BUANA
Jurnal Geografi, Ekologi dan Kebencanaan
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Artikel Penelitian

Geographic Artificial Intelligence and Unmanned Aerial Vehicles Application for Correlation Analysis of Settlement Density and Land Surface Temperature in Panggang Island Jakarta

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KATA KUNCI

GeoAI, Land Surface Temperature; Panggang Island; UAV

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A B S T R A K

This research aims to understand the relationship between high settlement density and land surface temperature associated with the Urban Heat Island (UHI) phenomenon. The data processing method involves collecting settlement density data using UAVs equipped with thermal sensors, as well as using GeoAI, namely GEE, to analyze LST on Panggang Island. The results showed a positive relationship between settlement density and LST on Panggang Island, with high settlement density contributing to an increase in ground surface temperature. The benefits of the application of GeoAI and UAVs in this analysis include accurate mapping, understanding the impacts of urbanization, sustainable urban planning, and fact-based decision-making. It is hoped that this research can contribute to better urban management and reduction of environmental impacts in Pulau Panggang, DKI Jakarta.

INTRODUCTION

Technological developments in the fields of science and engineering have had a significant impact on various aspects of human life. One field that continues to experience rapid progress is geography and remote sensing. The use of Geographic Artificial Intelligence (GeoAI) technology and Unmanned Aerial Vehicles (UAV) has provided new opportunities to collect, analyze, and visualize geographic data efficiently and accurately (Bordogna & Fugazza, 2022). Panggang Island, located in DKI Jakarta Province, Indonesia, is one of the areas facing challenges in sustainable urban development. Population growth and increased settlement density on the island have led to significant changes in land use and environmental quality (Rakuasa & Pakniany 2022). One parameter that is important to consider in analyzing the impact of such changes is land surface temperature (LST) (Moazzam et al., 2022)

Land surface temperature is a temperature measure that reflects the heat emitted by the land surface (Khan et al., 2022). Changes in settlement density can affect the LST in an area (Pertuack et al., 2023). High settlement density tends to cause an increase in surface temperature, which in turn can negatively impact thermal comfort and human health (Ghanbari et al., 2023). To address this challenge, the use of GeoAI and UAVs in analyzing the correlation between settlement density and LST on Panggang Island is important. GeoAI enables the processing of large and complex geographic data using intelligent algorithms to identify patterns, relationships and trends that cannot be seen directly by humans (Ermida et al., 2020). Meanwhile, UAVs provide flexibility in collecting high-resolution spatial data and acquiring accurate thermal images of LST (Neog, 2022).

https://doi.org/10.56211/buana.v1i1.340
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Using a combination of GeoAI and UAVs, analyzing the correlation between settlement density and LSTG can provide valuable insights for decision-makers in sustainable urban planning (Wei & Blaschke, 2018). This information can be used to identify areas with high settlement density and high LST, so that appropriate mitigation strategies can be established to reduce negative impacts on the environment and human quality of life. This study aims to determine the utilization of geographic artificial intelligence applications and unmanned aerial vehicles for correlation analysis of settlement density and land surface temperature on Panggang Island, DKI Jakarta.

LITERATURE REVIEW

Geographic Artificial Intelligence

Geographic Artificial Intelligence is an emerging field that combines the power of Artificial Intelligence (AI) with Geographic Information Systems (GIS) to analyze and extract insights from geographic data (Janowicz et al., 2020). It is a multidisciplinary field that draws from computer science, GIS, statistics, and spatial analysis to analyze and model geospatial data. Some of the key areas of GeoAI include, Geospatial deep learning, spatiotemporal data analysis, geospatial natural language processing and geospatial optimization (Arslan et al., 2020).

GeoAI has a wide range of applications in areas such as urban planning, environmental monitoring, transportation, and public/environmental health (Jozaghi et al., 2018). It can be used to improve the efficiency and accuracy of decision-making in these fields by providing insights that are difficult to obtain using traditional GIS techniques. It is important to note that GeoAI is a rapidly evolving field, and new techniques and applications are constantly being developed. In addition, as with other AI techniques, it is important to consider the ethical and social implications of using these techniques (Janowicz et al., 2020).

