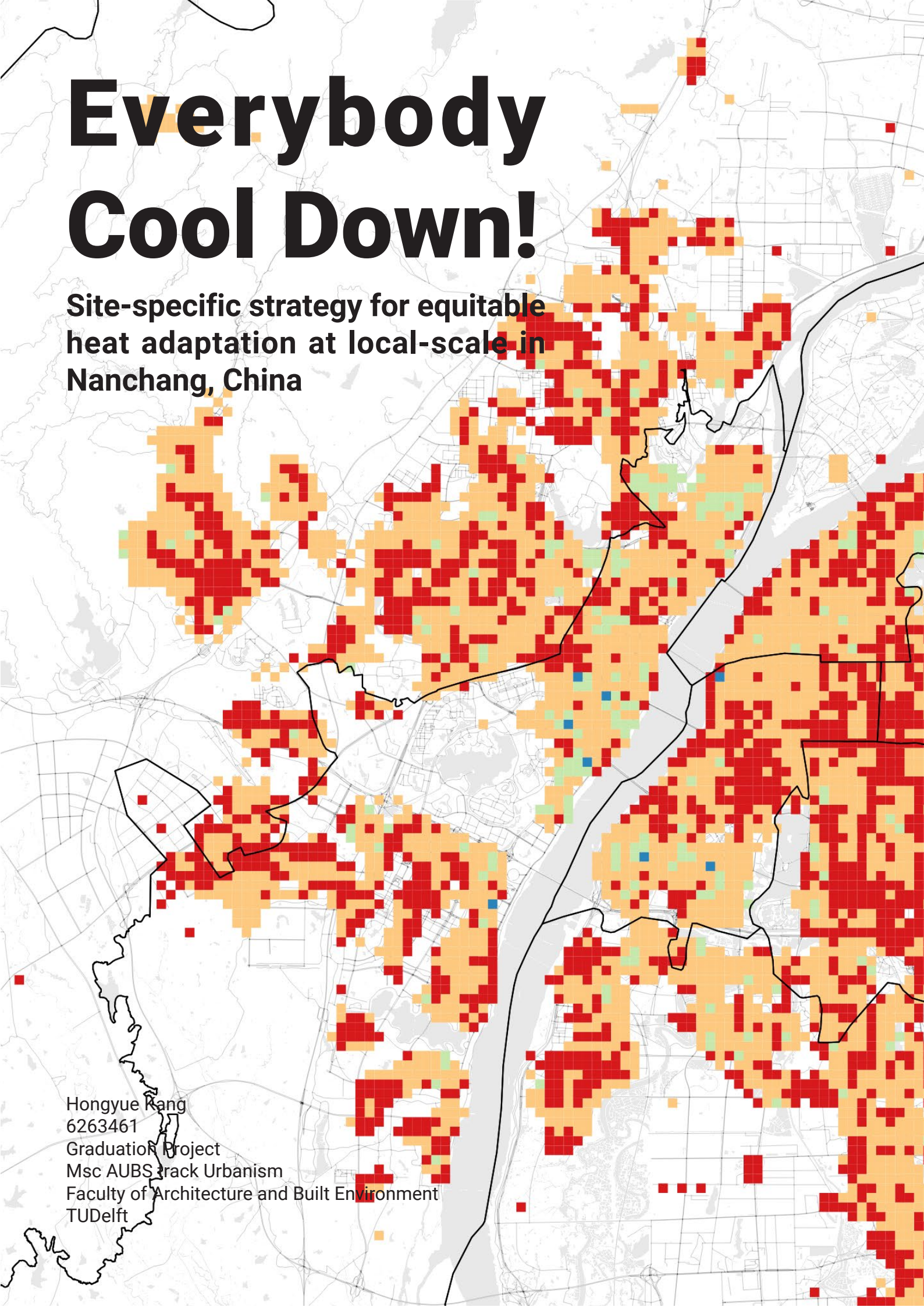


# Everybody Cool Down!

Site-specific strategy for equitable  
heat adaptation at local-scale in  
Nanchang, China

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Graduation Project  
Msc AUBS track Urbanism  
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# Colophon

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# Abstract

## Key words:

*Heat Risk, Equitable heat adaptation, Neighborhood, Pattern language, Participatory Design*

Urban heat has become an increasingly severe global challenge, bringing deteriorating thermal environments and growing heat stress for urban residents. While governments worldwide are attempting to adapt, many measures have been criticised as maladaptations – producing unintended consequences or exacerbating social inequity. Nanchang, widely recognised as one of China's "furnace cities", has seen extensive planning and research at macro and meso scales, yet effective local-scale solutions remain limited. This project addresses the inequities that emerge in Nanchang's heat adaptation process.

Drawing on the Crichton Risk Triangle framework, the research first maps heat exposure and vulnerability distribution, systemic inequity is also examined in current heat risk management. To translate these findings into actionable strategies, a heat adaptive pattern language is developed through literature review, providing residents with a structured set of locally grounded design tools. A two-part co-design workshop then engages residents directly – the first part surfaces their lived experiences, knowledge gaps, and concerns, which inform a refinement of the pattern language; the second invites residents to apply these patterns in producing neighbourhood design proposals. Drawing on specialist expertise, residents' ideas are filtered and reorganised into a consolidated intervention proposal. Thermal performance is tested through ENVI-met simulation, and results feed back into further refinement of the patterns. Finally, a feasibility-effectiveness matrix is produced as a practical recommendation tool for government and community committees.

Through this iterative process of spatial analysis, participatory design, and simulation, the project develops a proposal for locally grounded strategies that contribute to more equitable heat adaptation in Nanchang.

# Motivation

Growing up in Nanchang—a city long known as one of China’s “Four Furnace Cities”—I have witnessed how extreme summer heat has increasingly shaped daily life. Temperatures that once felt exceptional during my childhood, such as 36°C, have become the norm, with 38°C or higher now occurring regularly. For many residents, staying indoors with air-conditioning has become the primary coping mechanism. However, for children and the elderly—groups whose social life and daily routines still rely heavily on outdoor spaces—such heat conditions pose serious challenges. Their vulnerability underscores the importance of designing outdoor environments that offer adequate thermal comfort.

My motivation for studying heat adaptation originated from an observation made during a winter visit home in my bachelor years. I discovered that many small botanical gardens and green pockets in my neighborhood had been replaced by parking lots and recreational plazas. These vegetated areas once existed between residential buildings and beside public squares, providing shade, evaporative cooling, and spaces for social interaction. Their removal not only erased familiar community landscapes, but also coincided with noticeably harsher summer conditions that my parents and grandmother described in the following year. This experience made me aware of how urban renovation decisions—while addressing practical needs such as parking shortages—can unintentionally exacerbate heat stress, especially for vulnerable populations.

Such cases are unlikely to be isolated. In the broader context of Nanchang’s old-district renewal, thermal comfort is often sidelined amid competing priorities and limited participatory mechanisms within a top-down planning system. Yet ensuring equitable access to thermally comfortable outdoor spaces is essential for both public health and social well-being.

Therefore, through this thesis, I aim to develop a framework that integrates thermal comfort considerations into neighborhood-scale planning and design, with particular emphasis on supporting the elderly and children. My goal is to advocate for more equitable approaches to heat adaptation and to contribute design strategies that help communities better cope with increasingly extreme urban heat.

# Acknowledgement

I would like to express my sincere gratitude to my first supervisor, Daniela, who has accompanied my academic journey since Quarter 1 two years ago. Throughout this graduation project, her incisive perspectives and clarity of thought have been invaluable. She has a remarkable ability to cut through complexity and offer guidance that is both precise and genuinely useful. Beyond her intellectual contributions, Daniela has been a constant source of encouragement. I am someone who tends to doubt myself, and her belief in my work — expressed consistently and without reservation — gave me the confidence to keep going. Every conversation with her left me more grounded and more certain that the work was worth doing.

I am equally grateful to my second supervisor, Roberto, whose breadth of knowledge is matched by his generosity and approachability. His expertise was especially formative in shaping the co-design process — he brought thoughtful, well-considered suggestions that meaningfully improved the project. He was also unfailingly supportive during moments of self-doubt, offering encouragement and perspective that helped me through some of the harder stretches of this work.

I would also like to thank all participants who took part in the co-design workshops. Your willingness to share your everyday experiences of living with heat, and to engage thoughtfully with the design process, was the foundation of this research. This project would not exist without you.

Thanks to the research team of Chen Chaomin at Shanghai Normal University for generously sharing their Nanchang LCZ map, which was essential to this research.

My gratitude also goes to Marjolein, my supervisor during Quarter 2, who first opened my eyes to urban heat environment research two years ago. I am particularly thankful for the opportunity she gave me to serve as a student assistant at ICUC12, where I encountered many leading researchers in the field and deepened my thinking on the issues that would come to define this thesis.

To my parents: none of this would have been possible without your support. You made it possible for me to come to the Netherlands and grow in ways I could not have anticipated. I am also deeply grateful for the very practical role you played in this project — recruiting participants, helping coordinate workshops, and acting as my research assistants from thousands of kilometres away. Your involvement made the co-design process possible.

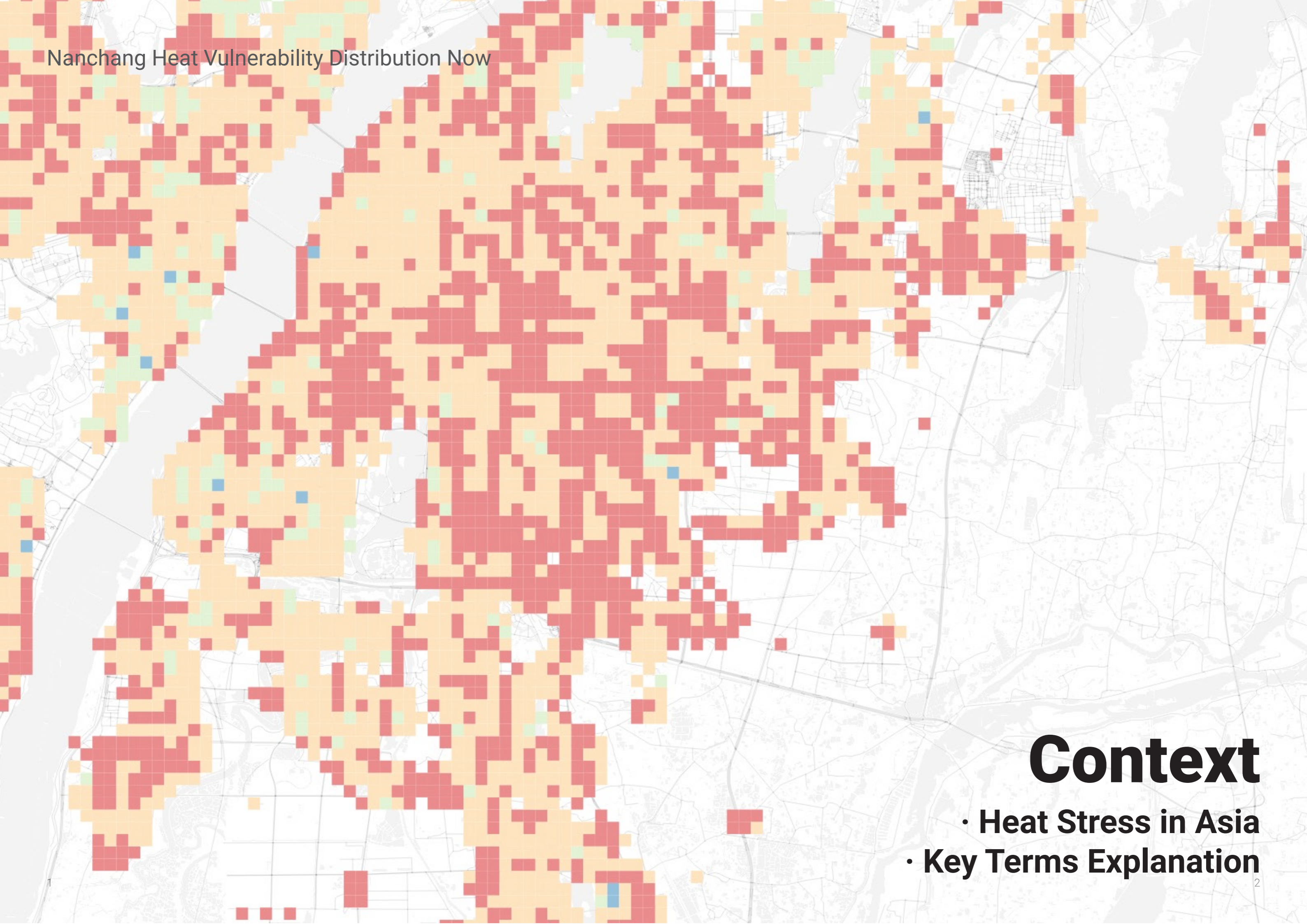
To my friends, both here in the Netherlands and back in China: thank you for being there during the difficult moments. Your encouragement carried me through more than you know.

Finally, I want to thank myself. Two years ago, I arrived alone in a country I did not know — someone who fears the unknown and struggles with the feeling of losing control, stepping deliberately into uncertainty. There were many moments of exhaustion and doubt along the way. But I made it. My future, like the one I faced at the end of my undergraduate years and again when I left for the Netherlands, remains unwritten. I know there will be new moments of anxiety, new stretches of not knowing where things are going. But I also know, eventually I will find my way through them. Thank you, Hongyue.

# Contents

<b>Context</b>	<b>1</b>	Site Selection	65
Heat Stress in Asia	3	Old Community Renovation Plan	67
Key Terms Explanation	4	Current thermal environment	69
<b>Scope</b>	<b>9</b>	Co-design Workshop	71
China is Getting Hotter	11	Interview	73
Nanchang, the Furnace City	15	- Behavior Pattern and Thermal Experience	73
Current Adaptation Context	19	- Thermal Comfort Perception	75
<b>Research Foundation</b>	<b>21</b>	- Stakeholders in Renovation	77
Problem Statement	23	Pattern language	79
Research Question	25	- Design	79
Conceptual Framework	27	- Basis: Heat Risk and LCZ	81
Methodological Framework	29	Participatory Design	83
<b>Analysis</b>	<b>33</b>	- Process Introduction	83
Spatial characteristic and heat exposure differentiation	35	- Residents' Proposals	85
Sensitivity: Where are the easily affected people?	41	- Proposal Synthesis	91
- Physically Sensitive Population	41	- Final proposal	93
- Socioeconomic predisposition	43	Simulation Result of Intervention	97
- Spatial Distribution	45	Recommendation Matrix	99
Adaptive Capacity: Where are the cooling resources?	47	<b>Conclusion</b>	<b>101</b>
- Passive Adaptation	47	<b>Self-reflection</b>	<b>107</b>
- Active Intervention	51	<b>Appendix</b>	<b>113</b>
- Spatial Distribution	57	Co-design Workshop Interviews	115
Vulnerability: Distributional inequity of cooling resources	59	Patterns	121
Vulnerability Beyond Morphology	61	Simulation of intervention	133
<b>Pilot Intervention: Liyuan Community</b>	<b>63</b>	<b>Bibliography</b>	<b>137</b>

Nanchang Heat Vulnerability Distribution Now



# Context

- Heat Stress in Asia
- Key Terms Explanation

# Heat Stress in Asia

According to the IPCC Sixth Assessment Report (Shaw et al., 2022), **most parts of Asia have experienced clear warming trends and increasingly frequent temperature extremes since the 20th century.** The report also documents the rising occurrence of extreme heatwaves in regions such as India, Pakistan, and **central-eastern China**. Furthermore, there is high confidence that under the RCP8.5 scenario, the wet-bulb globe temperature—an indicator of heat stress—will reach critical health thresholds in parts of East Asia (Seneviratne et al., 2021).

**Heat stress poses substantial risks to both society and human health.** As summarized by Shaw et al. (2022), higher temperatures increase cooling-energy demand and pose growing risks to infrastructure. For human populations, strong evidence indicates that **heat stress is associated with higher mortality and morbidity across Asia.** Elevated temperatures exacerbate circulatory, respiratory, diabetic, and infectious diseases, and also heighten the risks of mental health problems such as depression, anxiety, and psychological distress.

In response to the increasing risks of heat stress, there is an urgent need to advance the heat adaptation. In this case, **urbanists should first investigate heat through a spatial lens, which can become a critical foundation for developing a heat-adaptative urban design and planning.**

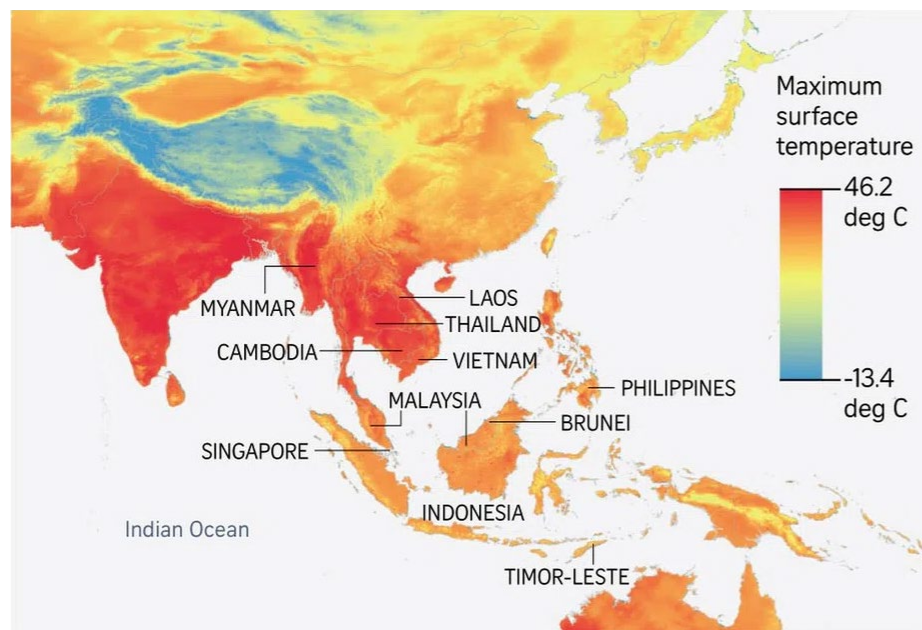


Figure 1. Maximum Surface Temperature in Asia, Data from April 1 to May 1, 2024

From Straits Times Graphics, with data from Environment and Climate Change Canada, and the Global Deterministic Prediction System.

# Key Terms Explanation

To have a comprehensive understanding of urban heat issues, it is better to rely on some key definitions and concepts that are related to urban heat adaptation.

## Macroclimate

Climate means “the typical sequence of weather events found at a place, often represented in terms of statistics of climatic elements (irradiance, wind, temperature, precipitation, etc.)” (Oke, Mills, Christen, & Voogt, 2017). And macroclimate is the statistics of such climate elements influenced by latitude, land and ocean as well as orography at global level. It is an important factor that causes the difference of heat stress worldwide.

According to the statistical relationship between annual and seasonal air temperature and precipitation, The Köppen Scheme (Kottek et al., 2006) was created. It identifies 5 macroclimatic types globally, they are: tropical (A); arid (B); mild temperate (C); continental temperate (D) and; polar (E). This framework plays an essential role in urban climate study, “it will provide a useful framework for examining how macroclimatic processes influence the magnitude and character of the urban effect over the course of a year.” (Oke, Mills, Christen, & Voogt, 2017).

## Heatwave

Heatwave does not have an absolute definition. It is regarded as a long period of abnormal high temperatures influenced by macroclimate, and it is frequently related with the cases when high temperature results in heat-related mortality and morbidity (Oke, Mills, Christen, & Voogt, 2017).

Strong evidences have proved that heatwave events are accompanied by the increasing magnitude of the Urban Heat Island (UHI), which is possibly due to the same kind of atmospheric condition (Li and Bou-Zeid, 2013).

## Urban Heat Island

Urban Heat Island (UHI) refers to an anthropogenic phenomenon that cities are usually hotter than surrounding areas. This phenomenon stems from the changes of energy balance that urbanization brought to the original site before city was built. According to Urban Climates, there are 4 types of UHI: The surface UHI ( $UHI_{surf}$ ), The canopy layer UHI ( $UHI_{UCL}$ ), The boundary layer UHI ( $UHI_{UBL}$ ) and The subsurface UHI ( $UHI_{sub}$ ). As for the  $UHI_{UCL}$ , “its magnitude is greatest after sunset when air above urban surfaces cools more slowly than air above rural ones.” (Oke, Mills, Christen, & Voogt, 2017). As has been introduced in heatwave part, UHI effect will be enhanced along with heatwave event, adding thermal stress and discomfort on human.

## Heat Stress

According to the energy balance framework (Oke, Mills, Christen, & Voogt, 2017), heat stress is the net thermal load imposed on the human body when the combined effects of environmental variables (high radiation, air temperature, and humidity) and metabolic heat production exceed the body's cooling capacity, forcing a positive response to prevent  $\Delta Q_s$  from rising above zero.

## Thermal Comfort

Thermal comfort cannot be assessed through any single meteorological parameter. Rather, it results from the integrated effect of all thermally relevant climatic factors on the human body's heat balance (Höppe, 1999). This balance is expressed as:

$$M + W + R + C + ED + ERe + ES_w + S = 0$$

Where each term represents a heat flow (in watts), with positive values indicating energy gain and negative values indicating energy loss:

**M** – metabolic rate (internal energy production)  
**W** – physical work output  
**R** – net radiation of the body  
**C** – convective heat flow  
**ED** – latent heat flow through imperceptible perspiration  
**ERe** – heat flow for heating and humidifying inspired air  
**ESw** – heat flow from sweat evaporation  
**S** – storage heat flow for heating or cooling body mass

This balance is influenced by two categories of factors: environmental parameters and personal factors (ISO 7730, 2005). The four environmental parameters are:

**Air temperature ( $t_a$ ):** the temperature of the surrounding air, measured in degrees Celsius.

**Mean radiant temperature ( $t_r$ ):** the temperature of an imaginary uniform enclosure in which a person would exchange the same amount of heat by radiation as in the actual environment (ISO 7730, 2005), measured in degrees Celsius. It primarily influences the net radiation absorbed by the human body.

**Air velocity ( $v_{ar}$ ):** the relative speed of air movement around the body, measured in metres per second. It affects convective heat exchange and, at perceptible levels, may cause localised cooling experienced as draught (ISO 7730, 2005).

**Air humidity ( $p_a$ ):** expressed as water vapour partial pressure in pascals, more commonly referred to as relative humidity (RH) in everyday contexts. It influences the body's capacity for evaporative heat loss through perspiration and respiration (ISO 7730, 2005).

The two personal factors are:

**Metabolic rate ( $M$ ):** the rate of internal heat production through physical activity, measured in watts per square metre ( $W/m^2$ ), where 1 met = 58.2  $W/m^2$ . It represents the primary source of heat that the body must dissipate to maintain thermal balance (ISO 7730, 2005).

**Clothing insulation ( $I_{cl}$ ):** the thermal resistance provided by clothing, measured in  $m^2 \cdot K/W$ , where 1 clo = 0.155  $m^2 \cdot C/W$ . It determines the rate at which heat is transferred from the skin surface to the surrounding environment (ISO 7730, 2005).

### Physiological Equivalent Temperature (PET)

PET is defined as the air temperature at which, in a standardised indoor environment, the human body's heat balance is maintained with the same core and skin temperatures as those produced under the outdoor conditions being evaluated (Höppe, 1999). The indoor reference conditions assume mean radiant temperature equal to air temperature, air velocity of 0.1 m/s, and water vapour pressure of 12 hPa. By translating complex outdoor thermal conditions into an equivalent indoor air temperature, PET allows non-specialists to intuitively interpret outdoor thermal stress based on everyday indoor experience (Höppe, 1999).

### Neighborhood

When a certain urban area shares homo-geneous urban characteristics to some degree, such as building dimensions, separation distance, impermeable and green cover, then this area can be defined as a neighborhood. Usually urban function or land use helps to distinguish neighborhood from each other, but such difference might not contribute to climatic terms. Instead, the notion of Local Climate Zone (LCZ) is more meaningful in climate topic.

