MASTER THESIS

Urban Sustainable Cooling Approach to Reduce Urban Heat Islands in the City of Yogyakarta

Double Degree Master Program:
1. Environmental and Infrastructure Planning (RUG)
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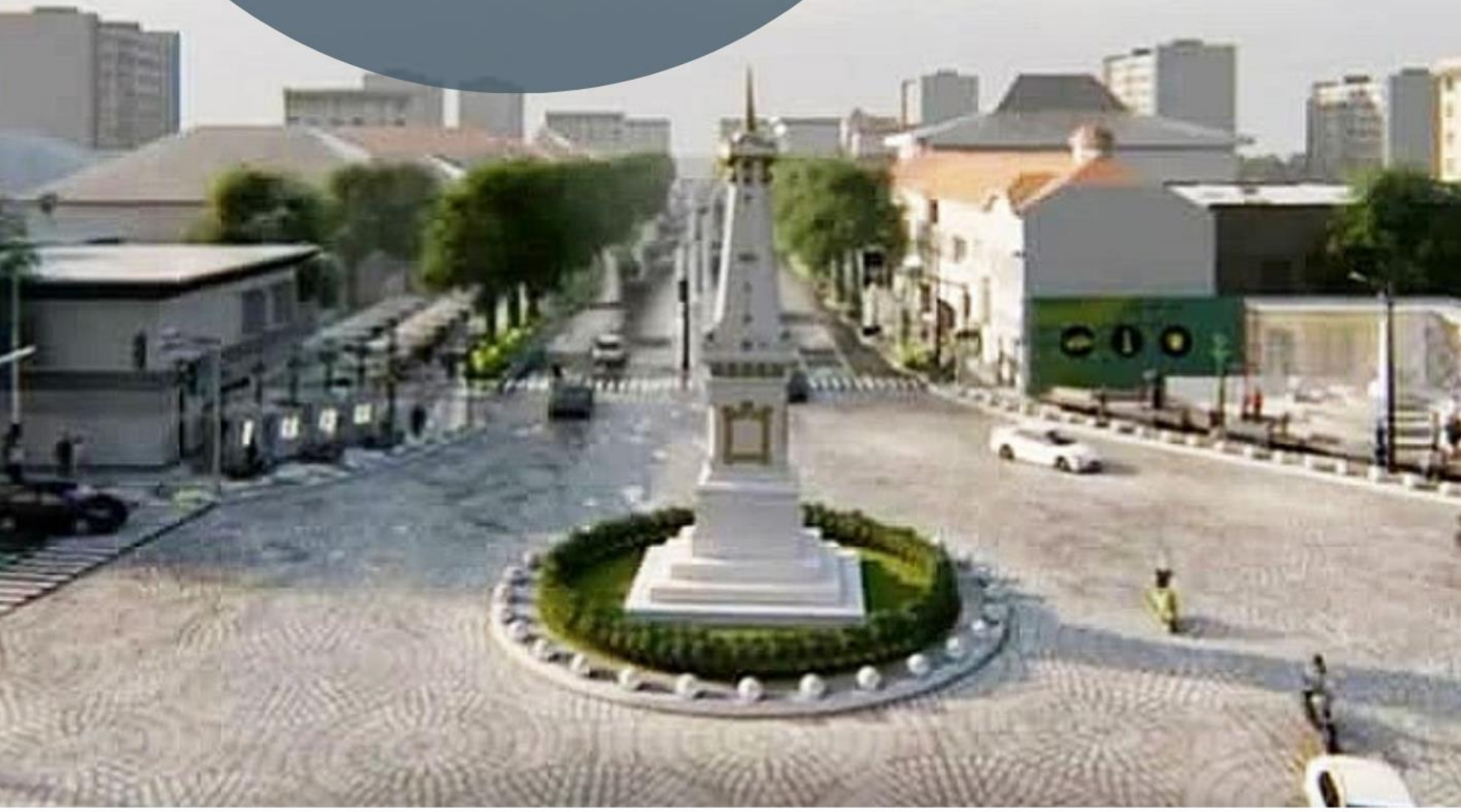

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Contents

List of Figures

List of Tables

List of Abbreviations

KPY	: Kawasan Perkotaan Yogyakarta (Yogyakarta urban area)
RTBL	: Rencana Tata Bangunan dan Lingkungan (Building and Environmental Plan)
LP2B	: Lahan Pertanian Pangan Berkelanjutan (Sustainable Food Farm)
Proklim	: Program Kampung Iklim (Climate Village Program)
RDTR	: Rencana Detail Tata Ruang (Detailed Spatial Plan)
RTRW	: Rencana Tata Ruang Wilayah (Spatial Plan)
RW	: Rukun Warga (hamlet)
RPJMN	: Rencana Pembangunan Jangka Menengah Nasional (National mid-term development plan)
RPJMD	: Rencana Pembangunan Jangka Menengah Daerah (Regional mid-term development Plan)
Musrembang	: Musyawarah Perencanaan Pembangunan (Participatory Forum)

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Abstract

UHIs are one of the challenges that has arisen from urbanization in Yogyakarta. They have changed the landuse proportion to be dominated by built-up areas rather than vegetated areas. This research offers the Urban Sustainable Cooling Approach as a means to reduce the impact of the UHI. This approach is formed from three concepts: UHI, Sustainable Cooling Capacity (SCC), and Spatial Planning. It is expected that this approach can create comprehensive understanding of the condition in Yogyakarta allowing for the formulation of the spatial planning policies solution. The methods used combine quantitative and qualitative analysis. Quantitative analysis was conducted through the analysis of information on UHI distribution and SCC, while qualitative analysis was conducted through the analysis of the data from interviews on spatial planning policies. The UHI identification (first component) explains the surface temperature and UHI intensity distribution. The UHI distribution in Yogyakarta is dominated by high UHI intensity. SCC measurement (second component) utilizes green urban infrastructure to cool the environment. The result of this measurement shows that Yogyakarta is predominantly of low cooling capacity. However, there are still areas that have potential for cooling capacity. The last component of USCA is the spatial planning policies solution which uses the concepts of urban sustainability and sustainable cooling. This component is divided in three solutions: technical policies, strategic policies, and partnership. The best spatial planning policies solution, as determined from the interviews, is from technical policies and should be implemented by expanding green areas and forming living labs.

Keywords: UHI, Sustainability, Sustainable Cooling, Green Urban Infrastructure, Spatial Planning

1. INTRODUCTION

1.1. Background

In recent decades, many parts of the world have begun facing climate change, including Indonesia. Sub-tropic countries and the north pole may be receiving the greatest impact from this phenomenon. It has caused ice at the north pole to start melting and changes in the hydrological cycle balance. This hydrological or water cycle is the natural recycling water system on Earth that causes the water from the earth to evaporate due to solar radiation, condense, precipitate, and then fall and stream on the Earth's surface and underground. It is expected that this cycle will be affected by the global warming as a result of the increase in global temperature. In Indonesia, climate change effects can be seen from various aspects, including differences in the length of seasons, extreme temperatures, and environmental disasters (floods, desertification, and fires). Big cities in Indonesia, based on data from the BMKG, experienced their hottest temperatures in 2019 and this has been caused by human activities.

Globally, more people live in urban areas than rural areas, with 54 % of the world's population living in urban areas in 2014. As the world continues to urbanize, sustainable development challenges will be increasingly concentrated on cities. In cities, the effect of climate change might be even more extreme because of population growth. The UN Sustainable Development Goals have precisely summarized this concept with goal 11: "Make cities inclusive, safe, resilient and sustainable" (MEA, 2017). A sustainable city can be identified from its environmental aspects or objective measures, such as health and social care, home environment, opportunities for recreation/leisure activities, air pollution, noise, traffic density, climate, transport facilities, and opportunities for acquiring new information and skills (Moser, 2009). One of the most essential aspects influencing the quality of urban life is the microclimate (Rehan, 2014). The urban climate can affect the local temperature while the temperature itself depends on land surface configuration, such as the existence of buildings and vegetation. Built areas in cities have high thermal conductivity thereby saving more thermal energy than rural areas (Husna, et al., 2018). This in turn causes urban areas to have a slow rate of cooling of the surface temperature at night. Since there are more buildings in the city, the green areas have less impact on increasing the albedo and decreasing the evapotranspiration.

Howard, in Miner, M.J. et al (2017), explains that the urban temperature has been recognized as a combination of thermal mass and albedo (surface reflection of radiation) effects, which contributes to elevated temperatures in urban areas, commonly referred to as "urban heat islands" (UHIs). Research about urban heat islands (UHI) is important, considering the rising temperature in urban areas causing uncomfortable living conditions in neighborhoods. This discomfort leads to decreased work performance and physical activities, poor behavior, and deterioration of social activities (Steeneveld et al, 2018). It has become the main concern for urban planners in the understanding of spatial distribution patterns which have an impact on the emergence of urban heat islands.

Many studies have identified adverse effects of UHIs. These effects lead to increased temperatures of cities, which then contribute to global warming, initiate storms, or precipitation events, increase energy demand of cities, and contribute to heat-related mortality (Deilami K. et al., 2018). On the other hand, the United States Environmental Protection Agency (USEPA) has explained that, although the majority of the effects are negative, some may actually be beneficial, such as lengthening of the plant-growing season. However, the USEPA has said that UHIs will elevate emissions of air pollutants and greenhouse gases and impair water quality. The effects of this will be devastating in the summertime, especially in the tropical and arid regions (Nuruzzaman, 2015). Tropical regions like Indonesia, which experience anthropogenic heat, will have more and more increases in temperature in the years ahead.

This heat problem will require the development of guidelines and planning policies which can manage the local climate.

One of the strategies to reduce the occurrence of UHIs is through the implementation of 'cool city': sustainable urban solutions for the city of tomorrow that depend on the application of the principles of urban heat management by a set of planning actions (Rehan, 2014). Rehan (2014) has mentioned that these strategies include identifying opportunities for urban greening, making buildings more energy-efficient, and following the concept of the urban green corridor, which contributes to the improvement of urban environmental quality. Another strategy for reducing the occurrence of UHIs is Green Urban Infrastructures (GUI) which can contribute to the reduction of temperatures and the associated health risks. GUI presents different typologies and consequently different key components, such as soil cover, tree canopy cover and shape, which determines capacity to provide cooling.

The cool city concept can be applied to urbanized areas by utilizing GUI consisting of green spaces and built systems. Green spaces, for example parks, gardens, green roofs, and urban forests, help improve the quality of the air, reduce noise, and mitigate extreme summer temperatures or peak flood events. They also provide non-material benefits, such as recreation, education, cultural and aesthetic values, and contribute to social interactions (Burkhard and Maes, 2017). Vegetation provides shade and thermal insulation that keeps the interior cool, and manages noise and air pollution (Roth, 2013; Filho et al, 2017). This positively impacts on the health and wellbeing of citizens through reduced mortality and morbidity, increased comfort and productivity, and reduced need for air conditioning (Sharp et al, 2020). Importantly, this is in line with efforts to achieve the 11th UN SDG goal of building sustainable cities where all citizens live a decent quality of life, form a part of the city's productive dynamic and create shared prosperity and social stability without harming the environment.

Nowadays, land for vegetated areas is limited and this affects the spatial pattern of urbanized areas and cause the increased surface temperature. Wicahyani et al (2014) have shown that Yogyakarta, a city in Indonesia, is dominated by built-up areas (90%). Meanwhile, outside the urban area, space is dominated by vegetation. This condition reflects the different level of urban and rural growth. The rapid growth of built infrastructure represents the urban growth due to urbanization. This growth causes urban sprawl, development intensity, and de-vegetation which is associated with population growth and can generate more UHIs. The magnitude and extent of UHIs has been found to be correlated with the population size of cities, indicating the significant impacts of urban growth on the UHI problem in Asia (Tran et al., 2006).

Yogyakarta, as one of the big cities of Indonesia, is facing climate change. As the city becomes more urbanized, the buildings and population also become denser, which thereby reduces the availability of open spaces that could be turned into green areas. Marwasta (2016) has stated that the more intensive the physical development, especially that occurring in the suburbs, the more degraded residential comfort is. One important aspect of comfort is daily temperature and humidity levels. In 2013, Wicahyani et al found that Yogyakarta City is dominated by temperatures ranging between 30-35 °C in built up or settlement areas. The study of Vina et al (2018) determined that the average temperature of Yogyakarta is 34.41 °C. The research was followed by Zahro et al in 2018 who showed the highest temperature range in 2015 was 28.99 - 41.85 °C, while in 2017 the highest temperature range was 24.72 - 37.54 °C. These findings show that temperatures are high and dynamic in Yogyakarta city and, thus, spatial planning intervention is needed to deal with UHI consequences.

1.2. Scientific Relevance

The concept of urban sustainability is widely used in the context of climate change solutions in cities based on the 11th SDG goal. While the concept of sustainable cooling to support sustainable cities was only recently introduced, in the context of global warming, it can be applied as part of the cool city. As cities get warmer, we need a solution that combines concepts of urban sustainability and sustainable cooling solutions. Rehan (2014) has devised Urban Heat Island (UHI) mitigation strategies that consider cooling and temperature reduction in cities at the level of urban design, which is used by planners and translated to spatial planning policies. An approach to estimate the cooling capacity provided by GUI has been found by Zardo et al (2017) which can help urban planners formulate spatial planning policies. Bartesaghi Koc et al (2018) has recommended focusing more on developing countries with limited resources to provide green areas that could reduce the effect of UHI. These are the countries that are experiencing significant urbanization and population growth and are severely affected by heatwaves, droughts, and bushfires. Another recommendation from C. Bartesaghi Koc et al (2018) is focusing on tropical climates since vegetation, irrigation, and cooling requirements in these climates are substantially different to those of temperate climates. Knowledge on sustainable cooling cannot be generalized or applied in one format to different countries, or even climate zones, without taking into consideration conditions and context. This research elaborates on the above statements of Bartesaghi Koc et al (2018) and Zardo et al (2017) that more focus should be on (sustainable) cooling in tropical climate zones, especially in the urban areas of Indonesian Cities (Yogyakarta). There is a research gap in sustainable cooling which is needed for the understanding of the urban sustainability system of developing countries in tropical climate zones to reduce UHI.

Sustainable cooling in developing countries can help alleviate poverty, reduce food loss, improve health, manage energy demand, and combat climate change (World Bank, 2019). Asian mega cities, particularly in India, China, Bangladesh, Pakistan, and Indonesia, are particularly at risk from the effect of the UHI phenomenon (World Bank, 2019). Governments can incorporate sustainable cooling in their climate pledges (nationally determined contributions) and ensure that sustainable cooling considerations are included in energy, urban planning, transport, agricultural and health service projects, among others (UN environments, 2019). Several cities in Indonesia, such as Jakarta and Surabaya, with the support of international funds, are trying to implement a sustainable cooling system through developing the necessary market infrastructure and financing mechanisms. Support is also provided for overseeing the preparation of policies and regulations for deploying sustainable cooling. Thus, the sustainable cooling concept in urban areas requires a land management system which includes vegetation and spatial planning innovation.

1.3. Research Objective and Questions

As described in the previous sections, the diverse effects of UHIs can be reduced by increasing GUI and managing planning interventions. The aim of this study was to develop an approach of urban sustainable cooling to reduce UHIs in the city of Yogyakarta. This approach can be described as an approach to reduce UHIs which combines physical characteristics configuration and spatial planning. Physical characteristics configuration consists of shade, evapotranspiration, albedo, and distance, and is needed to measure the sustainable cooling capacity of GUI in the urban area. In other words, the capacity can show the green area conditions required to reduce existing UHI. Then, using spatial planning policies a solution is recommended, based on the physical characteristics configuration and/ or the sustainable cooling capacity, which also can include sectoral policies. The spatial planning of Yogyakarta was discussed in detail with specific stakeholders, especially the government planners in the related sectors.

Following on from the background and scientific relevance described above and the objective of this research, the research questions have been formulated as follows:

How can the urban sustainable cooling approach be used to reduce UHI in the city of Yogyakarta?

In order to answer this main question, the following secondary questions have been established to show the stages of the research.

1. How can the urban sustainable cooling approach be theoretically understood in the context of Yogyakarta?
2. What is the distribution of the current intensity of UHI in the City of Yogyakarta?
3. What is the condition of the current physical characteristics configuration which can produce sustainable cooling capacity to reduce the UHI in the city of Yogyakarta?
4. How could spatial planning policies be used to reduce the UHI in the city of Yogyakarta?

1.4. Structure

Chapter 2: Literature Review

This chapter will describe the theories and concepts used in this research. It also contains the theoretical framework, which has been well-informed by, and critically reflects on, the related literature on Urban Heat Islands, green urban infrastructure, and urban cooling. Additionally, a conceptual model of these theories is presented which was used to guide the empirical work. This model then became the foundation for the methodological approach outlined in chapter 3.

Chapter 3: Methodology

This chapter explains the methodology of this research, including study design, data collection, research methods, data analysis, ethical issues, and limitations. The city of Yogyakarta, as the case study of this research, will also be explained.

Chapter 4: Spatial Analysis and Results

This chapter explains the results and analysis of the Urban Sustainable Cooling Approach which consists of UHI condition and sustainable cooling capacity. It also explains the focused sub-district that resulted from the analysis and interview.

Chapter 5: Spatial Planning Policies Intervention Solutions

This chapter presents the third component of USCA. It begins with the invention of relevant spatial planning policies which will be used to support USCA. It then explains the findings from the interview results and analyzes them based on the principles of urban sustainability and sustainable cooling. Finally, it proposes an alternative solution from the interviewees that has potential to improve existing spatial planning policies in the future.

Chapter 6: Conclusion and Discussion

This chapter concludes the research and offers suggestions for governments and discussion of further research opportunities.

2. LITERATURE REVIEW

This chapter will describe the theories and concepts used in this research which relate to Urban Heat Islands (UHI), Green Urban Infrastructure (GUI), urban sustainable cooling, and spatial planning policy. The concepts have been structured in a conceptual model which became the theoretical framework of the research.

2.1. Urban Heat Islands

This sub-chapter will explain the concept of UHIs, the formation of UHIs including the contributing factors, and the occurrence of UHIs in Indonesian cities, particularly in Yogyakarta.

2.1.1. Definition of UHI

There are various definitions of the UHI phenomenon. Deilami et al (2018) stated that Urban Heat Island (UHI) is a phenomenon when urban areas experience a higher temperature than their surrounding non-urban areas and is considered a critical factor contributing to global warming, heat related mortalities, and unpredictable climatic changes. The physical processes refer to the interactions between these parameters: decreased urban albedo, increased thermal mass per unit area, increased city roughness, increased anthropogenic heat released from buildings and vehicles, and decreased evaporative areas (fewer trees and more impervious materials) (Taha et al. 1988; Ryu & Baik, 2012). When the sun's reflectivity (albedo) of the urban surface decreases because of the urbanization and mobilization, the heat is absorbed which causes the thermal increase. The heat is trapped in the various heights of buildings which dominate the area. Streutker (2002) defined UHI as the temperatures of the central urban locations that are several degrees higher than those of nearby rural areas of similar elevation. UHI represents a significant increase in the ambient temperature of an urban area that decreases as the landscape changes from dense buildings to a more vegetated area, like that shown in the illustration of Figure 1.

Figure 1. Landscape changing
Source: USEPA (2008)

There are two common types of UHI based on USEPA (2008): surface UHI and Atmospheric UHI. Surface UHIs are typically present day and night but tend to be strongest during the day when the sun is shining. Meanwhile, atmospheric UHIs are often weak during the late morning and throughout the day and become more pronounced after sunset due to the slow release of heat from urban structures (Van Hove et al., 2011). The performance of each UHI results in various temperatures, as depicted in Figure 2, depending on the landscape surface. Thus, surface temperature often called Land Surface Temperature (LST). It can also mean how hot the surface of the Earth would feel to the touch in a particular location (NASA, 2017). This research focuses on surface UHIs which measure LST because they reflect the similar surface condition of land use composition.