Google Earth Engine

Google Earth Engine (GEE) is a platform that provides access to a large collection of satellite imagery and other geographic data derived from various sources such as Landsat, Sentinel, MODIS, and more. With Google Earth Engine, users can perform spatial and temporal analysis quickly and efficiently, combining various datasets to gain deep insight into the changing earth over time (Ermida et al., 2020).

Land Surface Temperature

Land Surface Temperature (LST) is defined as the temperature condition of the outermost part of an object on the ground surface (Latue et al., 2023). According to Rakuasa et al., (2023), Land surface temperature (LST) is a good indicator of the energy balance at the Earth's surface and one of the main parameters in the physics of land surface processes at regional and global scales. LST plays a role in hydrological, ecological, agricultural and meteorological processes at the Earth's surface (Tahooni et al., 2023). Land surface temperature is also important for detecting climate change. LST is used for a wide variety of scientific studies and it is a key parameter to measure the increase in surface temperature in a given area (Rakuasa, 2022). LST can be determined from satellite images that have thermal bands by various methods depending on the number of bands used.

LST determination is usually done using satellite imagery data that contains infrared information, such as data from Landsat or MODIS sensors (Ermida et al., 2020). These satellite images can measure the thermal radiation emitted by the Earth's surface, which is then used to estimate the temperature at the ground surface. Some of the important applications of Land Surface temperature include climate monitoring and climatic change, environmental health monitoring, urban heat island effect analysis, agriculture and conservation applications and disaster prediction and management (Ghanbari et al., 2023). With the help of monitoring technology from satellite imagery, Land Surface Temperature becomes important information that can be used to understand environmental conditions and provide insights for various scientific and environmental management applications (Latue, 2023).

Unmanned Aerial Vehicles

UAV drones or Unmanned Aerial Vehicles are unmanned aircraft that can be controlled remotely using a remote control (Andrio, 2019). With various sophisticated components, these drones have grown rapidly due to the many benefits they provide. UAV drones or Unmanned Aerial Vehicles are unmanned aircraft that can be controlled remotely using a remote control (Sugandhi et al., 2023). With various sophisticated components, these drones have grown rapidly due to the many benefits they provide. UAVs have a very wide variety of uses in various sectors, including: mapping and monitoring, oil

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and gas industry, agriculture, environmental surveying and monitoring, rescue and disaster relief, security and surveillance, media and filming, freight forwarding.

METHODOLOGY

This research was conducted on Panggang Island, Kepulauan Seribu, DKI Jakarta Province (Figure 1). The tools and materials used in this research include UAV or Drone DJI- Zenmuse L1 LiDAR and GPS RTK (Real-Time Kinematic). UAVs are used in research to produce high-resolution aerial photographs, good image accuracy. The aerial photographs were processed and analyzed using DJI Tera, Pix4D, Agisoft Metashape and Arc GIS software. The research was conducted in several stages including the preparation stage and data collection and data processing (interpretation and digitization) of land use, and analysis of Land Surface Temperature (LST) in Geogle Earth Engine (GEE).