LCZ is a classification based on “*their approximate ability to modify local surface climates due to their typical fabric, land cover, structure and metabolism.*” (Oke, Mills, Christen, & Voogt, 2017), see

table X. It is considered to be able to control micro- and local climate. This classification helps to distinguish a certain neighborhood from others according to its thermal performance.

### Local Climate Zone (LCZ)

Local Climate Zones (LCZ) are a standardised classification system for urban and rural land cover types, originally developed by Stewart and Oke (2012). The system defines seventeen zone types – ten built and seven natural – each characterised by a distinct combination of surface properties, including sky view factor, building height, surface albedo, and anthropogenic heat output. LCZs were designed to provide a consistent framework for comparing urban temperature observations across different cities and climatic contexts, and have since been widely applied in urban heat island research and outdoor thermal comfort studies.

### Heat Risk, Hazard, Exposure and Vulnerability

#### Heat Risk

Disaster risk is understood not as a fixed condition but as a continuum shaped by the interaction of hazard, exposure, and vulnerability (Cardona et al., 2012, as cited in IPCC, 2012). Risk is therefore not determined by the hazard event alone – the degree of adverse effects is substantially shaped by the vulnerability and exposure of the affected population.

Building on this understanding of risk as the interaction of hazard, exposure, and vulnerability, this research applies the same framework to the specific context of urban heat, where heat risk is understood as the potential for adverse effects on urban residents arising from the combination of heat hazard, their exposure to elevated thermal conditions, and their vulnerability to heat-related harm.

#### Hazard

Hazard refers to the possible future occurrence of natural or human-induced physical events that may have adverse effects on vulnerable and exposed elements (Cardona et al., 2012, as cited in IPCC, 2012). In the context of urban heat, hazard can be understood as the occurrence of extreme heat events and elevated thermal conditions that pose potential harm to urban residents.

#### Exposure

According to IPCC SREX (Cardona et al., 2012), “*Exposure refers to the inventory of elements in an area in which hazard events may occur*” (Cardona, 1990; UNISDR, 2004, 2009b).

#### Vulnerability

“*Vulnerability refers to the propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events*” (Cardona et al., 2012)

Previously, vulnerability primarily referred to the physical resistance of engineering structures within the field of disaster risk management (UNDHA, 1992). In recent decades, however, the concept has expanded beyond purely technical interpretations and has become increasingly associated with social and environmental dimensions.

#### Sensitivity

According to IPCC SREX (Cardona et al., 2012), Sensitivity means the physical predisposition that human beings, infrastructure, and environment shows when being affected by a dangerous phenomenon because of lacking resistance, it also refers to predisposition of society and ecosystems when suffering harm from intrinsic and context conditions. It indicates that such systems will break down or experience huge damage once influenced by hazard events.

#### Adaptive Capacity

There are many ways to define adaptive capacity in the context of climate change. For instance, “the ability of an individual, family, community, or other social group to adjust to changes in the environment guaranteeing survival and sustainability” (Lavell, 1999b). Dayton-Johnson (2004) defines it as “vulnerability of a society before disaster strikes and its resilience after the fact.” Another definition of adaptive capacity is the “property of a system to adjust its characteristics or behavior, in order to expand its coping range under existing climate variability, or future climate conditions” (Brooks and Adger, 2004). In short, adaptive capacity means the ability of an individual or system to adapt to climate change (Cardona et al., 2012).

In the IPCC Fourth Assessment Report (AR4), vulnerability is defined as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2007):

$$\text{Vulnerability} = f(\text{Exposure, Sensitivity, Adaptive Capacity})$$

Within this framework, vulnerability is positively related to exposure and sensitivity, and negatively related to adaptive capacity. In more recent IPCC reports (IPCC, 2014; 2022), however, exposure is no longer incorporated as a component of vulnerability. Instead, exposure is positioned alongside hazard and vulnerability, with the three concepts jointly constituting risk. Accordingly, vulnerability is redefined as:

$$\text{Vulnerability} = f(\text{Sensitivity, Adaptive Capacity})$$

This conceptual relationship is often operationalized in empirical studies in the following simplified form:

$$\text{Vulnerability} = \text{Sensitivity} - \text{Adaptive Capacity}$$

It is therefore important to distinguish clearly between vulnerability and exposure. As noted by Cardona et al. (2012), “*Exposure is a necessary, but not sufficient, determinant of risk. It is possible to be exposed but not vulnerable. However, to be vulnerable to an extreme event, it is necessary to also be exposed.*”

Furthermore, strong evidence suggests that high levels of vulnerability and exposure largely result from “*skewed development processes, including those associated with environmental mismanagement, demographic changes, rapid and unplanned urbanization, and the scarcity of livelihood options for the poor*” (Cardona et al., 2012).

### Heat Adaptation

In IPCC AR6 (Ara Begum et al, 2022), Adaptation is defined as “*in human systems, as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. It generally entails a process of iterative risk management.*”

Following this general framework, heat adaptation in this study is defined as the process of adjustment to actual or expected heatwaves and their effects, in order to moderate heat-related health risks or exploit beneficial cooling opportunities.

### Equity in Heat Adaptation

Equity is conceptualized as a set of moral and political principles aimed at ensuring fairness based on diverse needs and eliminating avoidable systemic disparities. In the context of environmental governance, this multifaceted concept encompasses distributive equity regarding the allocation of benefits and burdens (Rawls 2016), procedural equity in decision-making (Lind and Tyler 2013), recognitional equity concerning the rights of marginalized groups (Fraser 2008),

and epistemic equity, which validates the knowledge and lived experiences of all individuals (Fricker 2007).

Equity is very crucial during urban heat adaptation due to four interrelated dimensions of equity:

1 Heat exposure is unevenly distributed, which often disproportionately affects low-income and marginalized communities, causing spatial disparities (Gaffin et al. 2008; Hsu et al. 2021; Kim, Lee, and Cho 2017);

2 People’s adaptive capacity and sensitivity towards heat stress are unfairly distributed across the city, meanwhile, their historical experience of adaptation are different (Gibb et al. 2024; Hansen et al. 2013; Hoffman, Shandas, and Pendleton 2020; Wilhelmi and Hayden 2010);

3 Adaptation interventions themselves can trigger “green gentrification,” where the costs (e.g., rising housing prices) and benefits (e.g., thermal comfort) are unjustly shared (Markkanen and Anger-Kraavi 2019; Marks and Connell 2023);

4 Existing structural inequalities often bias resource allocation toward affluent areas (Putsoane, Bhanye, and Matamanda 2024).

### Top-down Governance

Top-down governance refers to pathways of public service delivery and decision-making that are initiated and led by government institutions, as distinguished from bottom-up approaches driven by citizens (Meerkerk, 2019). In the context of urban planning, this mode of governance is characterised by centralised authority over decision-making processes, with limited space for citizen initiation or leadership.

### Site-specific Design

Characterized by its responsiveness to local conditions, site-specific design derives its parameters from the distinct climatic, social, and historical background of a place. This approach prioritizes the alignment of architectural or planning interventions with local realities, fostering a seamless adaptation to the surrounding environment (Sustainability Directory, n.d.).

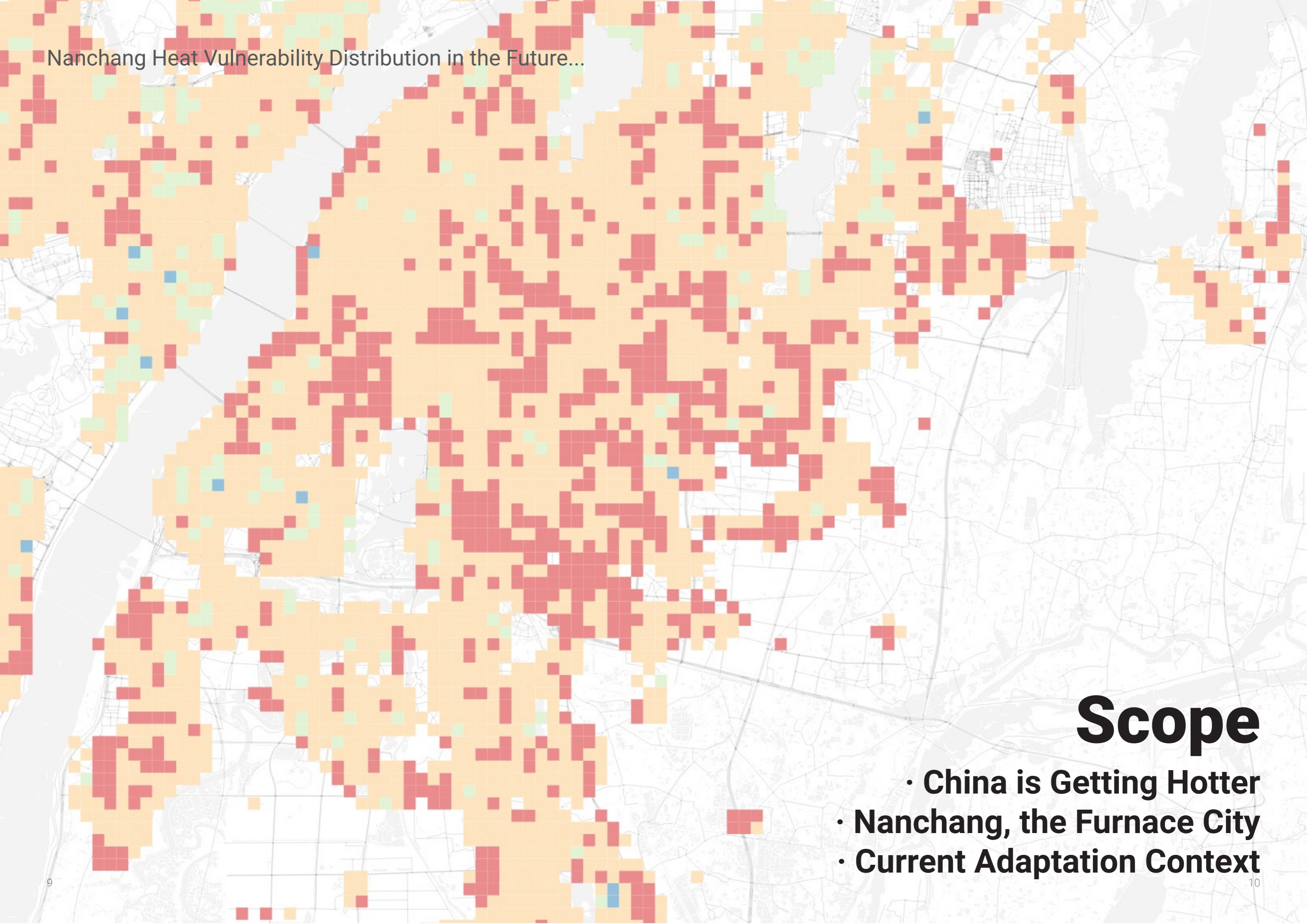
### Participatory Design

Participatory design is understood as the active involvement of people in the creation and management of their built and natural environments, based on the principle that environments function more effectively when citizens participate in decision-making rather than serving as passive consumers (Sanoff, 2022). Its core purposes include giving citizens a meaningful voice in planning and design processes, improving the quality of environmental outcomes, and fostering a sense of community among those who share common goals.

### Pattern Language

According to Dawes & Ostwald(2017), “A Pattern Language by Christopher Alexander is renowned for providing simple, conveniently formatted, humanist solutions to complex design problems ranging in scale from urban planning through to interior design.”

# Nanchang Heat Vulnerability Distribution in the Future...



## Scope

- China is Getting Hotter
- Nanchang, the Furnace City
- Current Adaptation Context

# China is Getting Hotter

Many evidences have shown that China is undergoing an increasingly serious problem of heat event. Frequency and the magnitude of regional heatwave events had doubled over 1960-2018 in China (Wang & Yan, 2021). By 2030, China will experience regional heat wave events with magnitude exceeding the 2013 heat event on a regular basis under a business-as-usual scenario (RCP8.5) (Wang & Yan, 2021).

In the recently published Blue Book on Climate Change of China 2025, the China Meteorological Administration (CMA) notes that “[China’s] warming rate is higher than the global average...and extreme weather and climate events are becoming more frequent and intense.” According to the CMA, when the daily maximum temperature reaches or exceeds 35 °C, the day can be defined as “a hot day,” and “high temperatures for several consecutive days constitute a heatwave.”

Heatwaves exert wide-ranging impacts on human activities across multiple dimensions, including public health, agriculture, and the

economy. According to Cai et al. (2024), “In 2023, more than 30,000 deaths were related to heatwaves in China—1.9 times higher than the average over 1986–2005,” a trend resulting from increasing heat exposure nationwide.

**Drought is another severe consequence induced by heatwaves, which has a substantial negative impact on agriculture in China.** As stated by the Ministry of Emergency Management in early 2025, “Droughts in 2024 hit more than 11 million people in China, with more than 1.2 m hectares of affected crops and direct economic losses topping nearly 8.4 bn yuan (\$1.2 bn).”

According to Guan and Sun (2024), “By 2060, China’s heat-induced economic losses could total about 1.5% of total GDP under 1.5 °C of global warming, 3% under 2 °C of warming and 4.9% under 2.5 °C of warming.” They further explain that, due to changes in global supply chains—such as shifts in production and consumption patterns—indirect economic losses are also included in these projected estimates.

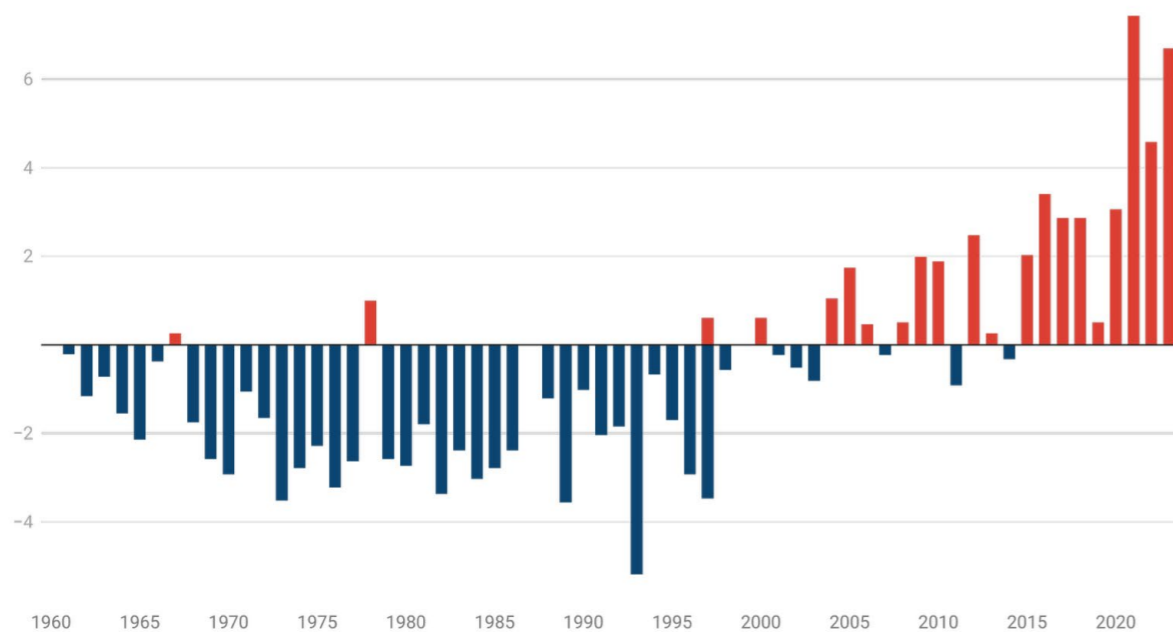


Figure 2. Average Annual Number of Days at or above 35°C in China, Relative to the 1991-2020 Average

From China Meteorological Administration, visualised by Carbon Brief (2023). Retrieved from <https://www.carbonbrief.org/qa-how-china-is-adapting-to-more-frequent-and-intense-heat-extremes/>  
Change in the average annual number of “hot days” – days at or above 35°C – at meteorological stations in China, relative to the 1991-2020 average. Data is taken from a chart in the CMA’s 2024 Annual Climate Bulletins.



Figure 3. Beijing Tiananmen Square during a hot summer day in August 2010.

Photo by Tactesh882 via Wikimedia Commons, licensed under CC BY-SA 3.0.

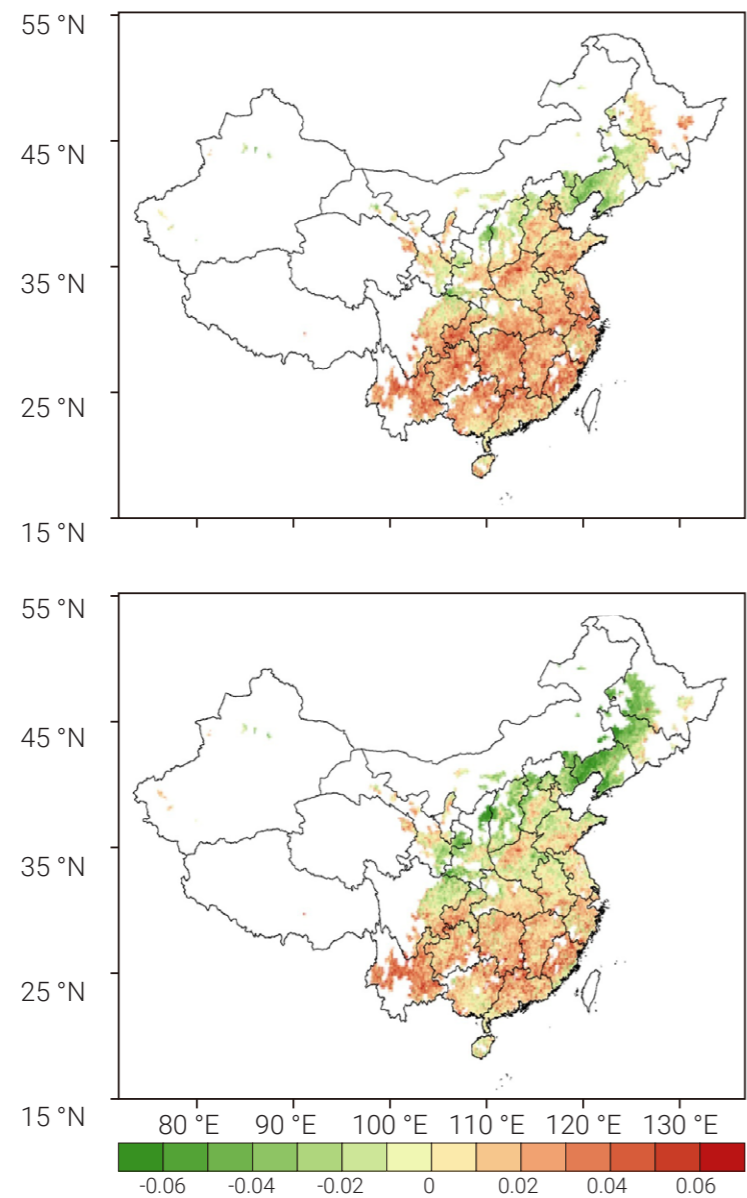


Figure 4. The Spatiotemporal Trends in MMT and ET for the Summer of 2001–2013: MMT (A), ET (B)

Redrawn by the author based on "Population exposure to extreme heat in China: Frequency, intensity, duration and temporal trends," by Long Li, Yong Zha, 2020, *Sustainable Cities and Society* 60 (6), 2020,102282: ISSN 2210-6707. <https://doi.org/10.1016/j.scs.2020.102282>.

According to Li and Zha (2020), most regions in East China has been through the increase of mean maximum temperature (MMT) (Figure A below). Figure 4 shows that those where latitude is lower than 32 °N, specifically central, eastern and south China, extreme temperature (ET) rise significantly.

As for China's urban agglomeration, heat danger day per year tends to increase to 3–13 day by 2041–2060 and 8–67 day by 2081–2100 under high-emissions shared socioeconomic pathways (SSP3-7.0 and SSP5-8.5), and approximately 310 million people, 39% of the total Chinese population

will be exposed to heat danger by then (Zhang et al., 2021). As has been demonstrated by Hu et al (2022), **among all the main urban agglomeration in the Eastern China, Middle Yangtze River (MYR) has mostly ranked the highest in Percentage of Heat Island (PHI) in 2000-2015** (Fig. 5). This mainly results from the anthropogenic heat as well as land surface change during fast urbanization (Fang et al., 2023). **Meanwhile, from 2000 to 2020, UHI spots in MYR kept growing and gradually concentrated in areas such as Wuhan, Changsha and Nanchang** (Fang et al., 2023).

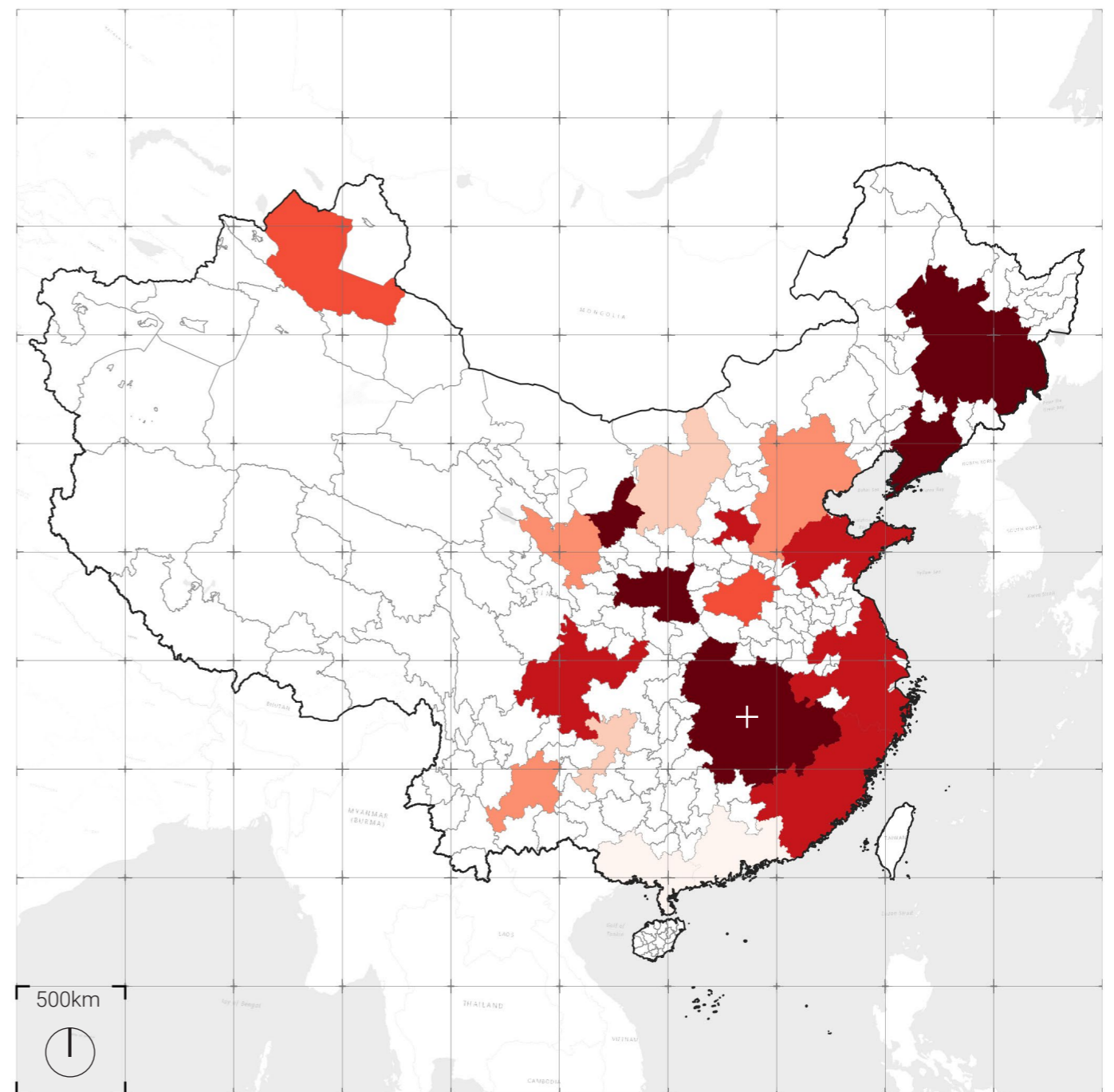


Figure 5. Mean Percentage Heat Island in Summer Daytime of Major Urban Agglomerations in China during 2000–2015

Redrawn by the author based on "Population exposure to extreme heat in China: Frequency, intensity, duration and temporal trends," by Long Li, Yong Zha, 2020, *Sustainable Cities and Society* 60 (6), 2020,102282: ISSN 2210-6707. <https://doi.org/10.1016/j.scs.2020.102282>.



