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Exploring neighborhood green space to mitigate UHI effect based on a spatial approach in Malang, Indonesia

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Abstract. Urban Heat Island (UHI) is detrimental to climate and ecological conditions. Combined with the UHI effect, this can result in high temperatures; overcrowding worsens UHI due to increased human activity, energy consumption, and waste heat production. This research aims to explore neighborhood green space potential as UHI mitigation. This research uses a spatial approach to explore the configuration of neighborhood and greenspace patterns for UHI mitigation efforts. The research took areas in Malang City. They were selected based on LST values from Sentinel 2 data in the extremely hot, very hot, and near normal categories according to STI (Standardized temperature index). Data collection was carried out using ArcGIS with a spatial approach. The results show a medium greenspace dispersion in the concentrated greenspace category has a potential effort to mitigate UHI. It should be noted that the high and low greenspace dispersion scattered and concentrated greenspace categories are not optimal in mitigating UHI. Future research can look for other factors that can influence UHI mitigation.

Keywords: Greenspace, land surface temperature, local climate zone, neighborhood, uhi mitigation

1. Introduction

Urban Heat Island (UHI) is a situation where urban areas experience higher temperatures than their surrounding rural areas due to various factors such as human activities, construction materials, and urban infrastructure, which can absorb and trap heat, leading to increased temperatures in cities compared to their natural surroundings. This phenomenon can have significant impacts on the local climate and environment. Urban areas exhibit traits conducive to rapid growth, often accompanied by localized climate changes resulting from increased energy demands and the concentration of pollutants [1].

UHI effect is a growing concern in urban areas worldwide, with rising temperatures posing risks to public health, energy consumption, and overall urban livability. Relating to this issue, neighborhoods can adopt specific patterns and strategies to mitigate the UHI effect [2]. UHI effect has become increasingly pressing as urbanization reshapes our cities. UHI occurs when urban areas experience higher temperatures than their surrounding rural areas due to human activities, infrastructure, and a lack of natural elements. This phenomenon can adversely affect public health, energy consumption, and urban livability.

One effective and sustainable strategy to combat UHI is creating and preserving neighborhood green spaces within urban environments; neighborhood green spaces, including parks, gardens, and tree-lined streets, play a crucial role in mitigating the UHI effect [3]. UHI effect is a complex urban climatic phenomenon characterized by higher temperatures in urban areas compared to their surrounding rural regions. While various factors contribute to the UHI effect, organizational patterns and the distribution of green spaces within a city can profoundly impact its intensity and extent [4].

Neighborhood and green space patterns significantly impact the environment and are UHI mitigation efforts. Previous studies predominantly focused on spatial configuration patterns, with limited attention to neighborhood greenspace patterns. The main objective of this study is to explore neighborhood green space potential as UHI mitigation. This research fills the scientific gap that discusses organizational and greenspace patterns as UHI mitigation efforts by a spatial approach, as shown in Fig 1. Heat temperature transformation in Malang City uses Sentinel 2 satellite data and is processed with ArcGIS. This research finds a configuration of neighborhood and greenspace patterns that potentially mitigate UHI in the Malang City neighborhood area.