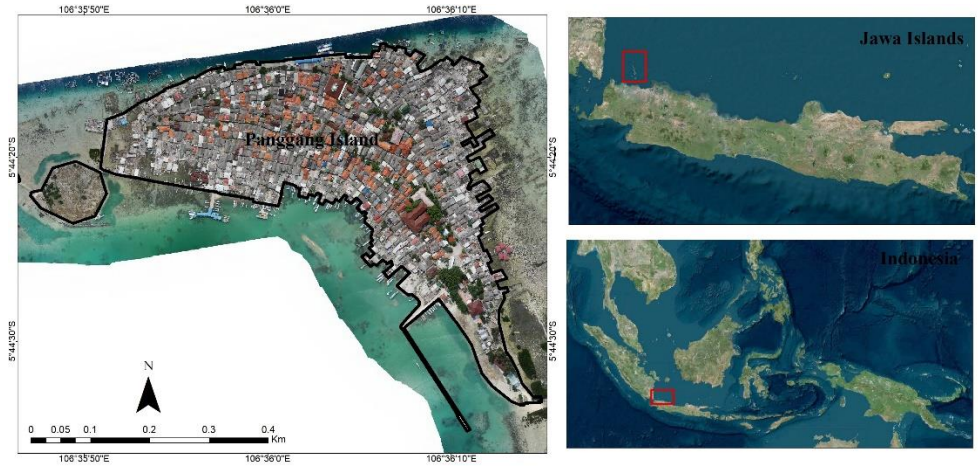

Figure 1. Research Location

Land use is classified into three classes namely settlements, open land and shrubs and Digital Terrain Model (DTM) is extracted from aerial photography data Land Surface Temperature (LST) analysis in Google Earth Engine (GEE using Landsat 8 Collection 1 Tier 2 TOA Reflectance image data accessed and analyzed in Google Earth Engine (https://earthengine.google.com/). USGS Landsat 8 Collection 1 Tier 2 TOA Reflectance is one of the image collections available on Google Earth Engine (GEE) for the Landsat 8 satellite. Tier 2 TOA (Top of Atmosphere) Reflectance is an image product that has been atmospherically corrected to obtain the actual land surface temperature reflectance. Analysis of land surface temperature in Ternate Tengah sub-district was conducted in the period 01-04-2013 - 30-04-2013 and in the period 01-04-2023 - 30-04-2023. To analyze land surface temperature (LST) on Landsat 8 images using Google Earth Engine (GEE) based on cloud computing by using the "Single Channel Algorithm" or "Split-Window Algorithm" formula. The complete results of the LST analysis in GEE can be seen in Figure 2.

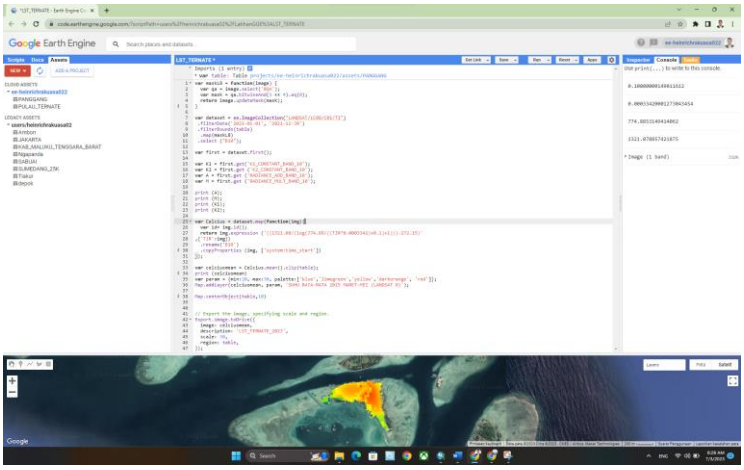

Figure 2. Display of LST analysis results

In the preparation and collection stage, it is carried out by collecting data from aerial photographs. Data from aerial photographs and DTM are then analyzed. The processing stage is carried out in Arc GIS 10.8 software which consists of the Georeferencing process, interpretation and digitization of the location of the reservoir plan then calculating the area. While the land surface temperature analysis was carried out in GEE after that a spatial correlation analysis was carried out to determine the relationship between settlement density and LST on Panggang Island.

RESULTS AND DISCUSSION

Land cover is a description of the physical appearance of the earth's surface caused by the interaction between natural processes and social processes (Achmadi et al., 2023). Land cover can also provide information about natural phenomena that occur on the earth's surface (Latue & Rakuasa, 2023). Land cover data is also used in studying climate change and understanding the relationship between human activities and global change (Somae et al., 2023). Land cover as a manifestation of the dynamic interaction process between human activities and land resources, which is spatially distributed over the land surface and identifies the biophysical cover of the land; this includes water, bare land or residential land (Latue et al., 2023). Land cover is a type of land that describes all the physical conditions on the earth's surface. The physical conditions on the land surface can be in the form of vegetation, water and soil cover (Rakuasa et al., 2023).