# Nanchang, the "Furnace City"

According to Nanchang Municipal People's Government (2025), Nanchang is the capital city of Jiangxi province as well as a key central city in the MYR Urban Agglomeration. The administrative area includes:

- Three counties (Nanchang County, Jinxian County and Anyi County)
- six districts (Donghu District, Xihu District, Qingyunpu District, Qingshanhu District, Xinjian District, and Honggutan District)
- Three state-level development zones (Nanchang National Economic and Technological Development Zone, Nanchang National High-tech Industrial Development Zone, and Nanchang Xiaolan Economic and Technological Development Zone)
- Wanli Administration Bureau.

It has **7,194.98 km<sup>2</sup>** with the population of **6.67 million**.

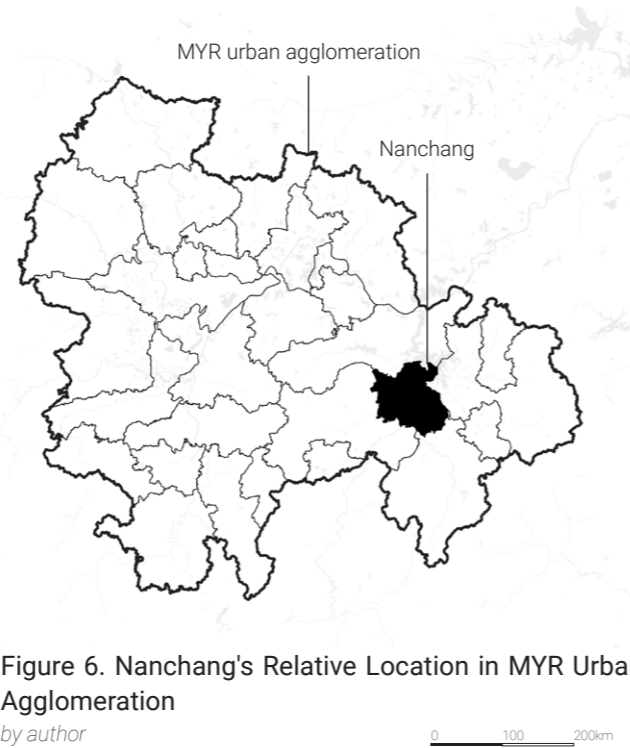


Figure 6. Nanchang's Relative Location in MYR Urban Agglomeration  
by author

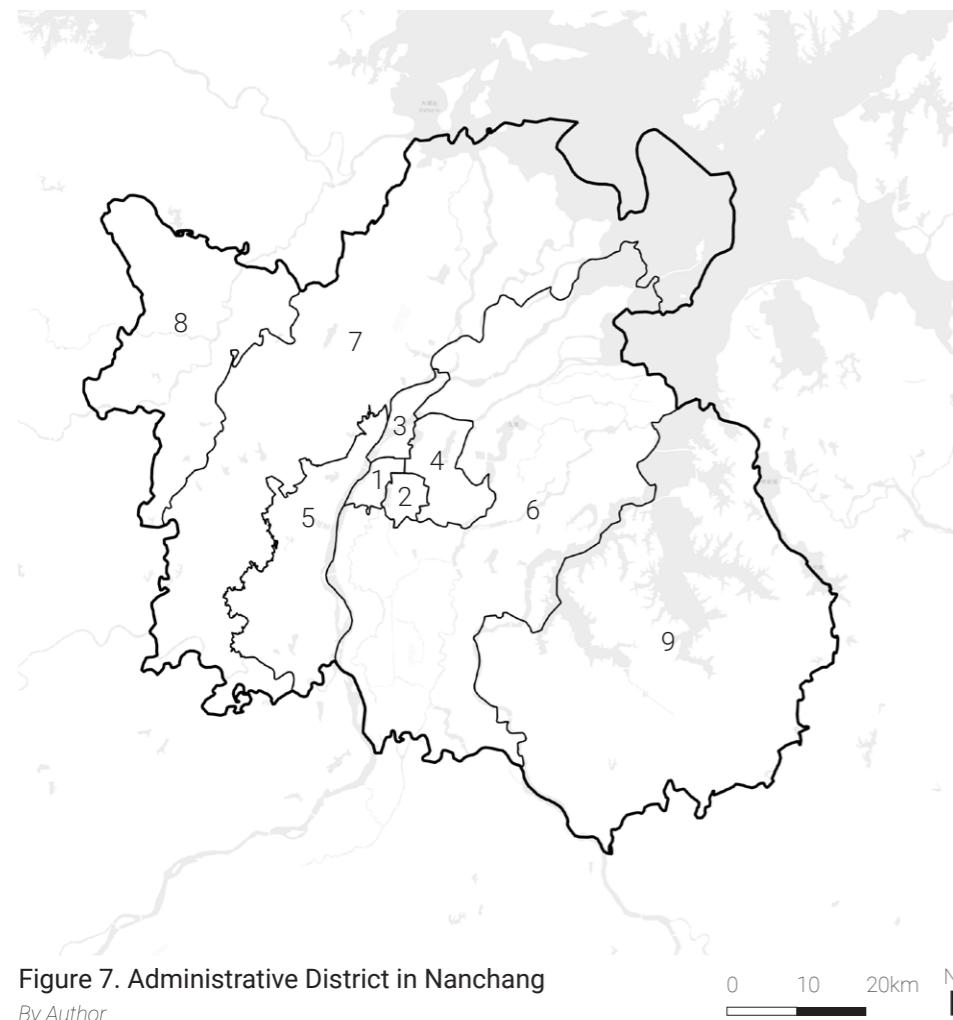


Figure 7. Administrative District in Nanchang  
By Author

## Ecological Environment of Nanchang

The Ganjiang River, the mother river of Nanchang, flows through the city and provides abundant water resources. In addition, Nanchang is situated adjacent to Poyang Lake, the largest freshwater lake in China. Together, these two water bodies form an extensive urban water network, with over 30% of the city's area covered by water. Nanchang also possesses substantial green spaces: according to the Nanchang Municipal People's Government (2021), **green spaces account for more than 43% of the city, while wetlands exceed 20%, earning Nanchang the title of "International Wetland City."** Furthermore, Wang et al. (2025) report that by 2023, 41.3% of the city consisted of built-up areas, while urban forests still covered 21.5% of the total area.

## Urbanization of Nanchang

During the past 30 years, a lot of areas in Nanchang has been through a transition from traditional farmland towards urban

area. Figure 8(b) shows the urban expansion happened between 1990 and 2020. Apparently built environment was originally centralized in Xihu District and Qingyunpu District, and has gradually extended to other 4 districts these years, which is quite a rapid urbanization process. Based on research by (Zhang et al., 2017), **urban area in Nanchang had increased from 4,830 ha to 12,090 ha (150.31% increase) between 2000 and 2013.** There is high confidence proving that within this process, many blue and green infrastructure has been replaced by impermeable surface, which has a positive relation with LST change, and is the main contribution to UHI (Xie et al., 2019; Zhang et al., 2017; Wang et al., 2025).

Research shows that citizens in industrial area and high-densed residential area are exposed to the highest land surface temperature (LST), namely the densely industrialized Jiangling Motors (Group) Co., Ltd. and the Huadong Building Materials Market in Qingyunpu District (Xie et al., 2019).

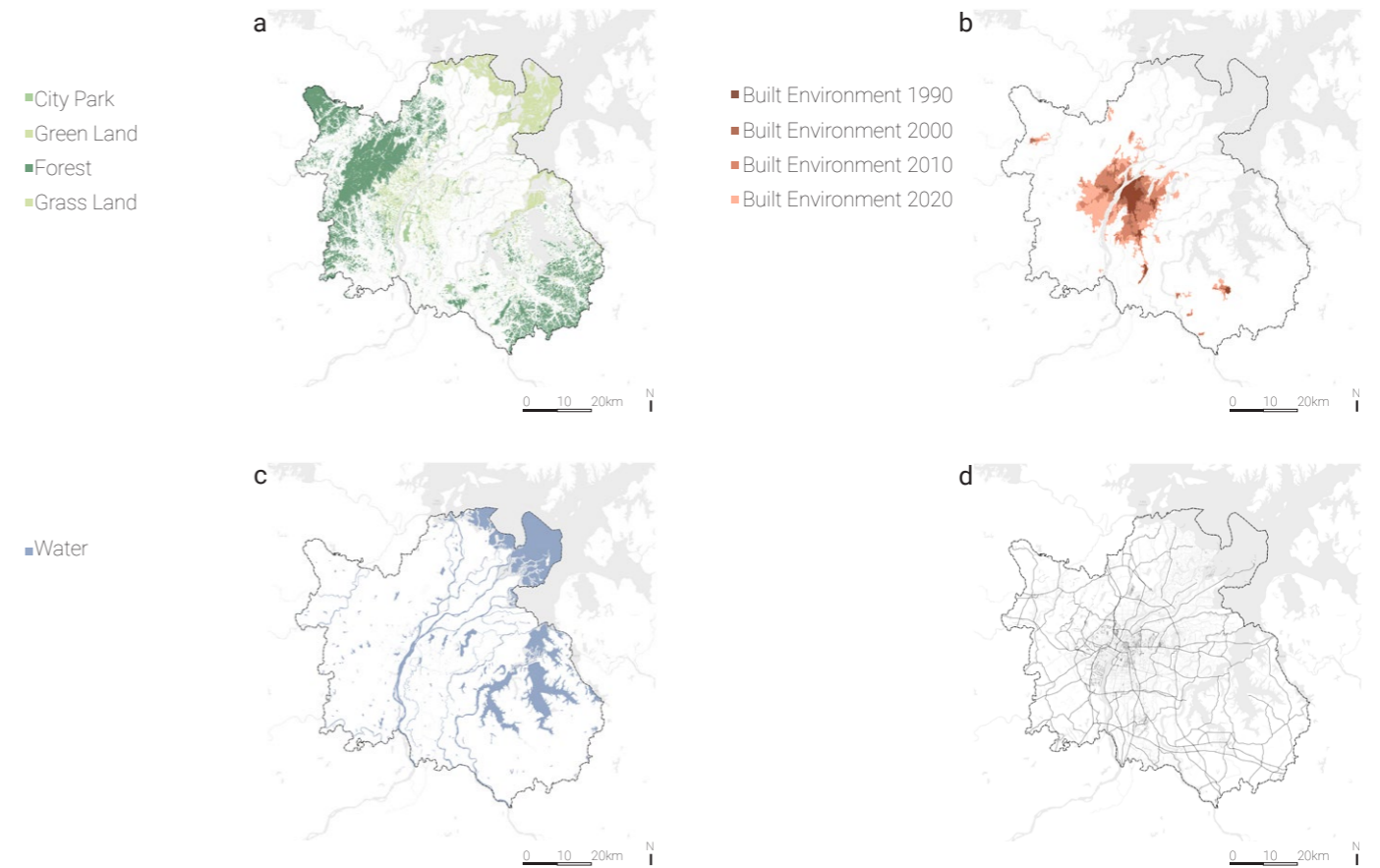


Figure 8. Overview of Nanchang's urban context. (a) Green Space, (b) Urban Expansion, (c) Water Network, (d) Road Map.

By Author

Besides the temperature rise caused by fast urbanization, Nanchang also has sub-tropical monsoonal climate, which is characterized by hot, humid summers with abundant rainfall and mild winters, driven by strong seasonal monsoon circulation. **Both of the factors contribute to the high average temperature in summer and long hot days per year, so that Nanchang is recognized as one of the**

### "Furnace Cities" in China.

In 2025, Nanchang has more than 78 high temperature day (daily maximum  $\geq 35^{\circ}\text{C}$ ), surpassed the previous record of 59 days set in 2022, making 2025 the year with the highest number of high-temperature days since meteorological records began in 1951 (China Meteorological News, 2025).

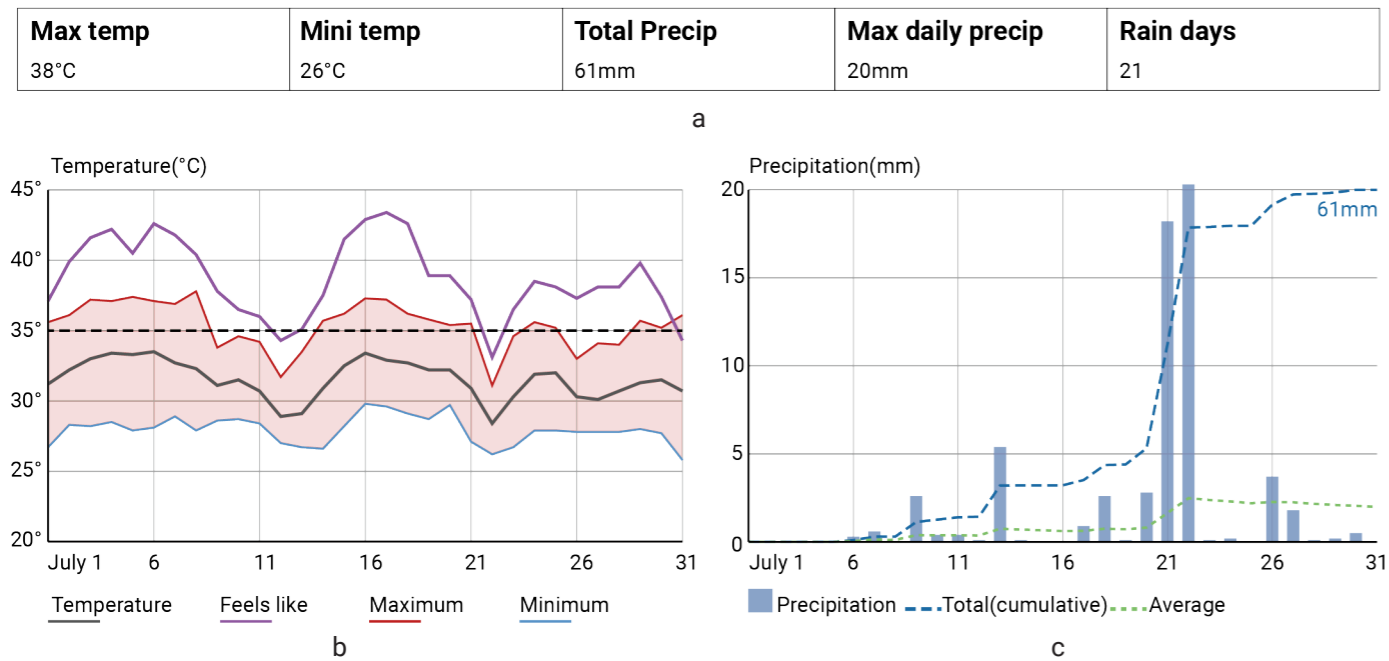


Figure 9. Climate Statistics of Nanchang in July, 2025 (a) key indicators, (b) Temperature, (c) Precipitation. Redrawn by the author based on Visual Crossing Corporation. (2025). Visual Crossing Weather (Nanchang, July 2025) [Data set]. Retrieved from <https://www.visualcrossing.com/>

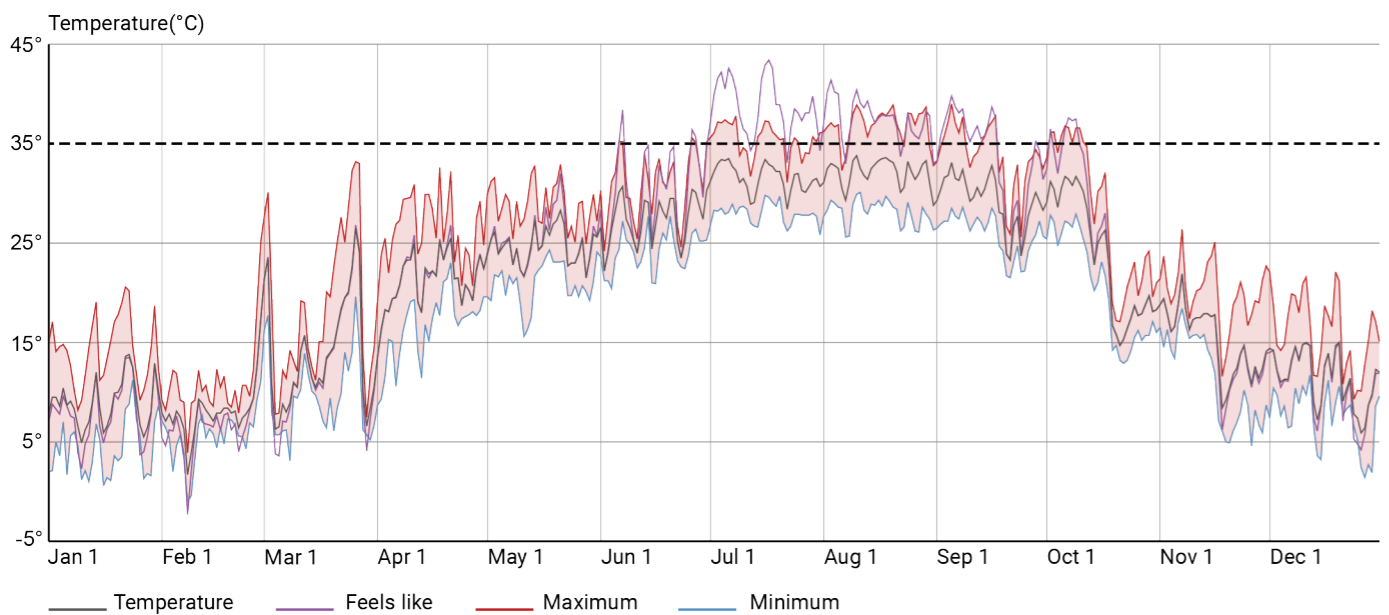


Figure 10. Temperature of Nanchang for the Whole Year 2025

Redrawn by the author based on Visual Crossing Corporation. (2025). Visual Crossing Weather (Nanchang, 2025) [Data set]. Retrieved from <https://www.visualcrossing.com/>

Figure 11. Nanchang Metro opens "Cool Zones" to cope with extreme heatwaves during the peak summer period. Photo by Tang Ying (China Daily), July 2025. Retrieved from <https://www.chinadaily.com.cn/>



# Current Adaptation Context

## Climate Action in China

Chinese central government have been developing climate change adaptation strategies for years.

In 2013, The first “national climate change adaptation strategy” was published by Chinese central government. This strategy represents an attempt to “implement the “clear requirement” of “enhancing our ability to adapt to climate change” included in the 12th “five-year plan” (2011-15)” (Carbon Brief, 2025).

In 2022, a new version of strategy was released, called Climate Change Adaptation Strategy 2035 (The Strategy 2035). As has been concluded by Carbon Brief (2025), “The strategy aims to “improve” and “reinforce” nationwide “labour protection standards”, as well as “work system that adapt to change and reduce agricultural disasters”. Another goal is to ensure the adaptive capacity of energy and electricity sectors under extreme weather and climate events, including heatwaves. Therefore, heatwave was integrated with sector of power, agriculture and health in this new version of strategy.

Within the section of City and Human Habitat Environments, **The Strategy 2035 mentioned the proposal of alleviate UHI effects via “a compound ecological network that is blue and green”**. Within this proposal, the strategy brings out the necessity of ecological planning in urban area, such as urban green belts, green corridors and green wedges. It also mentions the goal of “plants every 300 meters and parks every 500 meters.”, which relies on a systematically connected and evenly distributed urban park system.

Accordingly, provincial governments will

publish climate adaptation strategy based on the general instruction of national strategy. Unfortunately, there is not any specifically planning for heat stress mitigation within strategy published by Jiangxi Provincial Government which administrates Nanchang.

## Drawback of Current Planning

The strategy 2035 itself points out “Adaptation work has not yet been fully incorporated into local and departmental priorities; nor has a working system of climate-system observation—impact risk assessment—adaptation actions—action-effect assessments—been formed.” Revealing the incomplete adaptive procedure due to neglect from local government.

According to Yin et al (2021), other shortcomings of regulatory planning in Chinese climate adaptation lies in “the disconnection of regulatory plans from master plans” as well as “Unequal rights and responsibilities of local governments in climate change mitigation and adaptation”.

Overall, these shortcomings suggest that climate adaptation in China suffers from a top-down governance gap, in which national strategic goals are not effectively embedded in local governmental priorities, institutional arrangements, or regulatory planning processes. In fact, structure of Chinese environmental regulation is characterized by command and control approach (Mucahit et al, 2025), which is often considered less conducive to the flexible and iterative governance required for effective climate adaptation. As a result, climate adaptation governance in China remains structurally fragmented, with limited vertical coordination between strategic objectives and on-the-ground implementation.

## Research on Urban Heat in Nanchang

Up to now, a number of studies have examined urban heat issues in Nanchang and the MYR Urban Agglomeration. Some of these studies are grounded in the theory of the Urban Heat Network (UHN), as exemplified by Fang et al. (2023). In their research, Fang and his team classified urban heat island patches and their spatial morphological characteristics using the Morphological Spatial Pattern Analysis (MSPA) model across the MYR Urban Agglomeration. Based on this classification, they identified the UHN at a regional scale, along which urban heat is likely to expand and transfer.

Subsequent studies have further developed the UHN framework. For example, Lan et al. (2025) applied this network theory to Nanchang. After identifying the UHN at the city scale, they proposed mitigation strategies aimed at reducing urban heat by disrupting heat corridors, thereby limiting heat extension and transfer. Similarly, Wang et al. (2025) constructed nested cooling networks by connecting cooling sources and corridors.