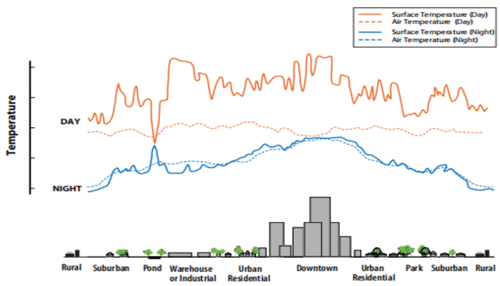

Figure 2. Variations of Surface and Atmospheric Temperatures
Source: USEPA, 2008

Nowadays, LST are easily identified using thermal infrared imagery to see the distribution of UHI phenomena on the surface. UHIs are more representative of the spatial variation of LST than air temperature because surface temperatures exhibit a much greater spatial variation than the concurrent air temperature (Streutker, 2002). Additionally, urban topography can cause the same effect because the surface relief has different radiative (brightness) and thermal (emissivity) characteristics. Realistically, in tropical cities, LST data can only be derived for the dry season (September – April) due to cloud-coverage problems during the wet season (Tran et al., 2006).

2.1.2. Parameters that produce UHIs in Indonesian Cities

The intensity of the UHI phenomena varies mainly as a function of local topographical characteristics, synoptic weather conditions, urban characteristics like density, form and landuse-landcover, anthropogenic heat released, materials used, and view factor (Mihalakakou et al., 2002; Santamouris et al, 2014). Other factors of UHI intensity reported by Li et al (2020) are building density (gross building volume per unit area, calculated as the product of total building plan area, and average building height within an urban area unit). High UHI intensity can trigger LST which can be caused by humans through such things as city design and structure and total population, but can also be caused by factors beyond the control of humans, such as season, cloud cover, and atmospheric dynamics (Rizwan et al., 2008; Wicahyani et al., 2013). All these studies show that the factor which strongly influences the intensity of UHI is landscape configuration of urban areas. Landscape configuration is the distribution, size, and abundances of patch types represented within a landscape (IPBES, n.d). The general term that can be used here is landuse-landcover which shows the spatial pattern and composition of the urban surface covers. The example of landuse pattern is conservation and/or cultivation areas, while composition represents the allocation distribution of each area.

A UHI study conducted in and around Jakarta city by Tursilowati, et al (2012) aimed to see the correlation of land cover changes and urban climate. This was carried out by looking at the influence of land use change on the UHI phenomenon in Jakarta city between 1989 and 2002. During this period, vegetated areas were en masse converted to non-vegetation areas. Results then indicated a correlation between land use change and increasing surface temperature in Jakarta especially in industrial and residential areas. Lower temperatures were found in more vegetated areas and waterbody areas. Another study of UHI conducted in Makassar City, Indonesia, showed that there is relationship between the distribution of land use with temperatures. This study of Maru et al (2015) explained that UHIs occur due to higher temperatures in the city center as a result of the density of the buildings, reduction of green areas, and high anthropogenic activity in the urban centers. A further study by Permatasari et al (2019) compared the UHIs of Jakarta. The results of this study indicated that UHI are caused by high population and the activities of citizens in the city. A higher population triggers the need for more housing and other buildings with different functions which results in built up areas dominating the landscape. Thus, the limited green areas cannot provide an adequate coolingeffect and stimulate UHI. The difference in this study from previous studies is that the vegetation index and building index were used to identify the vegetation and building distribution. In other words, the study focused more on the impact of green areas and built-up areas on LST.

Other studies mention that urban design can relate to urban temperature through parameters. The parameters which influence the urban temperature, according to Rizwan et al (2008) in Wicahyani et al (2014), are both factors controllable and uncontrollable by humans. The controllable factors consist of the population and city design and structure, while the uncontrollable factors are atmospheric dynamics. This study has been strengthened by a study from Zahro et al (2018). Their work showed a strong relationship between greenness and the occurrence of UHI phenomenon or LST in Yogyakarta City. More precisely, they found that LST decreases almost 1° C per kilometer from the city center and gets lower at crop field or vegetated land. This indicates that the design and structure of Yogyakarta City is to meet human needs by reducing human needs.

In general, the forming of UHI in many countries which produce high LST is characterized by one key cause: urbanization. Urbanization leads to an increasing population and changes the landscape of the city and also the land structures, such as transportation networks. Simply, there is a relationship between the population and temperature in the city center (Karl et al., 1988; Bulut et al., 2007). The city must accommodate the diverse needs and interests of people, leading to changes in the function of the land. The city serves as a center of development activities and thus continues to require more space or buildings with different functions. Some open spaces and greenspaces are replaced by built up areas based on the people's needs, and with the thought process that these spaces can be compensated for in sub-urban and even rural areas.

LST differences between inside and outside urban areas reflects the UHI intensity of a city. Urban–rural LST differences were identified by Heinl et al (2015) primarily through the use of Normalized Difference Vegetation Index (NDVI), together with solar irradiance and land use. NDVI is the fractional vegetation cover in a certain area obtained from imagery while solar irradiance reflects the output of light energy from the entire disk of the Sun, measured at the Earth (NASA, 2008). The solar irradiance can also be obtained from the imagery as brightness value. The average difference found was 4.2 K, indicating that the presence of vegetation creates a different surface temperature. Different surface temperatures (LST) affect surface UHI intensity during the day which can reach 10-15 °C (Wardana, 2012). The differences can vary between cities and the cities have different preferences on how to mitigate the UHI.

Based on some studies in Indonesian cities and in Yogyakarta particularly, the most important parameter contributing to the reduction of the UHI phenomenon impact is vegetated areas. High urban vegetation presence can significantly mitigate the LST for high density low rise residential areas (Li et al., 2011). Urban vegetation cover has various physical forms (i.e. parks, green rooves, yards, urban forests) and spatial distribution. When more vegetation is incorporated during urban development, land surface roughness increases, which promotes the transfer of heat to the air and the convection of heat away from the ground (Bonan, 1997; Mackey et al., 2012).

In the following section, a solution to the UHI problem is formulated based on various concepts. It incorporates the use of green areas and spatial planning to become the urban sustainable cooling approach. The green areas can mitigate the UHI through provision of sustainable cooling capacity. Spatial planning can provide a solution through the expansion of green areas with consideration of the distribution of UHI intensity and sustainable cooling capacity. This solution offered by governmental planners was classified as technical, strategical, and partnership.

2.2. Urban Sustainable Cooling Approach

This sub chapter will explain what constitutes the urban sustainable cooling approach and discuss various implementation concepts in European and African cities. The content consists of several key components which have helped to shape the urban sustainable cooling approach: urban sustainability, sustainable cooling, Green Urban Infrastructure (GUI), sustainable cooling capacity, and spatial planning.

2.2.1. Urban Sustainability

The goals of urban sustainability principally focus on lowering urban carbon footprints and reducing greenhouse gas emissions by targeting resource and energy consumption in the construction, operation, and maintenance of the urban built environment (Radzi, 2018). Urban sustainability has also been defined as the process by which the measurable improvement of near-and long-term human well-being can be achieved through actions across environmental (resource consumption with environmental impact), economic (resource use efficiency and economic return), and social (social well-being and health) dimensions (National Academy, 2016). According to Lehman and Droege (2008), there are eight key principles for urban sustainability: 1) low-rise, high density compact communities; 2) functional mix with local and culture-specific uses; 3) eco-buildings which better harness sun, daylight, wind, rain; 4) integration and reuse of existing buildings with elements of local identity; 5) fine grain, with attention to architectural detail and smallness; 6) high quality public space networks; 7) reliance on public transport and use of bicycles; and 8) variety of urban greenery, integrated in the building. Based on these principles, the main urban sustainability principle which will be used in this research is environmental actions to lower urban carbon footprints and reduce greenhouse gas emissions. The actions relate to the *urban green area* and *the policy* which can reduce UHI.

The circles of the sustainability displayed in the figure below provide a relatively simple view of the sustainability of a particular city, urban settlement, or region (James, 2015). The circle is a toolset to understand the condition and the quality in the cities based on four sectors: economics, ecology, politics, and culture. Each sector consists of the related detail aspects to assess the sustainability of the city. This research uses urban sustainability from an ecological or environmental perspective. The environmental perspective does not depart from social and economic development, but the natural resources have high priority. The 11th SDG goal also states that to make cities inclusive, safe, resilient, and sustainable we must address urban sustainability and include the following cross-cutting issues of affordable housing, sustainable transport, human settlement planning and management, green and public spaces, and support for positive economic, social and environmental links between urban, peri-urban and rural areas (United Nations, 2018; Verma & Raghubanshi, 2018). Urban sustainability in this research is focused on *an environmental perspective* which addresses the issues of *cross-sector* in urban area. The issues will be approached with *spatial planning as a policy solution*.

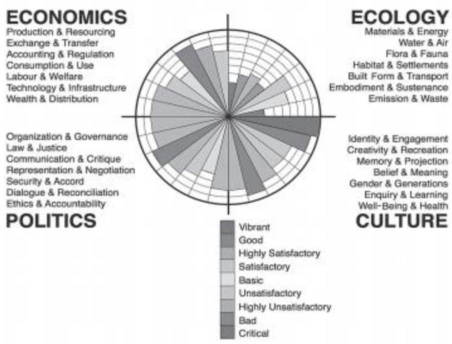

Figure 3. Circles of Sustainability
(James, 2014)

Building an approach to achieve urban sustainability can be carried out by combining the principle of urban sustainability by Lehman and Droege (2008) and the circle of urban sustainability, which focuses on the environmental perspective. This combination produces a classification that is in accordance with Indonesian conditions. Thus, when these concepts are considered in Indonesian spatial planning implementation, they can be classified into three characteristics: 1) technical policies, 2) strategic policies which adopt the 8 principles of urban sustainability, and 3) partnership as implementation with multisector stakeholder engagement and public involvement.

2.2.2. Sustainable Cooling

The term sustainable cooling was inspired by SDG7. The SDG 7th goal promotes sustainable cooling which ensures access to affordable, reliable, sustainable and modern energy for all. Sustainable cooling itself can be described as green, clean, efficient and climate friendly and it is an issue of equity and a service that must be delivered to all to achieve SDG7 (SEforall, 2020). Although this term is more focused on technology and an energy perspective, the principle can be applied to this research because it supports the cooling actions from green areas. The principles of sustainable cooling solutions consist of protect, reduce, shift, improve, and leverage. Each principle is described in the following table, with an emphasis on those outlined in the green row. The principles of reduce and leverage are considered suitable for the case of Yogyakarta as they utilize green areas and spatial planning as cooling solutions.

Table 1. Principles of Sustainable Cooling

Principle	Aspect	Description
Protect	affordability, safety, and reliability	reduce the vulnerability of people, businesses and governments to heat by using cooling solutions that are affordable, safe, and reliable
Reduce	passive cooling, urban planning, building design, nature	reduce the need for active or mechanical cooling solutions, and include using planning and design to reduce or even avoid the demand for active cooling
Shift	cooling approach, system type, refrigerant type, energy source	a change of approach can deliver energy or emissions savings, such as through the use of renewable energy, natural refrigerants or conservation measures
Improve	equipment efficiency and operation efficiency	pure efficiency measures to achieve the same cooling service while using less energy (i.e. not using energy conservation measures)
Leverage	partnership, cooperation, and collective impact	support the achievement of a collective impact that is greater than the sum of individual efforts through cooperation and collaboration

(Source: SEforAll, 2019)

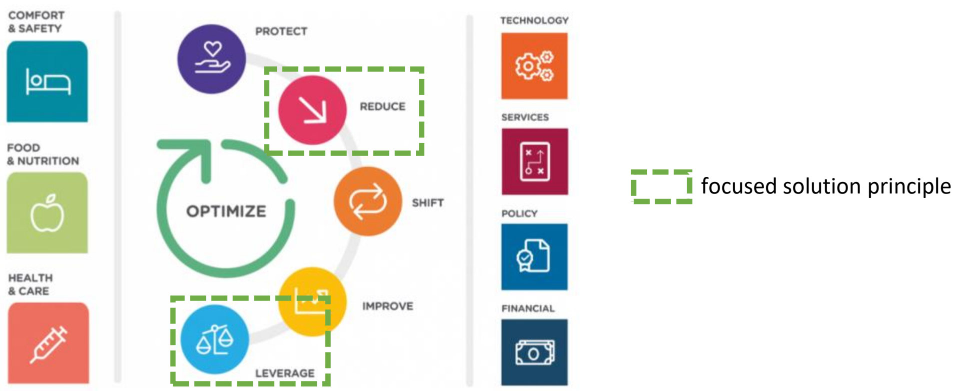

Figure 4. Cooling needs, solution approach, and solution pillars
Source: SEforAll, 2019

The sustainable cooling principle reduce can be found in several building design perspectives and has been explained by Vorster and Dobson (2011) who conceptualized four alternative-energy cooling systems. *Reduce* can be integrated in the spatial planning policies, especially in building plan, and considered in the lowering of heat gain of buildings by utilizing such features as roof-ponds and roof-spraying (Vorster and Dobson, 2011). The principle of *leverage* can be seen in the actors' action. Cool Coalition - an example of a global multi-stakeholder network - has a similar concept about clean cooling as the *leverage* principle. Clean cooling starts with what people can do today to reduce demand for unsustainable cooling and deliver incremental efficiency improvements in cooling systems (Shecco, 2020). The actions emphasize more on partnership and collaboration, such as information and knowledge sharing, implementation transfer, as well as finance and investment (Cool Coalition, n.d.).

2.2.3. Green (Urban) Infrastructure

Green infrastructure has commonly been defined as the interconnected network of natural and semi-natural features, including greenspaces, trees, water bodies, green roofs and vertical greenery, that provide a wide range of ecosystem services (ES), one of which is the regulation of climates (Benedict and McMahon, 2006; European Environment Agency, 2011; Mell, 2010; Naumann et al., 2011; Roy et al., 2012; Bartesaghi et al, 2018). The central idea behind Green Infrastructure is the understanding of the physical non-built-up environment as an infrastructure capable of delivering a wide variety of benefits to society, including the ability to preserve biodiversity, to provide food, feed, fuel and fiber, to adapt to and mitigate climate change and to contribute to enhanced human health and quality of life (Slätmo et al., 2019). The European Commission defines GI as a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services, such as climate mitigation and adaptation. Thus, it can be said that GI is an attempt to balance the reduced carrying capacity of the ecosystem, especially the impact of UHI. GI can provide many positive impacts for human and the surrounding environment.

In the urban area, GI is known as Green Urban Infrastructure (GUI) and includes all types of green spaces, from city parks to rooftop gardens and tree-lined streets to natural features containing water, such as lakes, rivers, wetlands and coastlines, which are sometimes also referred to as 'blue spaces' (European Green Capital, n.d.). These all count as public facilities that are supported by small scale greenery from the micro level (households). They can also reduce dependence on 'grey' infrastructure that can damage the environment and biodiversity and often be more expensive to build and maintain (European Green Capital, n.d). GUI promotes multifunctionality of areas that are more sustainable as they take advantage of more environmental features. They also provide many benefits to human society, including climate change mitigation and adaptation in urban areas and playing an important role as an urban planning tool to satisfy the environmental, social, and economic needs of urban areas (Sturiale and Scuderi, 2019). A good example of this multifunctionality is provided by the GUI of a green roof, which reduces storm water run-off and the pollutant load of the water, while also decreasing the urban heat effect, improving the insulation of the building (European Commission, 2012).

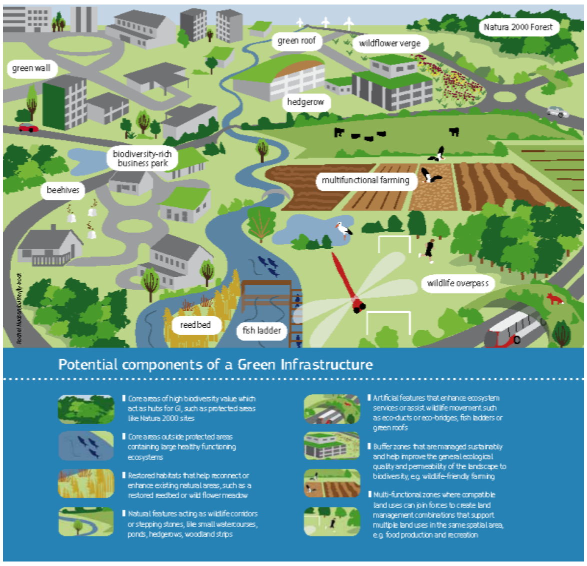

Figure 5. Components in GI
(Source: EEA, 2015)

The benefits of green infrastructure are widely recognized, yet the actual design, delivery, and maintenance of green infrastructure on the local level are found to be difficult (Jerome, Mell, & Shaw, 2017; Willems et al, 2020). In the case of Yogyakarta City, policies and power are needed to regulate the green areas in order for them to function as heat reduction. The reduction of heat will improve one of the ecosystem services - climate regulation. In the case of microclimate regulation in the city, the considered ecosystems are usually green urban areas (Burkhard and Maes, 2017).

2.2.4. Sustainable Cooling Capacity

Based on the outlined concepts of sustainable cooling and green urban infrastructure, the sustainable cooling capacity can be defined as a combination of those concepts. The sustainable cooling capacity is the capacity of green areas to provide cooling effects for surrounding areas, especially areas that experience UHI. Since UHI phenomena are mostly affected by land use change, the sustainable cooling capacity of the areas also varies based on the land use/ land cover (LULC) classification. LULC represents the composition and pattern of built-up areas and vegetated areas which is important for the identification of the sustainable cooling capacity. In this case, based on data from the Environmental Agency of Yogyakarta City on land use combined with detailed green areas, this city has 58 types of LULC. These types consist of vegetated and non-vegetated areas which can be seen in detail in Appendix A.

Many studies have found that cooling capacities are produced by GI. Based on USEPA, the cooling effect for urban environment comes from the shade of trees and smaller plants such as shrubs, vines, grasses, and ground cover. Trees and vegetation help cool urban climates through shading and evapotranspiration. Shading is provided by the tree canopy - the leaves and branches – and this reduces the amount of solar radiation that reaches the soil surface. It also reduces heat transmission to buildings and the atmosphere. Evapotranspiration is the combination process of transpiration (plants absorbing water) and evaporation (the water from the soil and plants changing into gas in the air). This process cools the air by using the heat from the air to evaporate the water. This cooling impact is evident in building environments surrounded green areas (Geneletti et all, 2020).

Cooling capacity can be assessed by several factors, such as shading, evapotranspiration, albedo, and the size of GUI. There is a linear relationship between the presence of tree cover and shading (Potcher et al., 2006; Zardo et al., 2017). Zardo et al (2017) have also stated that evapotranspiration can be assessed from tree canopy and soil cover, and that it is different for each climatic region. The factors of sustainable cooling capacity will be outline din the following sections.

Shade

Most studies investigated the air temperature within parks and beneath trees and are generally supportive of the fact that green sites are cooler than non-green sites (Bowler, et al., 2010). A 6-ft to 8-ft (1.8-m to 2.4-m) deciduous tree planted near home will begin shading windows in the first year (Energy.gov, n.d). Placement of trees is very important because it can ensure that trees shade the area most critical in lowering internal temperatures, and shade them at the most critical times of the day (Akbari, 2009). When placing trees in dense urban areas there needs to be consideration of any threats to humans or property. In this study, the shade characteristic used is that of tree shelter (for trees >2m) and is of the LULC vegetation classification. Its value is within the range of 0 and 1, with a higher value meaning the more vegetation or trees shading the area.

Evapotranspiration

Evapotranspiration (ET) is the process by which plants release moisture in the form of water vapor and it requires energy from solar radiation or warm air (Akbari, 2009). Urban areas tend to have less evapotranspiration relative to natural landscapes, because cities retain little moisture (USEPA, 2008).

Vegetation ET has great potential to reduce urban temperatures by 0.5 to 4.0°C (Qiu et al., 2013). Evapotranspiration is determined by multiplying the reference evapotranspiration ($ET0$) and the crop coefficient (Kc, related with the LULC type), and then dividing this by the maximum value of the $ET0$ in the area of interest ($ETmax$).

$$ETI = \frac{K_c \cdot ET0}{ET_{max}}$$

In this research, the ET0 was obtained from Walidatika (2017) who researched different characteristics of vegetation and different evapotranspiration values in the summer season (along with the thermal image recorded in May). The ET0, in this research uses the average value, 5.897, because this represents the GUI vegetation. The value for Kc is based on the FAO table. This associates the LULC with the categories of trees in the FAO table, for example, the alun-alun or town square is associated with turf grass and private canopy is associated with tropical fruit. The categories which remain the same are rice fields and moor.