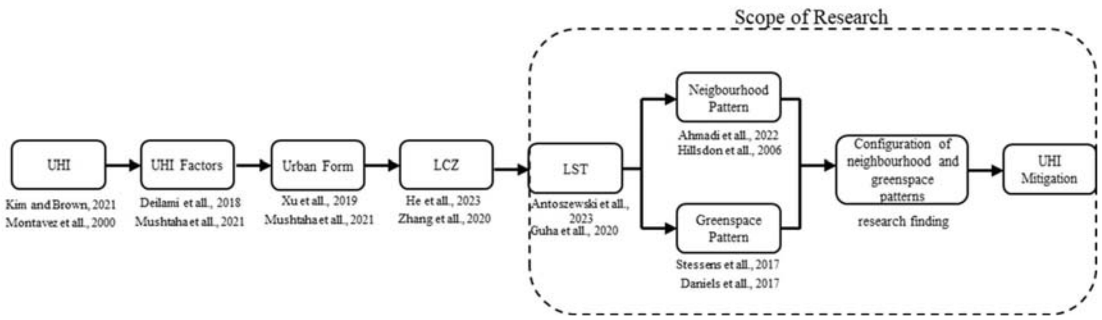


Figure 1. Research position

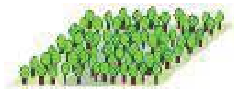
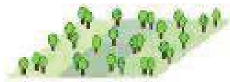
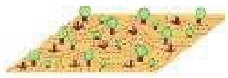
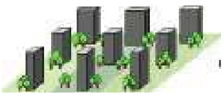
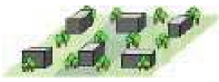
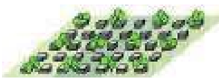
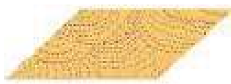
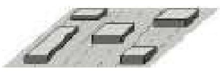
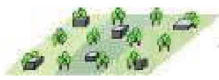
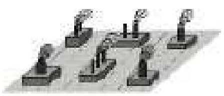
2. Methodology

The research employed a three-step methodology to investigate neighborhood green space patterns. The Local Climate Zone (LCZ) classification was initially identified to acquire regional characteristics specific to the studied area. Subsequently, the LST within the LCZ classification was ascertained to establish a standardized category for the temperature index. Finally, the neighborhood green space pattern was identified based on the nomenclature of the green space classification

2.1. LCZ Classification

The unique climate-centered LCZ classification system's main goals for urban and rural areas are to unify the rules regulating urban temperature observations globally and create a research framework for investigating UHI [5] Table 1. LCZs range from hundreds of square meters to several kilometres on a horizontal plane. They are defined as areas with constant surface cover, patterns of urban growth, building materials, traffic, and human activity [6-9]. This study examines land use conditions using the LCZ categorization. The third classification, which is primarily present in study areas, depicts the condition of compact low-rise land usage. Compact low-rise urban development represents a sustainable urban planning strategy to create liveable, efficient, and environmentally friendly cities [10-11]. Lower building heights and increased green spaces in compact low-rise neighborhoods contribute to a cooler urban environment, mitigating the UHI effect [12-14].

Table 1. Classification of LCZ

Built types		Land cover types	
LCZ1-Compact high-rise		LCZ A-dense trees	
LCZ2-Compact mid-rise		LCZ B-scattered trees	
LCZ3-Compact low-rise		LCZ C-bush, scrub	
LCZ4-Open high-rise		LCZ D-low plants	
LCZ5-Open mid-rise		LCZ E-bare rock/paved	
LCZ6-Open low-rise		LCZ F-bare soil/sand	
LCZ7-Lightweight low-rise		LCZ G-water	
LCZ8-Large low-rise			
LCZ9-Sparse low-rise			
LCZ10-Heavy industry			

2.2. Determination of Land Surface Temperature (LST).
LST is vital in modelling Soil-Vegetation-Atmosphere interactions within terrestrial ecosystems [15]. In an urban setting, LST has conventionally been regarded as a dependable indicator of the urban heat island effect [16]. Surface imperviousness percentage (SI) and LST have been employed to depict the attributes of the urban heat island phenomenon [17-18]. An in-depth grasp of the distribution and spatial fluctuations of LST can aid in creating models for LST dynamics and the discovery of eco-friendly solutions [19].

Based on the explanation about LST in the previous discussion and getting an idea of how LST has developed in Malang City in the last few years, the LST heat conditions are calculated using the Standardized Temperature Index (STI) based on LST from Sentinel 2 satellite data. The STI quantifies the temperature anomaly for a given month or timeframe by expressing it as a multiple of the standard deviation from the long-term average [20-21].

In this stage, researchers determine LST from the Sentinel 2 satellite data. Many researchers have demonstrated the usefulness of satellite data in exploring the relationship between greenspace patterns and LST. The LST categories in this research are extremely hot and near normal. In discussing the research conclusions, a configuration of environmental and open space patterns was conducted to determine the size of the LST built environment and green space patterns based on LST data. By knowing the magnitude, you will get an overview of the distribution of green open space and categories, which can be a solution to prevent the negative impact of UHI.

Table 2. STI measurements and situations.