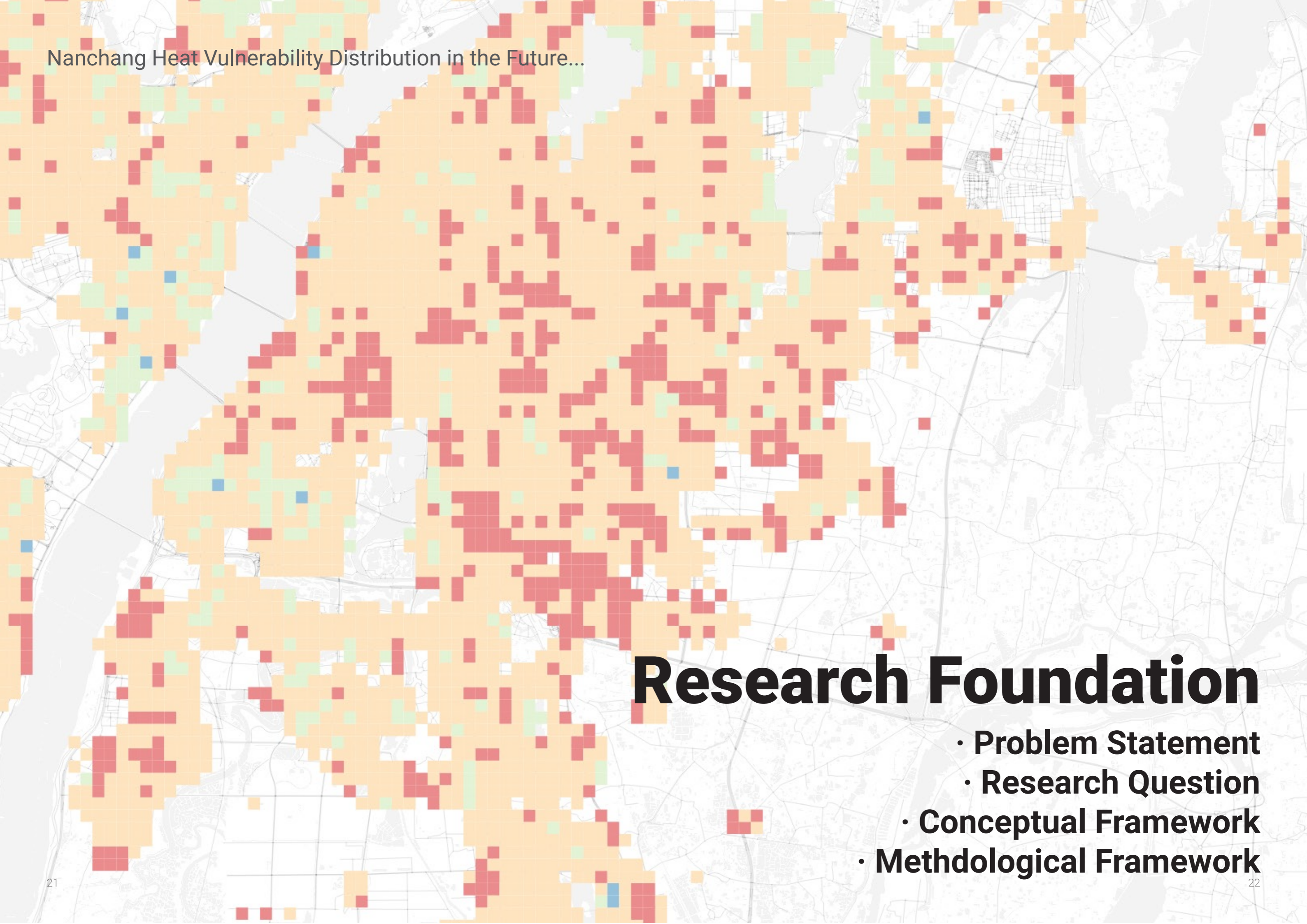
In addition, several studies have focused on the causes of the urban heat island (UHI) effect in Nanchang. It has been widely demonstrated that urban expansion is strongly correlated with increases in land surface temperature (LST) (Zhang et al., 2017; Xie et al., 2019; Zhang et al., 2022). More specifically, urbanization leads to land use and land cover (LULC) changes, increased impervious surfaces, and reduced green cover, all of which contribute to rising LST.

Correspondingly, these studies have proposed various mitigation strategies, among which blue and green spaces are most frequently identified as effective approaches. Zhang et

al. (2022) emphasize the role of extensive water bodies in urban cooling, while Xuan et al. (2025) suggest “enhancing small-scale green spaces and improving green network connectivity” to strengthen urban heat adaptation capacity.

## Conclusion

To conclude, both administrators and researchers have addressed heat adaptation strategies at multiple scales, ranging from the national level to the city level. Among the various strategies and studies, ecological structures—primarily referring to blue and green spaces within the built environment—are widely regarded as the most effective approach to urban heat mitigation. However, both governance practices and academic research share a common shortcoming: the lack of a clear linkage between general planning objectives and specific implementation measures, as well as insufficient post-implementation assessment.



# Research Foundation

- Problem Statement
- Research Question
- Conceptual Framework
- Methodological Framework

# Problem Statement

Both China and Nanchang have been undergoing an increasingly terrible heat stress for years. Although there are numerous heat adaptation approaches relying on blue-green structure, which is recognized as effective in reducing heat stress, a lack of site-specific guidance at local scale remains a challenge. This gap makes it difficult to transfer general planning into concrete and detailed implementation. Moreover, it may lead to forms of inequity experienced by residents in different neighborhoods.

For one thing, under China's top-down and regulation-driven urban governance, **local administrators sometimes overlook residents' thermal comfort needs while prioritizing other "urgent" agendas assigned by upper-level governments.** For example, in Liyuan Community in Qingyunpu District, Nanchang, botanical gardens between residential buildings were converted into parking lots and activity spaces. While these changes satisfy parking and social needs, they reduce the cooling capacity of public spaces for surrounding residents. **This reflects a procedural inequity in which residents' heat-related needs receive insufficient consideration in decision-making.**

**For another, general planning strategies may not fit all neighborhood conditions. Older or spatially constrained districts often have**

**limited capacity to implement blue-green structures,** leaving them exposed to persistent heat stress. **This results in distributional inequity, as these neighborhoods cannot benefit equally from macro-scale cooling networks.**

Moreover, **current adaptation frameworks also fall short on recognitional grounds.** Decision-making processes leave little room for residents to speak — existing regulatory frameworks provide few formal channels for community input, and the lived heat experiences accumulated through daily life in dense neighborhoods rarely reach those who design adaptation measures. **Practical, ground-level knowledge remains structurally unheard.**

Moreover, **many climate adaptation strategies lack post-intervention evaluation** (Ministry of Ecology and Environment, 2022; Nordgren et al., 2016), making it difficult to assess the actual effectiveness of implemented measures—especially at the microscale.

Therefore, more specific and context-sensitive design methods are needed for neighborhoods where blue-green strategies are not feasible or not sufficient to meet cooling demands



Google. (n.d.). [Satellite imagery of Liyuan Community, Nanchang, in 2020] [Map]. Retrieved January 9, 2026, from <https://earth.google.com/web/>



Google. (n.d.). [Satellite imagery of Liyuan Community, Nanchang, in 2025] [Map]. Retrieved January 9, 2026, from <https://earth.google.com/web/>

Figure 12. Environment Change of Liyuan Community, Nanchang from 2020 to 2025

These two images show the change of environment in Liyuan Community, Nanchang. In order to meet the needs of parking and activity, decision-makers replaces original botanic gardens with parking lots and hard ground areas, reducing tree shades and permeable land surface.

# Research Question

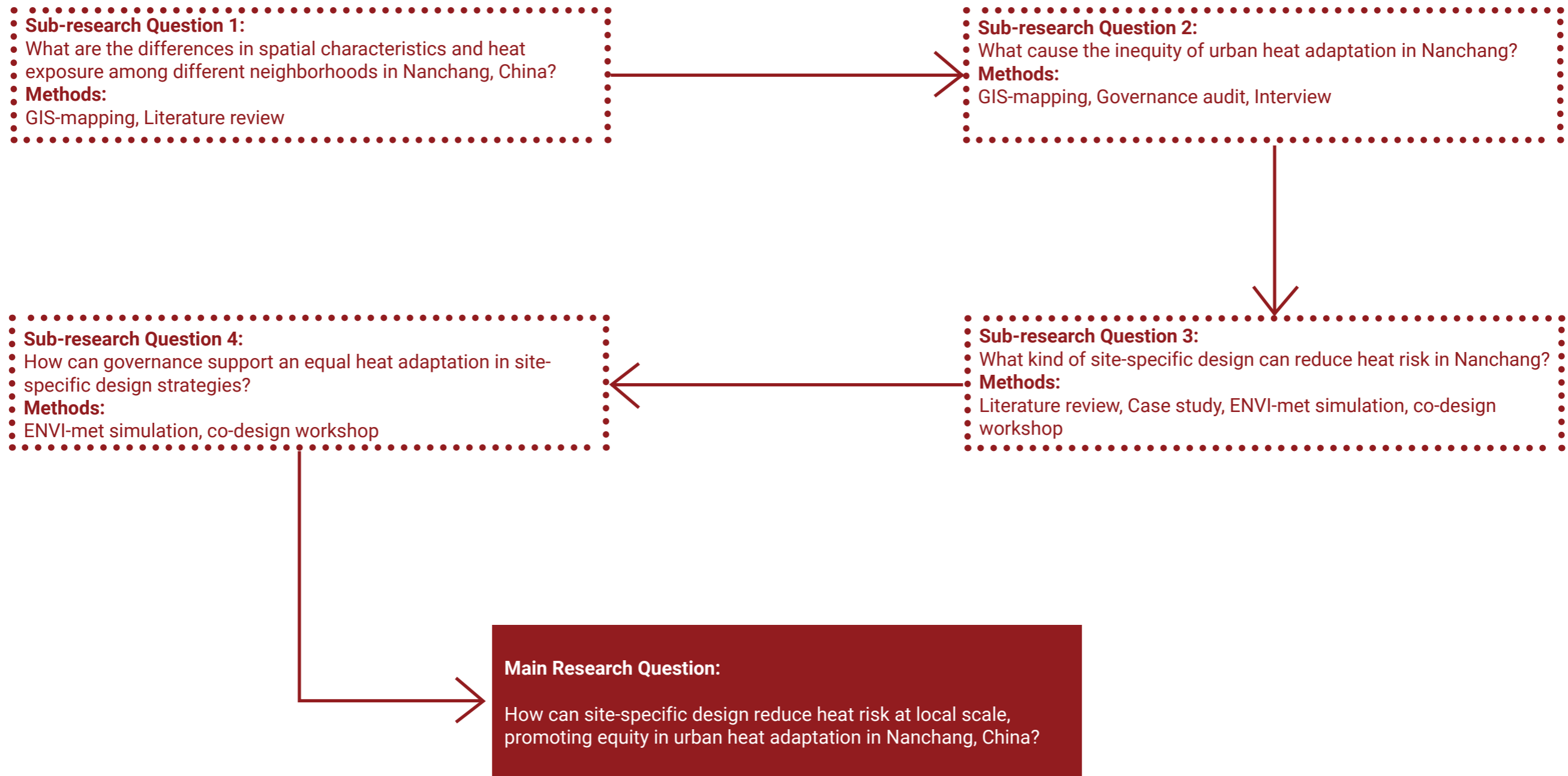


Figure 13. Research Question  
By author

# Conceptual Framework

(For definitions of "**Concept**" in bold font, please see chapter 1: Key Terms Explanation)

Based on the specific challenges China—and Nanchang in particular—faces in adapting to extreme heat, a clear problem statement is established, and relevant concepts are selected to construct a conceptual framework. This framework serves as a guiding structure for the transition from heat maladaptation toward equitable heat adaptation.

The literature review reveals that Nanchang continues to experience increasingly severe heat stress despite the existence of national and provincial climate adaptation strategies and a growing body of academic research on urban heat. At the planning and renovation level, heat adaptation remains procedurally absent, while governance structures remain predominantly **top-down**, leaving residents' knowledge and proposals largely unacknowledged. As a result, **heat risk** in Nanchang is never seriously addressed, leaving the city in a state of maladaptation.

The second layer emphasizes **site-specific, local-scale** design, an area that is largely absent from existing government planning. At this scale, the project investigates the spatial distribution of **vulnerability** across different **neighborhoods** and seeks to develop practical, context-sensitive design

interventions to reduce **heat exposure** for residents, as well as mitigating **heat vulnerability** through enhancing **adaptive capacity**, which is considered both effective and feasible at the local scale.

Because design interventions at this scale rely heavily on participatory processes to achieve meaningful outcomes, the conventional top-down governance approach prevalent in China needs to be combined with **co-design**. This combined model emphasizes continuous learning from residents' feedback, allowing local knowledge and residents' voices — especially those of vulnerable groups — to be more considered during decision-making.

By embedding heat adaptive **pattern language** into existing renovation process, **procedural equity** can be strengthened. When site-specific interventions reduce heat exposure and improve heat adaptive capacity, **distributional equity** can also be enhanced. Finally, by valuing residents' lived experiences and everyday knowledge of heat stress, as well as integrating residents' proposal into intervention, **recognitional equity** is advanced — ensuring that those most affected are neither overlooked nor silenced in the adaptation process. Together, improvements across these three dimensions contribute to the realisation of equitable heat adaptation in the long term.

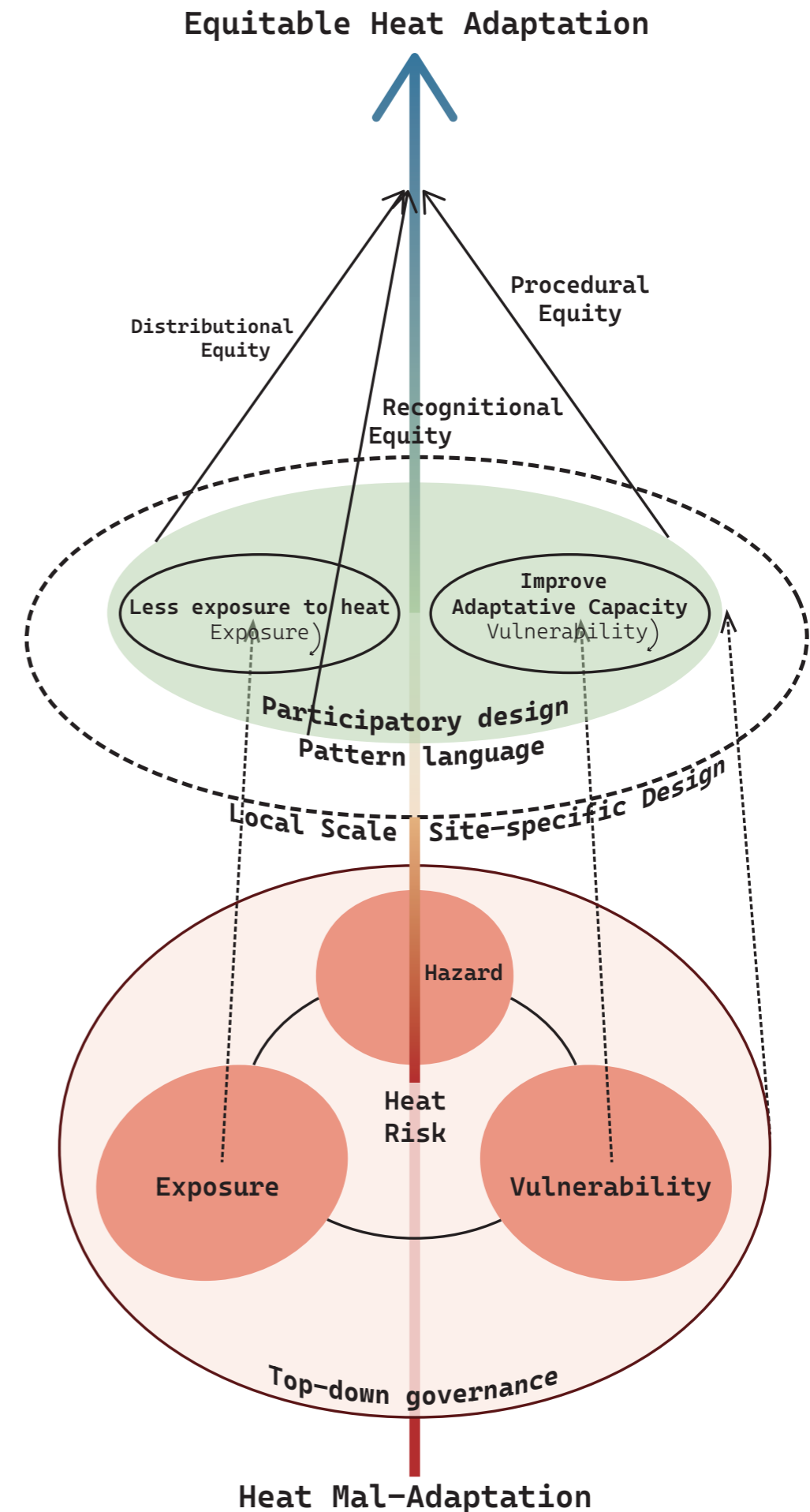


Figure 14. Conceptual Framework  
By Author

# Methodological Framework

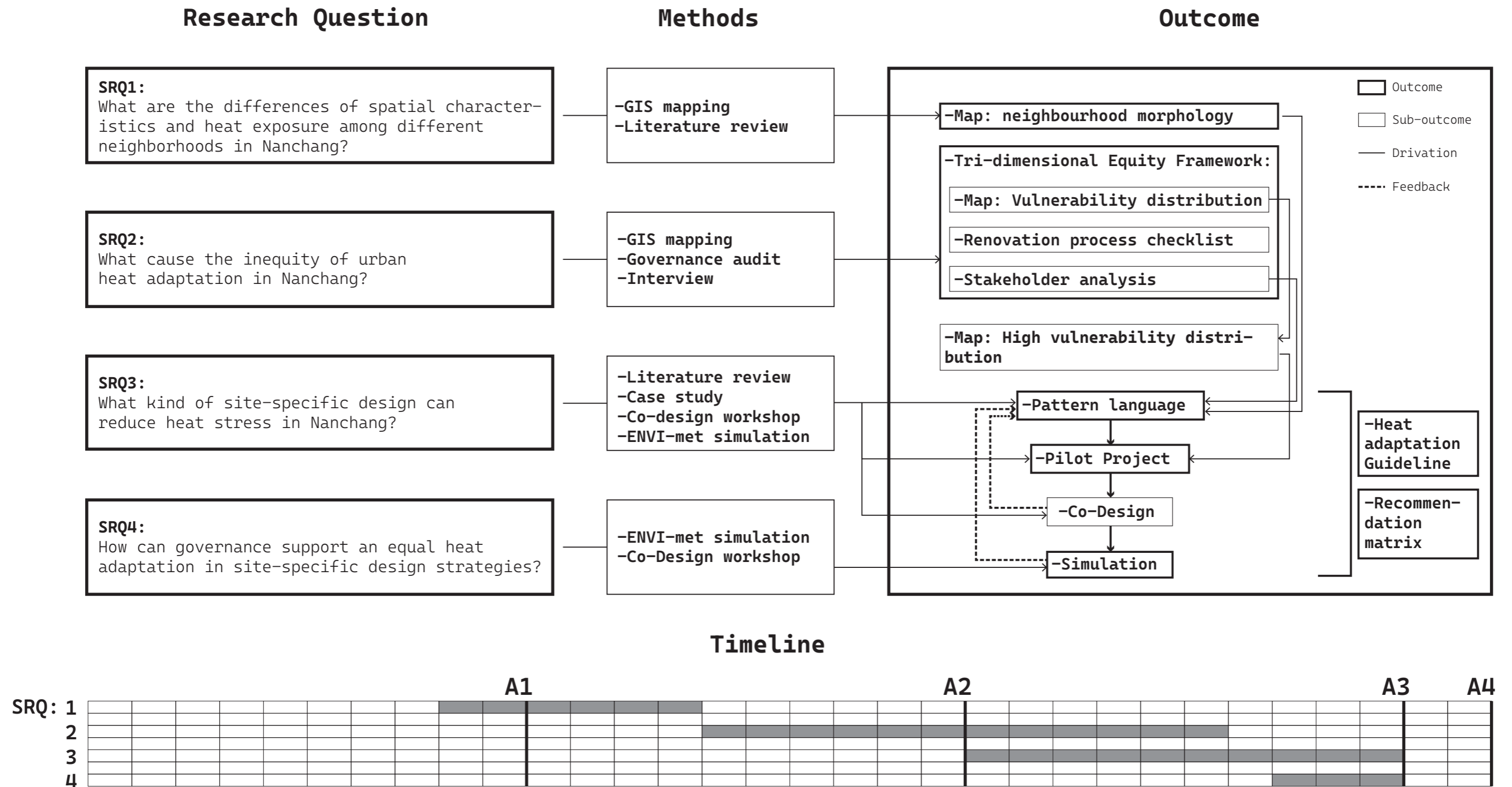


Figure 15. Methodological Framework

This methodological framework is based on 4 sub research questions (SRQ) oriented from the main research question. The framework shows the methods to solve these questions as well as expected outcome of them, it also informs different phases for each question during the whole project.

### Phase 1: Diagnostic Phase (SRQ 1-2)

Objective: To identify the "hotspots of inequity" by translating global climate stressors into the local urban fabric of Nanchang.

- SRQ1 (Physical Exposure Analysis): This stage employs geo-spatial analysis to correlate neighborhood morphology with thermal comfort. By mapping spatial characteristic differentiation, for instance, urban density, greenery, and building patterns, the research identifies the physical drivers behind different heat exposure across Nanchang.

- SRQ2 (Social Equity Assessment): A tri-dimensional equity framework is applied to evaluate the social impact of heat:

- Distributional Inequity: Identified via vulnerability analysis, **mapping the spatial mis-match between sensitive population and cooling source distribution (adaptive capacity).**

- Procedural Inequity: Identified through a governance audit of Nanchang's renovation process, **revealing that heat adaptation and heat risk reduction are systematically absent from the current urban renovation process.**

- Recognitional Inequity: Constructed through a co-design workshop, capturing residents' lived experiences of exclusion from the renovation process — **revealing that their knowledge, preferences, and spontaneous initiatives are neither formally recognised nor incorporated into urban heat adaptation decision-making.**

### Phase 2: Generative Phase (SRQ 3)

Objective: To bridge the gap between scientific

evidence and local lived experience.

- Pattern language development: SRQ3 synthesizes findings into a comprehensive a heat adaptive pattern language. This includes technical cooling measures (derived from literature reviews and international case studies) and residents' proposal (extracted from co-design workshop), ensuring the interventions are both scientifically sound and context-responsive.

### Phase 3: Experimental Phase (SRQ 3-4)

Objective: To validate interventions through iterative technical and social testing.

- Co-design workshop: The pattern language is applied to a Pilot Project selected from high vulnerability distribution map. And several residents are invited to make design proposals, which are finally summarized and improved by author.

- Technical Validation (Quantitative): Iterative ENVI-met simulations are conducted to assess the micro-climatic performance of the design, to explore a measurable reduction in heat stress.

### Final Research Outcomes

- **Governance Recommendation Matrix:**

A prioritised implementation reference for government and community committees, classifying heat adaptation patterns according to their effectiveness and feasibility to guide future renovation decisions.

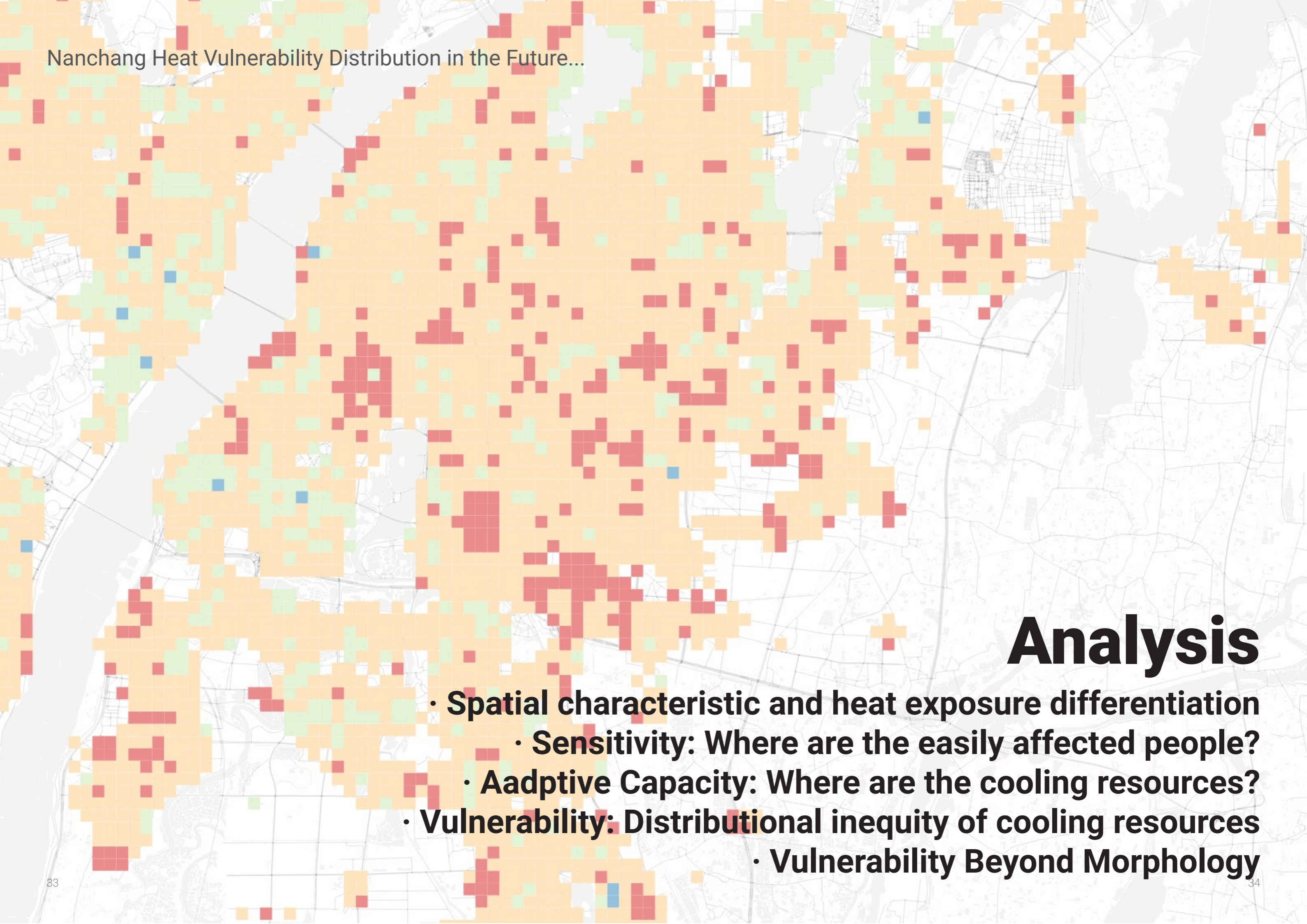
- **Pilot Design Projects:** A portfolio of "Proof of Concept" designs demonstrating site-specific applications.

