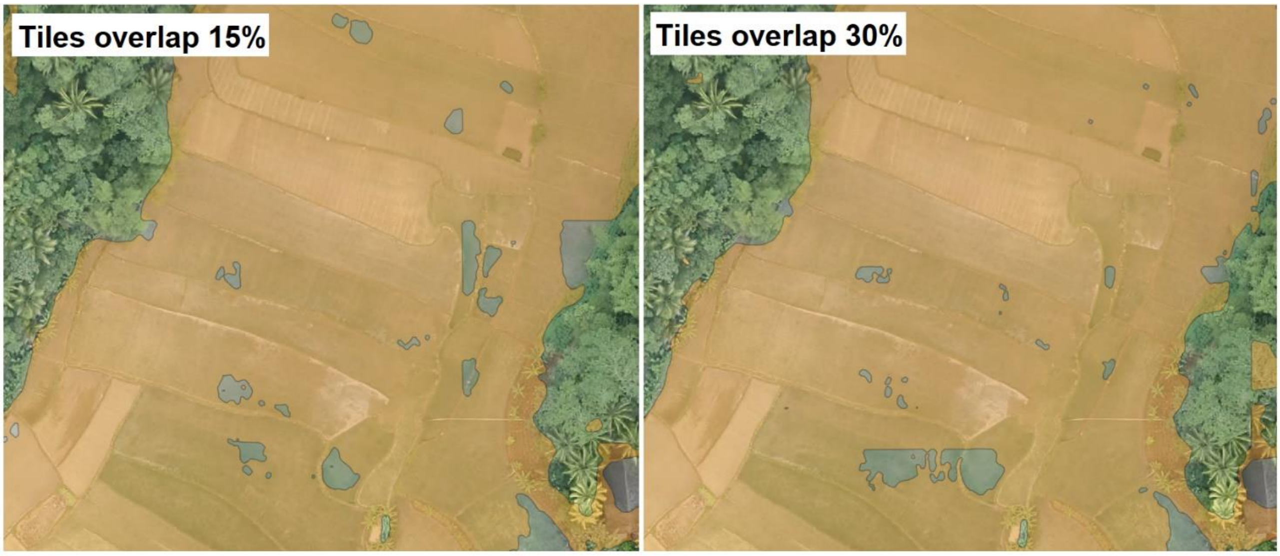

Figure 6. Result of background area object segmentation

For future work, we recommend exploring the application of DEEPNESS in urban areas, as the model may be better suited to such environments. Additionally, fine-tuning the model using localized training data that reflects the specific land cover characteristics of village areas could significantly improve segmentation accuracy. Incorporating higher-resolution datasets or multi-spectral imagery, as suggested by Kumar et al (2024), Zhao et al (2022) and Zhou et al (2025), could also enhance the model's ability to distinguish between complex land cover types. These advancements would not only improve the accuracy of land cover mapping but also expand the applicability of DEEPNESS to diverse landscapes, including transitional volcanic regions like the study area. This reminds us that land cover mapping is very important not only for land resource management and disaster management, but also as data for low-carbon and climate-resilient development policies. However, it is important to remember that data quality, scale of analysis, and proper data interpretation are essential to ensure that land cover data is used effectively.

4. CONCLUSIONS

In conclusion, this preliminary study highlights the potential and limitations of using DEEPNESS, a deep learning tool accessible via QGIS, for land cover mapping in village areas, particularly in transitional volcanic landscapes like Tubansari Sub-village. While the tool demonstrated exceptional efficiency in processing large-scale data (85.1 hectares in ~5 seconds), its segmentation accuracy was unsatisfactory due to a mismatch between the model, likely trained on datasets from regions like Poland, and the unique characteristics of the study area, such as buildings with clay roofs and triangular structures. Future work should focus on fine-tuning the model with localized training data, exploring urban areas, and incorporating higher-resolution or multi-spectral imagery to enhance accuracy and applicability in diverse landscapes. This study lays the groundwork for advancing land cover mapping techniques to support sustainable land management, disaster mitigation, and environmental conservation in similar transitional volcanic landscapes.

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