Albedo

The albedo, α, is the reflectance of a material integrated over solar wavelengths (Phelan et al, 2015). Materials which have light color reflect more sunlight has and so have higher albedo than dark colored materials. The unreflected sunlight energy will be converted into heat energy and increase the temperature of the surrounding area. Thus, materials which are highly reflective can maintain lower surface temperatures and be a viable solution to the mitigation of UHI (Morini et al., 2019).

The albedo value given to land cover classification is based on albedo table from Setiawan (2006), which contains both minimum and maximum values. This information needs to be reclassified based on the LULC types of the City of Yogyakarta.

Table 2. Estimation of Albedo Value per LULC

LULC	Albedo (unitless)		
	Min	**Max**	**Mean**
Forest	0.043	0.056	0.051
Agroforest (Rubber)	0.048	0.058	0.052
Monoculture (Rubber)	0.051	0.065	0.053
Palm oil	0.052	0.070	0.060
Shrubs	0.057	0.077	0.064
Ferns	0.057	0.077	0.067
Fields	0.066	0.090	0.077
Settlement	0.070	0.140	0.093
Water bodies	0.141	0.257	0.190

Source: Setiawan (2006)

Distance

Distance can be described as how near or far an object is with the cooling system or large urban green area. Based on the findings of Zardo et al (2017), sustainable cooling is still evident at approximately a 100 m radius or five times the height of the tree. Another study from Bao et al (2016)has stated that the cooling still has an effect at 180 m. The effect lowers by 1°C outside the radius while within the buffer of 300 m at a radius of 120 – 300 m, the cooling temperature is between 1.9 – 3.1 °C. Monteiro et al (2020) investigated the distance combined with the size of green area. The research was conducted on calm warm nights with greenspaces of around 3-5 ha in size and indicated that the cooling effect is felt within a radius of 100-150 m.

This physical-characteristics information is very much related to the GUI for the formation of sustainable cooling. Therefore the characteristics can be retrieved from LULC data. Each type reflects different values of shade, evapotranspiration, and albedo. The shade is given a value that considers the differentiation of the vegetated area because each area has different use thus gives a different degree of cooling capacity. The value of evapotranspiration is also reflected by the different types of vegetated areas which evaporate water to contribute to sustainable cooling in urban areas. The distance value is determined from the proximity between the non-vegetated areas and the vegetated areas. Capacity decreases as distance from vegetated areas increases. The albedo factor represents the sun's reflection value of all the land use types.

2.3. Spatial Planning

The final aspect of the Urban Sustainable Cooling Approach (USCA) is spatial planning. Spatial planning from government seeks to offer solutions for the reduction of UHI using the principles of *reduce* and *leverage* (sub chapter 2.2.2) in the form of interventions, strategies, and opportunities. Spatial planning can be defined as a set of governance practices for developing and implementing strategies, plans, policies and projects, and for regulating the location, timing and form of development (Healey, 1997; Acheampong, 2019). The interventions that can be applied in the spatial plan include zoning plans and related policies, such as green open space regulation or GI planning. The intervention should incorporate the physical characteristics of green areas in the creation of sustainable cooling capacity. Interventions in zoning regulation (detail spatial plan) are effective because spatial planning has a profound impact on the internal layout and functional organization of land uses and their regulation at the level of towns and cities (Acheampong, 2019). Policies and regulations must be put in place to reduce the need for unsustainable cooling (such as air conditioning) in residential, commercial, and industrial buildings (UN Environment, 2019). Inefficient states arising from UHIs could almost completely be avoided if urban design employed effective mitigation strategies from the outset (Miner et al, 2017). Meanwhile, the opportunities are a set of actions which may be carried out by the non-governmental stakeholders, such as the community and private sectors, in the form of participation and collaboration.

Spatial planning of the Urban Sustainable Cooling Approach is also possible in a specific form, such as GI planning, which addresses sustainable indicators (economic, social, and environmental). Monteiro et al (2020) have explained the eight principles of GI planning: connectivity, multifunctionality, applicability, integration, diversity, multiscale, governance, and continuity. The description of these principles can be seen in Table 3 below. The principles in this study can be used to understand the commitment level of the government to the management of the microclimate to reduce UHI.

Table 3. Principles of GI Planning and Principles of Urban Sustainability, Sustainable Cooling Solutions, and Classification of Solution in Spatial Planning

Principles of GI	Description	Urban Sustainability Principles	Principle of Sustainable Cooling Solutions	Spatial Planning Solutions
connectivity	create a well-connected green space network that can serve both humans and other species	variety of urban greenery (integrated in the building)	Reduce	Technical policy
integration	synergies between green and grey infrastructures			
multifunctionality	provide multiple social, ecological and economic functions and possess a much higher resilience			
applicability	the plan (and the green projects) is realistic, can be implemented and developed, and if the solutions presented are adaptable to the considered area or not	variety of urban greenery integrated in the building	Reduce	Strategic policy

diversity	the diversity of the solutions presented to solve a specific issue			
continuity	must have a monitoring system, well identified or periodic reports with the evolution of the planned green projects			
multiscale	should take into account all different scales, so that the interactions between and in these spaces can be enhanced (from city to building perspectives)	Cross-sector issues with environmental perspective	Leverage	Partnerships
governance	aims for collaboration between the government actors and the citizens in the planning processes			

Source: Author, 2021 based on Monteiro et al, 2020; Lehman and Droege, 2008; James, 2015

Employing principles of GI planning, the urban sustainable cooling approach will be able to optimize the GI function through spatial planning, especially the GI planning policies. Spatial planning as the solution will offer strategies, intervention, and opportunities to regulate the land configuration so the composition between vegetated and built-up areas will be balanced and this is expected to reduce the UHI. Spatial planning will also regulate the stakeholders' participation and collaboration in UHI management. Yogyakarta's spatial plan and GI regulation to date has not explicitly regulated and planned UHI mitigation, except for the designation of green areas.

2.4. Application of Urban (Sustainable) Cooling Approach

Urban Cooling Model

Urban cooling solutions can be deployed in the short term to help mitigate the risk of rising urban air temperatures (ESMAP, 2020). A study in Lausanne, Switzerland by Bosch et al (2020) utilized the urban cooling model to determine the cooling capacity of green areas. The cooling capacity was calculated by considering biophysical criteria, such as shade, evapotranspiration, albedo, and distance, and can explain the formation of UHI forming. These criteria have been obtained from LULC data and LST or UHI intensity. This result can be used to evaluate the spatial planning policy reducing the UHI and the synthetic scenarios, such as those stemming from master plans, urbanization prospects or the like, and to spatially design solutions (Bosch et al, 2020). This computational workflow can perform automatic processes of the cooling principle that will also help the understanding of UHI in other cities.

A similar study on the urban cooling model by Ronchi et al (2019) investigated how ecosystem services assessment could support the definition of urban design parameters and influence the cooling capacity of cities. The criteria identified in the urban planning were green areas, permeability, built-up footprint, tree density, and cover. This study was conducted in four different cities with specific urban designs so that a comparison of the different cooling capacities could be made. The highest cooling capacity is supportive of a climate-proof city.

Cool Cities

A study by Rehan (2014) analyzed the coolest city concept in Stuttgart, Germany with the aim of applying it to development Greater Cairo. The cool city is one of the sustainable urban solutions for the city of tomorrow which depends on the application of the principles of urban heat management and is the key factor to diminishing urban heat release, creating solutions for future climate change by reducing the volume of global emissions, and creating smart growth and cool community scenarios (Rehan, 2014). Through the application of the cool city concept, cities are expected to have proper GI, cleaner air, less carbon footprint, and minimal unnecessary energy use (electricity consumption for air conditioning) to promote sustainable cooling of the environment.

Another concept of cool cities has been introduced by the Energy Sector Management Assistance Program (ESMAP), which is a global knowledge and technical assistance program administered by the World Bank. This concept is a set of examples from some countries of how to reduce UHI impacts which consist of practical and actionable guidance in policy making. The technical cooling solutions or smart surface strategies covered by ESMAP in some countries are in the form of cool roofs, cool walls, cool pavements, green roofs, green walls, permeable pavements, tree canopies and parks. The ESMAP also analyzed some policies and categorized them as regulations of awareness rising, leading by example, incentives, and mandatory activities. This was followed by a compilation of actions recommended by ESMAP (2020) and used by most cities, which are as follows: a) develop a cooling action plan, b) identify heat vulnerable areas and populations, c) demonstrate urban cooling strategies with pilot projects, d) engage the public, e) lead by example, f) make urban cooling measures the standard, g) consider incentives: properly designed and well targeted incentives can encourage adoption, h) expand urban forestry efforts, and i) work with other cities and city networks.

Cool World: Cooling for all

This concept is a project that was introduced by the University of Birmingham in 2008 to spread the approach of Sustainable Energy for all to the world. This concept gives some recommendations based on the analysis of global data from the Green Cooling Initiatives. The recommendations are suitable for the national level, but modification at the city level is also possible.

The recommendation from cool world can be summarized in the following table which consists of three main parts: roadmap, delivery, and accelerate. The roadmap is the preparation for the implementation of the approach or the next process. The roadmap step should entail stakeholder engagement, system level analysis, and the roadmap itself. The delivery process for cooling needs some actions like fund innovation development, validation proof of the living labs, and a scale-up of the model if it is become the industry. The last step is accelerate, which includes policies to increase the funding, upgrade skills, and transfer knowledge.

Table 4. Recommendation from Cool World Approach

WHAT NEEDS TO HAPPEN TO DELIVER COOLING FOR ALL SUSTAINABLY?

Roadmap	Delivery	Accelerate
All-stakeholder Engagement Engage and drive collaboration across the main stakeholder groups (policy, customers, industry, developers and financiers).	**Fund Innovation Development** Connect research institutes, OEMs, VCs, policy makers and customers to collaborate on the delivery of high impact innovation.	**Policies to Unlock Finance** Create the market environment (policies and business models) to attract infrastructure investment to deliver Cooling for All.
Systems Level Analysis Assess Cooling for All at the systems level - size of the challenge and alternative technologies, energy sources, business models and cross-industry resource efficiency sharing mechanisms.	**Prove** Eliminate the performance risk and demonstrate impact through live market testing and validation in Living Labs.	**Skills** Identify the skills gap (design through to installation and maintenance) and connect educational institutes, OEMs, policy makers and customers to collaborate on the delivery of accelerated solutions.
Roadmap Create the Intervention roadmap (technology, policy, finance, etc) to deliver 70% reduction in electricity usage for cooling.	**Scale-Up** Design manufacturing processes and engage industry to scale novel technologies; ideally using a global science, local delivery model.	**Effective Knowledge Transfer** Use system level model, in-country living labs and manufacturing accelerator to roll out "fit for market" solutions across new geographies.
Unintended Consequences Identify, plan for and mitigate potential unintended consequences.		

Source: Cool World, 2018

Cooling For All allows access to cooling for developing countries and, based on the Kigali Report (2018), it helps deliver many socio-economic and health benefits in line with the SDGs and also help these countries 'leapfrog' to sustainable cooling solutions that are affordable, energy efficient and have low or no global warming potential. Some of the countries targeted by this approach are populous countries, such as Brazil, India, Indonesia, and China. This report gives some sectoral guidance or the cooling of urban environments:

- The reducing UHI effect action should be incorporated in the planning, including the zoning and building regulation
- Expanding the incentives and maintaining promotion of the collaboration between public-private model in multi sectors
- Providing heat stress management plans and their implementation to protect affected people from extremely hot weather
- Providing leadership from the city governments by giving examples of sustainable cooling solutions. Governments have the authority to provide cool pavements and expanded vegetation areas which individuals can then imitate on a neighborhood scale.

Table 5. Application of Urban Sustainable Cooling Approach

Aspect	**Urban Cooling Model** (Bosch et al, 2020)	**Urban Cooling Model** (Ronchi et al, 2020)	**Synthesis**
Aim	• provides understanding of the UHI phenomenon • evaluates the spatial planning policy that is reducing the UHI and the synthetic scenarios	• demonstrates the importance of ecosystem services modelling in defining urban criteria and for steering urban transformation • helps achieve greater efficiency in plans and project	
Cooling capacity source	Green area	Green area	Green area
Main component	Shade, evapotranspiration, albedo	green areas, permeability, built-up footprint, and tree density and cover	Shade, evapotranspiration, albedo, green areas
Suggestion	enhancement of green infrastructure	design compact green areas and select trees species with high shadowing capacity	
	Cool Cities (ESMAP, 2020)	**Cool World** (SE For all, 2018)	**Synthesis**
Aim	Urban heat management	Help developing countries 'leapfrog' to sustainable cooling solutions that are affordable, energy efficient and have low global warming potential	
Technical Policies Solution	• Smart surface strategy • Demonstrate urban cooling strategies with pilot projects • Expand urban forestry efforts	• Living labs (strategy, funding, technology) • provide cool pavements and expanded vegetation area	• Smart surface strategy • Expanded vegetation area • Living labs
Strategic Policies Solution	• Cooling action plan • Make urban cooling physical the standard • Consider incentives • Identify heat vulnerable areas and populations	• Incorporating the UHI reducing value in the planning • Expanding the incentives	• Cooling action plan which has incorporated the UHI reducing value in the planning • Considering incentives-disincentives mechanism
Partnership solution	• Engage the public • Lead by example • Work with other cities and city networks	• Maintaining promotion of the collaboration (public-private) model in multi sectors • Lead by example	• Engage with the public • Collaborate with other cities or private parties

Source: Author, 2021

2.5. Conceptual Model

Reducing UHI in this study will use the urban sustainable cooling approach (USCA), depicted in the figure below, which is composed of: UHI intensity and location, sustainable cooling capacity, and interventions in spatial planning (zoning regulation and sectoral policies). Each component of USCA in the grey box can be obtained from the existing condition of Yogyakarta in the blue boxes. The first component, UHI intensity and location, can be obtained by analyzing the surface temperature condition of UHI in Yogyakarta. The next component, sustainable cooling capacity, can be measured by valuing the land use based on the physical characteristics which determine the capacity. The physical characteristics used are shade, evapotranspiration, albedo, and distance. Consideration of these characteristics will be more for the vegetated areas, while albedo will be considered across all land use types. Both components will be analyzed by quantitative analysis. The last component, intervention in spatial planning, which is the next process of sustainable cooling, will be conducted via qualitative analysis. This process is an attempt to evaluate the successful models applied in other countries in the conditions of Yogyakarta's spatial planning policies.

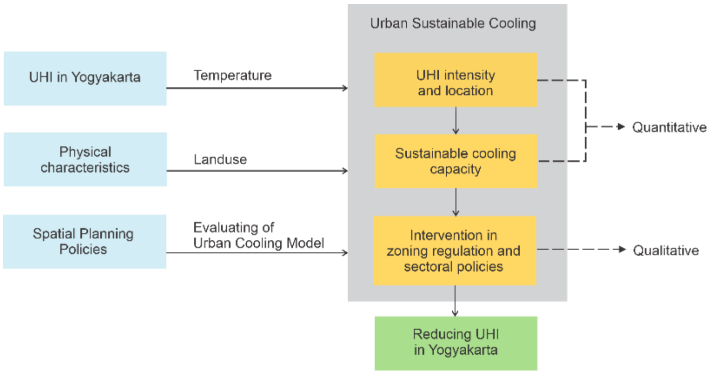

Figure 6. Conceptual Model
Source: Authors, 2021

3. Methodology

3.1. A case-study: The City of Yogyakarta

3.1.1. Case study approach

This research uses the case study approach which investigates a contemporary phenomenon in depth and assumes that such an understanding is likely to involve important contextual conditions pertinent to the case (Yin, 2018). A researcher is required to make deliberate choices in defining the type of (case) study, the logic of research design, data collection techniques, approaches to data analysis, interpretation and reporting (Yin, 2003). If the case study is completed, the findings can be useful to encourage new research in this field and area. The findings will enrich the knowledge and experience obtained from different cases (even if the context is different but a similar general theory is applied) then the findings will be accumulated so that they can be shared to other researchers in different cities.

Based on Zainal (2007), case studies have three categories: exploratory, descriptive, and explanatory. An exploratory case study is one which attempts to explore the phenomenon from specific aspects and digs deeper for information. Researchers should have carried out some pre-work or have obtained some data to be able to make some assumptions before exploring the case. A descriptive case study is one which describes the natural phenomena of the case in a narrative way. This type of case study needs descriptive theory and various information sources in order to support the narration of the phenomenon. The final case study category is the explanatory case study which is one that examines the data phenomenon which explains the cause, the effects, and solutions. This study has attempted to describe the UHI phenomenon and sustainable cooling capacity, explain the causalities, and explore the recommended actions or policies to reduce UHI in Yogyakarta.

Different scholars present different characteristics of case studies. According to Johansson (2003), the characteristics of case studies are that they are contemporary, have units that function in a complex manner, and can be examined in their natural context with various combinations of methods. This research assumes UHI phenomenon in Yogyakarta city is a complex unit which has different characteristics in different times. To analyze the phenomenon, various methods can be combined to allow for a more general context and in-depth perspective. In this study, the reduction of UHI uses a combination of quantitative and qualitative analysis methods.

3.1.2. The City of Yogyakarta

The city is the urban planner's lab (Birch, 2012) and is the unit of analysis in this case study research with point interest in UHI phenomenon. Case study research in urban planning revolves around such questions that uncover phenomena to be considered in formulating urban public policy; describing the decision-making processes in urban planning; and providing exemplars of what the authors consider best practices, frequently focusing on urban design or physical development (Birch, 2012). Specific case study research is needed in urban planning because urban planners use case studies as translators from knowledge to action, to explain the phenomena of the area with detailed evidence, and to participate in research through many ways. Case studies can also be revisited many times.

The City of Yogyakarta was selected as a (single-)case study area because of some rationales from Yin (2018), such as critical, common, revelatory, and longitudinal cases. The critical is addressed in the theoretical framework from the related previous research. The common case is reflected in the UHI phenomena which happens in some of the urban areas in Indonesia and around the world. The revelatory case can be seen when there is the opportunity to create new policies which will specifically reduce UHI, in this case, in the City of Yogyakarta. The longitudinal rationale is seen at different times of the UHI phenomena identification and in different sources of planning policies.

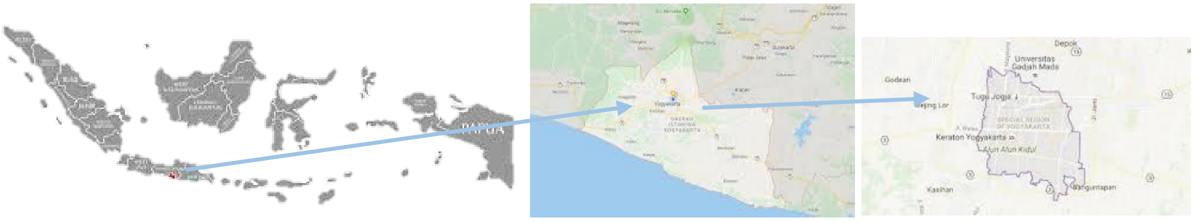

Figure 7. Yogyakarta City's Location
Source: Author, 2021

Yogyakarta City is the capital city of Daerah Istimewa Yogyakarta (DIY) Province and is situated on the island of Java. It covers an area of 3,250 ha which comprises 14 sub-districts, 45 villages, and is inhabited by 428,282 people with a population density of 15,197 people per km2 (Pemkot Yogyakarta, 2020). Yogyakarta is 128 m above sea level and has a tropical climate. Most months of the year are marked by significant rainfall. The short dry season has little impact. The climate in Yogyakarta is classified as Am by the Köppen-Geiger system. Zone A means tropical or equatorial zone while Am means having a short dry season (National Geographic, 2019). With an average of 27.1 °C and precipitation of about 2157 mm per year, April is the warmest month and the lowest average temperatures in the year occur in July, when it is around 25.4 °C (Pemkot Yogyakarta, 2020). The precipitation varies by 376 mm between the driest month and the wettest month.