- **A Heat Adaptation Guideline:** An upgraded framework built upon the existing old community renovation process, integrating pattern language, co-design, and thermal simulation to embed heat adaptation into neighbourhood-level planning and implementation.

Figure 16. Nanchang Citizens are Splashing in the River to Cool Off During Hot Summer

Photo by China Daily, August 2025. Source: China Daily.





# Analysis

- **Spatial characteristic and heat exposure differentiation**
  - **Sensitivity: Where are the easily affected people?**
  - **Adaptive Capacity: Where are the cooling resources?**
- **Vulnerability: Distributional inequity of cooling resources**
  - **Vulnerability Beyond Morphology**

# Spatial Characteristic and Heat Exposure Differentiation

## Heat Exposure

Heat exposure, as defined in this thesis, refers to the thermal conditions within an area where heat hazard is likely to act directly on residents. Traditionally, urban heat research has focused on Land Surface Temperature (LST) or the Urban Heat Island (UHI) effect. However, air temperature is also influenced by factors beyond LST, such as wind speed (Probst et al., 2022), **and both LST and UHI primarily describe thermal conditions at meso or macro scale, with limited neighbourhood-level variation. At the local scale where heat directly affects human physiology, a comfort-oriented index is more appropriate.** Following Wang et al. (2025), the Physiologically Equivalent Temperature (PET) is adopted here as the heat exposure indicator, as it integrates the combined effect of air temperature, radiation, humidity, and wind on the human body.

However, it is not feasible to measure or simulate the PET for the whole city in this project. **Consequently, the Local Climate Zone (LCZ) classification is adopted as a spatial proxy, linking neighbourhood-scale morphological characteristics to likely heat exposure patterns across the city.**

PET is shaped by micrometeorological variables – most notably mean radiant temperature ( $T_{mrt}$ ) and wind speed – which are in turn determined by urban morphological properties such as building density, green coverage ratio, and spatial layout. Since LCZ classification is grounded in these same

parameters – Sky View Factor (SVF), aspect ratio (H/W), building surface fraction – the LCZ framework provides a consistent basis for differentiating outdoor thermal environments at the city scale (Stewart & Oke, 2012).

In climatic contexts comparable to Nanchang, this relationship is particularly well evidenced. Lau et al. (2019), studying sub-tropical high-density cities including Hong Kong – sharing Nanchang's summer heat stress, humidity, and solar radiation regimes – found that LCZ classification effectively stratified outdoor thermal conditions, with PET among the most responsive indices to LCZ-associated morphological variation. At a smaller scale, a study in Wuhan – another Yangtze River city with the same climatic profile – quantified this relationship within a single LCZ5 area, **finding that LCZ morphological parameters explained up to 82% of the variance in mean outdoor thermal comfort, with SVF as the dominant predictor** (Zhou et al., 2025). This confirms that spatial differences in LCZ composition across a city translate directly into differentiated heat exposure for residents.

There are also evidences from different climate contexts which can confirm this alignment, including in Berlin and Szeged, where PET levels were found to vary systematically across LCZ types (Langer et al., 2021; Unger et al., 2017). In a study based in Switzerland (Fahy et al., 2025), statistical analyses also proved LCZ to be the strongest predictors of thermal discomfort.

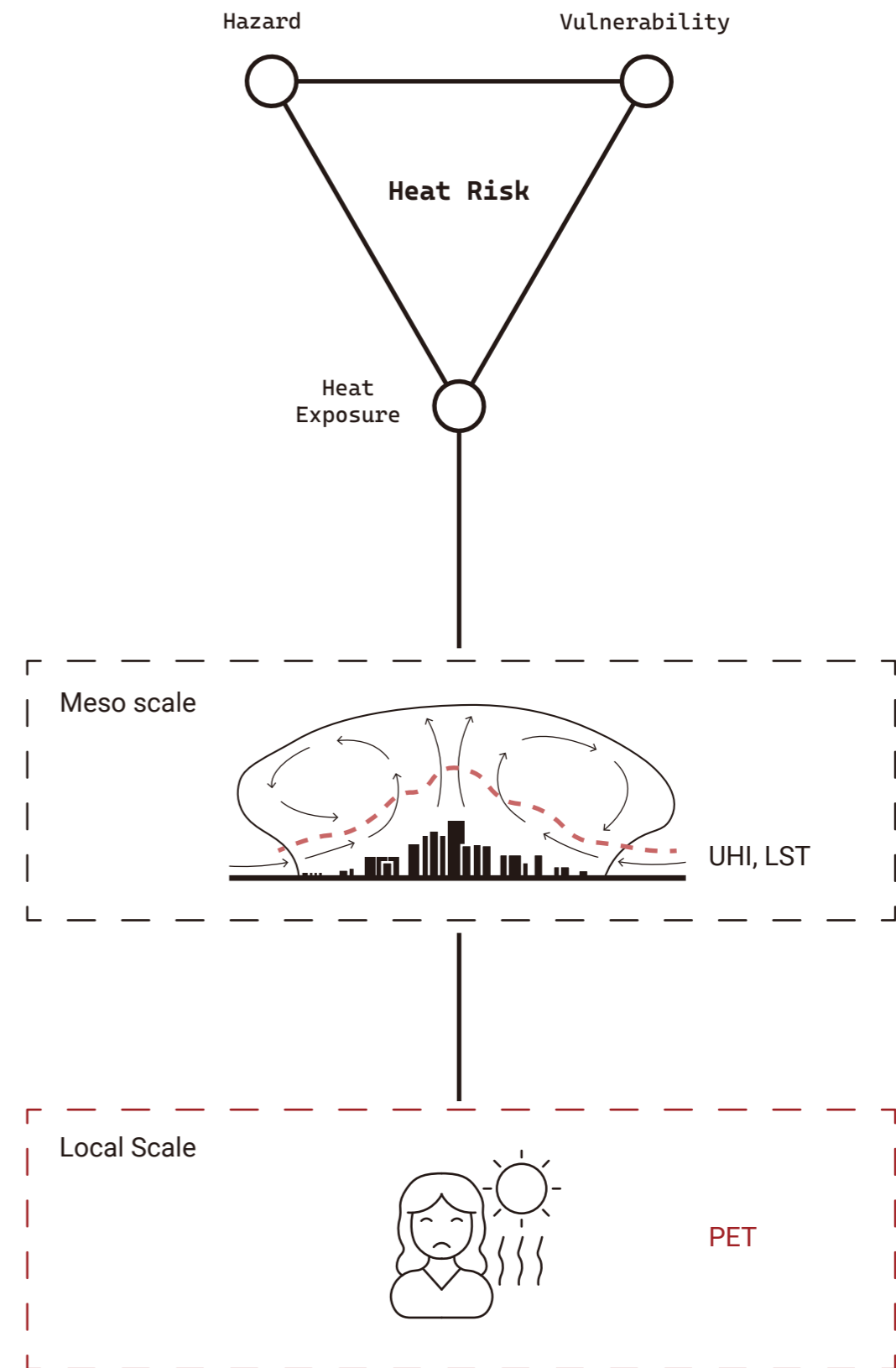


Figure 17. The Effects of Heat Exposure at Different Scales  
By Author

### LCZ Classification in Nanchang

According to Stewart & Oke (2012), the LCZ system comprises 17 standard types divided into two main categories: Built types, classified by building height, density, and surface properties, and Land Cover types, describing natural surfaces defined by vegetation or substrate. However, local urban conditions in Nanchang deviate from this standard typology in two respects. First, Chinese building regulations impose minimum inter-building distances for fire safety (GB 50016), and residential spacing standards under GB 50180-93 further require sufficient winter solar access for indoor spaces, effectively preventing the formation of LCZ 1 (Compact High-rise)

in Chinese mainland cities. Second, LCZ 7 (Lightweight Low-rise) – typically associated with informal or vernacular construction – has largely disappeared in Nanchang through successive rounds of urban densification and building material renovation.

LCZ mapping for this project draws on Chen et al. (2021), who generated an LCZ classification for Nanchang by combining Sentinel-2 multispectral imagery with dual-polarized (HH + HV) PALSAR-2 SAR data. This dataset represents the highest classification accuracy currently available for the study area and forms the spatial foundation of the subsequent analysis.

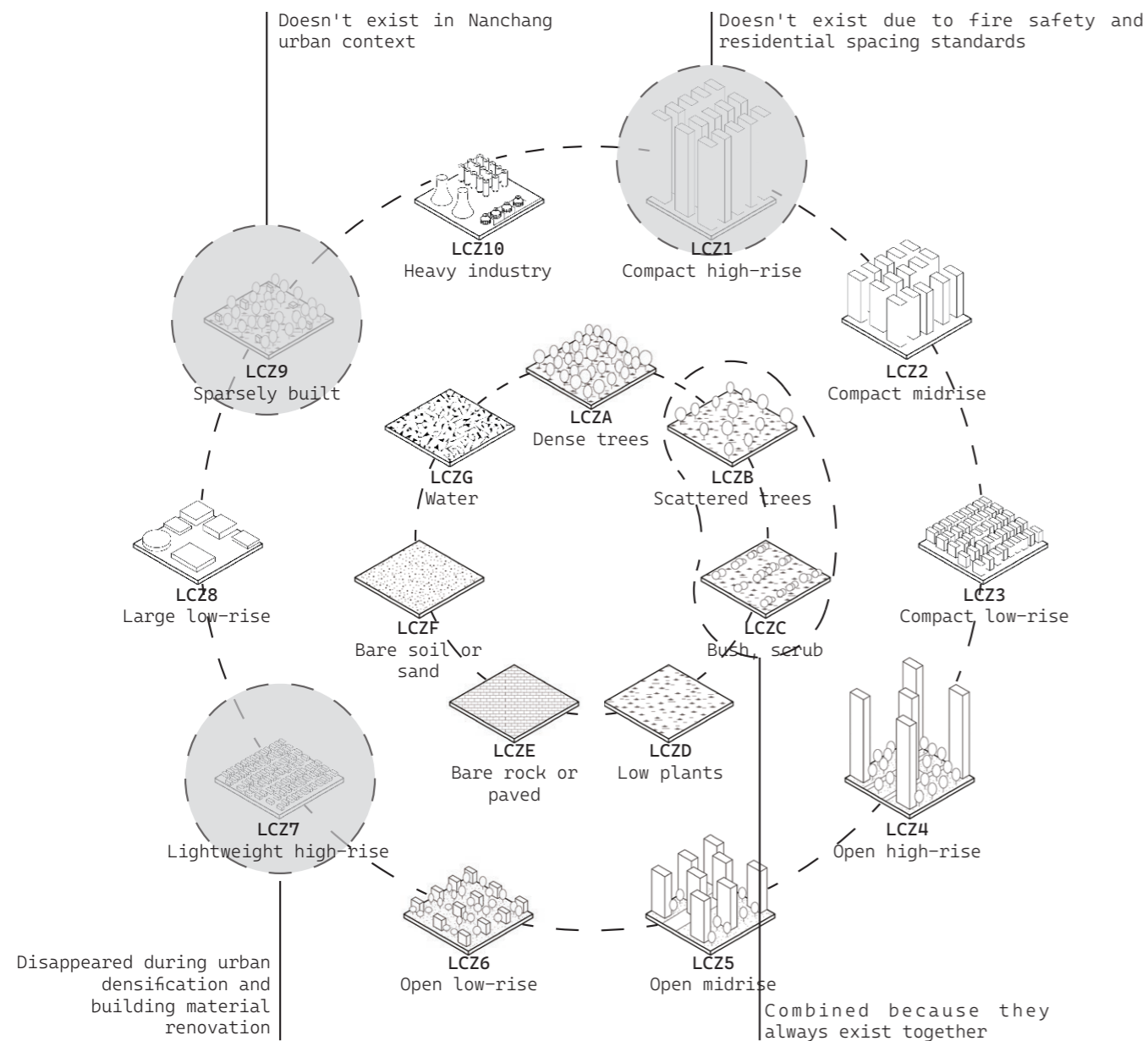


Figure 18. LCZ Classification in Nanchang Urban Context

Redrawn by the author based on Chen, C.; Bagan, H.; Xie, X.; La, Y.; Yamagata, Y. Combination of Sentinel-2 and PALSAR-2 for Local Climate Zone Classification: A Case Study of Nanchang, China. Remote Sens. 2021, 13, 1902. <https://doi.org/10.3390/rs13101902>

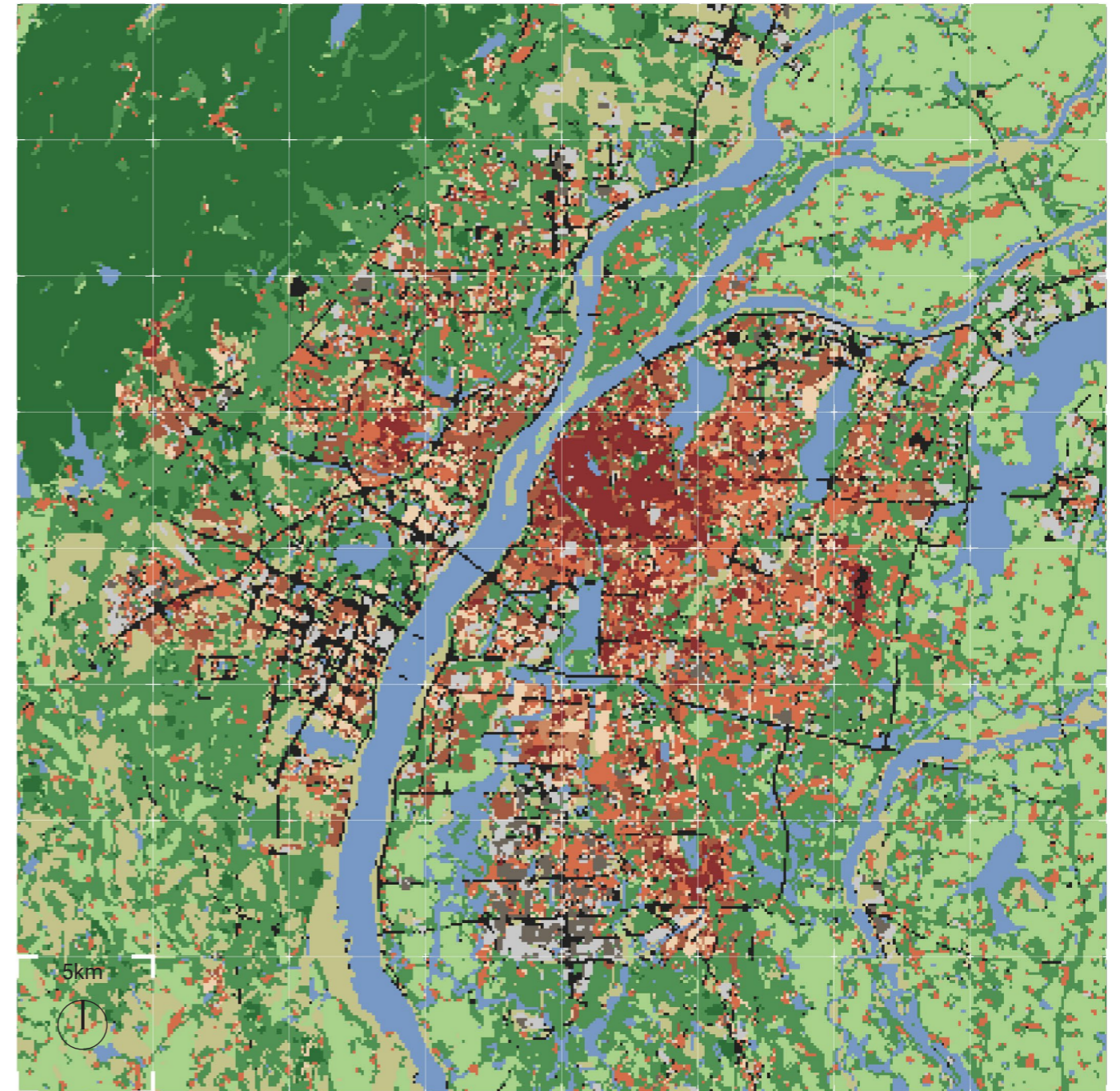
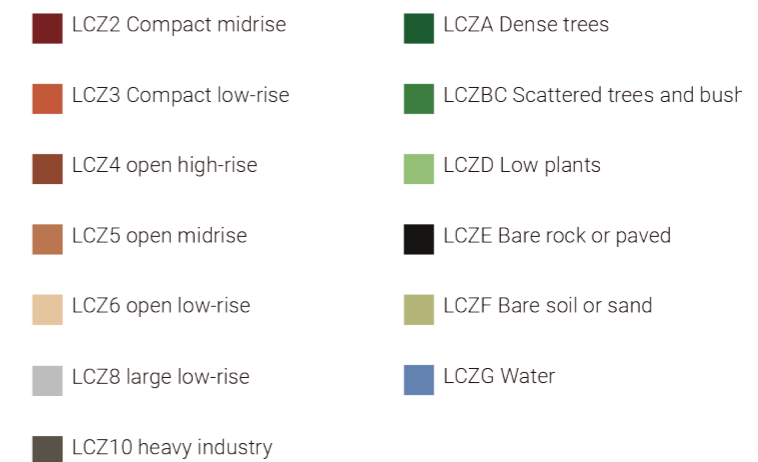


Figure 19. LCZ Distribution in Nanchang

Redrawn by the author based on Chen, C.; Bagan, H.; Xie, X.; La, Y.; Yamagata, Y. Combination of Sentinel-2 and PALSAR-2 for Local Climate Zone Classification: A Case Study of Nanchang, China. Remote Sens. 2021, 13, 1902. <https://doi.org/10.3390/rs13101902>



### MCDA of Vulnerability

Following the IPCC SREX framework (Cardona et al., 2012), vulnerability in this project refers to the predisposition of Nanchang residents to suffer harm from urban heat in summer. It is decomposed into two dimensions: sensitivity, representing the physical and socioeconomic predisposition of residents to heat stress, and adaptive capacity, representing their ability to cope with or recover from heat exposure (Cardona et al., 2012). Given that both dimensions involve multiple criteria without a clear evidential hierarchy, this project adopts Multiple-Criteria Decision Analysis (MCDA) as the methodological framework for quantitative vulnerability assessment (Fig. 21).

### Sensitivity Analysis

Sensitivity is operationalized through two criteria: age and income, representing physical and socioeconomic predisposition respectively. Two age groups are selected – under 14 and over 65 – as both are consistently identified in epidemiological literature as physiologically vulnerable to heat stress and at elevated risk of heat-related illness (Kovats & Hajat, 2008). Income is proxied by community-level housing prices, as individual income data are not publicly available in China.

### Adaptive Capacity Analysis

Adaptive capacity is divided into active intervention and passive adaptation. Active intervention is represented by health system accessibility – ranging from pharmacies to hospitals – and heat shelter availability, defined as indoor public spaces with air conditioning. Passive adaptation is represented by green canopy coverage and building shade, both of which are well-established cooling resources in the urban summer environment. Water bodies are excluded from this analysis: while blue infrastructure can reduce air temperature through evaporative cooling during daytime, it releases stored heat and elevates humidity at night (Yao et al., 2012), making its net thermal effect ambiguous in Nanchang's humid subtropical climate.

### Unit of Analysis

The spatial unit of analysis is set at 250m × 250m, corresponding to the average size of a residential community in Nanchang (Fig.20). This scale is appropriate for neighbourhood-level comparison and aligns with the site-specific design focus of the project.

### Weight for different criteria

Equal weights are assigned to all criteria within each dimension. This decision reflects the absence of strong empirical evidence supporting a hierarchy among the selected indicators, and avoids the subjectivity inherent in researcher-assigned differential weights.

### Aggregation and Output

Vulnerability is computed by combining sensitivity and adaptive capacity scores through normalization and weighted aggregation, following the formula in which vulnerability increases with sensitivity and decreases with adaptive capacity. The resulting vulnerability map visualizes the spatial distribution of heat vulnerability across Nanchang's neighbourhoods, forming the analytical basis for subsequent site selection and design intervention.



Figure 20. MCDA spatial unit definition

By Author

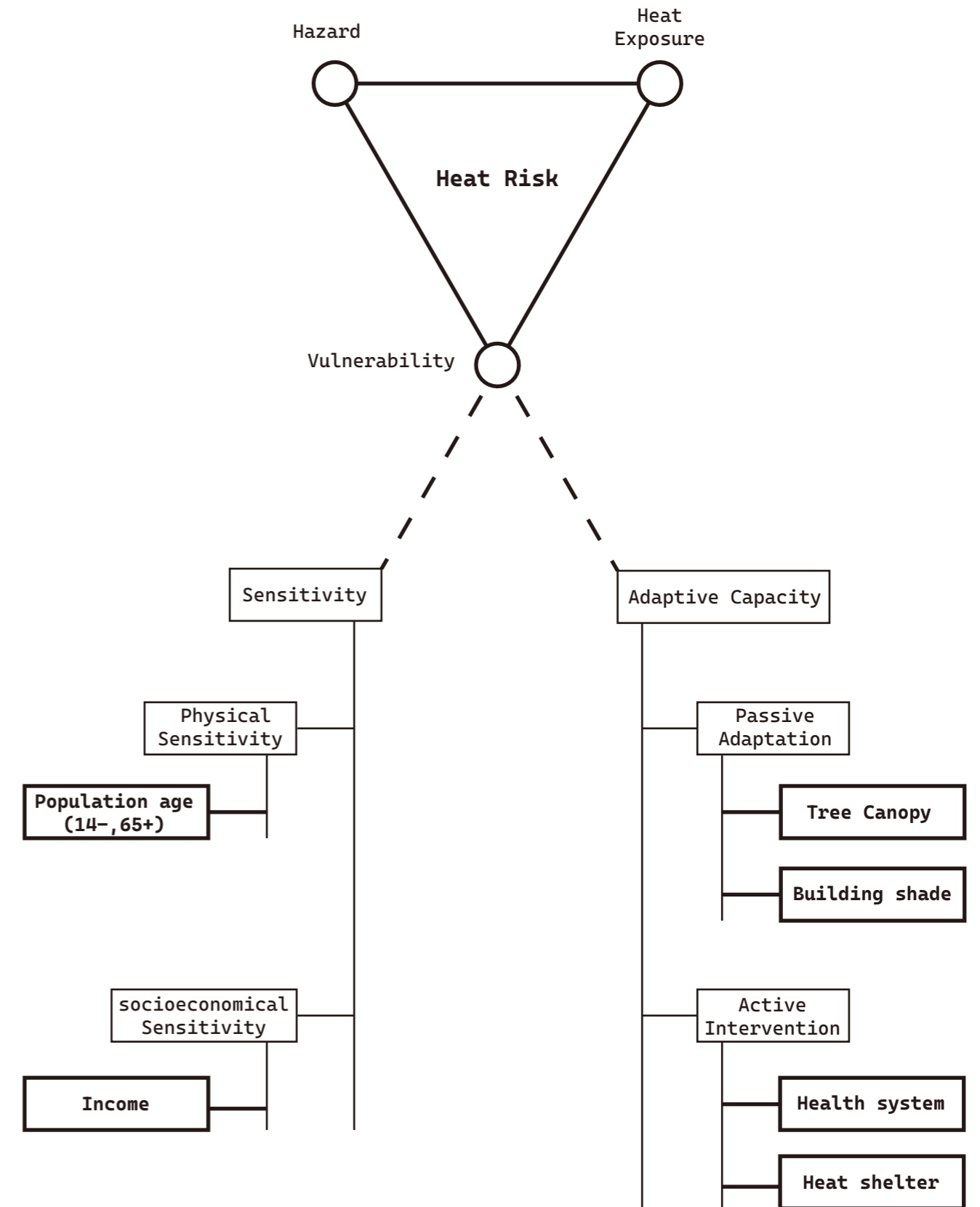


Figure 21. MCDA of Vulnerability Indicators

By Author

# Sensitivity: Where are the Easily Affected People?

## -Physically Sensitive Population

The spatial distribution of physically sensitive populations reveals two distinct patterns across the study area. Neither age group exhibits a clear concentration within a single administrative district, suggesting that heat-sensitive populations are dispersed across the urban fabric.