No.	Conditions	Standardized Temperature Index (STI)
1.	Extremely hot	≥ 2.00
2.	Very hot	≥ 1.50 and < 2.00
3.	Moderately hot	≥ 1.00 and >-1.00
4.	Near Normal	<1.00 and >-1.00
5.	Moderately cold	≤-1.00 and >-1.50
6.	Very cold	≤-1.50 and >-2.00
7.	Extremely cold	≤-2.00

2.3. Neighborhood Greenspace Classification

Green spaces within urban areas play a vital role in the intricate urban ecosystem, including parks, woodlands, and agricultural lands [22-23]. The allocation of green areas, typically found in urban or suburban settings, encompasses spaces with varying degrees of vegetation, ranging from small squares to expansive gardens with planted pathways. These green spaces serve multiple purposes, such as enhancing the urban environment in various ways. They provide social benefits as accessible places for relaxation and strolls. Biologically, they contribute to oxygen production through the presence of trees and play a role in mitigating particular climate-related challenges. They also offer advantages for human health and economic benefits [24]. In urban or sub-urban regions, green spaces refer to vegetated areas categorized according to specific criteria determined by their size [25].

Table 3. Classification and nomenclature of green spaces.

No.	Category	The Size of The Area
1.	Square	area less than 1 ha
2.	Proximity garden	the area between 1 and 4 ha
3.	Urban park	area greater than 5 ha
4.	Periurban park	area greater than 100 ha

2.4. Research samples

Human actions, construction materials, and ineffective land utilization contribute to the UHI phenomenon. Malang City, one of the big cities in East Java, Indonesia, is developing rapidly with significant population growth and increasing housing needs. Compact low-rise building development is generally found in most Malang City land uses. This case study will focus on Malang City to see how applying this concept can provide concrete benefits for a developing city. This study will explore neighborhood greenspace in Malang City as urban areas undergoing rapid expansion-green space functions as a potential mitigation for the UHI effect.

The study samples included specific areas within Malang City, explicitly focusing on the five sub-districts with LST categories falling into the extremely hot, very hot, and near-normal ranges. Aerial images of the environment surrounding the research area are presented in Table 4 to help identify organizational and green space patterns using spatial methods. Spatial methods and validation were employed to verify the base geometry and pattern model ratios.

3. Result and Discussion

3.1. LST of Malang City

LST conditions in Malang City are significantly impacted by factors such as the season, weather conditions, land use, land cover, vegetation index, building index and water index. During the summer, LST temperatures in Malang City are expected to be higher, particularly in densely populated urban zones. Surfaces like rocky roads and concrete buildings absorb solar heat effectively, leading to higher ground surface temperatures [26]. Furthermore, human activities, such as vehicular traffic, can also play a role in elevating LST temperatures, particularly during daylight hours. Conversely, in the rainy season or following rain showers, LST temperatures typically decrease due to rainwater's cooling influence and direct solar radiation reduction. Locations featuring lush vegetation, such as parks or urban forests, may also exhibit lower LST temperatures than densely urbanized areas.

The LST data utilized in this study is sourced from the Sentinel 2 satellite, covering the land surface temperature conditions in Malang City over the previous three years, specifically in 2018, 2019, and 2020, as shown in Fig. 2. The chosen areas encompass all the sub-districts within Malang City, totaling five sub-districts (Blimbing, Kedungkandang, Klojen, Lowokwaru and Sukun), with the district within each sub-district being selected through the higher value of LST.