3.2. Research Data and Information Collection Strategy

3.2.1. Data and Information Collection

Based on the work of Yin (2009), quality case study research can be obtained through collecting data and information which is named as construct validity and reliability. Construct validity means using the correct operational measures regarding the studied objects. Reliability can also be seen in this step by demonstrating that the technical methods of data collection can be reapplied to get the same results in other cases. The data was collected using two methods: quantitative and qualitative. In the first quantitative step, information of UHI distribution and sustainable cooling capacity was collected, while the qualitative method was used to derive the data from the planner with regards to spatial planning policies. The data collection steps have been summarized in the table below based on research questions that were asked. This table is a framework of the research data collection which describes data type, source, and collection methods, and analysis method.

Table 6. Data Collection Framework

Based on research questions	Data	Type	Source	Retrieval Method	Analysis Method
How can the urban sustainable cooling approach be theoretically understood in the context of Yogyakarta?	Secondary data	Conceptual framework	Digital literature	Literature review	
What is the distribution of the current intensity of UHIs in the City of Yogyakarta?	LST and UHI intensity	Primary data	Earth explorer	Spatial analysis	Spatial analysis (UHI Measurement)
What is the condition of the current physical characteristics configuration which can	Land use	Secondary data	Environmental Agency	Request for data from government institution	Spatial analysis (Sustainable Cooling Capacity Measurement)

produce sustainable cooling capacity to reduce the UHI in the city of Yogyakarta?	Physical Characteristics	Secondary data	Digital literature	Literature review	
	Green Area	Secondary data	Environmental Agency	Government's data collection	
How could spatial planning policies reduce UHI in the city of Yogyakarta?	Strategies/ intervention/ opportunities	Primary data	Interview	Semi-structured Interview	Triangulation, Coding

Source: Author, 2021

Literature review

Literature review is needed to construct the theoretical framework of research which consists of abstract concepts. It is also needed for the process of collecting the reference values of physical characteristics (shade, evapotranspiration, and albedo) of Yogyakarta City's LULC. Furthermore, literature review provides the basic values for InVEST input, which will be explained in the following section. These results become the basis of the spatial analysis of sustainable cooling capacity measurement.

Spatial Analysis

This spatial analysis is an initial process of analyzing the UHI. This analysis started by taking Landsat images from the USGS website which covers Yogyakarta City. The most recently recorded data for the city area is for 2018. Landsat 8 thermal does not require geometric correction related to location coordinates but still requires radiometric correction, which will be explained in the UHI measurement process.

Government Data Collection

LULC data of Yogyakarta City was collected from the government's data collection, specifically from the Environmental Agency. This data is in the form of a map which was last updated in 2017 and is still within the spatial planning period of Yogyakarta City. Other additional data, such as detailed data on green open spaces, was needed because LULC does not distinguish the use of each vegetation area. This secondary data, in the form of map, was also obtained from the Environmental Agency in its most updated form (2019).

Stakeholder semi-structured interview

The interview was conducted to collect the primary data for the last step of this research. Interviews are most commonly in the form of qualitative data collection (Harrison et al, 2017). According to Gubrium and Holstein (2002) in Marvasti (2004), the modern interview is a democratization of opinions which assumes that 1) human beings share a common experience, 2) there is division between the two formalized roles of the researcher and the respondent, and 3) that the respondent is viewed as a 'vessel of answer', that could be turned on or off by the right questions. Interviews allow the researcher to collect open-ended data, explore participant thoughts, feelings and beliefs about a particular topic, and delve deeply into personal and sometimes sensitive issues (DeJonckheere and Vaughn, 2018). Semi-structured interviews are based on a semi-structured interview guide, which is a schematic presentation of questions or topics that need to be explored by the interviewer (Jamshed, 2014).

Interviews of stakeholders are usually done to get the answers of *why* and *how* or to get evidence of the case study research. The format resembles guided conversations rather than structured queries (Yin, 2003) so the process of interview flows more in depth. The interviews are also based on the identified factors and guided principles of the research, so questions can be developed as they are needed. The stakeholders interviewed in this study are the governments from local, regional, and national governmental institutions which are involved in the spatial planning of Yogyakarta City, in particular green areas. The interviewees are described in Table 7. There was an additional university practitioner who was involved in the spatial plan-making process and as an observer of the Yogyakarta sub-urban area. The stakeholders were approached through Internet Mediated Research (IMR). They were contacted via email then interviewed online using a video-based approach. Various video conference facilities were used in this research to provide convenience of conversation between the informant and the interviewer.

This interview helped obtain data, especially data of policies that contribute to and support the spatial plan making process which can reduce UHI. The interview explored the urban sustainable cooling approach in the perspective of spatial planning policies based on the principle of urban sustainability and sustainable cooling. This is reflected in the solution steps. The interviewees were asked questions regarding the various steps of spatial planning solutions, technical policies, strategic policies, and partnership. The interview aimed to get the best formulation of spatial planning policies as a solution for the reduction of UHI in the City of Yogyakarta. It must be remembered though, that this issue is not only affected by spatial planning but also other related sectoral policies. These various sectors can integrate with spatial planning to more efficiently solve the problem and to provide many alternatives that could be used to reduce the UHI. The planners from various sectors provided different perspectives on how to deal with the UHI phenomenon, either by utilizing green infrastructure or physical characteristics. The diversity of the interviewed planners also allows for the emergence of new innovations which might be effective in Yogyakarta. The question interview guideline can be seen in Appendix E.

Table 7. Overview of Interviewees

Level	Interviewees	Organization	Date	Code
National	Planner	Ministry of Environment and Forestry (MoEF) – directorate general of climate change control planning division	7/6/21	P1 N1
National	Head of sub-division	Ministry of Environment and Forestry (MoEF) – directorate general of climate change control – mitigation and adaptation	10/6/21	H1 N2
National	Planner	National Planning Board (Bappenas) – Directorate of Environmental	11/6/21	P2 N3
Regional	Head of sub-division	The Center of Development Control in Java Ecoregion (CDCJE/ P3EJ) – Forestry sector	8/6/21	H2 R1
Regional	Head of sub-division	Provincial Planning Board (Bappeda) – Sector Environmental and Forestry	30/6/21	H3 R2
Local	Planner	Agrarian and Spatial Affair Agency (ASSA) of Yogyakarta City	15/6/21	P3 L1
Local	Academia	University – Urban and Regional Planning Department	30/6/21	A L2

Source: Author, 2021

3.3. Research Data Analysis

This research data analysis consists of spatial analysis and interview results analysis. The spatial analysis measures the UHI and sustainable cooling capacity. The process of this is outlined in the following section

3.3.1. Spatial analysis (UHI Measurement)

The efficient technique to measure UHI is using remote sensing in regional analysis with availability of data, consistency, recurrence of recording, and the ability to measure the condition of the earth to a good degree (Husna et al, 2018). This research use Landsat 8 thermal year 2018 as the primary data source of UHI because it can reveal temperature differences at very fine scales (EPA, 2020). The process of UHI measurement using ENVI can be seen in Figure 8. The full process along with the formula can be found in the Appendix B.

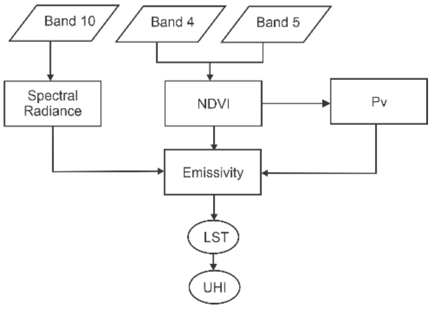

Figure 8. The framework of UHI measurement (with modification)
Source: Kaplan et al, 2018

3.3.2. Spatial Analysis (Sustainable Cooling Capacity Measurement)

Sustainable Cooling Capacity measurements can be done following the framework depicted in the Figure 9. The physical characteristics table is needed to obtain the cooling capacity using the InVEST urban cooling model 3.9.0. The InVEST urban cooling model calculates an index of heat mitigation based on shade, evapotranspiration, and albedo, as well as distance from cooling islands, for example, parks. (InVEST, 2020). The index is then used to measure the cooling capacity by vegetation.
The main inputs are an LULC raster map, a physical characteristics table containing model information of each LULC class, and the related data (Bosch et al, 2020). The rows of the table represent the different LULC types and the following physical features based on InVEST (2020) are as follows:

a) lucode: Land use/land cover class code in the LULC raster map
b) Shade: a value between 0 and 1 representing the proportion of tree cover (for trees >2m) in each LULC type.
c) Kc: Crop coefficient
d) Albedo: a value between 0 and 1 representing the proportion of solar radiation directly reflected by the LULC type.
e) Green area: A value of either 0 or 1 which reflects whether the LULC type can be considered a green area

The other data required in the process, based on InVEST (2020), is as follows:

a) reference evapotranspiration (ET0). This uses the value reference (5.897) from Walidatika (2017)
b) green area maximum cooling distance (d cool): distance (in meters) over which large urban parks (>2 ha) will have a cooling effect. The common cooling distance is 100 m.
c) reference air temperature (T ref): rural reference temperature (28.76 °C)
d) magnitude of the UHI effect (UHI max): the difference between the rural reference temperature and the maximum temperature observed in the city. Based on the process of UHI identification, the maximum temperature in Yogyakarta is 42.51 °C for extreme conditions. So, the magnitude here is 13.75 °C.
e) air temperature maximum blending distance (d Tmax): the default value of 2000 m is used here.

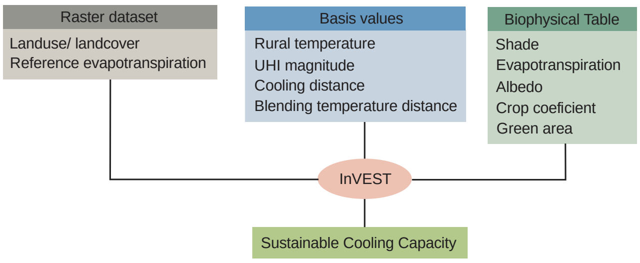

Figure 9. Framework of Sustainable Cooling Capacity Measurement
Source: Author, 2021

3.3.3. Interview Results Analysis

This analysis of the interview results was conducted in four steps:

a. Interview Result Tabulation

   This initial step involves the tabulation of the interview results of spatial planning policy solutions based on the government level. The levels are divided into national, regional (province), and local (city). This tabulation is performed to highlight the main answer from the interviewees.

b. Interview Result Description

   This step is involves describing the interview results previously tabulated as findings. The description is supported by quotes from the interviewees and describes the policies and the implementation of spatial planning policies.

c. Triangulation Analysis

   Triangulation data analysis is performed to analyze the interview results so that they become more comprehensive. Triangulation also is seen as a way of adding complexity and depth to the data and analysis (Marvasti, 2004). In other words, to understand the results or the data, multiple perspectives from different scholars should be employed. Triangulation is highly valued and commonly employed in the analysis of multiple sources of evidence (Harrisson et al, 2017). This analysis connects the interview results to the principles of sustainable cooling, urban sustainability, and the application of the concepts of cool city and cool world (spatial planning policies solution).

d. USCA Analysis Summary Diagram

   This diagram is built to summarize the analysis results. It shows the relationship between spatial analysis and interview results analysis. It also connects back to the theory used in the spatial planning policies solutions.

3.4. Ethical Considerations

This research has been conducted with consideration of ethical issues, especially in the semi-structured interviews. The personal information of participants/ informants has been kept confidential and will only be used for research purposes. The information will not be available to public so none of it can be traced back to an informant.

The Faculty of Spatial Sciences also has four principles of ethical code for research:

1. The principle of reliability (to ensure the quality of the research)
2. The principle of honesty (being transparent, fair, full and unbiased)
3. The principle of respect (for research participants, society, and the environment, amongst others).
4. The principle of accountability (from idea to publication and its wider impacts)

3.5. Research Strategy

Chapter 3 is summarized in Figure 9. The figure is divided in two parts - the theoretical part on the left side and the empirical part on the right. The blue box represents all research questions. The red box represents data collection and analysis methods. Then the green box represents the expected answers, while the yellow box represents the indicators which explain each answer. The main research question can be answered by the following sub-questions which act as the stepping stones to reach the end result: UHI reduction.

The first sub-question, the theoretical part, aims to understand the urban sustainable cooling approach by using conceptual analysis. This approach consists of the combination of UHI phenomena, sustainable cooling capacity, and spatial planning policies. The theoretical part is then followed by the empirical part, which is composed of three sub-questions designed to determine the UHI intensity distribution, sustainable cooling capacity, and the policy recommendations. This will be analyzed through quantitative and qualitative analysis. Then, based on the results of spatial analysis (quantitative), the semi-structured interview (qualitative) is held to discover the spatial planning policies formula. The final objective is that the new spatial planning policies reduce UHI.

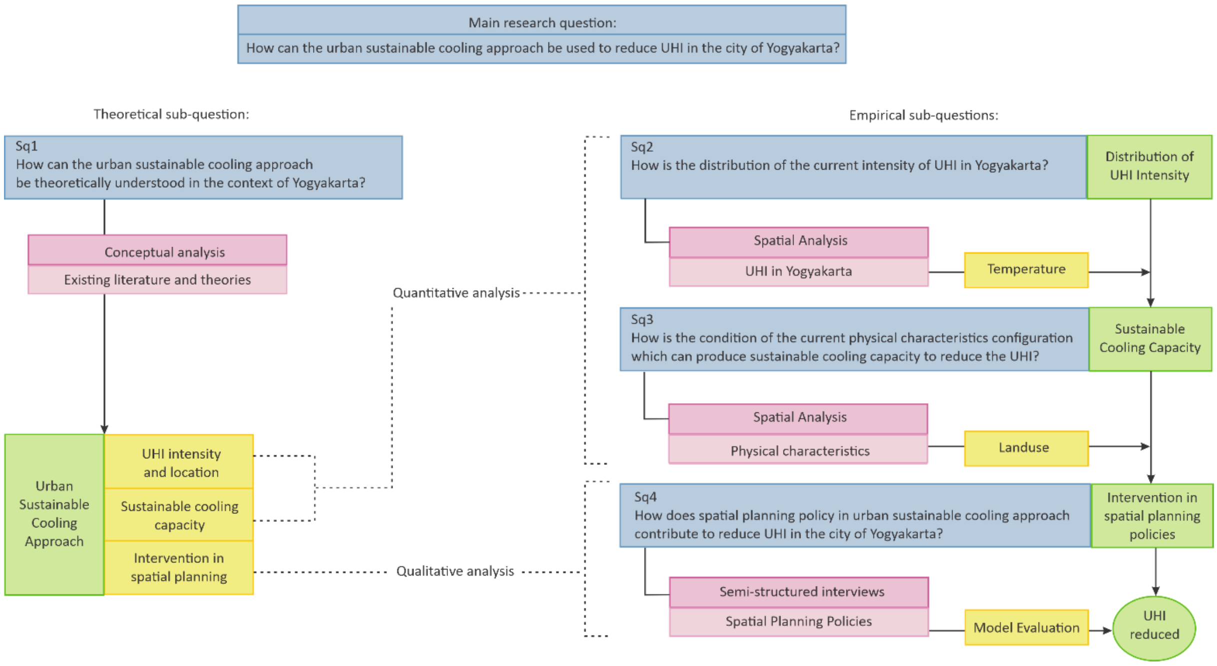

Figure 10. Research Strategy Diagram
Source: Author, 2021

4. Spatial Analysis and Results

4.1. UHI Yogyakarta

The results of the identification of UHI in the city of Yogyakarta indicate that the city of Yogyakarta has a fairly high temperature. This can be seen from the UHI threshold value of a temperature of 37.51 °C. Although T mean is lower than the UHI threshold, the temperature distribution of 37° - 42°C dominates the city area (Appendix C). Thus, the intensity of UHI in Yogyakarta is also high. The UHI intensity of 5.41 °C indicates the temperature difference between UHI and the non-UHI surrounding areas. This result has been obtained by considering the area of the city of Yogyakarta and its surroundings with a buffer of 2 km. This buffer is included as an anticipation of the urban area of Yogyakarta growing. In addition, the buffer area can also reduce bias because UHI measurements also need to involve temperatures outside urban area (sub-urban or rural areas).

Table 8. UHI Measurement Result

Area	Temperature (C)				UHI Threshold	UHI Intensity
	Min	Max	Mean	Std Dev		
Yogyakarta + Buffer 2 km	28.76	44.10	36.29	2.45	37.51	5.41

Source: Author, 2021

Based on the UHI distribution map, Yogyakarta has high UHI which means high LST in the Sub-districts of Gondokusuman, Ngampilan, Gedongtengen, Kraton, and Gondomanan. Low UHI was found in the Sub-districts of Umbulharjo and Tegalrejo. The distribution of UHI is classified into 6 classes based on the UHI intensity. High UHI intensity reflects high human activity, high building density, and low green area, while low UHI reflects a larger green area. The high LST is presented by the darker color of red while the lighter color reflects the lower UHI (Figure 11). The UHI distribution figure (Figure 11) shows that areas outside the city of Yogyakarta have low UHI values along with reduced building density. The UHI intensity shows the areas which have a temperature difference with their surrounding areas. UHI 5 mean there are 4°-5°C difference with the surrounding area.

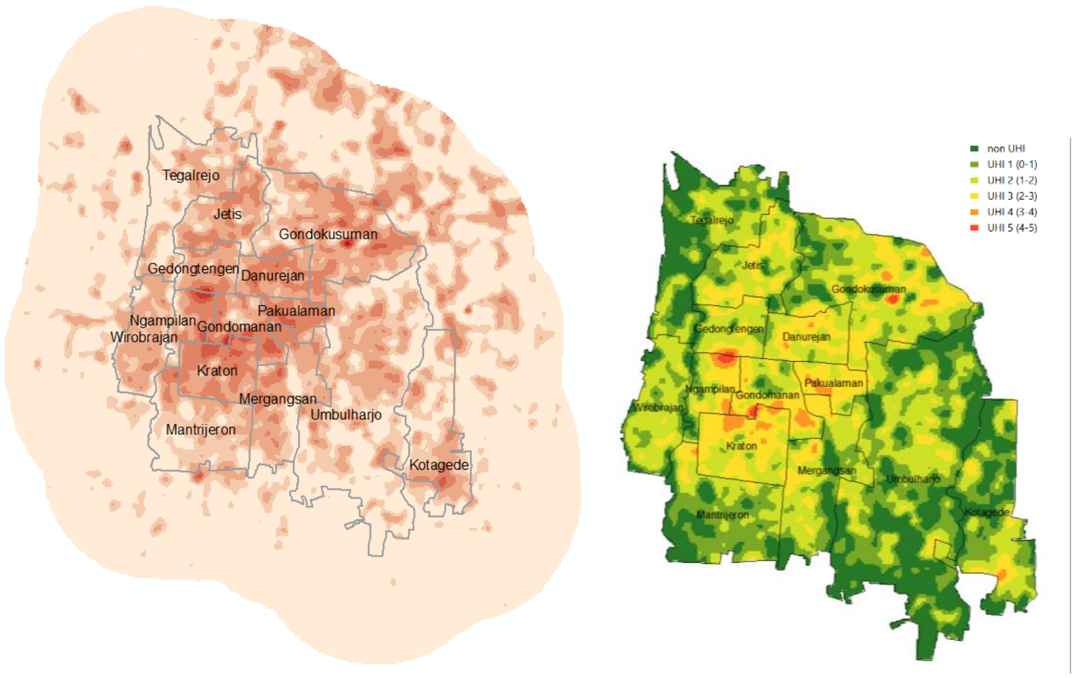

Figure 11. UHI distribution (LST) with 2 km buffer (left) and UHI Intensity (right)
Source: Author, 2021

The results of the interviews confirmed the results of the identification of UHI conditions. Interviewees indicated that areas with high LST and UHI are the centers of urban activities, for example, Malioboro which is adjacent to the Kraton District. Malioboro is a multifunctional area used for tourism, offices, and trade areas. A lot of activities take place there and so it is dominated by built up area. Meanwhile, the Gondokusuman Sub-district has high temperatures in the area along Solo Street. Solo Street is an inter-provincial road that is heavily traversed by vehicles and is high in activity because there are many accommodation and leisure facilities, such as hotels and shopping centers, and universities. Areas with low UHI were found to be in the Umbulharjo District because many green area projects have just been started here and there are still many areas that can be utilized for green area expansion. However, some interviews did claim that Gondokusuman has some fairly cold areas, such as Baciro and Kotabaru villages.