However, the two age groups differ markedly in their spatial logic. The elderly population (65+) shows a relatively centralized distribution, predominantly clustering in areas built before 1990, indicating a strong association between ageing-in-place and older residential fabric in Nanchang's historic urban core (Fig. 22). In contrast, the under-14 population displays multiple high-density clusters dispersed across the city, spatially corresponding with the locations of primary and middle schools, possibly related to the school-district housing phenomenon prevalent in Chinese cities (Fig. 23).

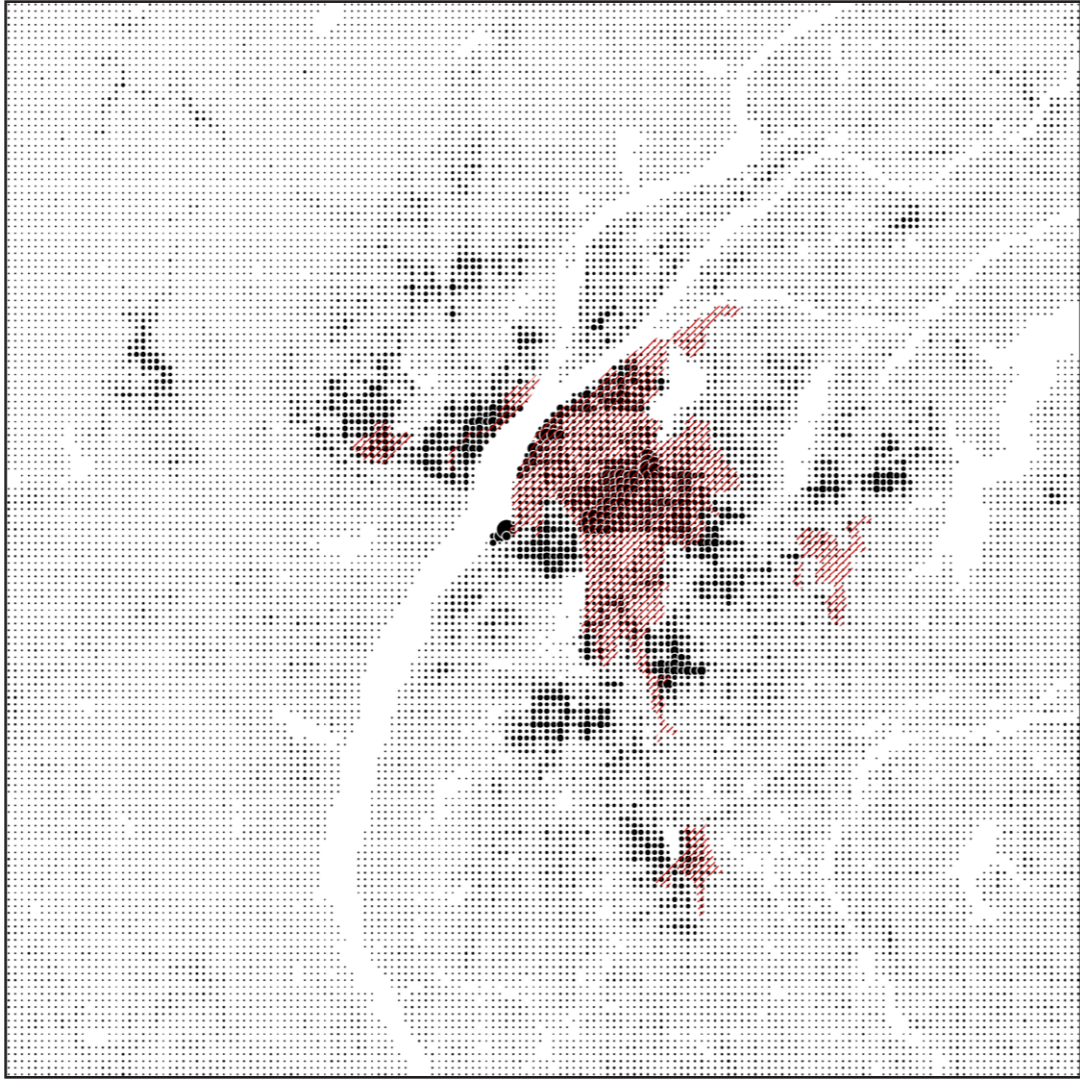


Figure 22. Spatial Distribution of the Elderly beyond 65

By Author

- Large number
- 
- 
- 
- 
- Small number
- ▨ Urban area constructed before 1990

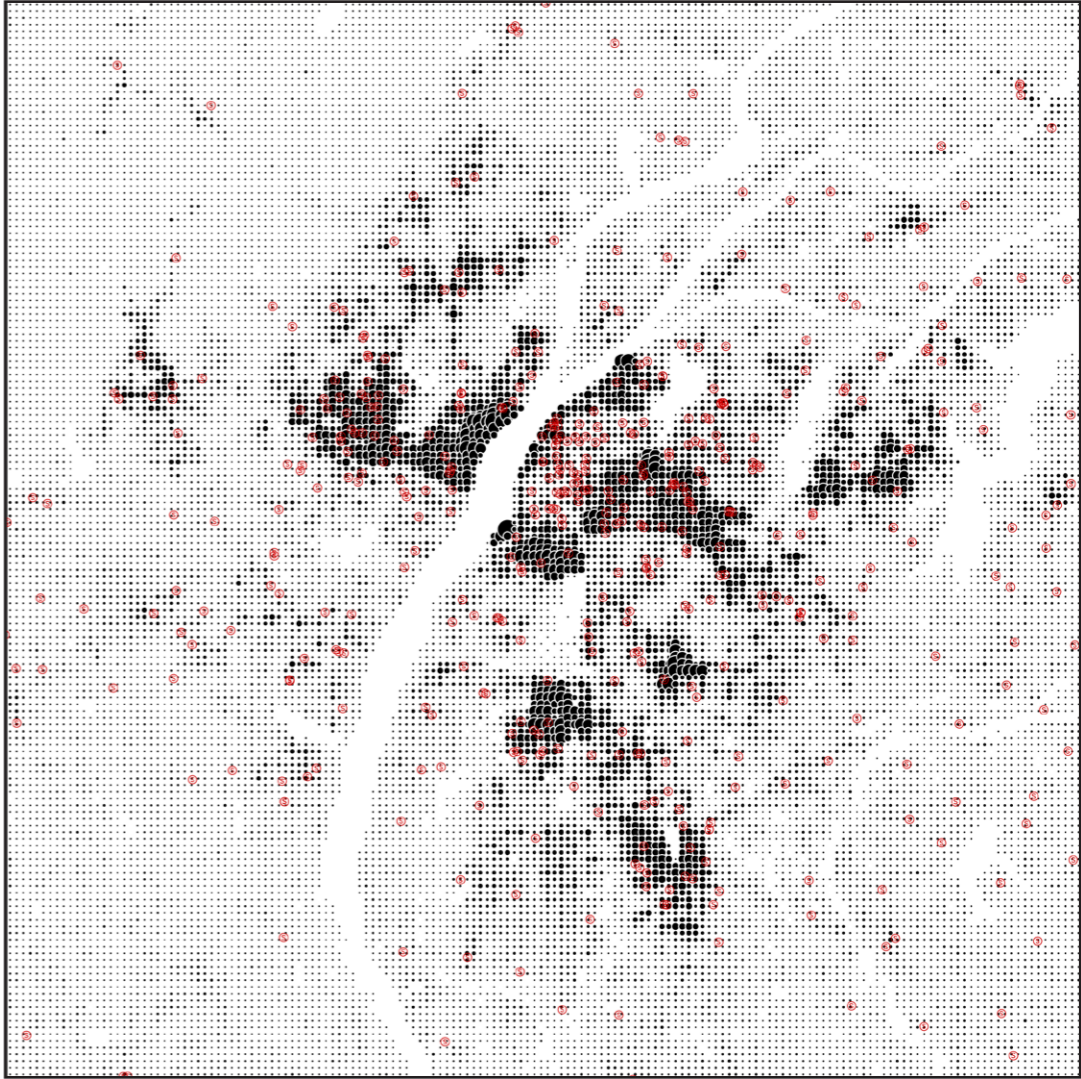


Figure 23. Spatial Distribution of the Youth under 15

By Author

- Large number
- 
- 
- 
- 
- Small number
- ⊙ Primary and middle school location

# Socioeconomic Predisposition

Housing prices are used as a proxy for socioeconomic predisposition across Nanchang. Low-income areas – as indicated by lower housing prices – do not show a strong concentration within a particular administrative district or a specific period of urban development, but are instead dispersed across residential areas of varying construction eras. Spatial comparison with the city's blue-green infrastructure reveals that higher-priced communities tend to cluster along water networks, which is consistent with Nanchang's identity as an internationally recognized wetland city (Nanchang Municipal People's Government, 2021). This pattern is noteworthy in the context of heat vulnerability: Water evaporation reduces ambient air temperature and open water surfaces facilitate ventilation (Yao et al., 2012). **This suggests that higher-income residents may disproportionately benefit from proximity to natural cooling infrastructure, while lower-income communities are more likely to be located in areas with limited access to such resources.**

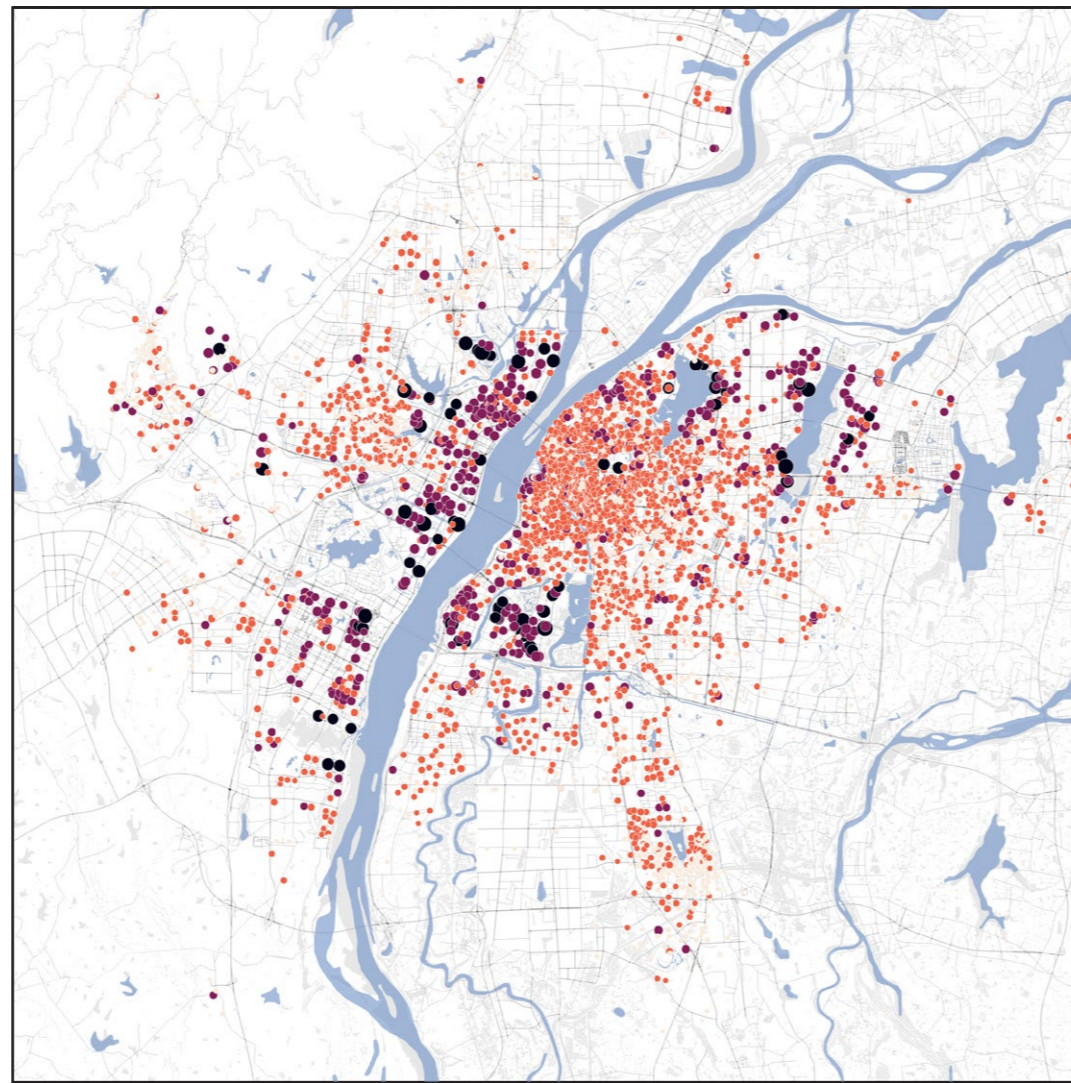


Figure 24. Spatial Distribution of Different Housing Price Level

By Author

- Very high
- High
- Medium
- Low
- Water area

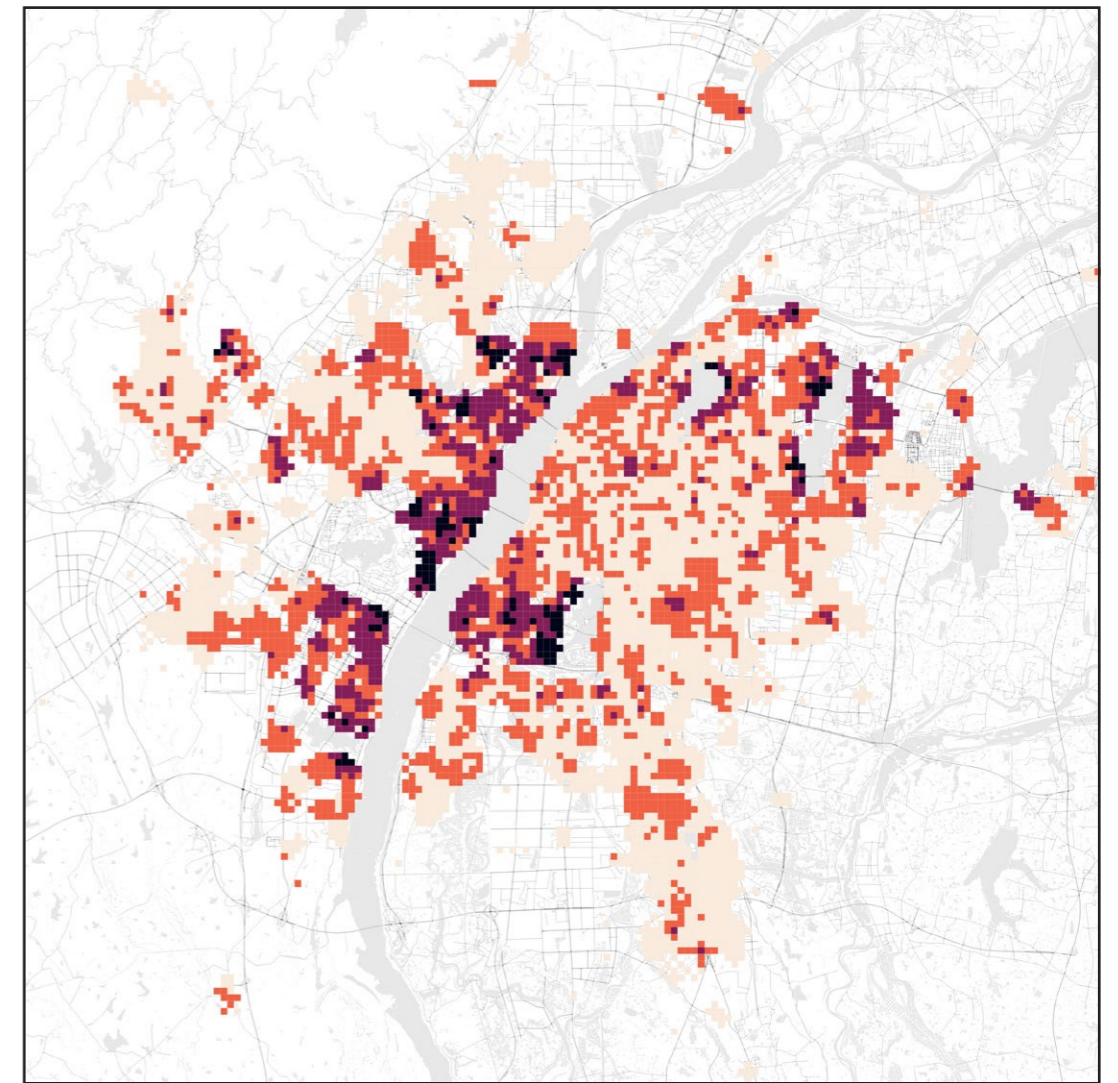


Figure 25. Aggregation Result of Different Housing Price Level

By Author

- Very high
- High
- Medium
- Low

# Spatial Distribution

According to the plot and chart (Fig. 26b), the distribution of sensitivity values is relatively concentrated, with the majority of grid cells falling within the Low (value: 0.25–0.45, 62.9%) to Medium range (value: 0.45–0.60, 35.0%), and a mean value of 0.43. Very low sensitivity (value: 0–0.25) accounts for 2.0% of cells, while only 0.2% are classified as High sensitivity (value: >0.60). This indicates that communities with extremely high heat sensitivity are relatively rare in Nanchang.

At the district level (Fig. 26a), this pattern holds across all seven administrative units,

though notable differences emerge in the balance between Low and Medium classes. Honggutan stands out with 82.5% of cells classified as Low, reflecting its newer built environment, while Xinjian and Qingyunpu show the highest Medium shares (43.7% and 41.4% respectively), indicating greater concentrations of sensitive populations. High sensitivity cells are rare and limited to the three inner-city districts – Donghu (2.4%, n=7), Qingyunpu (0.6%, n=3), and Xihu (0.5%, n=2) – pointing to localized pockets of elevated population vulnerability in the older urban core.

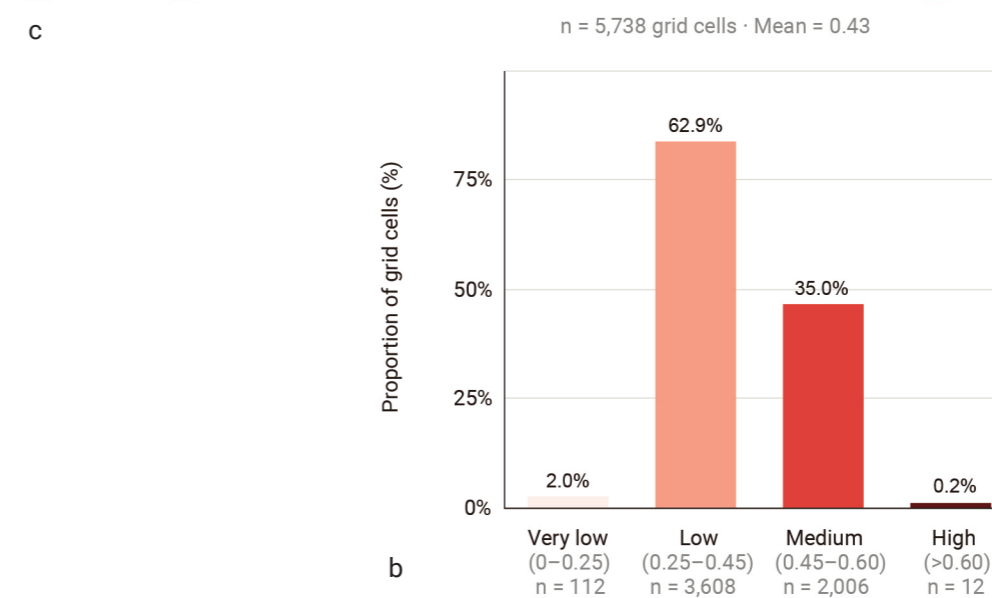
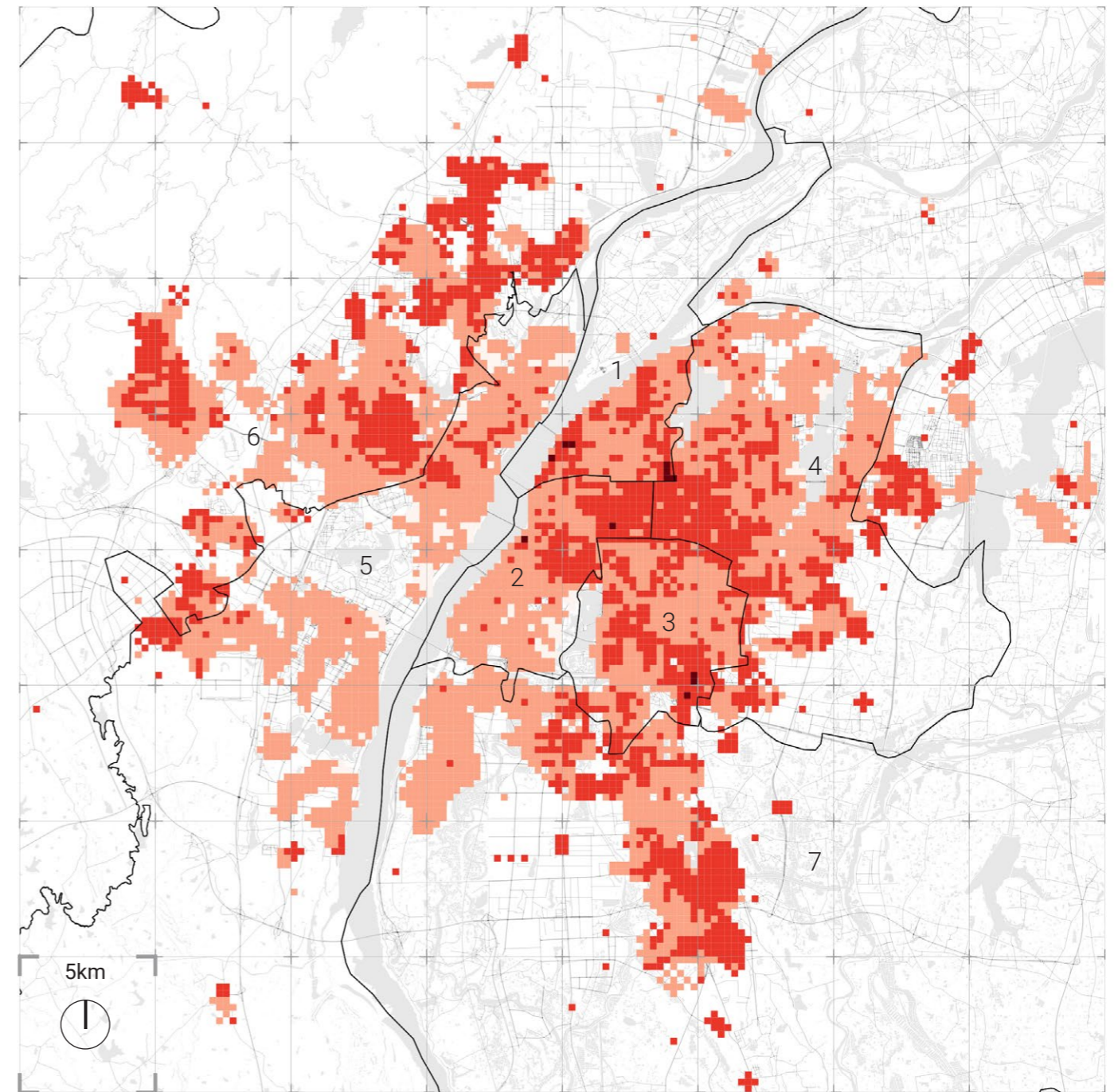
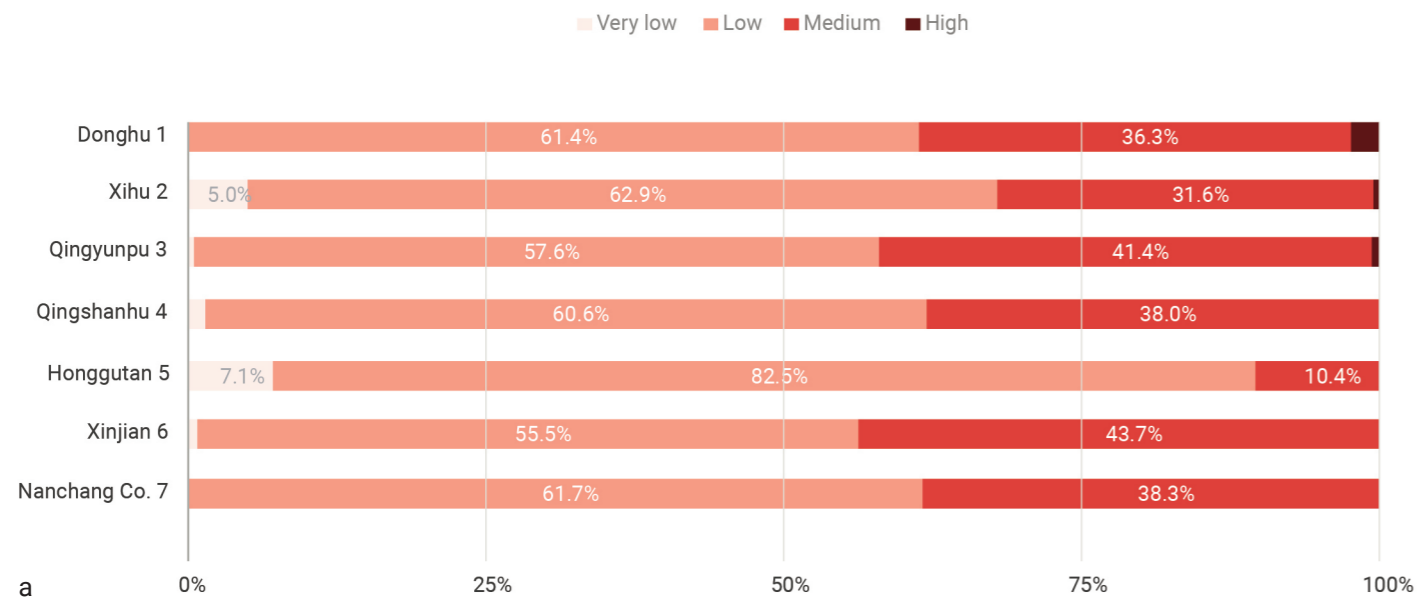