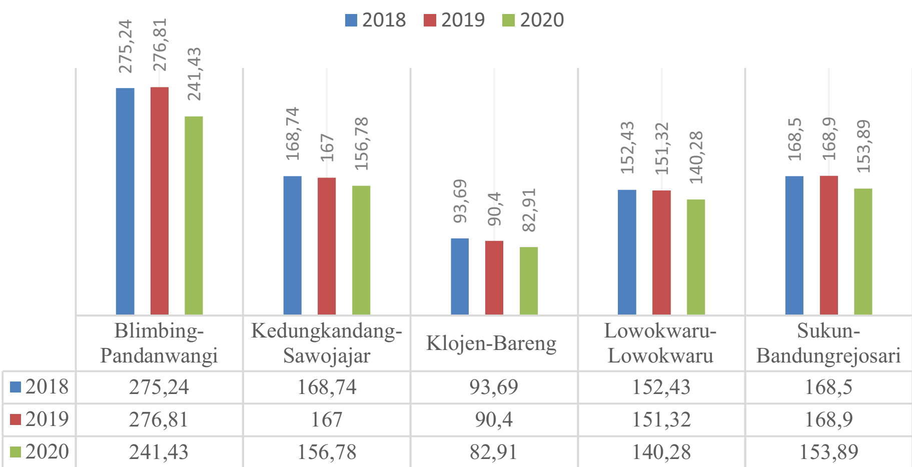


Figure 2. LST Area of Malang City

3.2. Malang LST categories by STI

LST data for Malang City from 2018, 2019, and 2020 were classified using the STI. It was found that only Pandanwangi fell within the "extremely hot" category. The sub-districts categorized as "very hot" include Sawojajar, Lowokwaru, and Bandungrejosari. The remaining category, "near normal", is represented by the sub-district named Bareng.

Table 4. Malang city area LST category by STI

No.	Sub-District	2018	2019	2020	STI	Conditions
1.	Pandanwangi	275.24	276.81	241.43	≥ 2.00	Extremely hot
2.	Sawojajar	168.74	167.00	156.78	≥ 1.50 and < 2.00	Very hot
3.	Bareng	93.69	90.40	82.91	<1.00 and >-1.00	Near Normal
4.	Lowokwaru	152.43	151.32	140.28	≥ 1.50 and < 2.00	Very hot
5.	Bandungrejosari	168.50	168.90	153.89	≥ 1.50 and < 2.00	Very hot

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3.3. Research locations

This discussion aims to provide a clearer depiction of the research site, complete with its coordinates, making it easily traceable using an appropriate web browser. The research location is an example of the LST and STI categories in five sub-districts of Malang City, both planned and unplanned environmental patterns.

Table 5. Research locations

No.	District	STI	Conditions	Research Sample Location	Description Location Characters	Data Mining
1.	Pandanwangi	≥ 2.00	Extremely hot	Pandanwangi-Neighborhood Jl. Simpang Sulfat Sel. III	High-density terrace, neighbor hood village	
2.	Sawojajar	≥ 1.50 and < 2.00	Very hot	Sawojajar-Neighborhood Jl. Danau Bratan I	High-density terrace, neighbor hood village	
3.	Bareng	<1.00 and >-1.00	Near Normal	Bareng-Neighborhood Jl. Bareng Kulon VI	High-density terrace, neighbor hood village	
4.	Lowokwaru	≥ 1.50 and < 2.00	Very hot	Lowokwaru-Neighborhood Permata Jingga	High-density terrace, neighbor hood village	
5.	Bandungrejosari	≥ 1.50 and < 2.00	Very hot	Bandungrejosari-Neighborhood Jl. Klayatan	High-density terrace, neighbor hood village	

The study site encompasses an area neighborhood with identical attributes, which include a densely populated terrace, neighborhood, and village. The specifications for the research site outlined in Table 4 pertain to LCZ category 3, characterized as compact low-rise buildings.

3.4. Greenspace pattern category

The spatial organization of land within residential zones pertains to how land is laid out and utilized in a particular region or urban setting. This arrangement impacts urban planning, the environment's visual appeal, inhabitants' well-being, and various urban functions. The configuration of open spaces can differ according to the land use purpose within a community, encompassing residential, commercial, industrial areas, parks, and green areas. Green space patterns can enhance residents' quality of life, strike a harmonious equilibrium between the environment and urban development, and offer a venue for diverse activities that foster sustainability and enrich urban living experiences. It is shown in the distribution pattern and categories.

Table 6. Neighborhood pattern and Greenspace dispersion and category

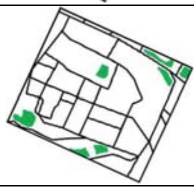
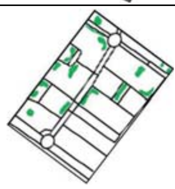
No.	Research Location	Google Earth Map	Neighborhood Pattern	Greenspace Dispersion	Greenspace Category
1.	Pandanwangi-Neighborhood Jl. Simpang Sulfat Sel. III			High	Scattered
2.	Sawojajar-Neighborhood Jl. Danau Bratan I			Low	Concentrated
3.	Bareng-Neighborhood Jl. Bareng Kulon VI			Medium	Concentrated
4.	Lowokwaru-Neighborhood Permata Jingga			Medium	Scattered
5.	Bandungrejosari-Neighborhood Jl. Klayatan			Low	Concentrated

Table 6 indicates that the arrangement of green spaces is categorized into high, medium, and low dispersion patterns. These green space patterns fall into two categories: concentrated and scattered. Using the provided samples, we can compare high green space dispersion and the scattered green space category, low green space dispersion and the focused green space category, and medium green space dispersion with both concentrated and scattered green space categories.