4.2. Sustainable Cooling Capacity

Sustainable Cooling Capacity (SCC) is obtained from the information of green area and landuse composition in the city of Yogyakarta. Based on the previous framework, producing SCC, in addition to physical characteristic parameters, requires supporting data, such as basic values and raster datasets. The combination of this data is required for analysis in InVEST. The raster datasets used here are LULC and Reference Temperature. For LULC, Yogyakarta's landuse is dominated by settlements, offices, and service areas. In other words, there is limited space for green areas. The vegetated area used here involved parks, agriculture area, and open spaces, such fields. The LULC map (Appendix A) shows the greatest proportion of open space and green areas is in the Umbulharjo sub-district. Locations that also show a fairly highly vegetated areas are in the Sub-districts of Tegalrejo and Mantrijeron. These two sub-districts have public green open spaces that have been developed by the government, whereas Umbulharjo has a zoo with a high level of vegetation cover. From another dataset, the reference temperature raster, shows a uniform distribution because it uses one reference value for the entire city area. This single data reference is used because the type of vegetation in the city area is relatively uniform, and the type of vegetation is not the focus of this study

Other data, such as basic values (3.3.2.) and biophysical (Appendix D), can be directly input into the InVEST process. The InVEST process generates a lot of information such as the Heat Mitigation Index and Average Temperature. In addition, by adding other parameters, such as building footprint and energy consumption, the size of energy savings can be determined. However, the only result that will be used is the cooling capacity, or SCC in USCA.

SCC is obtained from the combination of the following physical characteristics: shade, evapotranspiration, and albedo. The numbers in the biophysical table are further presented in the distribution map of the three physical characteristics. Each characteristic produces a different distribution picture. In the shade and evapotranspiration parameters, the distribution of conditions shows similarities because the main consideration of this parameter is the green area. The difference is seen in certain types of land use, such as agricultural areas, especially rice fields, which have low shade even though the evapotranspiration value is high. This is evident in the Tegalrejo Sub-district which still has quite a lot of rice fields while being located adjacent to a sub-urban area (near Sleman Regency). The areas with high levels of vegetation, such as Umbulharjo Sub-district, have high values of shade and evapotranspiration. The albedo condition is dominated by high albedo. The high albedo condition is influenced by the surface area, which in this case is the roofs of buildings. The roofs reflect the heat that hits them so that energy is reflected back into the atmosphere. Meanwhile, areas with low albedo values have vegetation covering them. This demonstrates that the presence of vegetation can absorb heat and not return it to the atmosphere, which cools the surface temperature of the city.

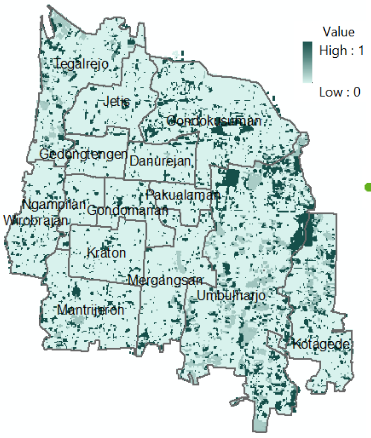

Figure 12. Shade condition of Yogyakarta City

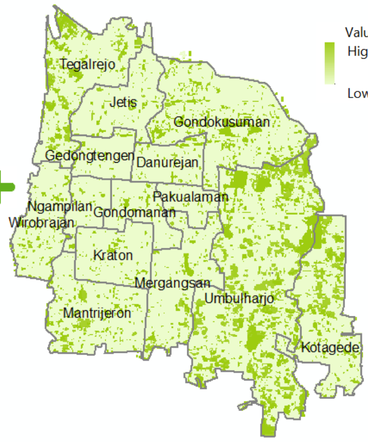

Figure 13. Evapotranspiration condition of Yogyakarta City

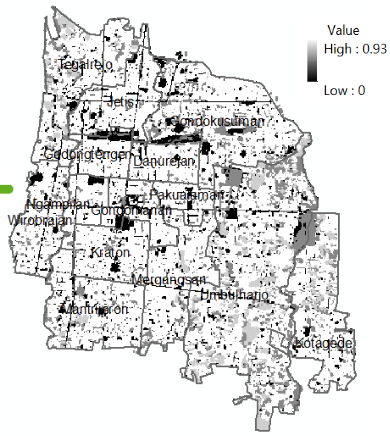

Figure 14. Albedo condition of Yogyakarta City

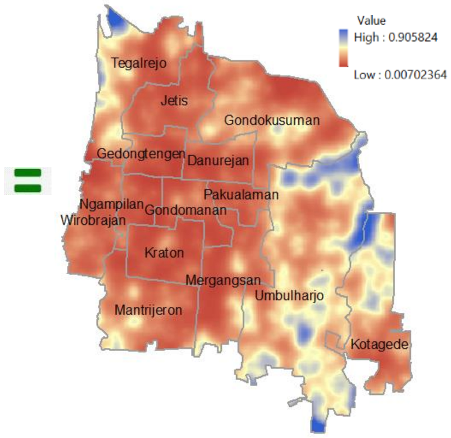

Figure 15. Sustainable Cooling Capacity

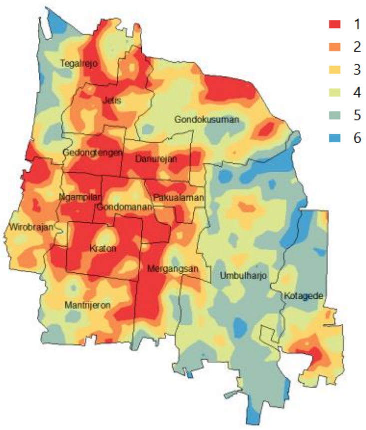

Figure 16. Reclassified Sustainable Cooling Capacity

Based on the results of processing the three parameters using InVEST, which gives more weight to the shade parameter (0.6), SCC in Yogyakarta shows very minimal results. Almost all sub-districts have low SCC, except for the Umbulharjo, Kotagede, and Tegalrejo sub-districts. This shows that the existence of a green area in Yogyakarta is still not able to provide a cooling effect for the surrounding environment. There is some potential for moderate SCC values in Gondokusuman and Mantrijeron Sub-districts. These sub-districts are located on the border of the city which shows that they are close to both sub-urban and rural areas. This does not apply to the border of the northern and western parts of the city of Yogyakarta because the city's development is directed at Sleman and Kulonprogo Regencies. The development is based on the local wisdom development of Yogyakarta Palace which states that there is to be no development behind the Yogyakarta Palace. The urbanization process appearing in Kulonprogo is the result of the aerotropolis development, namely the new infrastructure in the form of the New Yogyakarta International Airport (NYIA), which has been a discourse since 2015.

The results of the interviews show that green areas can have a cooling effect on the city of Yogyakarta. An interviewee from CDCJE said that green areas along the road can provide a cooling effect because it reduces emissions from vehicle pollution. Emissions produce carbon that will cause solar radiation to be trapped on the surface of the city area. Thus, the presence of urban vegetation or trees will help lower urban temperatures. In addition, confirmation was obtained from interviews that the areas of Kotabaru and Baciro sub-districts have a comfortable temperature for the local community. CDCJE and ASSA also suggested that the composition of each house should be such that there is a large yard with enough plants surrounding the house. However, the constraint of this is that urban areas have limited land while the demand for this land is getting higher and more competitive.

4.3. The Concerned Area

Based on the spatial analysis of UHI intensity and SCC class, almost all sub-districts show potential for intervention by spatial planning policies, except for Tegalrejo, Umbulharjo, and Kotagede (Figure 16). The selected areas are the sub-districts which have low UHI intensity (UHI 1 and UHI 2) and low SCC class (class 1 and 2). These conditions are considered 'potential' because it is expected that by improving the low SCC condition, the UHI area can be reduced (from UHI1 to non-UHI).

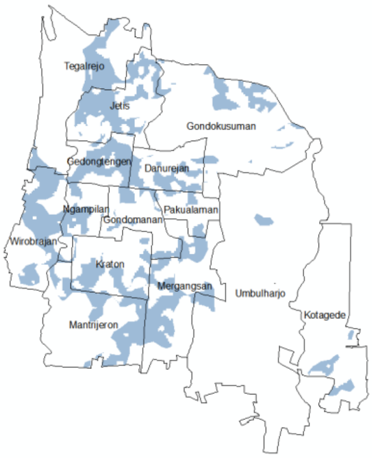

Figure 17. Potential Area to be Intervened by Spatial Planning Policies
(Source: Author, 2021)

When compared to the interview results, there is an agreeance on the areas of the Sub-districts of Gondokusuman and Danurejan. Although Gondokusuman has cooling potency (medium SCC) in the middle area, it is still dominated by low SCC, especially in Klitren Village. The area has very compact LULC which is dominated by settlements and trading areas in Solo Street. CDCJE and Bappenas said that the trees along the roadside are fewer than in the past and that many of these trees were cut down due to hurricane threats in the area. This wind threat also actually comes from the difference in temperature so that there is a very strong wind flow trapped between urban buildings. This is further exacerbated by traffic jams from the city streets that lead to Solo Street during the peak hours in the morning and afternoon.

The same condition is observed in Danurejan which is part of the tourist destination of Yogyakarta, Malioboro. Most of the interviewees stated that the Malioboro area needs to reconsider its planning. MoEF added that the area near Malioboro, Mataram Street, also has an uncomfortable temperature. Malioboro has been redeveloped and renovated aesthetically to support tourism activities. The pedestrian strip is covered by impervious surface and the trees do not function properly as shade. The trees do not have many leaves to create a canopy along the road of Malioboro. In addition, the Malioboro area has developed more accommodation facilities, which adds more buildings. ASSA added that the development focus in Yogyakarta is still partial based on aesthetic value. Malioboro is an example of an economic sector that has been developed without considering environmental aspects. Therefore, the intervention of spatial planning solution needs to be applied in both sub-districts.

5. Spatial Planning Policies Intervention Solution

5.1 Relevant Spatial Planning Policies

The City of Yogyakarta has not regulated UHIs specifically in its policy but makes general mention of the climate. One of the regulations which regulates the climate indirectly is Law of the Republic of Indonesia number 26 of 2007 concerning spatial management. Article 29 explains that a 30% proportion of public open green space (Ruang Terbuka Hijau/ RTH) constitutes the minimum measure to secure the city ecosystem balance, including hydrological, microclimate, and other ecological systems balance. It increases the availability of fresh air needed by society and the city's aesthetic value. Public open green space is the cooling system which needs to be factored into urban management.

Another law which has a relationship to climate is Law of The Republic of Indonesia number 32 of 2009 concerning protection and management environment. This law stipulates that the development should include strategic environmental analysis (SEA), including the assessment of carrying capacity of ecosystem services. One of the ecosystem services is climate regulation which could become the starting point to develop actions of UHI reduction. In the case of Yogyakarta, this law is translated in the Province Regulation number 3 of 2015 as a basis of city development and it could provide the opportunity to set local regulations with the new value of UHI reduction.

Other spatial planning policies used in this research can be seen in the Table 9. These regulations are considered relevant based on the interview results. The interviewees mentioned various planning policies which represent multilevel planning from national to the local level. The spatial planning here is mostly about the green area, spatial plan, development plan, and climate adaptation and mitigation.

Table 9. Relevant Policies Used to Reduce UHI

Policies	Contents
Law No. 26/2007 on Spatial Management	a. Spatial Planning Classification b. Regulation and Establishment of Spatial Planning c. Execution of Spatial Management d. Supervision of Spatial Planning e. Right, Liability, and Role of the society
Government Regulation No. 12 of 2012 about Incentives of LP2B	a. Types, considerations, and procedures for giving incentives to productive farmers b. Research financing c. Ease of accessing information and technology
Presidential Decree No. 18 of 2020 about National Medium-Term Development (2020-2024)	Section 7 about building the environment, improving disaster resilience, and climate resilience
Regulation of The Minister of Public Works No. 30 of 2006 about Technical Guidelines of Facilities and Accessibility in Building and Environment, Technical guidelines of green building	Technical requirements and arrangements for provision of facilities and accessibility in buildings and the environment.
Regulation of The Minister of Public Works No. 5 of 2008 about Guidelines for Provisions and Utilization of Green Open Spaces in Urban Areas	a. Provision of Green open space in urban area b. Green open space utilization in urban area c. Planning procedure and the role of community
Regulation of The Minister of Public Works No. 5 of 2012 about Tree Planting Guidelines on the Road Network System	a. Plan of planting b. Implementation of planting c. Plant maintenance
Regulation of The MoEF No. 33 of 2016 about Guidelines for Developing Climate Change Adaptation Actions	a. Identification of Specific Area and/or Sector Coverage Targets and Climate Change Impact Problems b. Preparation of Climate Vulnerability and Risk Assessment c. Preparation of Climate Change Adaptation Action Options d. Prioritizing Climate Change Adaptation Action and Integrating Climate Change Adaptation Action into Development

	e. Funding
Regulation of The MoEF No. 84 of 2016 about Proklim	a. Operationalization b. Proklim appreciation c. Construction d. Funding
Governor's Regulation No. 2 of 2021 about Spatial Plan of Daerah Istimewa Yogyakarta Province in 2021 – 2041	a. Planning areas b. Goal and strategies c. Structure Planning of Urban Areas d. Spatial Pattern of Urban Areas e. Urban Strategic Areas f. LU guide plan g. LU control guide plan h. Institutional i. Enforcement and Investigation j. Criminal provisions

Source: Author, 2021

5.2 Spatial Planning Policies Solution

The next stage of the UCSA approach is to use spatial planning as a solution to reduce UHI problems. Spatial planning should be used to intervene in the selected areas. The spatial planning formula here comes from the concept of urban sustainability (2.2.1) combined with sustainable cooling (2.2.2) which is shown in Table 3 (2.3) and its application in Table 5 (2.4). This formula will be a comparison of the interview results. The policy solution is detailed in three division as a stepwise approach to reduce UHI: technical policies, strategic policies, and partnership solutions.

5.2.1 Technical Policies Solution

Technical policies solution is the combination of principles of various urban greenery (from urban sustainability) and reduce (from sustainable cooling). These principles can be defined as active and passive strategies to reduce the high temperature in the urban area. The technical solution is considered as a passive cooling strategy which utilizes and modifies the landuse and physical condition of the urban surface area. The proposed strategies offered by Cool City and Cool World are smart surface strategy, expanded vegetation area, and living lab projects. The strategies were discussed with the interviewees to determine what policies they have and how they could be implemented to reduce the UHI phenomena in Yogyakarta.

a. Smart Surface Strategy

Based on the interview results, the smart surface strategy has not been applied optimally at every level of government. However, at the national level, the government has attempted to create a special institution that handles Green Buildings, namely the Green Building Council Indonesia (GBCI). This institution has a green building standard that mentions one of the physical characteristics of a green area (albedo). Most of the interviewees said that the existence of the smart surface strategy was only in urban commercial buildings. Even large urban areas like Jakarta had not been able to apply the strategy in all buildings. In the case of Yogyakarta, only several hotels have green roofs.

"Since 2009, we have joined the GBCI to formulate green building concepts in Indonesia. However, currently the implementation of green building is still within the scope of Jakarta... There is an albedo principle in the technical guidelines for green building" (Bappenas, Planner 2 – P2 at National level – N3)

At the regional and local levels, this solution has not been implemented due to high operational and maintenance costs. Another obstacle in Yogyakarta is city image which can be seen from its distinctive buildings. Changing parts of the buildings means changing the culture value.

"*Smart surface strategy solutions such as green roofs and green walls are difficult to implement because of the high maintenance costs. Only a few hotels can install these facilities.*" (CDCJE, H2 R1)

"*Smart surface strategy needs a high operational budget.*" (Bappeda H3 R2)

"*This strategy sometimes changes the shape of Yogyakarta city buildings. Yogyakarta has its own culture, including the shape of the roof. If the building shape changes, the city image, which is rich in cultural values, changes.*" (University, A L2)

Interviewees also stated that regional and local governments had actually made policies to regulate this smart surface strategy. At the regional level, this can be seen in RTRW DIY Province, Regional Regulation No. 2 of 2021 which contains a section that regulates the proportion of green areas. Meanwhile, at the city level, the smart surface strategy is regulated in the RTBL of the city of Yogyakarta which is a derivative of the RTRW and RDTR (a set of zoning regulations).

"Smart surface strategy is regulated and mentioned in a small part of RTRW and RTBL." (ASSA, P3 L1)

"The implementation of this strategy is also found in the DED" (University, A L2)

b. Expanded Vegetation Area

Interview results show that expanding vegetation areas is always a reliable solution because it is relatively easy to do. At the national level, MoEF has made efforts to add green area through revegetation of critical lands. The same thing has been done at the regional level by planting trees outside urban areas. These actions are expected to contribute to reducing urban temperatures.

"*The addition of green areas is carried out by rehabilitating critical lands. This activity is expected to contribute to decreasing the urban temperature because the reference temperature in rural areas changes*" (MoEF, P1 N1)

"*A lot of green areas have been added in Sleman Regency and Bantul or areas outside the city*" (Bappeda, H3 R2)

Meanwhile, at the city level, the implementation of this strategy is quite challenging due to limited areas and land competition. However, the interviewees still said that urban areas need green areas even though they may have to position these on roofs of buildings, cemetery areas, and streets.

"*We see that technical government agencies are really trying to plant trees in the limited area. They ended up using the cemetery area, along the road, and on building roofs*" (Bappenas, P2 N3)

"*We are still looking for suitable locations for adding green areas. Meanwhile, we maintain the existing green areas.*" (ASSA, P3 L1)

The regional and local government still want to add green areas to the urban activity centers. Interviewees said the urgent locations to immediately add green areas are Malioboro in Danurejan Sub-district and inter-provincial roads as the forerunners of the urban sprawl of Yogyakarta City to the east (Solo Street in Gondokusuman Sub-district). These developments, however, still do not prioritize environmental values. City centers such as Malioboro and Tugu are developed aesthetically to support tourism but do not consider environmental development, especially green area.

"*Malioboro and the surrounding area need more vegetation. The trees have now disappeared. And Solo St. now has so many activities, buildings, and traffic.*" (CDCJE H2 R1)

"*Malioboro and (other) urban activity centers need more green areas. Sometimes the development has only prioritized aesthetic values and not environmental issues. For example, the small park between Malioboro and Kota Baru was replaced by pavement block*." (ASSA, P3 L1)

"*The redevelopment of Malioboro and Tugu is still focused on the economic sector to support tourism activities. These developments do not consider the environmental values."* (University, A L2)

At the city level, the Mayor of Yogyakarta City has made regulation No. 5 of 2016 regarding public green open space. It regulates how to build and manage the public green area. At the regional level, regulations regarding expanding green areas are contained within the spatial plan of the DIY Province. In the section related to green open space, it is stated that 30% of Yogyakarta must be green areas.

c. Living Labs

An (Urban) Living lab, based on interview results, is defined as an experimental program that applies climate mitigation and adaptation in a village or RW. The most successful living lab in the city of Yogyakarta is the Climate Village Program (Proklim). This program has been regulated in the national regulation (MoEF), Minister Regulation No. 84 of 2016. This regulation is the basis for the government at every level to realize Proklim's objectives.

The implementation of the regulation was seen in 2019, with 10 new Proklim villages across 10 sub-districts in Yogyakarta (Danurejan, Kotagede, Gondomanan, Jetis, Mergangsan, Pakualaman, Wirobrajan, Tegalrejo, Gondokusuman, Ngampilan). Jetis sub-district had the highest number of RWs in the submission of the new proklim (7 RW). The increase in the number of Proklim projects proves that people's perceptions and behavior towards climate change have changed. Communities are considered to have become more adaptive to climate change.