Land cover refers to various land surface coverings such as vegetation, urban infrastructure, water, bare soil and so on (Latue et al., 2023). Wang et al., (2021), revealed that land cover is an important description of the earth's terrestrial surface and spatially explicit and statistical land cover information is a requirement in various natural resource management decision-making at local, national and international scales. The results of the land cover analysis show that settlements have a larger area presentation of 65.67% or 12.14 ha, open land of 5.88 ha or 31.84% and shrubs of 0.46 ha or 2.48%. Details of the land cover map can be seen in Figure 3.

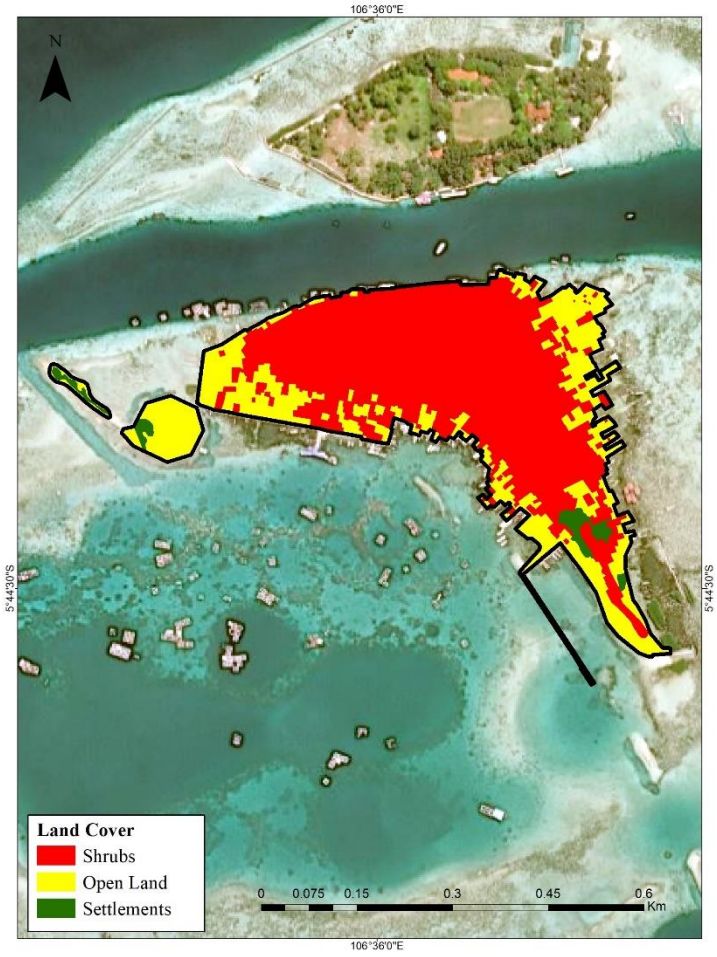

Figure 3. Land Cover Map of 2023

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Changes in land cover on Panggang Island can affect the land surface temperature on the island. For example, if there is conversion of forest land to agricultural or urban land on Panggang Island, this change can lead to an increase in land surface temperature. More open and dense land surfaces such as agricultural or urban land tend to absorb more solar radiation than forests that have lush canopies. As a result, land surface temperatures on Panggang Island may increase.