3.5. Configuration of neighborhood pattern and lst performance

A neighborhood pattern encompasses the arrangement, structure, and architectural composition of residential zones within an urban or town setting, encompassing street configurations, housing varieties, land use diversity, and ease of access. In contrast, the greenspace pattern pertains to how green areas are distributed, planned, and made available within an urban landscape, encompassing parks, gardens, natural reserves, and other open expanses. Based on data from Sentinel 2 in 2018, 2019, and 2020, there was a decrease in the earth's surface temperature in 2020. This decrease could be caused by the COVID-19 pandemic that hit and resulted in people staying indoors more to reduce the spread of the virus. In this research, the 2020 LST map was used because even though the values decreased compared to the previous year, they still have relatively similar figures to 2018 and 2019 (see Table 4).

Table 7. Neighborhood pattern and Greenspace dispersion and category

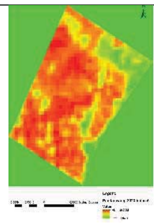
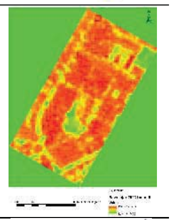
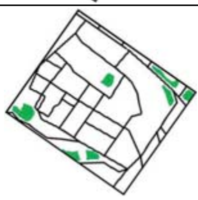
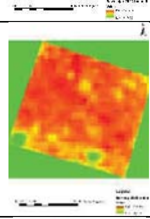
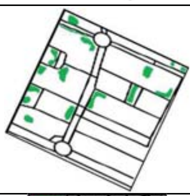
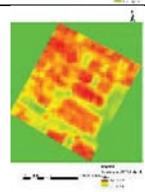
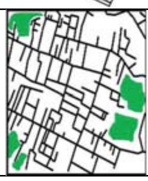
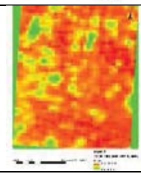
No.	Research Location	Pattern	Green space Dispersion	Greenspace Category	STI and Conditions	LST (year 2020)
1.	Pandanwangi-Neighborhood Jl. Simpang Sulfat Sel. III		High	Scattered	≥ 2.00 Extremely hot	
2.	Sawojajar-Neighborhood Jl. Danau Bratan I		Low	Concentrated	≥ 1.50 and < 2.00 Very hot	
3.	Bareng-Neighborhood Jl. Bareng Kulon VI		Medium	Concentrated	<1.00 and >-1.00 Near Normal	
4.	Lowokwaru-Neighborhood Permata Jingga		Medium	Scattered	≥ 1.50 and < 2.00 Very hot	
5.	Bandungrejosari - Neighborhood Jl. Klayatan		Low	Concentrated	≥ 1.50 and < 2.00 Very hot	

Table 7 explains that the distribution of high green space in the distributed green space category has a high STI value ≥2.00 and is included in the very hot category. It can be noted that high greenspace distribution in the dispersion greenspace category does not have the potential to mitigate UHI. Low green open space distribution with a centralized green open space category has an STI value of ≥1.50 and <2.00 with a very hot category. It proves that the low greenspace dispersion method with the concentrated category has insufficient potential to mitigate UHI. Medium greenspace dispersion with the concentrated greenspace category has an STI value of <1.00 and >-1.00, with a category close to normal. It can be noted that medium greenspace dispersion with the concentrated greenspace category can potentially mitigate UHI.

Configuring neighborhood and greenspace patterns is about designing urban areas with the well-being of residents and the environment in mind. It involves balancing efficient land use, sustainable development, and creating vibrant, livable communities. Effective urban planning considers each neighborhood's unique needs and characteristics, ensuring they are safe, accessible, and enjoyable living places.

4. Conclusion

LST can be used to see potential UHI intensity. UHI phenomenon is becoming an increasingly significant issue in cities globally, as elevated temperatures threaten public health, energy usage, and the overall quality of urban living. Neighborhoods can implement distinct designs and tactics to alleviate the UHI effect.