"*When we monitored Yogyakarta in 2019, there were 10 new villages proposed as Proklim. The increase in the number of Proklim means that there is improvement in the public's mindset towards climate change*." (MoEF, H1 N2)

Interviewees stated that the Proklim in Yogyakarta took the form of green villages, vegetable aisles, and medicinal plant gardens. The scope of Proklim is not limited to the adding of green areas, but also other elements of climate adaptation, such as waste management through waste banks.

"*There are various forms of Proklim, including green villages, vegetable aisles, urban farming, and medicinal plant gardens, and even a waste bank. It depends on the community needs*" (MoEF, H1 N2)

"*The current development program in Jogjakarta is located in Bausasran Village, Gondokusuman District in the form of a Vegetable Aisle. In addition, other successful (projects in the form of) Green Villages are in Gambiran, Pandeyan, and Umbulharjo Villages which are part of the Umbulharjo Sub-districts.*" (Bappeda, H3 R2)

There are additional activities conducted by local government and academia which provide other forms of living labs, such as urban farming and Culture Parks. These can be the forerunner of Proklim in Giwangan, Umbulharjo Sub-district.

"*We have been trying to develop urban farming in collaboration with local communities. Maybe it will become the forerunner of Proklim" (University, A L2)*

"The municipality has worked together with some stakeholders to create a culture park in Giwangan which is environment based" (ASSA, P3 L1)

5.2.2 Strategic Policies Solution

The strategic policies solution is a combination of principles from urban sustainability and *reduce* from sustainable cooling. These principles can be defined as using planning or design which involve multi-sector stakeholders to reduce UHI. The proposed strategies offered by Cool City and Cool World are the cooling action plan and the incentive-disincentive mechanism. These strategies were evaluated with the interviewees to determine which policy they use and what could be implemented to reduce the UHI phenomena in Yogyakarta.

a. Cooling action plan

The interview results show that at the national, provincial, and city levels there is currently no cooling action plan that leads strategically to reduced city temperatures or reduced UHI. The national government stated that the problem of the increasing city temperature or the UHI phenomenon could be included in the 6th National Priority (PN) in the 2020-2024 RPJMN which aims to protect the environment, increase disaster resilience, and mitigate climate change. The UHI problems could be addressed in the climate change section.

"*Our directorate has considered surface temperatures and their impacts when making adaptation and mitigation action plans even though we have not addressed it directly in the indicators. Thus, we cannot evaluate the environment just based on the temperature, even if the final effect is decreasing the temperature*" (MoEF, H1 N1)

"*There is no specific plan which directly addresses UHI or temperature. However, there is a 6th NP in the 2020-2024 RPJMN which has the aim of solving problems of environmental issues and climate change*" (Bappenas, P2 N3)

However, each institution at every level of government actually has regulations that have the final objective of lowering the temperature. For example, at the national level, MoEF has regulations to reduce GHG emissions from the forestry sector. These are also evident in the relevant ministries whose sectors are sources of GHG emissions. At the regional level, the RPJMN was adjusted in the 2017-2022 RPJMD. A more detailed regulation has been included, according to local and regional governments, and is the existence of an RTBL at the city level (Environmental and Building Plan).

"*At the city level, there is also no cooling action plan. However, RTBL includes detailed planning of green areas and buildings. This can be categorized as a cooling action*" (CDCJE, H2 R1)

"*RTBL might be the cooling action plan at the local level*" (ASSA, P3 L1)

The implementation of NP6 is the implementation of development and spatial plan. At the city level, the implementation is seen from the consideration of RTBL in granting building permits. However, previous studies related to UHI have been conducted by academia and these were not immediately followed up by the (local) governments with the making of strategic plans.

"*The implementation of NP6 at each level is the implementation of development plan and spatial development*" (ASSA, P3 L1).

"*Actually, there have been many studies on UHI, but the government did not immediately follow these up with the making of a strategic plan to solve the problem*" (University, A L2).

b. Incentives and disincentives mechanism

Based on the results of the interview, incentive and disincentive mechanisms for reducing the UHI impact are indirectly contained in the planning documents at each level. Interviewees stated that these mechanisms can be seen in RTRW and sectoral policies at the national level. Some sectoral policies, such as the regulation of Proklim and sustainable agriculture, mention this mechanism. Through the Proklim regulation, the government has tried to motivate the community by providing incentives such as appreciation for reforestation activities as part of climate adaptation. Meanwhile, the disincentive mechanism tries to prevent deviations.

"*Mechanisms of incentives and disincentives have been stated in every planning document, both development plans and spatial plans*." (Bappenas, P2 N3)

"*The mechanism has been stated in RTRW at the regional level.*" (ASSA, P3 L1)

"*The LP2B regulation also provides a mechanism to prevent the conversion of agriculture areas (to other land uses). The agriculture area is still counted as green area.*" (Bappeda, H3 R2)

Implementation of the incentive mechanism at the national level, for example through the MoEF, is in the form of providing special allocation funds to agencies and communities that have succeeded in maintaining and even adding to green areas. Interviewees also stated that communities need to realize that the provision of incentives is not always in the form of material incentives. Therefore, MoEF calculates the carrying capacity of ecosystem services as a form of environmental incentive.

"*The incentives we give are in the form of awards and operational assistance to Proklim who have succeeded in developing their villages. We also consider that ecosystem services are an invaluable incentive from the environment.*" (MoEF, H1 N2)

At the local level, there has been a suggestion made about the incentive mechanism from academia. The incentive should be in the form of compensation for private parties who have constructed buildings with smart surface strategy or green building concepts.

"*Implementation of the incentive mechanism at the city level can be done by providing compensation to buildings that can add green roofs to their roofs.*" (University, A L2)

On the other hand, disincentive mechanisms, according to all the interviewees, are not working due to weak law enforcement. Many cities have not fulfilled the 30% green area requirement but are still processing new building permits.

"*The disincentive mechanism is not working well. There is no punishment when a region or city cannot meet the green area requirements.*" (Bappenas, P2 N3)

"In Yogyakarta, if the agencies don't meet the target of green area, they are only asked to make commitment statement." (ASSA, P3 L1)

5.2.3 Partnership Solution

The partnership solution is a combination of cross-sector issues from urban sustainability principles and *leverage* from sustainable cooling. These principles can be defined as the collective action from multisector stakeholders. The proposed strategies offered by Cool World and Cool Cities are engagement with the public and collaborations with other cities or private parties. The strategies were evaluated with the interviewees to determine what they have already done and what could be done to reduce the UHI phenomena in Yogyakarta.

a. Engagement with the public

Based on the interview results, all levels have engaged the public in planning which focuses on the environment, especially climate change. Bappenas and Bappeda mentioned the regulations of development plan and spatial plan. These regulations contain a public participation mechanism in their articles. MoEF mentioned public engagement in the Proklim policy because the main goal of this project is to empower the local community to adapt to climate change. The Proklim policy has also made efforts to coordinate with governments at the local, regional, and national levels. Local and regional levels are planning to synchronize their policy contents to support low carbon development.

"*Proklim is our means to engage with the public.*" (MoEF, P1 N1)

"The Proklim policy regulates the coordination between the public and government at each level." (MoEF, H1 N2)

"*In the stage of making the development plan and spatial plan, we involve community representatives*" (Bappenas, P2 N3)

Basically, all the institutions, when implementing spatial planning policies, involve the public in their activities. MoEF, for example, has Proklim which is managed mainly by the community. National institutions, for example Bappenas and MoEF, are not technically involved with the communities. However, at least once a year, MoEF engages with the public by inviting the local champions of Proklim to inspire Proklim in other regions.

"We invite the local champions of Proklim to be the national speakers in our annual events, Proklim awards." (MoEF, H1 N2)

"The national institution is technically not involved in programs with the local community." (Bappenas, P2 N3)

In addition, Bappenas also conducts public engagement through Musrembangnas by inviting representatives from community organizations. Routine programs that involve the community at the local and regional level are socialization based and related to the impact of climate change in urban areas and tree planting activities outside urban areas. At the local level, the community participates in providing land for green areas by selling their land not to the private sector for commercialization, but to the government.

"*We usually have socialization programs regarding climate change issues and the routine program which is tree planting*." (CDCJE, H2 R1)

"*There is a policy to sell land to the government rather than to private parties. The government will turn this vacant land into green areas.*" (ASSA, P3 L1)

In addition, newer methods of engagements have become a trend, especially during this pandemic. The government now has a digital platform to engage with the public, especially millennials. Social media is considered an effective means for campaigning environmental messages.

"*In the last few years, we have had a media team actively taking care of the agency's social media. This is very influential on environmental perceptions among youth*." (CDCJE, H2 R1)

"*Nowadays, especially in the pandemic era, social media is a really effective media to convey environmental messages.*" (Bappenas, P2 N3)

b. Collaboration with other cities or private parties

The last partnership solution is collaboration with other cities or private parties. At the national level, collaboration between cities is delegated to the regional level. The coordination of Proklim in different cities is carried out by provincial governments. Successful villages can guide other villages that are just starting Proklim.

"*Collaboration with other cities and coordination of villages in different cities is implemented at the regional level. Successful Proklim projects can guide newer Proklim startups everywhere.*" (MoEF, H1 N2)

Collaboration that has been carried out at the regional level has included camping activities targeting students and encouraging them to care about the surrounding environment. These activities involve student representatives from schools located in cities on the island of Java.

"*One of our annual events is to coordinate environmental issues with schools' representatives in Java.*" (CDCJE, H2 R1)

At the city level, the Yogyakarta City government cooperates with other cities in low-carbon development programs in the JogloSemar (the cities of Yogyakarta, Solo, and Semarang located in Central Java Province) area which is a special development area on the provincial border. Collaboration with other cities is also carried out by the city of Yogyakarta in the KPY cluster (an internal province consisting of Yogyakarta, Bantul, and Sleman). This collaboration tackles the issue of disposing of city domestic waste in the circumstance of not having enough space for landfill.

"*Collaboration between cities can be seen in the low-carbon development program for Joglo-Semar and the waste disposal cooperation KPY*" (ASSA, P3 L1)

"The KPY collaboration between Yogyakarta, Bantul, and Sleman is carried out to dispose of urban domestic waste." (Bappeda, H3 R2)

Collaboration with the private sector and universities has also been carried out by the Yogyakarta city government through the addition of green areas. This project is the Giwangan Culture Park which has made this area into an eco-district. Giwangan will also be used as a TOD with plans to collaborate with the World Bank while still maintaining emphasis on environmental principles by adding green areas. Another collaboration project is the reforestation taking place around the Gajah Wong River which has encouraged residents to be more concerned about the cleanliness and sustainability of the river.

"*Collaboration with the private sector has been carried out in the Giwangan area through the building of a cultural park. In addition, there is a plan to create an environment-based TOD Giwangan in collaboration with the World Bank. In addition, the Gajah Wong River revitalization project has involved academia to prepare the concept and design." (ASSA, P3 L1)*

5.2.4 Spatial Planning Recommendation

Based on information gained from the interviews, the governments recommend two main solutions to reduce UHI in Yogyakarta. Those solutions are from the technical policies solution and comprise the expansion of green area and urban living labs.

Expanding Green Area

Expanding green area is the priority and the efficient way to cool the environment of Yogyakarta City. It utilizes green urban infrastructure such as parks, agricultural areas, fields, or other vegetated areas. This solution is considered effective because Yogyakarta City has not fulfilled its 30% requirement of green area. In addition, expanding green area is supported on a regulatory basis, such as by laws that state the provision green open space, development plan, and spatial plan.

Urban Living Labs

The other solution is urban living labs which involve the participation of the local community in the cooling of the environment. The urban living labs solution offers a set of rules regarding the technique, knowledge, strategy, and funding scheme (SEforAll, 2018). Urban living labs, which in the case of Yogyakarta is Proklim, have been successful pilot projects which added value to the environment and the local community. Proklim regulations also encourage good coordination between local communities and multilevel governments in different sectors. As the number of Proklim grows in Yogyakarta, so will climate adaptation and mitigation actions in the urban area.

5.3 Analysis of Spatial Planning Policies

5.3.1 Technical Policies Solution

a. Smart Surface Strategy

Smart surface strategy has been regulated in the regulations of each level. Each level makes efforts to use the principles of eco-building and variations of urban greenery that are integrated in the building. In addition, these regulations also mention passive cooling to reduce the urban temperature. One of the regulations at the national level is the Ministry of Public Works regulation No. 30 of 2006 concerning Technical Guidelines of Facilities and Accessibility in Building and Environment. An application at the national level is the establishment of a national platform, Green Building Council Indonesia (GBCI), which is responsible for transforming buildings to become more sustainable. One of the indicators in green building is microclimate which explains one of the physical characteristics - albedo. Based on a GBCI document (2010), the minimum albedo value is 0.3. The regional and local level regulate this strategy in spatial plans. However, only city parks and green roofs were planned for building in the city.

The regional and local levels have not implemented this strategy due to unclear funding mechanisms. The only implemented is urban park and green roof from private sectors. Thus, this strategy has not become a development priority in the city. The regional or local government should collaborate with the private sector for the provision of subsidies for this program. There are, however, several hotels in Yogyakarta that have installed smart surfaces in the form of green roofs. Although these installations were motivated by commercial and aesthetic purposes, it is hoped that this action will contribute to a decrease in the temperature of the city.

b. Expanded Vegetation Area

Expanding the green area is also one of the urban greenery variation and passive cooling action. It aims to create urban sustainability and sustainable cooling through the utilization of green areas to reduce the urban temperature. This solution is considered the easiest and most funding efficient at every level. Implementation, however, is hindered by the lack of land to add green areas. A combination approach with previous solutions in urban surface engineering is needed here. Additional forms of green areas do not always have to be in one large area of land; it could be done on sidewalks, roofs, or building walls. The urgent area for this expanding is Malioboro and Solo Street. Furthermore, adding green areas could be done by rehabilitating critical land outside the city because urban areas can no longer accommodate vegetation. The addition of green areas in sub-urban or rural areas is expected to reduce the UHI.

c. Living Lab

Living Labs test and demonstrate not only technologies but also mitigation, business, governance, and funding models (Cool World, 2018). Proklim, which is an urban living lab, strives to achieve urban sustainability and sustainable cooling through reducing GHG emissions with climate adaptation actions, as mentioned earlier. Proklim is a fairly comprehensive program, which utilizes all principles of urban sustainability and sustainable cooling, that deals with the local climate in urban areas. The urban sustainability principles such as variety of GUI and sustainable cooling such as reduce can be seen in Proklim activities which vary from green villages, vegetable aisles, urban farming, to waste banks. The cross-sector principle is also included in the variety of activities because it has different emphasis. These activities facilitate the prioritized needs of the village. For example, certain villages fit the waste bank type as they are areas designated for landfill by the government. The leverage in sustainable cooling can be seen more in the explanation of partnership solution.

Through climate adaptation actions from the community, it is expected that urban temperatures can decrease and reduce the UHI phenomenon. Proklim is not only a transfer of technical knowledge, but also a matter of governance in managing a village and community. That being said, currently the city of Yogyakarta is still dominated by the transfer of technical knowledge to obtain the ideal type of Proklim.

5.3.2 Strategic Policies Solution

a. Cooling action plan

The city of Yogyakarta does not have a set of strategic regulations regarding the Cooling Action Plan. However, development and spatial planning at every level have raised environmental issues which have ultimately had implications for cooling action. For example, RTBL, which is a part of the zoning regulation in the local level, includes the proportion of building and green areas. This RTBL does not mention temperature or physical characteristics as indicators. At the national level, NP6 is also only translated into multilevel actions regarding GHG emission reduction, climate adaptation, and solving environmental issues such as pollution and natural disasters.

The absence of a (cooling) strategic plan at the city level is the result of an absence of planning at the national level. The absence of the specific plan means that the impact of development planning on temperature cannot be monitored and evaluated. Thus, the government in each level needs to initiate plan making. Cooling action plans should be made based on the concepts of urban sustainability and sustainable cooling. The plan also should be cross-sectoral and include the reduce principle.

b. Incentives and disincentives mechanism

Incentive and disincentive mechanisms have been included in the basis of regional development plan and sectoral policies at various levels. This mechanism also uses the principle of cross-sectoral issues from urban sustainability and reduce from sustainable cooling. Incentives embedded in spatial planning (include sectoral policies) have played a role in motivating the community to participate in environmental programs including adding green areas. Meanwhile, disincentives which can become *reduce* solution have not particularly been applied in Yogyakarta City due to the weak law enforcement. In strategic policies, this mechanism is needed to motivate the local community to achieve the objectives of urban sustainable cooling with a diversified green urban infrastructure. This mechanism can also anticipate the occurrence of deviations from the objectives.

5.3.3 Partnership Solution

a. Engage with the public

Engagement with the public is part of the cross-sector issues in the ecological perspective of urban sustainability and leverage in sustainable cooling. Engagement with the public has been implemented by the city of Yogyakarta as can be evidenced by the increasing number of Proklim. Based on the policies, Proklim is mainly managed by the public. As mentioned in the previous section, Proklim has connected multilevel and multisector government to coordinate in reaching the aim of urban sustainability and sustainable cooling approach. Community involvement with mitigation and adaptation actions is expected to have an impact on the local climate which in turn can reduce urban temperatures. To increase the impact of this collective action, with the principle of leverage, the government could use a communication platform in the form of social media that will attract the public, especially youth, to contribute according to their interests and capacities.

b. Collaboration with other cities or private parties

The collaboration uses the principles of cross-sector issues and leverage. Partnerships in the city of Yogyakarta, as a form of *leverage*, have been carried out by involving other cities, both within the province and outside the province (with Central Java Province). Joglo Semar is the collaboration with other cities from different provinces and this collaboration aims to produce less carbon. It is also in accordance with the results of the previous UHI and SSC analysis that found that the area along Solo Street needs additional greenery. The collaboration within the province is KPY which also contributes to reducing carbon emissions by managing landfill.

Collaborations are also carried out with various stakeholders and private sectors, especially international donor foundations to obtain technical assistance and funding. These collaborations intend to reduce GHG emissions from development in various sectors. Reducing the GHG emissions that increase city temperatures as a result of collaboration between cities and multi-stakeholders is an application of the principle of multi-sector coordination on urban sustainability.

5.3.4 Spatial Planning Policies Solution Alternatives

Based on the results of the interviews, new alternative spatial planning is offered for each solution as a policy innovation and is outlined as follows:

Expanding Green Area (with smart surface strategy)

The main solution that is considered quite effective is a technical policy solution, especially with expanding green areas combined with a smart surface strategy. This solution was chosen because of the limited land area in the city of Yogyakarta for replanting even though there is a target of 30% green area. This solution is planned to be carried out through the installation of green roofs on the roofs of commercial buildings in the city of Yogyakarta. However, due to high operational costs, this temporary solution can only be carried out by private parties, such as hotels and shopping centers.

Cooling Strategic Plan

Another alternative solution is to create a set of strategic policies called Cooling Strategic Plan. This cooling strategic plan is comprehensive, starting from the plan, strategy, and implementation of the cooling plan. This plan should also contain technical arrangements for monitoring and evaluation. This plan ultimately aims to create sustainable cooling and urban sustainability in the city of Yogyakarta. The cooling strategic plan could be initiated by the city government directly because it has a regional character that is different from other regions. By basing it on PN6 from the RPJMN, the city government could prepare a cooling strategic plan with specific objectives for reducing the impact of UHI.

Penta-helix Collaboration

The next alternative offered can be said to be a scale-up of a partnership solution. In the penta-helix collaboration, the community does not only work with the government and the private sector but also with universities and the media. Looking at the achievements of the city of Yogyakarta with Proklim, it is clear that the existing successful Proklim could be redeveloped as a collaboration. The involvement of universities will increase the knowledge base for the efficient and effective use of technology. In addition, media involvement can strengthen the delivery of messages of adaptation and climate mitigation to achieve urban sustainable cooling. The voice of the media also can strengthen communication networks between stakeholders, even in other cities.