In addition, land cover change can also affect airflow patterns and evaporation. Forests have a significant air filtering effect and can maintain local humidity (Achugbu et al., 2022). If deforestation or land cover change from forest to other land occurs on Panggang Island, the cooling and humidifying effects produced by the forest may be reduced. This could contribute to an increase in land surface temperature on the island. However, it is important to remember that other factors such as global climate and human activities can also play a role in the increase of land surface temperature on Panggang Island. Increased greenhouse gas emissions globally can lead to global warming which affects surface temperatures around the world, including on Panggang Island. To reduce the rise in land surface temperature on Panggang Island, it is important to maintain and properly manage land cover. The preservation of forests and natural vegetation, sustainable land use, and efforts to reduce greenhouse gas emissions can help reduce surface temperatures and maintain a balanced ecosystem on Panggang Island.

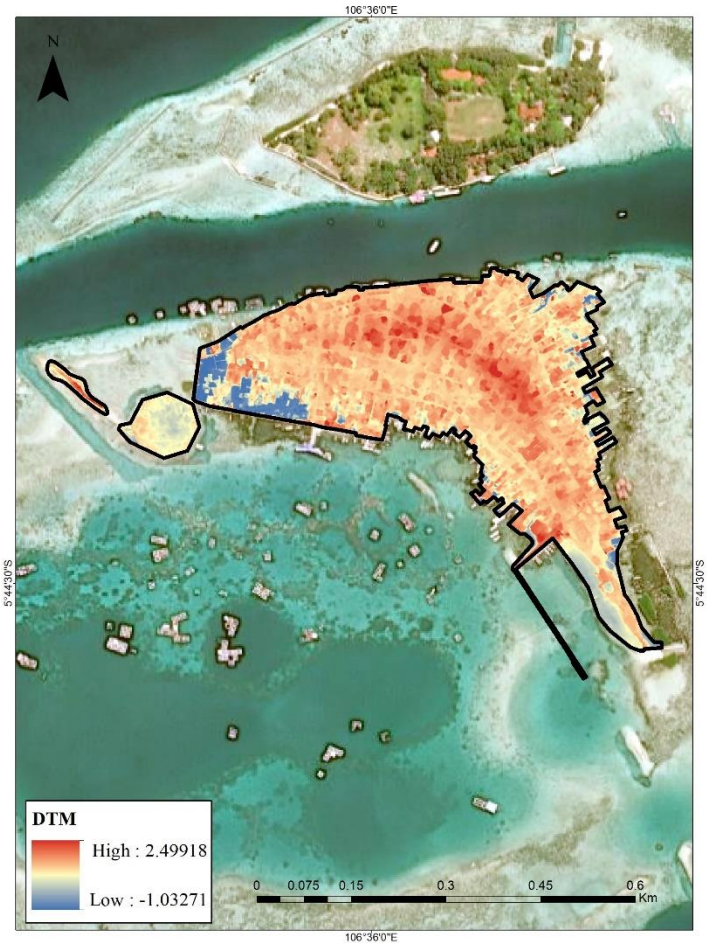

Figure 4. Digital Terrain Model map of 2023

Digital Terrain Model (DTM) is a three-dimensional digital representation of the Earth's surface that reflects the topography and shape of the land in detail (Julzarika & Harintaka, 2019). DTM presents information about the elevation or height of each point on the earth's surface with high precision. DTM data can be used to model and analyze surface shapes such as hills, valleys, plains, or rainfall of an area. DTMs are created using remote sensing data, such as aerial photographs or satellite images, which are processed using digital processing techniques (Wibowo et al., 2019). This process involves using algorithms to remove irrelevant objects, such as buildings or vegetation, so that only topographic information is captured (Binta & Sukojo, 2017). DTM can also be created using terrestrial mapping technologies, such as laser scanners (LiDAR) mounted on drones or airplanes. Panggang Island has the lowest DTM value of -1.03 m and the highest value of 2.49 m. Details of the land cover map can be seen in Figure 4.