Designing urban areas with the welfare of residents and the environment as the top priority involves arranging neighborhood and green space patterns. This process necessitates finding an equilibrium between resourceful land utilization, sustainable progress, and the establishment of dynamic, habitable communities. Proficient urban planning considers each neighborhood's distinct requirements and attributes, guaranteeing their safety, accessibility, and desirability as places of residence.

Medium greenspace dispersion in the greenspace concentered category is included in the normal near category and can be a UHI mitigation potential effort. A high distribution of green space in the scattered green space category and a low distribution of green space in the centralized green space category can be a record neighborhood, and green space pattern has not been able to mitigate UHI. It can be done in further research that looks more closely at factors that might influence non-optimal green space distribution patterns and categories in UHI mitigation efforts. For example, the type of greenspace orientation and tree species intensification [27], the extent of green space, morphology, and characteristics of the research area may also influence future research results.

References

[1] Syafitri R, Pamungkas A and Santoso B 2021 *Ser. Earth Environ. Sci.* **764** 012030
[2] Li X and Zhou W 2019 *Urban For Urban Green* **41** 255–63
[3] Hall C, Ave S M and Murry A T 2017 *Sciencedirect* 1–41
[4] Kong F, Yin H, James P, Hutyra L R and He H S 2014 *Landsc. Urban Plan* **128** 35–47
[5] Stewart I D and Oke T R 2012 *Bull. Am. Meteorol. Soc.* **93** 1879–900
[6] He F, Liu L, Huang Y, Bedra K B and Zhang M 2023 *Sustain. Switz.* **15**
[7] Zhang Y, Zhang J, Zhang X, Zhou D and Gu Z 2021 *Sustain. Switz.* **13** 1–14
[8] Kaloustian N and Bechtel B 2016 *Sciencedirect.* **169** 216–23
[9] Lehnert M, Savić S, Milošević D, Dunjić J and Geletič J 2021 *Int. J. Geo-Inf.* **10**
[10] Newman P W G and Kenworthy J R 1996 *Land Use Policy* **13** 1–22
[11] Wolch J R, Byrne J and Newell J P 2014 *Landsc. Urban Plan.* **125** 234–44
[12] Talen E 1999 *Urban Stud.* **36** 1361–79
[13] Ewing R and Cervero R 2010 *Plann. Assoc.* **76** 265–94
[14] Akbari H, Pomerantz M and Taha H 2001 *Sol. Energy* **70** 295–310
[15] Rayan H. Alhawiti D M 2016 *Int. J. Res. Eng. Technol.* **05** 457–66
[16] Hofierka J 2023 *Assoc.* 5–6
[17] Vlassova L, Perez-Cabello F, Nieto H, Martín P, Riaño D and Riva J D La 2014 *Remote Sens.* **6** 4345–68
[18] Kim H-M, Kim B-K and You K-S 2005 *J. Inf. Process. Syst.* **1** 102–6
[19] Kumar K S, Bhaskar P U and Padmakumari K 2012 *Int. J. Eng. Sci. Technol.* **4** 771–8
[20] Athukorala D and Murayama Y 2021 *Remote Sens.* **13**
[21] Sti D, Datenbasis A and Braunschweig S 2009 *Standardized Temperature Index* (STI)
[22] Li F, Wang R, Paulussen J and Liu X 2005 *Landsc. Urban Plan.* **72** 325–36

[23] Lütz M and Bastian O 2002 *Agric. Ecosyst. Environ*. **92** 159–70
[24] Li H, Chen W and He W 2015 *Int. J. Environ. Res. Public. Health* **12** 12889–904
[25] Kimpouni V, Nzila J D D, Watha Ndoudy N, Kokolo Bilongo E C, Yallo Mouhamed S, Kampe J P and Louembe D 2020 *Int. J. Ecol*. **2020**
[26] Kusumadewi T, Husna A Z, Faqihuddin M I, Mutiara E and Kurniawaty P 2021 Proc. Int. Conf. Green Technol. vol 11 (Indonesia: Faculty of Science & Technology, State Islamic University of Malang) p 41
[27] Kusumadewi T, Maryunani, Surjono, Arif Y M, Samudro H, Samudro G and Mangkoedihardjo S 2023 *J. Adv. Res. Appl. Sci. Eng. Technol*. **31** 183–96