The overall results of the USCA analysis can be seen in the diagram below. On the left side are the concepts used in each USCA step. Then, in the middle is the empirical or technical part. The final part is the results or the answers of the Research strategy diagram (Figure 10). Each step is highlighted with a different color. The first color pink indicates the stages of UHI identification in Yogyakarta. High UHI is located in centers of urban activity. In the context of Yogyakarta City, the city centers are located at Maliboro and Solo Street. Next, the second block shows the SCC measurement which is calculated from the green urban area. High SCC results are shown in areas that have high vegetation and high values of shade and evapotranspiration but low albedo values. In the case of the city of Yogyakarta, the highest SCC is found in Umbulharjo Sub-district. In the last block, the blue color indicates the spatial planning solution policies. These solutions are divided into three parts, namely technical policies, strategic policies, and partnerships. Each solution has some points and applications from the Cool Cities and Cool World concepts with the principles of urban sustainability and sustainable cooling. For example, the technical policies consist of smart surface strategy, expanding green areas, and urban living labs. The smart surface strategy uses a combination of a variety of GUI concepts: (a) from urban sustainability and the concept of reduce, and (b) from sustainable cooling. It also explains the most effective solutions, the alternative solutions, and unimplemented solutions based on the analysis.

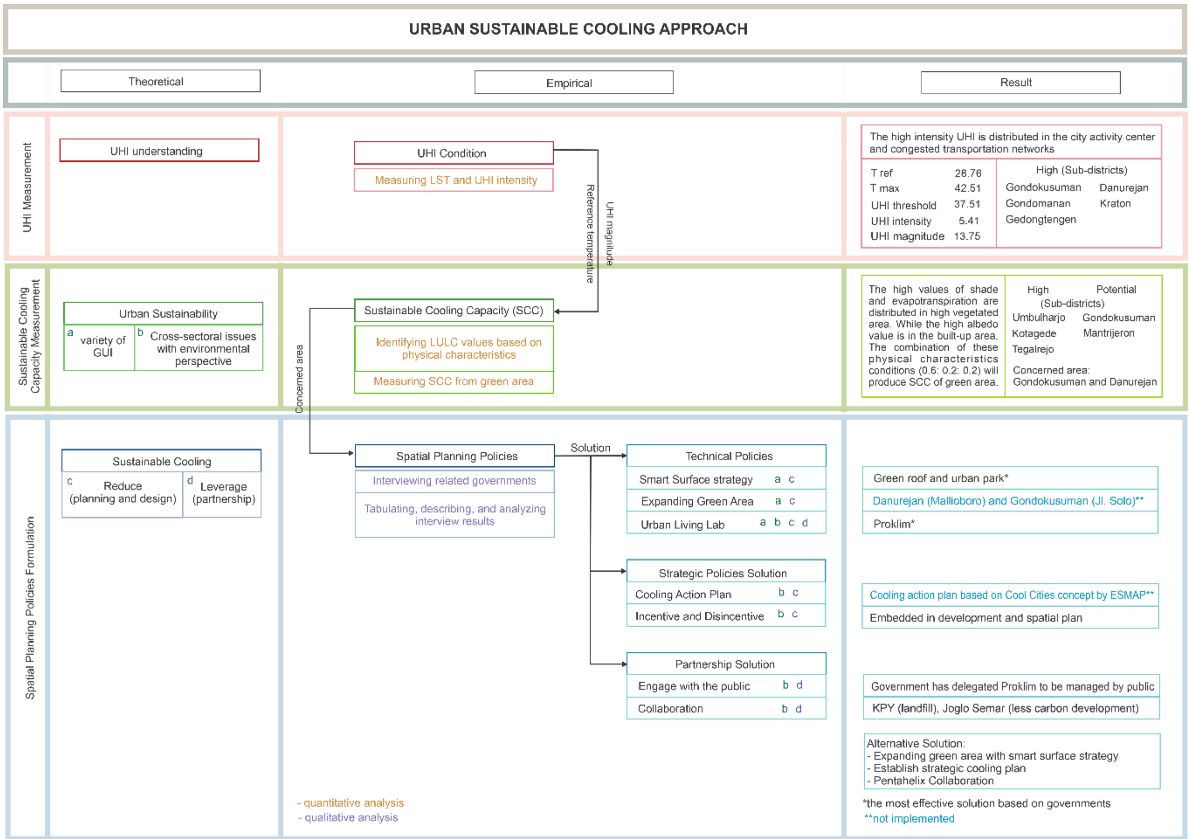

Figure 18. USCA Analysis Summary Diagram
Source: Author, 2021

6 Conclusion and Discussion

This chapter concludes the analysis results from each component of USCA. Then, for each component there is theoretical and methodological reflection. This chapter also connects to planning theory and makes recommendations for future research. Suggestions are also given for the local government regarding the spatial planning policies.

6.1 Generalization of USCA Formula

The Urban Sustainable Cooling Approach (USCA) has been formed from the main concepts: UHI, Sustainable Cooling Capacity, and Spatial Planning Policies. USCA, in this study, is used as a way to reduce the UHI. UHI is a phenomenon when urban areas experience a higher temperature than their surrounding non-urban areas (Deilami, 2018). UHI identification is the first step of USCA, and it has been used to understand the current condition of the city of Yogyakarta. It explains the location, intensity, and the surface temperature. UHI distribution shows the heat pattern and allows for the provision of sustainable cooling. The UHI distribution in Yogyakarta is dominated by high intensity UHI. The UHI threshold was 37.51 °C which is quite high. The highest UHIs were found in the Sub-districts of Gondokusuman, Kraton, Ngampilan, Gondomanan, and Gedongtengen, while lower UHIs were found in the Sub-districts of Umbulharjo and Tegalrejo. The results have been confirmed by interviews which stated that the urban activity centers, such as the Sub-districts of Gondokusuman (along Solo Street) and Danurejan (Malioboro), are in the high temperature stage and need cooling actions.

The second component of USCA is Sustainable Cooling Capacity (SCC). SCC utilizes green urban infrastructure to cool the environment. High urban vegetation presence can significantly mitigate the LST for high density low rise residential areas (Li et al, 2011). The cooling capacity is produced by the combination of physical characteristics values of green area (shade, evapotranspiration, and albedo). The SCC has indicated the existing cooling capacity of the Yogyakarta City. Umbulharjo Sub-district has high value of shade and evapotranspiration as it has the largest vegetated area. Then a high albedo value dominates the city of Yogyakarta, especially in the sub-districts which have high building density. The results of SSC measurements show that Yogyakarta is dominated by low cooling capacity; however, there are high SSC in the Sub-districts of Umbulharjo, Kotagede, and Tegalrejo. The medium level SCC was found in the Sub-districts of Gondokusuman, Mantrijeron, and Mergangsan.

The third or last component of USCA is the spatial planning policies solution which uses the concept of urban sustainability and sustainable cooling. The urban sustainability goal is based on SDGs 11 and Radzi (2018) which aims to make cities sustainable by lowering urban carbon footprints and reducing GHG emissions. The other concepts are from Lehman and Droege (2008) and James (2014) which explain the principle of urban sustainability and the environmental perspective. The concept of sustainable cooling adopts the principle of sustainable cooling from SEforAll (2020): reduce and leverage. From the spatial planning solution, recommended policies were formulated and offers of alternatives of policies were made.

The Spatial Planning Policies solution is divided in three main solutions: technical policies, strategic policies, and partnership. These solutions are formed from the concepts of urban sustainability, sustainable cooling, and also those of Cool World and Cool Cities. The technical policies consist of smart surface strategy, expanded vegetation area, and living lab. The strategic policies consist of cooling action plan and the incentive and disincentive mechanism. Finally, the partnership solution consists of engaging with the public and collaborating with other cities or private parties. From all of the solutions offered, the best spatial planning policies solution for Yogyakarta is to expand the green areas to fulfill the need for urban green areas. Another solution for consideration is Urban Living Labs, known as Proklim. The government also recommends alternatives of spatial planning policies, such as: 1) expanding green areas with a smart surface strategy, 2) establishing a cooling strategic plan, and 3) collaborating with penta-helix.

6.2 Theoretical and Methodological Reflection

Theoretical Reflection

There are three reflections of theory used in this research. The first theory regards the main cause of UHI as the dominance of built-up land. This was conveyed by Li et al (2020), that a factor contributing to UHI is building density. However, when the results of spatial analysis were compared to the interview results, it became clear that busy transportation also produces high GHG emissions, which then increases UHI. Thus, transportation networks need consideration in the future theory as the solutions will address cross-sectoral issues.

Second, the SCC concept in this study uses green area as the main cooling element. Bowler et al (2017) have said that the parks which have green sites are than non-green sites. The green area parameters used in this research are in accordance with the work of Phelan et al (2015) and Zardo et al (2017) and consist of shade, evapotranspiration, and albedo. Each parameter has its own weight - 0.6, 0.2, and 0.2 respectively. These default weight values can be adjusted to different combinations to meet various green area conditions in different regions.

The third concept of spatial planning from Healey (1997) cannot be fully implemented in Indonesia because it is not very suitable with the characteristics of planning implementation in Indonesia. To be more compatible with spatial planning in Indonesia, this study used additional principles, such as GI planning and urban sustainability. Thus, spatial planning incorporated the urban sustainability value, which involves the specific ecology, economic, culture, and politics characteristics.

Methodological Reflection

This research encountered opportunities and limitations in methodological process. First, in the UHI measurement framework from Kaplan et al (2018), there is a section of NDVI which can be used as an opportunity to verify or support the results of the SCC analysis related to green areas. NDVI supports evapotranspiration and shade identification when filling out the biophysical table as input to the InVEST process. This increases the accuracy of the SCC measurement. Second, in the SCC measurement methodology, using InVEST software means that the reality is approached by the parameters. It might not show the comprehensive condition reality. The results should be verified and justified through interview with experts. This will avoid errors when processing and reading digital results. Third, the interview method conducted online had limitations, such as information clarity because the related document could not be shown. Another issue affecting the outcome of the interviews was the time difference (5-6 hours). Some interviews were conducted at less than effective times. In addition, complicated bureaucracy meant that some interviewees had to replaced. The fourth limitation was experienced during the obtaining of spatial data from Yogyakarta city government agencies. Detailed spatial data such as RDTR and RTBL are inaccessible even for academic research purposes. Furthermore, there are limitations in language when mentioning policy terminology in Bahasa Indonesia. Important terms and abbreviations have been described in the abbreviation section. However, some of these terms are contextual and could lead to misinterpretation. Therefore, the researcher included an email to clarify some of these terms and possible misinterpretations.

6.3 Link to Planning Theory and Possible Further Research

This study offers an approach, USCA, which could be used to reduce the UHI phenomenon in urban areas. USCA is formed from the main concepts: UHI, Sustainable Cooling Capacity, and Spatial Planning Policies. The concept of UHI and Sustainable Cooling Capacity are used to determine the conditions of the urban temperature and urban vegetation. An understanding of the distribution of UHI intensity and the capacity of sustainable cooling can contribute to the development of planning theory, especially in the development of green urban infrastructure planning. The benefits of green infrastructure are widely recognized, yet the actual design, delivery, and maintenance of green infrastructure on the local level are found to be difficult (Jerome, Mell, & Shaw, 2017; Willems et al, 2020). Thus, USCA is an attempt to formulate a green urban infrastructure planning formula for government at the local level. This planning formula recommends including the concepts of urban sustainability and sustainable cooling in order to manage green urban infrastructure, which in turn can reduce UHI. These two concepts essentially use cross-sector values, a variety of green urban infrastructure, and the principle of reduce and leverage.

Suggestions for further research concern planning. Research should be carried out to make a projection and scenario based on SCC. This enables the cities to know the suitable proportion and distribution of green area needed in the future. The proportion of each city may not always be 30% as it is dependent on regional conditions. This would be very useful for evaluating the spatial plan and development plan of a city. It could also be used to understand the impact of existing spatial planning policies on urban temperature. In addition, as mentioned in the previous section, albedo engineering by implementing the smart surface strategy in Yogyakarta, especially green roofs, needs a cultural approach. Yogyakarta City has a uniqueness among Indonesian cities. The governor is the king of Yogyakarta Palace and thus development is strongly influenced by the palace. The renovated or new buildings should not reduce the cultural values of Yogyakarta. Cultural considerations can be included in the USCA component for several cities in Indonesia that have a distinctive city image. This research is expected to make USCA more comprehensive.

6.4 Suggestion for the Local Government to Enhance the UHI Reduction Process

Three suggestions for the government, especially the municipality government of Yogyakarta, have arisen from the results of this research. First, the government needs to have a strategic cooling plan for solving UHI problems. This can be done at various levels including at the initiation of the city level government. The strategic cooling plan should cover various integrated sectors. The second is using SCC as a consideration in the evaluation of the proportion of green open space in Yogyakarta. This proportion may be bigger or smaller than 30%. The calculation of this proportion can be replicated in other cities close to Yogyakarta to allow for a provincial perspective. A wider perspective will open up opportunities for collaboration to expand the SCC effect to reduce UHI. Finally, revival of Yogyakarta's local wisdom transportation, which is environmentally friendly, is recommended. These are traditional types of transportation without machines. The other sector that contributes significantly to UHI, besides built-up areas, is motorized vehicles.

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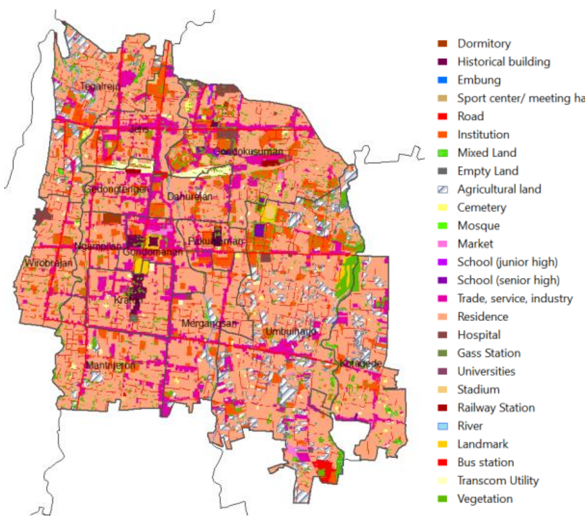
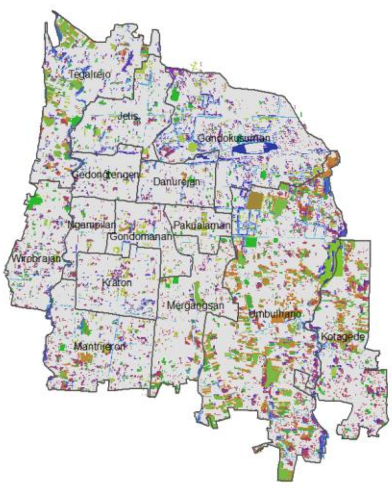
Cover photo source: https://www.krjogja.com/berita-lokal/diy/yogyakarta/begini-penampakan-wajah-baru-tugu-saat-tahun-baru/

Appendix A: Land use type of Yogyakarta City





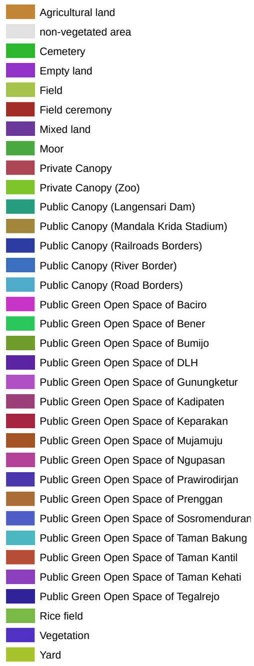


Figure A1. LULC of Yogyakarta City (left) and Detailed Vegetation Types (right) (Source: Environmental Agency, 2018)

Table A1. LULC Types of Yogyakarta City

LULC Type	Area (ha)
Square	5.378
South Square	1.672
Dormitory	6.091
Historical building/ cultural heritage	16.18
Sport center/ meeting hall	0.741
Yard	39.755
Road	183.685
Private Canopy	192.528
Private Canopy (Zoo)	17.392
Public Canopy (Langensari Dam)	1.403
Public Canopy (Road Borders)	73.71
Public Canopy (Railroad Borders)	10.882
Public Canopy (River Border)	37.375
Public Canopy (Mandala Krida Stadium)	7.518
Institution	209.196
Mixed land	8.966
Empty land	4.293
Agricultural land	124.504
Field	17.007
Sealing of field	2.14
Container parking lot	3.612
Field ceremony	0.114
Cemetery	34.494
Mosque	0.12
Market	8.1
School (junior high)	3.336
School (senior high)	5.036
Trade, Services, Industry	307.839
Residence	1610.19
Public Green Open Space of Bumijo	0.057
Public Green Open Space of Prawirodirjan	0.034
Public Green Open Space of Sosromenduran	0.078
Public Green Open Space of Baciro	0.054
Public Green Open Space of Bener	0.112
Public Green Open Space of DLH	0.046
Public Green Open Space of Gunungketur	0.075
Public Green Open Space of Kadipaten	0.035
Public Green Open Space of Keparakan	0.034
Public Green Open Space of Mujamuju	0.022
Public Green Open Space of Ngupasan	0.045
Public Green Open Space of Prenggan	0.04
Public Green Open Space of Taman Bakung	0.069
Public Green Open Space of Taman Kantil	0.136
Public Green Open Space of Taman Kehati	0.045
Public Green Open Space of Tegalrejo	0.121
Hospital	11.537
Rice field	73.563
Universities	1.894
Gas station	0.079
Stadium	3.124
Railway station	4.892
River	26.504
Moor	91.384
Landmark	7.488
Bus station	5.406
Transcom Utility	29.582
Vegetation	116.431
Total	**3306.144**

Source: Environment Agency of Yogyakarta, 2018

Appendix B: UHI measurement process

a. Conversion of Digital Number (DN) to spectral radiance
The DN in Landsat 8 needs to be converted to spectral radiance to correct the atmospheric effect on the reflectance value (Yaro et al, 2017). The conversion is done in band 10 (thermal), band 4 (red), and band 5 (near infrared) using the following formula (Fawzi, 2017):

Table B1. Conversion formula for spectral radiance

Band	Formula
	$L\lambda = MLQcal + AL$
10	0.00033420*b10+0.10000
4	0.0060117*b5-7.47526
5	0.0098238*b4-49.11910

b. Conversion of DN to spectral reflectance
This conversion is done only for band 4 and band 5 to get the at surface reflectance of vegetation using the formula displayed below (Yaro et al, 2017). It also important to reduce (masking) the cloud in this step so the image represents the right DN.

Table B2. Conversion formula for spectral reflectance

Band	Formula
	Rƛ = (ƛ) / ƛ () = ($MR\ Qcal + AR$) / sin Qse
4	((0.00002*b4)-0.100000)/sin (54.19672095)
5	((0.00002*b5)-0.100000)/sin (54.19672095)

c. Calculation of Normalized Difference Vegetation Index (NDVI)
NDVI is a simple graphical or numerical indicator (Yaro et al, 2017) that can be utilized for vegetation extraction and emissivity correction. It is calculated using the following formula (Kaplan, 2018):

NDVI = (NIR – Red) / (NIR + Red)
= (b5-b4)/(b5+b4)

d. Calculation of Proportion of Vegetation (Pv)
NDVI is used to determine the Pv in an area by using the formula displayed below (Kaplan, 2018). PV itself is defined as the ratio of the vertical projection area of vegetation on the ground to the total vegetation area (Deardorff, 1978; Neinavaz, 2020).