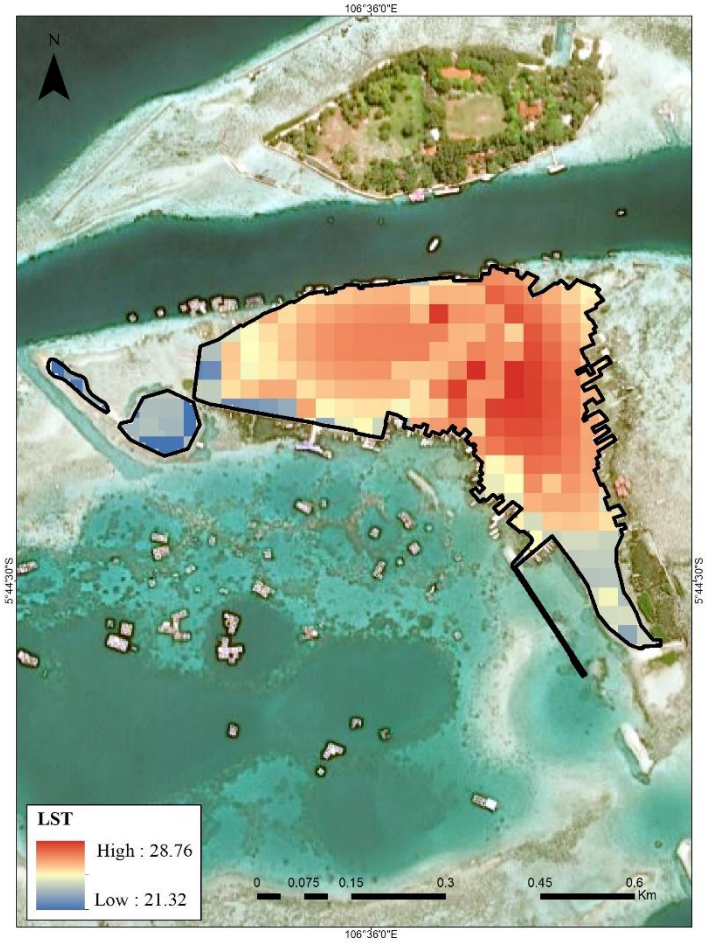

Figure 5. Land Surface Temperature map for 2023

Land Surface Temperature (LST) refers to the land surface temperature measured at the Earth's surface. It is the temperature measured at the thin layer directly in contact with the atmosphere, including soil, vegetation, and other physical objects at the surface (Kanga et al., 2022). LST is measured using different technologies and sensors, such as remote sensing satellites, infrared radiometers, or ground thermometers (Gadekar et al., 2023). LST data provide important information on land surface temperature that can be used in a variety of applications, including environmental monitoring, climate research, and urban analysis (Mansourmoghaddam et al., 2023)

Information on LST can help understand the temperature dynamics and thermal change patterns in a region (Wei & Blaschke, 2018). This is important in understanding climate change impacts, heat flow patterns, and temperature variability in urban and rural environments. LST data can also provide insight into heating and cooling patterns related to settlement density, land cover, and other environmental factors. In the context of application in Pulau Panggang, DKI Jakarta, LST analysis can help identify land surface temperature patterns related to settlement density. For example, areas with high settlement density may tend to have higher surface temperatures due to heat contributions from buildings, roads, and human activities. The average Land Surface Temperature in Panggang Island in 2023 is the lowest temperature of 21.32°C and the highest is 38.76°C (Figure 5).

In addition, LST data can also be used in local climate modeling and sustainable urban planning. Information on LST helps in identifying urban heat islands, which are areas with higher temperatures compared to the surrounding region (Stoyanova et al., 2022). By understanding these warming patterns, smart and sustainable urban design strategies can be implemented to reduce excessive surface temperatures and create a more comfortable environment for residents (Wei & Blaschke, 2018). Overall, Land Surface Temperature is the land surface temperature measured at the earth's surface and provides important information about temperature patterns and thermal changes in a region. In the context of application in Pulau Panggang, DKI Jakarta, LST analysis helps in understanding the correlation between settlement density and land

surface temperature, and provides important insights in sustainable urban planning and mitigation of climate change impacts.