Figure 26. Spatial distribution of heat sensitivity in Nanchang. (a) Sensitivity index per district; (b) Sensitivity index map by grid cell; (c) Sensitivity level distribution across all grid cells *by author*

# Aadaptive Capacity: Where are the Cooling Resources? -Passive Adaptation

## Nanchang Building Shade Index calculation

There is research proving building shade to be the most effective passive cooling resource in outdoor space (Middel et al., 2021). To quantify the thermal comfort provided by building shade, a Building Shade Index (BSI) was developed for each 250m × 250m grid cell. This index evaluates the intensity of shading relative to the pedestrian-accessible ground area.

However, building shade coverage varies with the sun's altitude and azimuth, meaning that this cooling resource changes from day to day and hour to hour. In 2025, Nanchang experienced more than 78 high-temperature days (daily maximum  $\geq 35^\circ\text{C}$ ), lasting from June to October. This prolonged heat period indicates that building shade coverage on a single day cannot adequately represent cooling capacity over the entire summer, given the substantial variation in solar position throughout the season. Accordingly, this study selected building shade maps at 14:00 – typically the hottest time of a summer day – from three dates: 21st June, 22nd July, and 21st August, to calculate the Building Shade Index (BSI).

## Data Scoring and Pre-processing

This project applied GDAL hillshade to generate building shade map from DSM map, to balance computational efficiency with spatial detail, map was aggregated into 2m resolution.

The shadow raster utilizes a weighted scale (0, 1, 2, 3) representing shading frequency at 14:00 in 3 dates. (e.g., 0: full exposure to sun, 1: only covered by shade in 1 day; 2: covered by shaded in 2 days ...)

## Zonal Statistics

Zonal Mean operations were performed to extract the average raw shadow score ( $Shade_{raw}$ ) and building coverage ratio ( $Build_{ratio}$ ) for every cell.

## Normalization: The Shade Index Formula

The final index accounts for the "effective ground area" accessible to pedestrians. By excluding water bodies and building footprints, the index measures the actual shading intensity experienced on the ground.

**Step A:** Define Effective Ground Ratio ( $A_{ratio}$ )

$$A_{ratio} = \max(1 - Water_{ratio} - Build_{ratio}, 0.05)$$

A minimum threshold of \$0.05\$ is applied to prevent numerical instability in ultra-high-density areas.

**Step B:** Calculate BSI

$$BSI = Shade_{raw} / A_{ratio}$$

This index reflects the density of shade available on walkable surfaces, providing a direct proxy for urban heat mitigation potential.

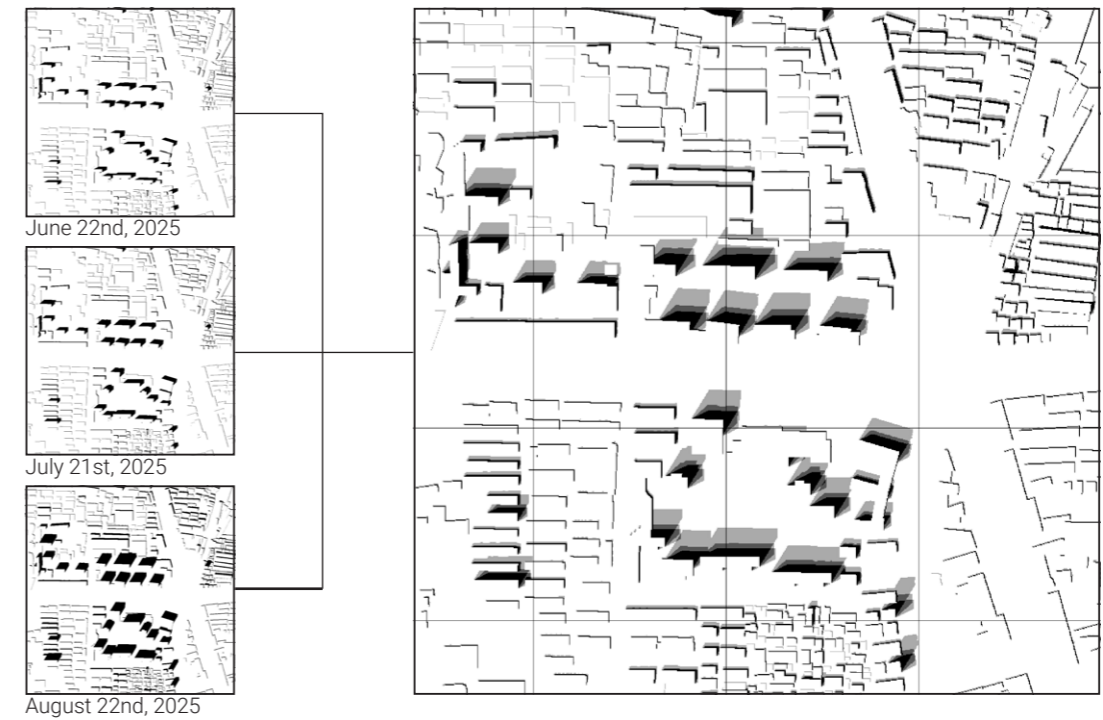


Figure 27. Building Shade Coverage Scoring Process

By Author

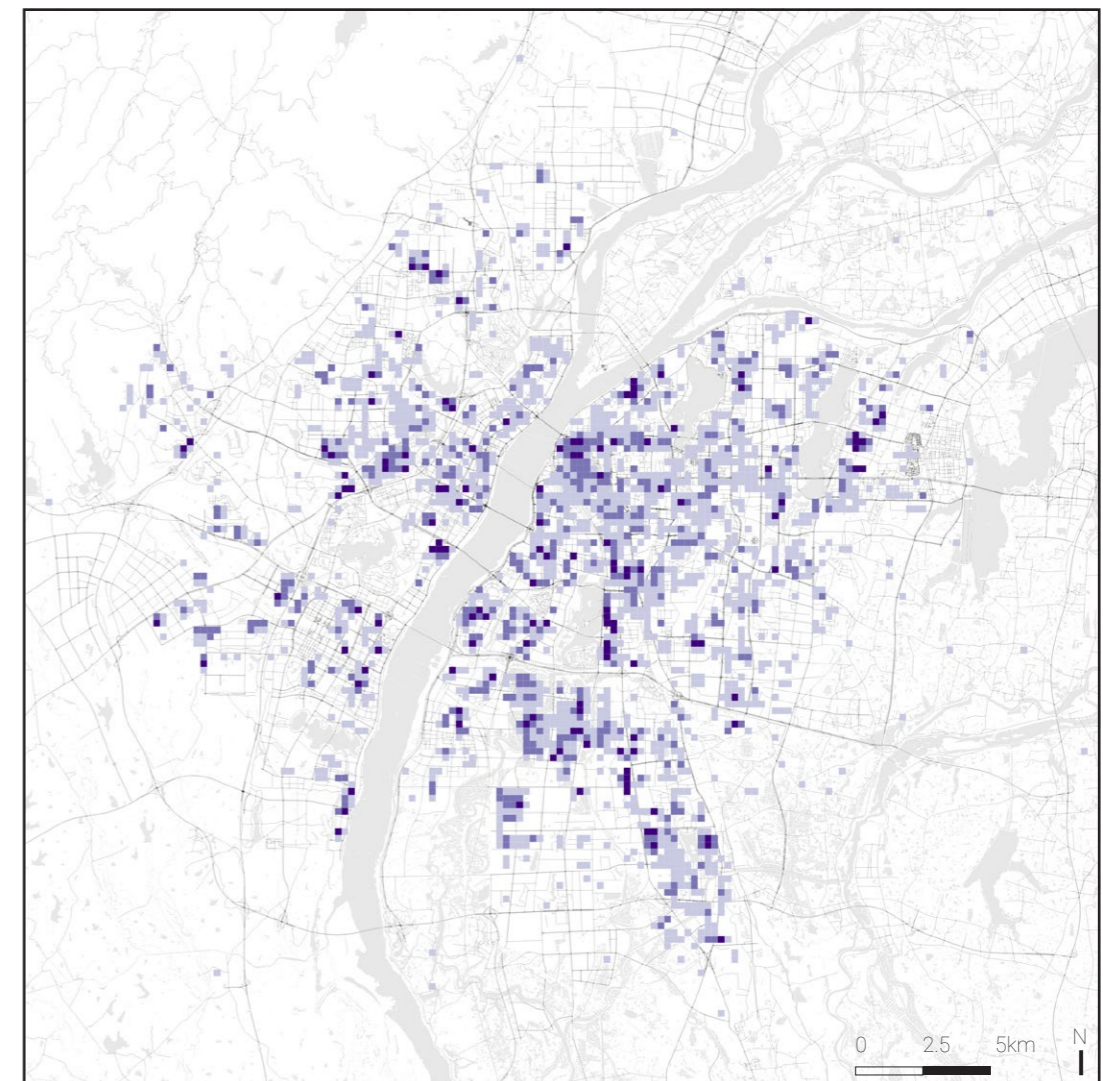


Figure 28. Building Shade Coverage Aggregation Result

By Author

Low Medium High Very high

### Nanchang Tree Canopy Index calculation

Canopy is considered as another effective cooling resource as it can provide shade as well as evapotranspiration to reduce MRT and AT (Probst et al., 2022).

### Data Retrieval and NDVI Processing

The workflow began with the extraction of vegetation data using the Google Earth Engine (GEE) platform:

**Satellite Source:** Sentinel-2 Level-2A surface reflectance imagery was filtered for the peak growing season (e.g., June–August) to ensure maximum canopy expression.

**Spectral Calculation:** The Normalized Difference Vegetation Index (NDVI) was calculated to distinguish live green vegetation.

**Thresholding & Masking:** A NDVI threshold (NDVI > 0.65) was applied to isolate Canopy Pixels from grass or bare soil.

### High-Resolution Pre-processing (2m Resampling)

To bridge the gap between the 10m Sentinel-2 data and the BSI, a 2m-resolution resampling was performed. During resampling, binary values were converted into local coverage probabilities (0.0 to 1.0) using an averaging function. This ensures that the fine-scale vegetation density is accurately represented before being aggregated into the final 250m grids.

### Zonal Statistics and Normalization

The 250m x 250m vector grid was utilized as the unit of analysis. Through Zonal Mean operations, the raw canopy ratio ( $G_{raw\_ratio}$ ) was extracted for each cell and normalized against the  $A_{ratio}$ .

The Canopy Index (CI) Formula:

$$CI = \min(G_{raw\_ratio} / A_{ratio}, 1.0)$$

This approach provides a relatively high-fidelity proxy for urban heat mitigation and the ecological quality of the pedestrian environment.

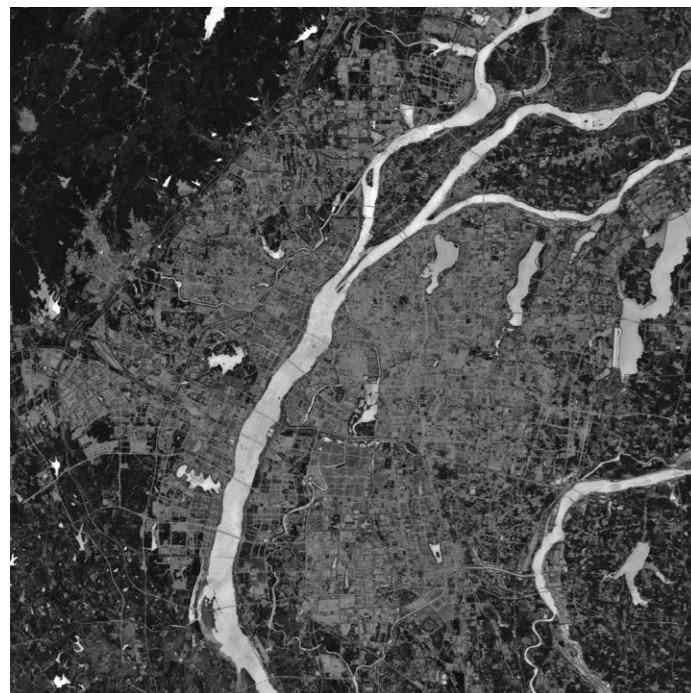


Figure 29. Nanchang NDVI

Generated by author using Google Earth Engine(GEE)

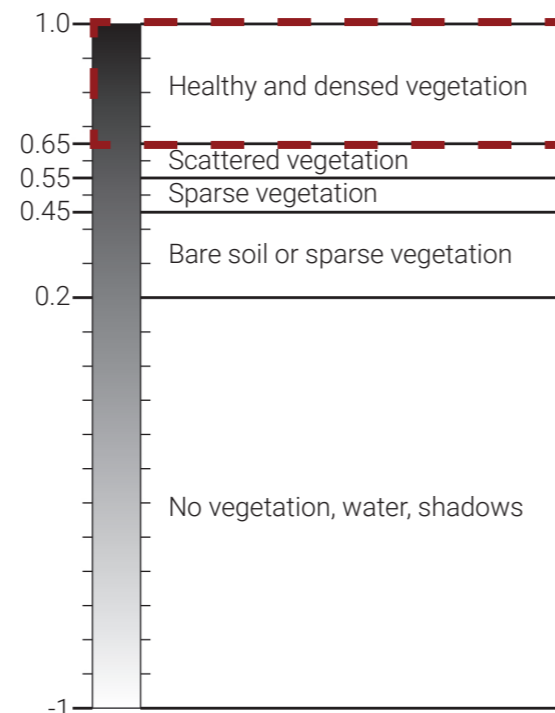


Figure 30. NDVI Value Interpretation

By Author

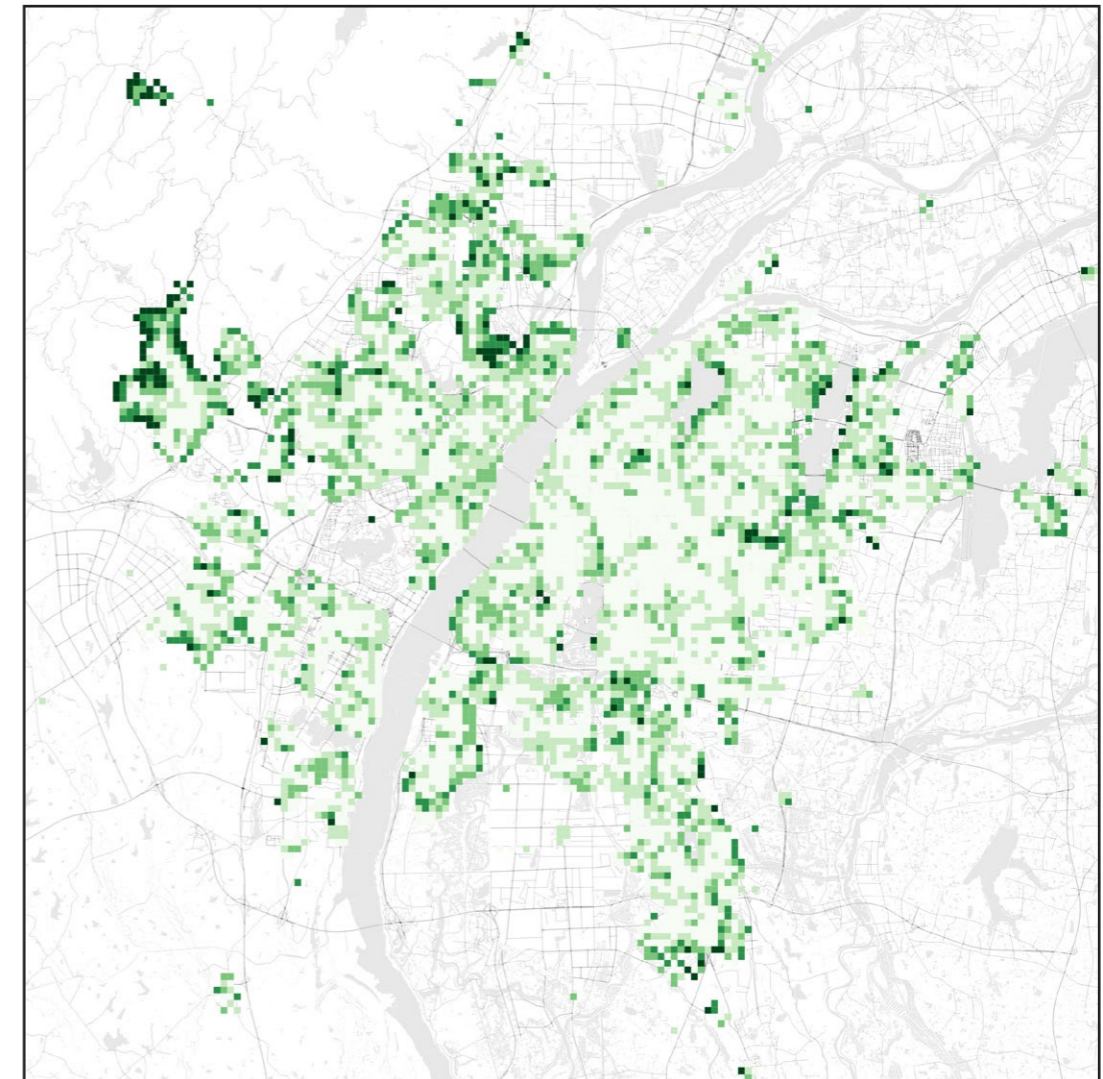
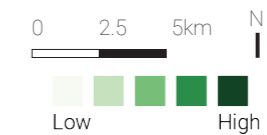


Figure 31. Green Canopy Distribution Across all Grid Cells

By Author



# Active Intervention

## Accessibility of active intervention (based on Network Kernel Density Estimation)

During summer, accessibility to active cooling interventions—such as shelters (indoor public spaces with air conditioning) and the medical system—serves as an indicator of an area's adaptive capacity.

While traditional accessibility metrics such as Buffer Analysis and Kernel Density Estimation (KDE) (Fig. a, b) are widely used, they often fall short in complex urban environments. Buffer Analysis ignores the distance decay effect and fails to effectively quantify the service gains resulting from the superposition of multiple facilities. Although KDE incorporates

the principle of distance decay, it relies on Euclidean distance, failing to account for physical obstacles and the actual street configuration. To address these limitations, this project employs Network Kernel Density Estimation (NKDE), which constrains the analysis to the transport network, thereby providing a more realistic representation of urban accessibility.

Unlike classical KDE, NKDE constrains density estimation to the road network by replacing pixels with lixels (linear equivalents of pixels on a network), calculating network distances rather than Euclidean distances, and adjusting the kernel function to account

for the anisotropic nature of network space (Gelb, n.d.). A bandwidth parameter defines the search radius within which surrounding facilities contribute to the density estimate at each lixel, with the influence of each facility decreasing with network distance according to the kernel function. This approach is more appropriate for urban facility indicators such as healthcare facilities and cooling shelters, where accessibility is determined by street-based movement rather than straight-line distance.

## Network-Based Sampling and Lixelization

To perform a high-resolution NKDE, the continuous road network was dis-

cretized into a series of analytical units known as lixels (linear elements).

**Lixelization:** The raw road geometry was fragmented into segments of a uniform length (150m). This process ensures that the density calculation is distributed evenly across the network, preventing spatial bias caused by varying road lengths.

**Sample Point Generation:** For each lixel, a sampling point was generated at its geometric center. These points serve as the discrete locations where the accessibility scores—calculated from the surrounding POIs—are recorded.