Pv = ((NDVI – NDVImin) / (NDVImax – NDVImin)) ^{2}
= ((NDVI-0.15) / (0.801-0.15)) ^2

e. Emissivity correction
Emissivity is the effectiveness in emitting energy as thermal radiation (Hamid and Sayel, 2019). Emissivity can be measured using the formula below (Fawzi, 2017):

ε = 0,985Pv + 0,960 (1-Pv) + 0,06Pv (1-Pv)

f. Top of Atmosphere (TOA) correction
This correction is used to minimize the difference in the intensity of solar radiation hitting the earth and can be calculated using the following formula (Fawzi, 2017):

$Lsensor, \lambda$ = $((L\lambda - Latm\_up)/\ \varepsilon\ T) - ((1 - \varepsilon)/\ \varepsilon)\ Latm\_down$
= $((L\lambda$ -3.16)/(ε * 0.64)) - ((1- ε)/ ε)*4.92

g. LST Estimation
LST is the response of different land covers and can be determined using the formula displayed below from Fawzi, 2017:

LST = (K2 / (ln (K1 / $Lsensor, \lambda$) + 1)) − 273.15
= (1321.0789/Ln((774.8853/L) + 1))-273.15

h. Threshold temperature for UHI

This threshold temperature is used to determine the temperature considered as UHI phenomenon. In this case, if the temperature is higher than 35.95 °C, it is considered as UHI.

$$T = \mu + 0,5\ \alpha$$
$$= 34.082582+(0.5*3.751307) = 35.9582355$$

i. UHI Map

UHI map is derived from the formula of Fawzi (2017) displayed below. The temperature used in this formula is the value obtained from adjusting local neighborhood temperature. Adjustment temperature analysis is needed because the temperature in particular places affect each other places (pixel).

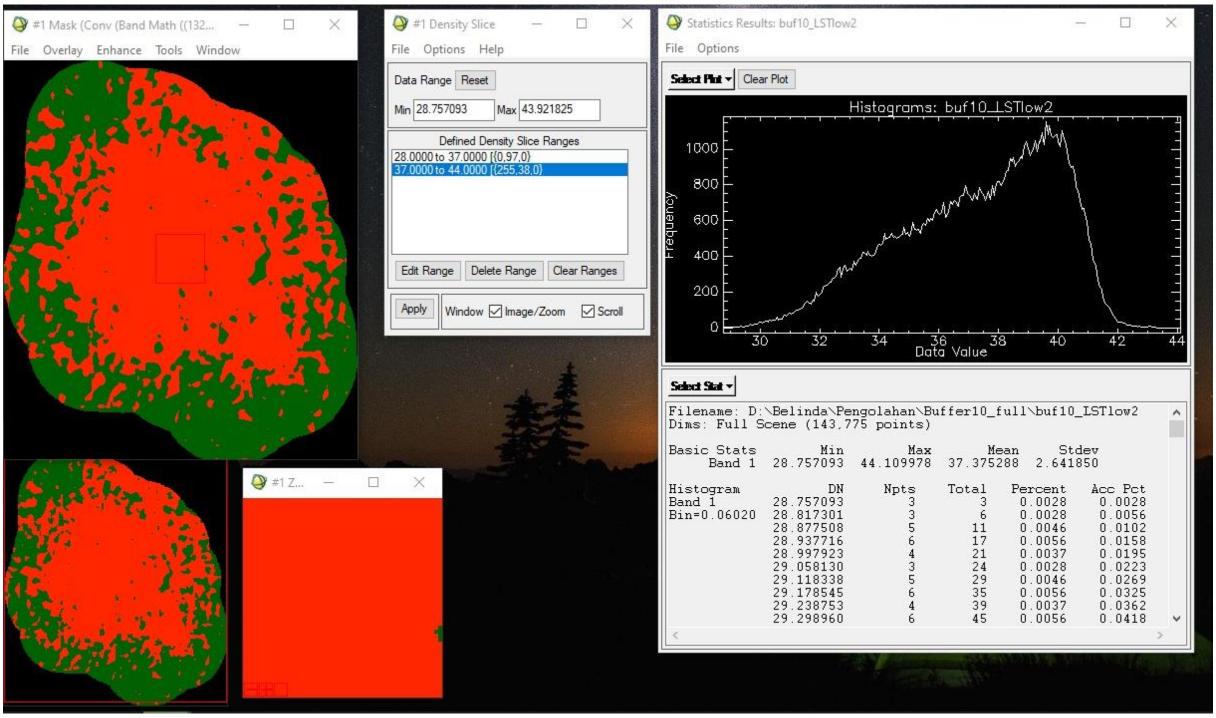
$$\text{UHI Map} = Tmean - (\mu + 0,5\ \alpha)$$
$$= Tmean-(34.082582+(0.5*3.751307))$$
$$= Tmean-37.814834$$

Table B3. Nomenclature from the formula

Notation	Description	Notation	Description
L_λ	spectral radiance at sensor	$L_{sensor,\lambda}$	radian sensor at TOA
Q_{cal}	DN	L_{atm_up}	atmospheric radiance upwelling
M_L	rescaling constant from metadata	L_{atm_down}	atmospheric radiance downwelling
A_L	adder constant from metadata	T	atmospheric transmittance value
R_λ	spectral reflectance at sensor	TB	Temperature of Brightness
M_R	rescaling constant from metadata	$K1$	Calibration constant of radiance spectral from metadata
A_R	adder constant from metadata	K2	Calibration constant of absolute temperature from metadata
Q_{SE}	sun elevation angle	Ln	Antilog
NIR	Near Infrared	μ	average temperature
Pv	Proportion of vegetation	Α	deviation standards temperature
Ε	Emissivity	Tmean	LST from neighboring (3x3) filter analysis

Source: Author, 2021

Appendix C. UHI Distribution based on Threshold



Appendix D. Biophysical table for model input

lucode	LULC Type	Shade	Kc	Albedo	Green_Area
1	Square	0	0	0	0
2	South Square	0	0	0	0
3	Dormitory	0	0	0	0
4	Historical building/ cultural heritage	0	0	0.93	0
5	Sport center/ meeting hall	0	0	0.93	0
6	Yard	0	0	0	0
7	Road	0	0	0	0
8	Private Canopy	1	1	0.52	1
9	Private Canopy (Zoo)	1	1	0.52	1
10	Public Canopy (Langensari Dam)	1	1	0.52	1
11	Public Canopy (Road Borders)	1	1	0.52	1
12	Public Canopy (Railroads Borders)	1	1	0.52	1
13	Public Canopy (River Border)	1	1	0.52	1
14	Public Canopy (Mandala Krida Stadium)	1	1	0.52	1
15	Institution	0	0	0.93	0
16	Mixed land	0.5	0.93	0.52	1
0	Bare land	0	0	0	0
17	Agricultural land	0.25	0.882	0.77	1
18	Field	0	0	0	0
19	Sealing of field	0	0	0	0
20	Container parking lot	0	0	0	0
21	Field ceremony	0	0	0	0
22	Cemetery	0	0	0	0
23	Mosque	0	0	0.93	0
24	Market	0	0	0.93	0
25	School (junior high)	0	0	0.93	0
26	School (senior high)	0	0	0.93	0
27	Trade, Services, Industry	0	0	0.93	0
28	Residence	0	0	0.93	0
29	Public Green Open Space of Bumijo	1	1	0.52	1
30	Public Green Open Space of Prawirodirjan	1	1	0.52	1
31	Public Green Open Space of Sosromenduran	1	1	0.52	1
32	Public Green Open Space of Baciro	1	1	0.52	1
33	Public Green Open Space of Bener	1	1	0.52	1
34	Public Green Open Space of DLH	1	1	0.52	1
35	Public Green Open Space of Gunungketur	1	1	0.52	1
36	Public Green Open Space of Kadipaten	1	1	0.52	1
37	Public Green Open Space of Keparakan	1	1	0.52	1
38	Public Green Open Space of Mujamuju	1	1	0.52	1
39	Public Green Open Space of Ngupasan	1	1	0.52	1
40	Public Green Open Space of Prenggan	1	1	0.52	1
41	Public Green Open Space of Taman Bakung	1	1	0.52	1
42	Public Green Open Space of Taman Kantil	1	1	0.52	1
43	Public Green Open Space of Taman Kehati	1	1	0.52	1
44	Public Green Open Space of Tegalrejo	1	1	0.52	1
45	Hospital	0	0	0.93	0
46	Rice field	0.2	1	0.77	1
47	Universities	0	0	0.93	0
48	Gas station	0	0	0.93	0
49	Stadium	0	0	0.93	0
50	Railway station	0	0	0	0
51	River	0	0	0.1	0
52	Moor	1	0.93	0.52	1
53	Landmark	0	0	0	0
54	Bus station	0	0	0.93	0
55	Transcom Utility	0	0	0	0
56	Vegetation	1	1	0.52	1

Appendix E: Interview Guide

Introduction and Preparatory Steps

- Introduce yourself
- What happens with the data? (The interview is being recorded and the result will be kept confidential so their privacy is guaranteed)
- Tell (the respondent) why you are doing the research
- Does the respondent agree to recording the conversation?

Opening Questions

- How long have you worked in this government office and what is the work area? (For national government) Have you visited or had projects in Yogyakarta City (within the urban area)?
- What type of planning do you do that affects the urban temperature or local climate?
- What do you think about the temperature of Yogyakarta (densely populated city)?

Transitioning Questions

- What do you think about the Urban Heat Island phenomenon in Yogyakarta City (Urban area)?
- Which place do you think has the highest temperature in Yogyakarta City (Urban Area)? What do you think about the temperature in Umbulharjo and around Ngampilan sub-district?
- Has there been spatial planning of Yogyakarta City (Urban area), including Green Open Space policies, and any physical characteristics (shadow, evapotranspiration, albedo)?
- What do you think about the impact of spatial planning on the local climate in Yogyakarta City (Urban area)?

Key Questions

Strategies (Technical Solution)

- (Smart surface strategy) Are there any cool roofs, cool walls, cool pavements, green roofs, green walls, permeable pavements, or tree canopies and parks?
- (Expanded vegetation area) Where should there be urgent addition of green areas?
- (Living labs) What do you think of the use of Proklim (Climate village program) in reducing UHI?

Intervention (Policy Solution)

- (Cooling action plan) Does Yogyakarta already have a cooling action plan or strategic plan?
- (Incentives - disincentives mechanism) Is there a policy regarding incentives when adding green areas?

Opportunities (Management Solution)

- (Engage with the public) How many times does the government engage with the public in a year?
- (Lead by example) Are there any government efforts to disseminate information regarding the addition of green areas by the government to reduce UHI?
- (Collaboration with other cities or private parties) Which cities or private parties have been invited to cooperate?
    - What forms of collaboration have been used?

Concluding Questions

- Which of the discussed solutions is the most important for Yogyakarta City (urban area)? (Provide list of the discussed elements)
- What do you want to see or offer in the future for Yogyakarta City (urban area)?

Closure

Well, thanks a lot for your time and your insightful data. I would personally like to close without any comments on your answers (I don't want to rank or react to any responses) but I appreciate your input. Your data will be very helpful for this research and handled confidentially without the involvement of any third parties, other than my supervisor. How did you find out about this interview? Is there anything else you like to share about your neighborhood?

Do you know anybody else that would be willing to participate in an interview?

Appendix F: Interview Results

NO	Solution		National		Regional (Provincial)		Local (City)	
			Ministry of Environment and Forestry (MoEF)	**Bappenas**	**The Center of Development Control in Java Eco-region (CDCJE)**	**Bappeda DIY Province**	**Agrarian and Spatial Affairs Agency (ASSA)**	**University**
1	Preliminary questions regarding UHI and SCC	UHI understanding	Increasing earth surface temperature. Cause: GHG emission from multi-sector activities (agriculture, industry, energy-transportation, waste, and forestry) Anthropogenic phenomenon because of mobility	Increasing urban average temperature. Cause: • Increasing urban social aspect • Urban development • Low cloud level in the city	Increasing urban temperature Cause: High building density	The increase of urban temperature Cause: emission increase from the sector of transportation, industries, and sewage	The urban temperature is getting warmer	The high temperature of the urban area especially in the Greater Jogja Cause: • high building density • high emission levels from transportation sector
		Location which has high temperature	Malioboro area as it is the centre of economic, transport, and government	Solo Street	City center - Malioboro and surrounding area (Mataram Street, Mangkubumi, Terban, Alun-Alun Kidul, Ngabean)	Solo Street (eastern part of Jogjakarta) Fast growing area along toll roads and ring roads	Solo Street (eastern part of Jogjakarta)	• Malioboro area • Tugu area • Multiple nuclei/ city center of Yogyakarta City
		SP policies (different level) mentioning physical characteristics?	• Not mentioned in the (sectoral) Minister Regulation • Policy emphasizes climate change and mitigation in five sectors.	• The minimum proportion of green areas is mentioned but not the physical characteristics of green areas in the national spatial plan • Spatial plan and development plan emphasizes National Priority 6 (less carbon and energy efficiency)	Not mentioned in the regional regulations	-	• Not technically mentioned in the local regulation • The local regulation emphasizes the proportion of public green open space (target: 20%) • Existing green area proportion in local level: 6%	• Mentioned in the Environmental and Building Plan • The plan emphasizes the effect of green area ratio and building coverage ratio • Environmental and Building Plan and other spatial plans of Yogyakarta City are not accessible
		What are the impacts of existing SP on regulating the temperature?	• Carbon emission reduction • For Forestry, compared to 2015, there has been a decrease forest fire area because the regional temperature has dropped	• The temperature has not become an indicator of regulating local climate. • Regulating local climate needs specific indicators, such as the amount of emission.	The impacts on the temperatures cannot be measured since the temperature has not become an indicator of environmental monitoring	GHG emission reduction which could eventually reduce the temperature	• Temperature has not become the planning indicator so the impact cannot be measured • Only focuses on fulfilling the green area target requirement	• There is no specific local regulation addressing temperature or UHI • Studies about UHI were not followed up by the local governments.
2	Technical Policies Solution	Smart surface strategy	Policy: Climate adaptation action regulation Implementation: Ecosystem-based and artificial ecology-based adaptation action	Policy: Regulation of Ministry of Public Works No. 30/2006 concerning Technical Guidelines of Facilities and Accessibility in Building and Environment, Technical guidelines of green buildings Implementation: GBCI	Policy: - Implementation: -	Policy: Local Government Regulation No. 2 of 2021 about local spatial plan of DIY Province Implementation: no implementation due to high operational budget	Policy: environmental and building plan (RTBL) Implementation: only implemented by hotels	Policy: RTBL and DED Implementation: no implementation of green architecture - the city image has a strong influence on the buildings.
		Expanded vegetation area	Policy: Ministry Regulation No.2/2020 about implementation procedures, support activities, giving incentives, as well as counting and controlling forest and land rehabilitation activities Implementation (location): critical land	Policy: Law 26/2007 about spatial plan and national spatial plan Implementation (location): roofs, cemeteries, roads	Policy: Governor Regulation No. 2/2021 about the spatial plan of DIY Province Implementation (location): city Center	Policy: Local Government Regulation No. 2 of 2021 about local spatial plan of DIY Province (in the part of establishing green area) Implementation (location): in the sub urban or rural area outside the City of Yogyakarta	Policy: Regulation of Mayor No. 5/2016 regarding public green open spaces Implementation (location): Solo Street or urban activity centers	Policy: - Implementation (location): roofs

		Living lab	Policy: Minister Regulation No. 84/2016 Implementation: Proklim • Proklim is the most successful and favorable program and can be the urban living lab • Proklim is accelerated with higher requirements and various activities • Proklim can be used to evaluate community perception towards climate change in five years	Policy: - Implementation: there is no direct program to engage with the public except Musrembangnas	Policy: - Implementation: -	Policy: Minister Regulation No. 84/2016 Implementation: Proklim with the focus activities on waste management and revegetation	Policy: Minister Regulation No. 84/2016 Implementation: • Taman Budaya (Cultural Park) in Giwangan which is environment-based. • Along with the national target (20,000 new Proklim) of 2019, Yogyakarta has added 10 new Proklim across the 10 sub-districts.	Policy: - Implementation: Urban farming to add more green areas which aims to reduce urban temperature
3	Strategic Policies Solution	Cooling action plan	Policy: Ministry Regulation No.33/2016 about Guidelines for Developing Climate Change Adaptation Actions Implementation: Climate Adaptation Action Plan, reduce GHG emission	Policy: RPJMN 2020-2024 in National Priority 6 Implementation: the action tried to address environmental pollution issues	Policy: RPJMD 2017-2022 Implementation: -	Policy: RPJMD 2017-2022 and related sectoral policies Implementation: -	Policy: RTBL Implementation: building permits with green area requirements	Policy: RTBL Implementation: -
		Considering incentives - disincentives mechanism	Policy: • Minister regulation No. 84/ 2016 about Proklim • National spatial plan Incentives: • reward from Proklim • appreciation certificates for greening activities • Special allocation funds (Dana Alokasi Khusus/ DAK) Disincentives: no mechanism implemented	Policy: - Incentives: local community should be aware of the benefits Disincentives: Low law enforcement for cities which cannot meet the green area target. The minimum disincentive is in the form of making a commitment to add more green areas in the future.	Policy: RPJMD and RTRW Province Incentives: appreciation certificates for greening activities. Special allocation funds (Dana Alokasi Khusus/ DAK) Disincentives: -	Policy: Presidential Decree No. 12 of 2012 because of maintenance of the sustainable farms (LP2B) from LU change Incentive: - Disincentive: -	Policy: RTBL Incentives: using compensation such as ease of permit Disincentives: -	Policy: RTBL Incentives: government appreciation for communities who have sold their land to the government Disincentives: -
4	Partnership Solution	Engage with the public	Policy: • Minister regulation No. 84/ 2016 about Proklim • Minister Regulation No. 5/2017 about Guidelines for Calculation of Greenhouse Gas Emissions for Community-Based Climate Change Mitigation Action Presidential mandate to involve the community in each of the government's program effectively Implementation: • The Ministry has claimed that there is increasing community awareness of climate change. They have begun mitigation and adaptation action by increasing the number of Proklim along with the new target 20,000 villages by 2024. • The local champion of Proklim has been invited as a national speaker.	Policy: RPJMN 2020-2024 – National Priority 6 Implementation: • Musrembangnas event to discuss the national development plan • Public Consultation by inviting the local communities and green area representatives. • Social media campaign regarding environmental issues	Policy: - Implementation: • Socialization to the community and students to adapt to climate change • Campaigns (climate change, plant trees) via social media	Policy: RPJMD, RTRW Province, Proklim regulation Implementation: Musrembangda but Bappeda is not really involved in this planning action because it is not technical agency	Policy: RTBL Implementation: • Local communities are encouraged to sell their land to local government so that the government can use it to expand the GI • Proklim	Policy: RTRW Implementation: Proklim
		Collaboration with other cities or private parties	Policy: Multi-sector climate change mitigation policies to reduce GHG effects (reduction of CO2)	Policy: RTRWN and RPJMN	Policy: applying the national policy from MoEF	Implementation: sanitary landfill in Piyungan, Bantul is a collaboration to reduce the	Implementation: • Revitalization of Gadjah Wong River Area which is in	Implementation: • The Greater Jogja (KPY) control development.

			Implementation: Comparative study from best practice location Private sector at the national level which work with other cities: companies (Chevron, Indosemen, Astra), universities, NGO, local foundations Mechanism: CSR	Implementation: Yogyakarta has a collaborative program to make integrated working groups with JogLoSemar. The target of this is less carbon production Mechanism: integrated in local development	Implementation: Environmental day camp inviting student representatives in Central Java	GHG emission from domestic waste	collaboration with the World Bank • Establishment of eco-districts in Giwangan, which are a collaboration with the France Foundation and universities • Developing environment-based TOD Giwangan which is a collaboration with the World Bank	• Urban sprawl is now heading to the west (New Yogyakarta International Airport) and east (provincial corridor: Joglo Semar)
	Best solution		Living labs (Proklim)	All of them are cooling action plans which integrate various types of solutions. Next, formulation of implementation strategies is needed in relation to funding and stakeholder collaboration	Socialization to raise community awareness to add more green areas	All of them because they relate to each other. However, the first priority is expanding green areas	Collaboration with Surabaya City to adopt the method of identifying potential locations of GI	Smart surface strategy to the specific green roofs
	Recommendation		Environmental Policy Integration. Integrating environmental issues into the policies of transportation and settlement (limitation of private transportation, building permits)	Pentahelix Collaboration which involves the media to communicate climate issues	• Change into eco-friendly transportation • Improve the quality of public transportation • Regulating the transportation can reduce carbon and decrease the temperature.	Penta-helix collaboration	• Identifying potential locations of GI in the limited urban area • Adopting the building concept of Kotabaru and Baciro residences which has spatial harmonization.	-