The results of aerial photography using the DJI Zenmuse L1 Drone show that almost 99% of the research area, namely Panggang Island, is residential and the results of this study also show that Panggang Island has an altitude of 2.48 meters above sea level. The results of Land Surface Temperature (LST) processing show that Panggang Island has the highest LST temperature of 28.76 ℃ and the lowest temperature of 20.44 ℃. This indicates that the development of built-up land in an area can have a significant effect on the increase in land surface temperature, as is the case on Panggang Island. The application of Geographic Artificial Intelligence (GeoAI) and Unmanned Aerial Vehicles (UAVs) in analyzing the correlation between settlement density and Land Surface Temperature (LST) on Panggang Island, DKI Jakarta, has various benefits, including that GeoAI and UAVs can provide accurate mapping and monitoring related to settlement density and land surface temperature on Panggang Island. By using remote sensing technology and thermal sensors on UAVs, specific and detailed data collection can be carried out.

According to Dutta et al., (2019), correlation analysis between settlement density and LST can provide a better understanding of the impact of urbanization on land surface temperature on Panggang Island. This is important in understanding the "urban heat island" phenomenon and its impact on the environment and human quality of life. The information obtained through correlation analysis can be used in more sustainable urban planning. The data can help in the development of strategies for mitigating high surface temperatures, better environmental management, and more efficient urban spatial design (Salakory & Rakuasa, 2022).

According to Albarqouni et al., (2022), GeoAI and UAVs can provide accurate data and information for fact-based and evidence-based decision-making. This allows stakeholders, such as local governments and related agencies, to make more effective decisions in urban and environmental management in Pulau Panggang. By understanding the correlation between settlement density and LST, efforts can be made to reduce negative environmental impacts. This information can be used to optimize land use, improve building design, enhance urban environmental quality, and minimize the impact of high surface temperatures on human comfort (Latue et al., 2023). Overall, the application of GeoAI and UAVs in the correlation analysis of settlement density and LST provides significant benefits in environmental understanding, sustainable urban planning, natural resource management, and climate change mitigation efforts in Pulau Panggang, DKI Jakarta.

The correlation of settlement density and Land Surface Temperature (LST) on Panggang Island, DKI Jakarta, can be an important subject in environmental analysis and urban planning. High settlement density can cause Urban Heat Island effects on Panggang Island. UHI is a phenomenon in which surface temperatures in urban areas tend to be higher than the surrounding rural areas (Çolak & Sunar, 2023). High settlement density leads to increased heat by human activities, low albedo of building surfaces, and reduction of heat-absorbing vegetation. Thus, areas with higher settlement density may have higher LST (Wang et al., 2019)

The local topography on Panggang Island may also influence the relationship between settlement density and LST. Areas with flat topography or with enclosed valleys may experience greater heat buildup, which can lead to increased LST. On the other hand, areas with more open topography or hills can have better airflow and lower LST. It is important to note that the relationship between residential density and LST may vary depending on local factors such as land use, building orientation, vegetation, and airflow patterns. Therefore, careful correlation analysis using GeoAI and UAVs data can help identify and better understand this relationship. This information can be used for better decision-making in sustainable urban planning and environmental management in Pulau Panggang, DKI Jakarta.

CONCLUSION

The results of aerial photography using the DJI Zenmuse L1 Drone show that settlements have a larger area presentation of 65.67% or 12.14 ha, open land of 5.88 ha or 31.84% and shrubs of 0.46 ha or 2.48%. The results of this study also show that Panggang Island has an altitude of 2.48 meters above sea level. The results of Land Surface Temperature (LST) processing show that Panggang Island has the highest LST temperature of 28.76 ℃ and the lowest temperature of 20.44 ℃. This indicates that the development of built-up land in an area can have a significant influence on the increase in land surface temperature, as is the case on Panggang Island. The application of GeoAI and UAVs in the correlation analysis

of settlement density and LST on Panggang Island has great potential in providing a better understanding of the impact of urbanization on the environment and providing a solid basis for sustainable decision-making.

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