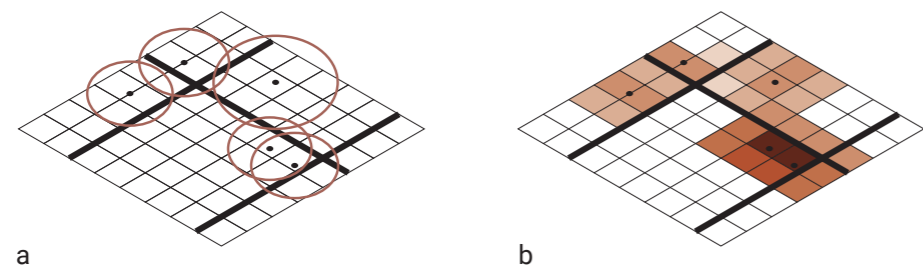


Figure 32. Traditional Accessibility Analysis Methods. (a) Buffer Analysis, (b) Kernel Density Estimation (KDE)

Redrawn by author based on Gelb, J. (n.d.). Network kernel density estimate. spNetwork. <https://jeremygelb.github.io/spNetwork/articles/NKDE.html>

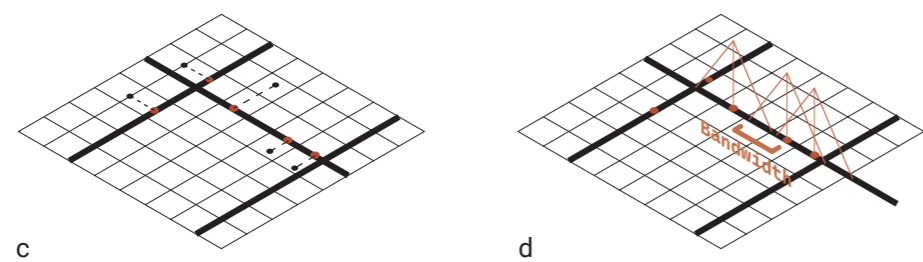


Figure 33. Network Kernel Density Estimation (NKDE) Demonstration

Redrawn by author based on Gelb, J. (n.d.). Network kernel density estimate. spNetwork. <https://jeremygelb.github.io/spNetwork/articles/NKDE.html>

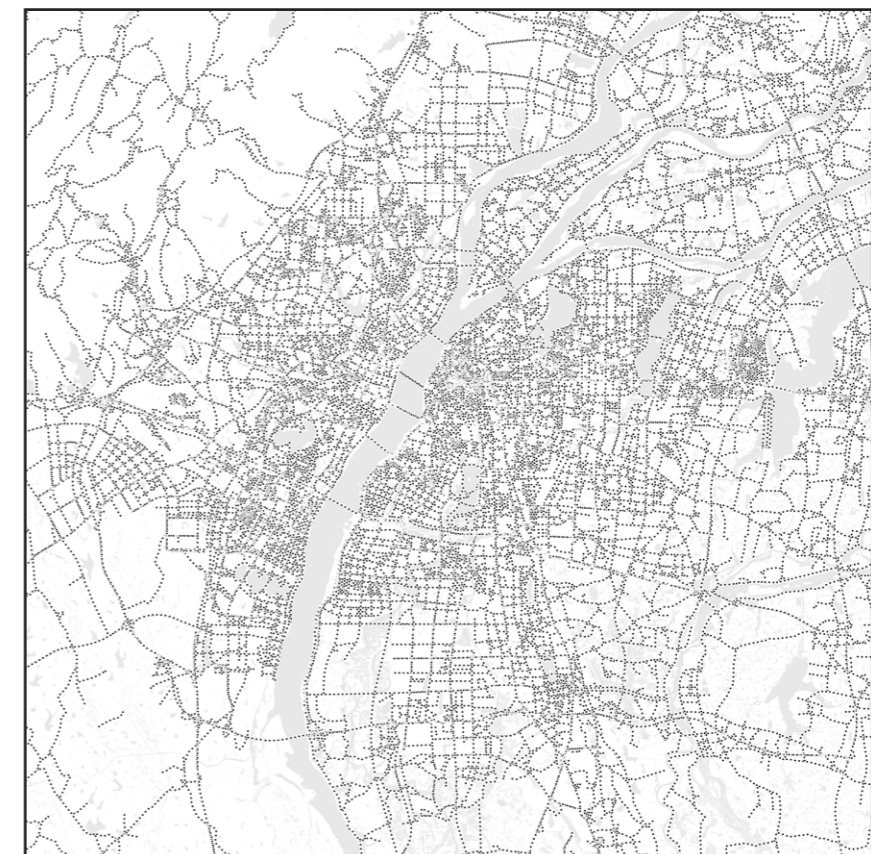


Figure 34. Sample Points for NKDE in Nanchang

By Author

**Accessibility of Health system**

According to the National Health Commission of the PRC, China is actively developing "15-minute healthcare service circles" to ensure medical access within a short walk. However, during extreme summer heat, the effective accessible distance for vulnerable populations must be significantly reduced. China's healthcare system operates on a distinct hierarchy; therefore, this project applies Network Kernel Density Estimation (NKDE) with differentiated weights and search radii to reflect the varying rescue capacities of each tier.

**Tier 1: Basic Community Level**

This level consists of pharmacies and community clinics, which provide the most immediate access for residents suffering from minor heat-related ailments. Due to their limited medical resources and patient capacity, they are assigned the lowest weight (Weight: 1) and a bandwidth of

400m—representing a 5-minute walking distance adjusted for the physical constraints of sensitive groups in summer.

**Tier 2: General Medical Facilities**

This level refers to general hospitals with larger patient capacities and stronger emergency rescue capabilities. Reflecting their higher importance in the urban healthcare network, they are assigned a weight of 5 and an 800m bandwidth, representing approximately a 10-minute walk under heat-stress conditions.

**Tier 3: Tertiary Hospitals (Excluded)**

Nanchang hosts several Level 3 (Tertiary) hospitals, which possess comprehensive rescue capabilities and serve the entire city or province. Despite their importance, they are excluded from this specific pedestrian accessibility model because their service logic is based on city-wide coverage via motorized transport rather than local-scale pedestrian cooling relief.

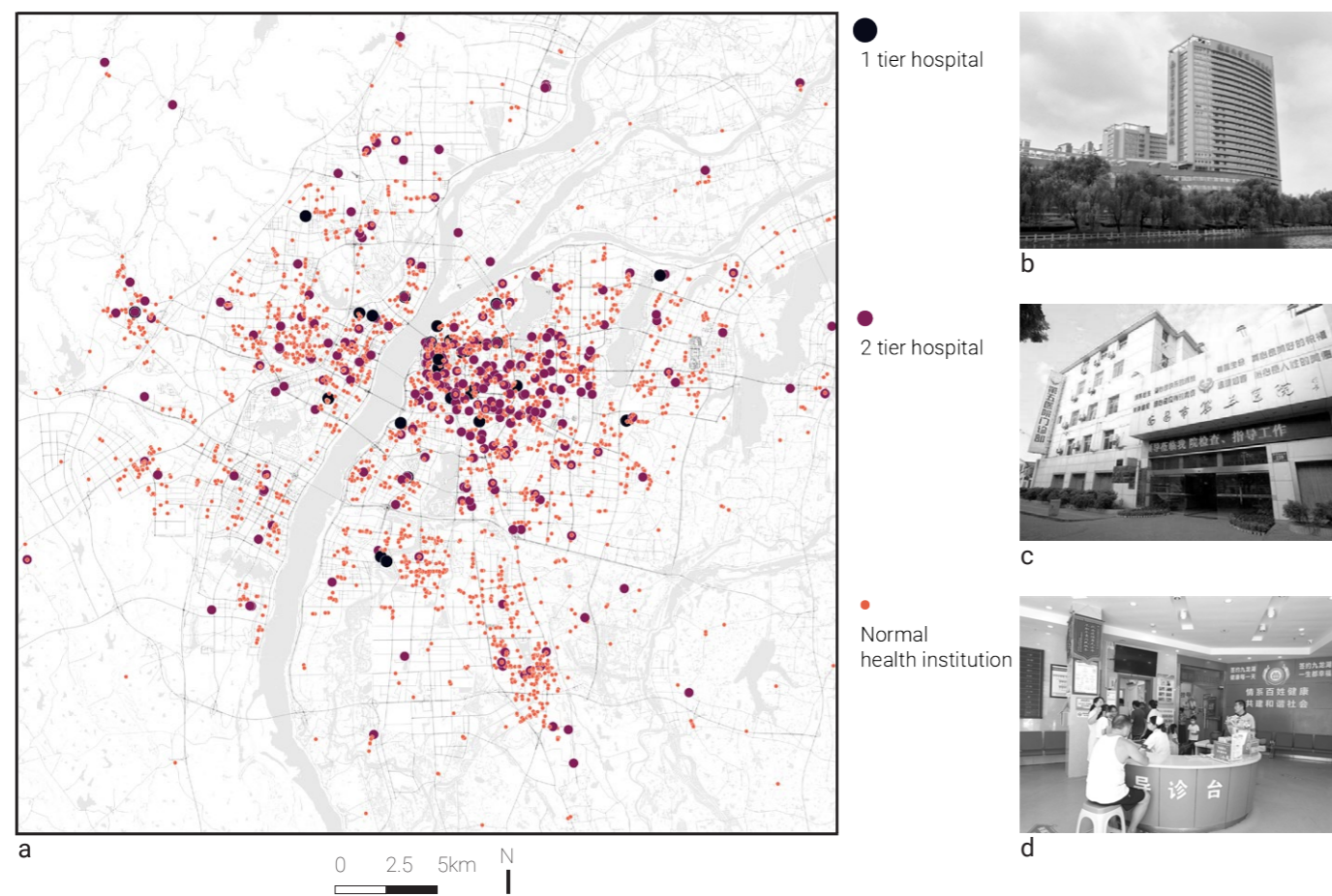


Figure 35. Hierarchy and Spatial Distribution of Health System in Nanchang. (a) Distribution map, (b) 1st tier hospital, (c) 2nd tier hospital, (d) Normal health institution.

Map by author, images are from: 1 [https://www.sohu.com/a/411199027\\_632002](https://www.sohu.com/a/411199027_632002), 2 <https://www.wy120.com/xwzx/20201010572.html>, 3 <https://jx.ifeng.com/c/8clbsnvV5ll>.

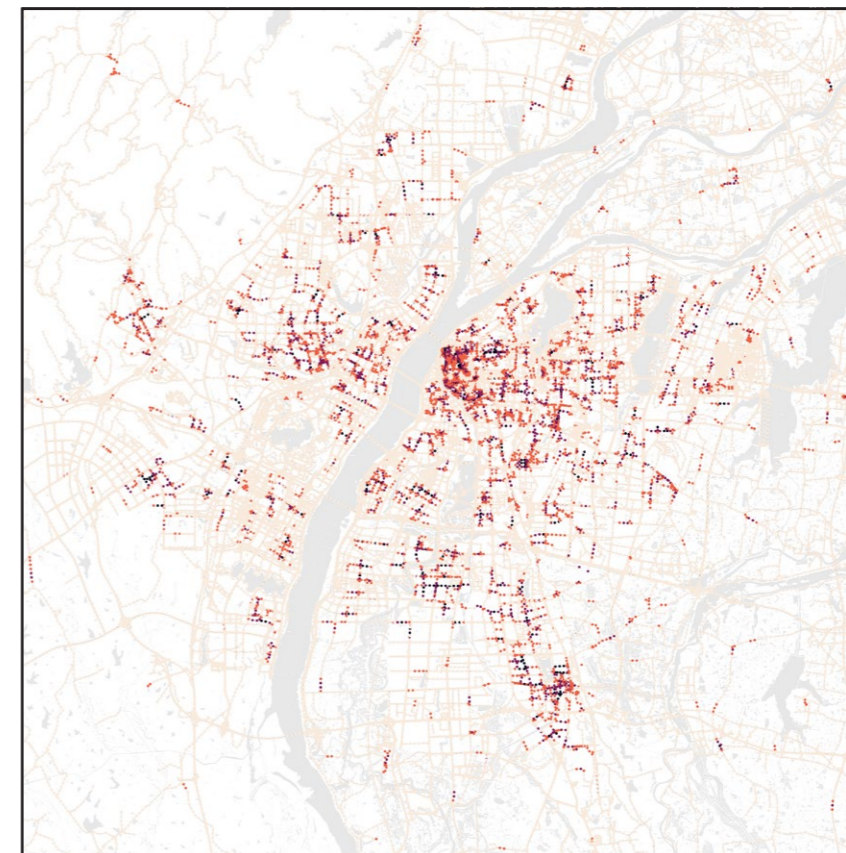


Figure 36. Health System NKDE Analysis Result

By Author  
0 2.5 5km N

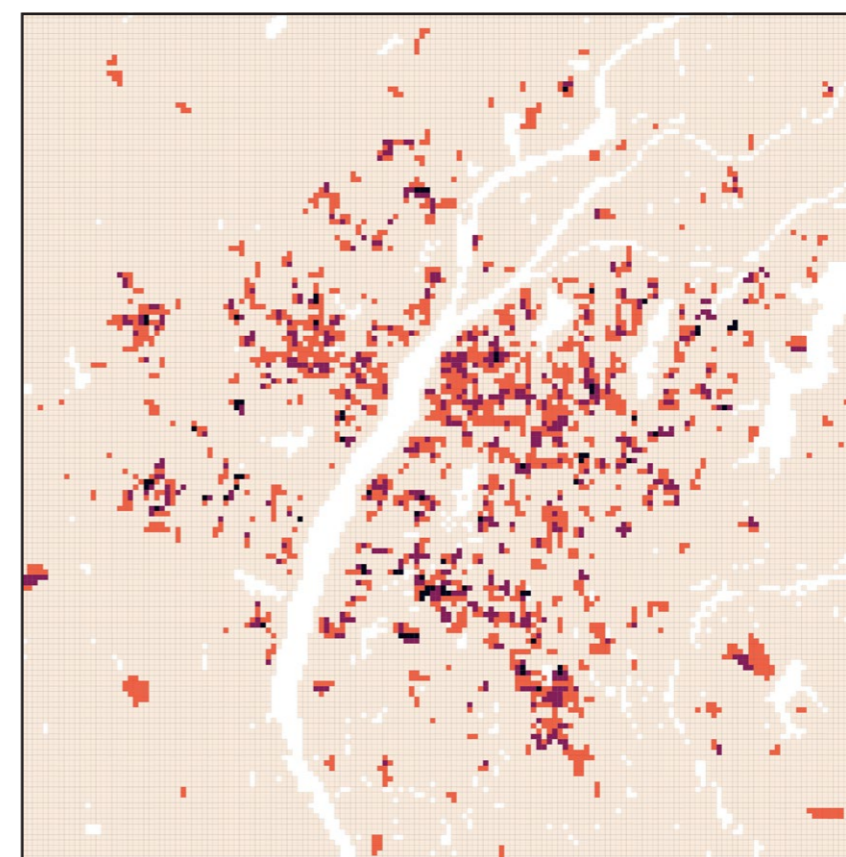


Figure 37. Health System NKDE Aggregation Result

By Author

Low Accessibility High Accessibility

### Accessibility of Heat Shelter

In cities with extreme summer temperatures like Nanchang, air-conditioned indoor environments are the most effective resources for personal heat mitigation. Consequently, this study defines heat shelters as indoor public spaces equipped with air conditioning. Similar to the healthcare system analysis, NKDE was employed to evaluate the accessibility of these shelters based on two primary dimensions: Publicness and Capacity.

### Publicness (Bandwidth)

Publicness determines the service range of a facility based on its administrative level and intended user base. Metropolitan-scale venues — such as libraries, cultural centres, museums, subway stations, and galleries —

are assigned a bandwidth of 1,000m, while community-scale facilities such as community centres and local reading rooms are assigned 500m.

### Capacity (Weight)

Weights reflect the physical size and accommodation capacity of each facility. Small facilities including subway cooling zones and community reading rooms are assigned a low weight of 1. Standard public facilities such as galleries, museums, and district-level libraries receive a weight of 5. Large landmark institutions such as city or provincial libraries, capable of accommodating large crowds, are assigned the maximum weight of 10.

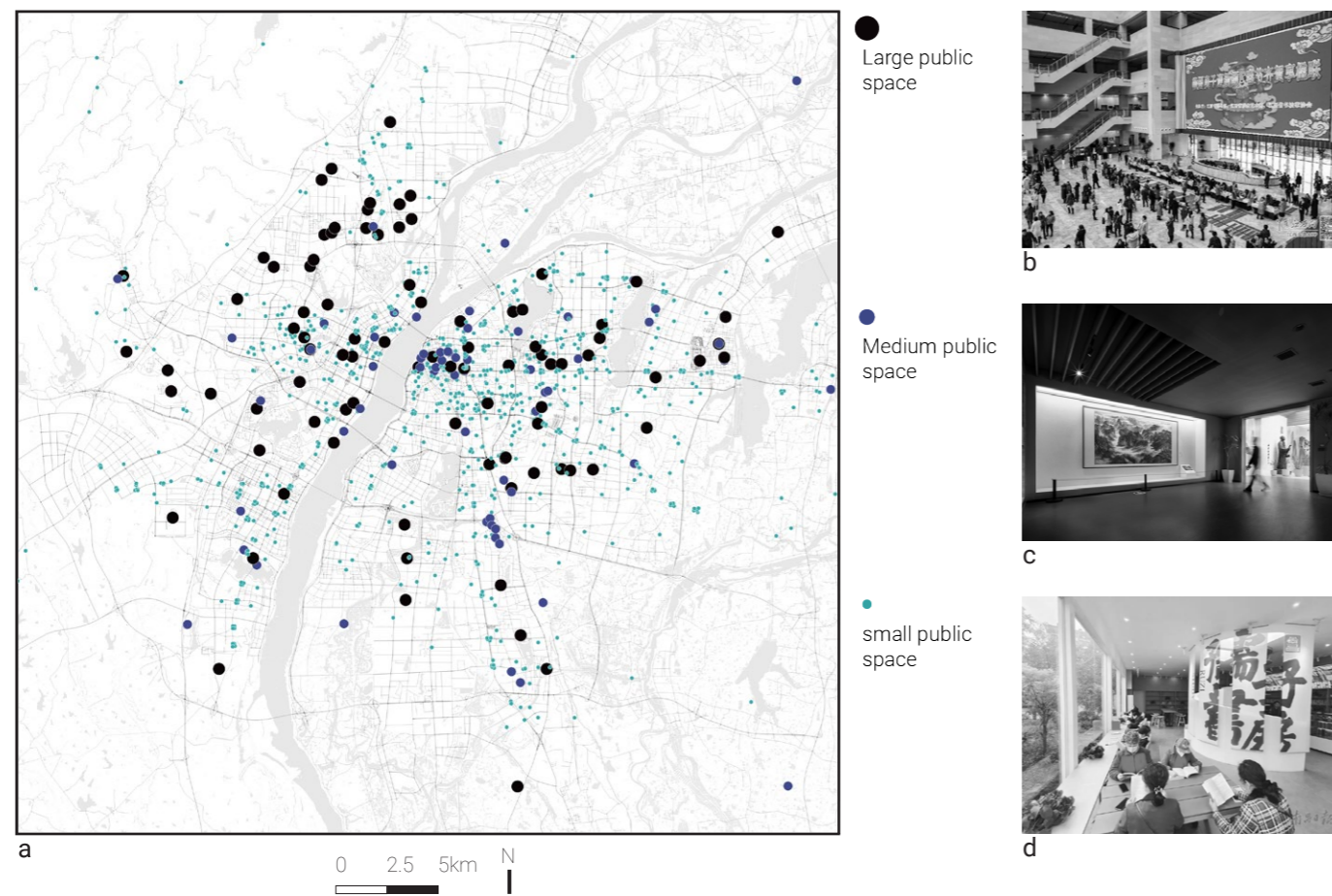


Figure 38. Hierarchy and Spatial Distribution of Heat Shelter in Nanchang. (a) Distribution map, (b) 1st tier Shelter, (c) 2nd tier Shelter, (d) 3rd tier Shelter.

Map by author, images are from: 1 <https://tt.jxnews.com.cn/news/899752>, 2 <https://www.archdaily.cn/cn/961607/nan-chang-ba-gong-yuan-liang-shu-mei-zhu-guan-gai-zao-xaa>, 3 [https://k.sina.com.cn/article\\_3632086395\\_d87d3d7b04001epk6.html](https://k.sina.com.cn/article_3632086395_d87d3d7b04001epk6.html).

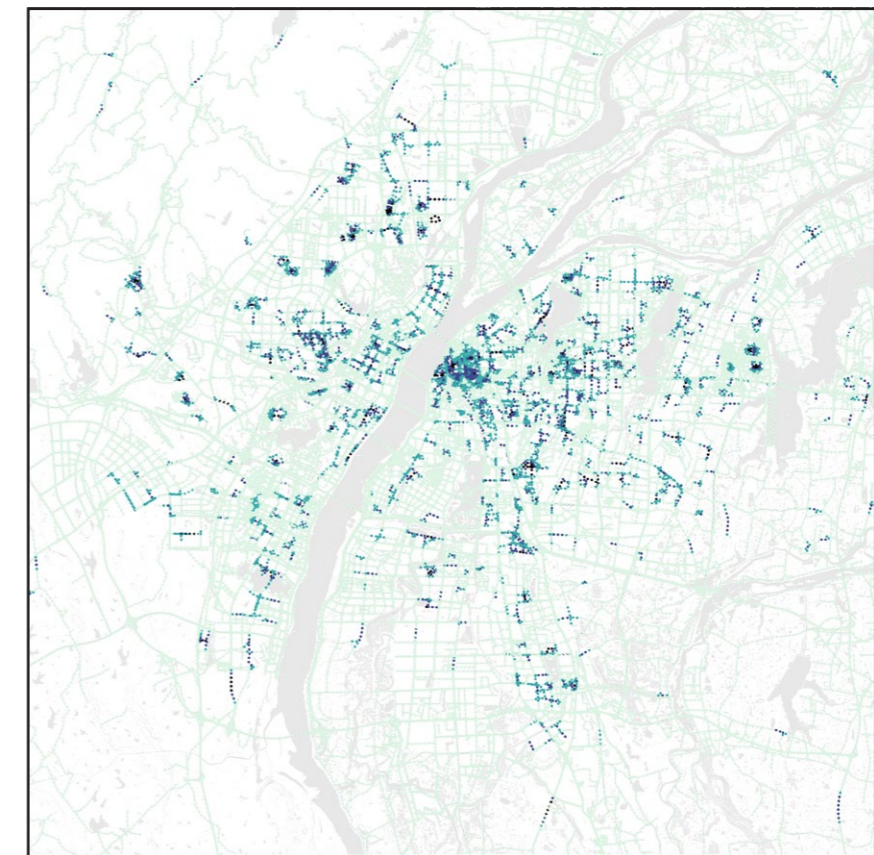


Figure 39. Heat Shelter NKDE Analysis Result

By Author  
0 2.5 5km N

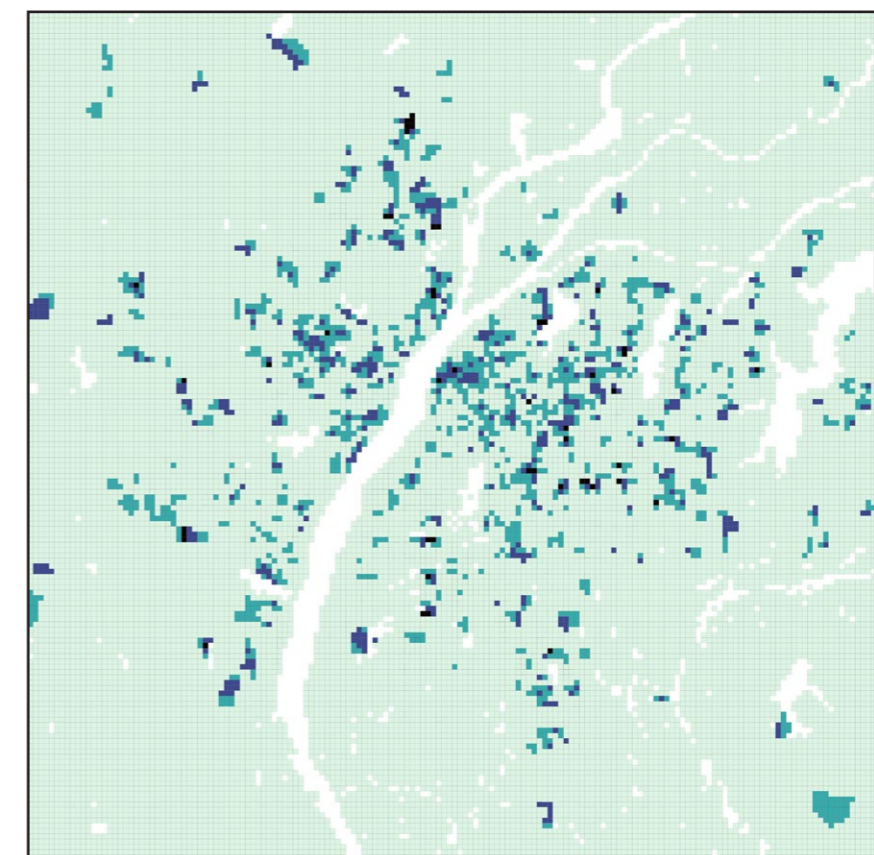


Figure 40. Heat Shelter NKDE Across all Grid Cells

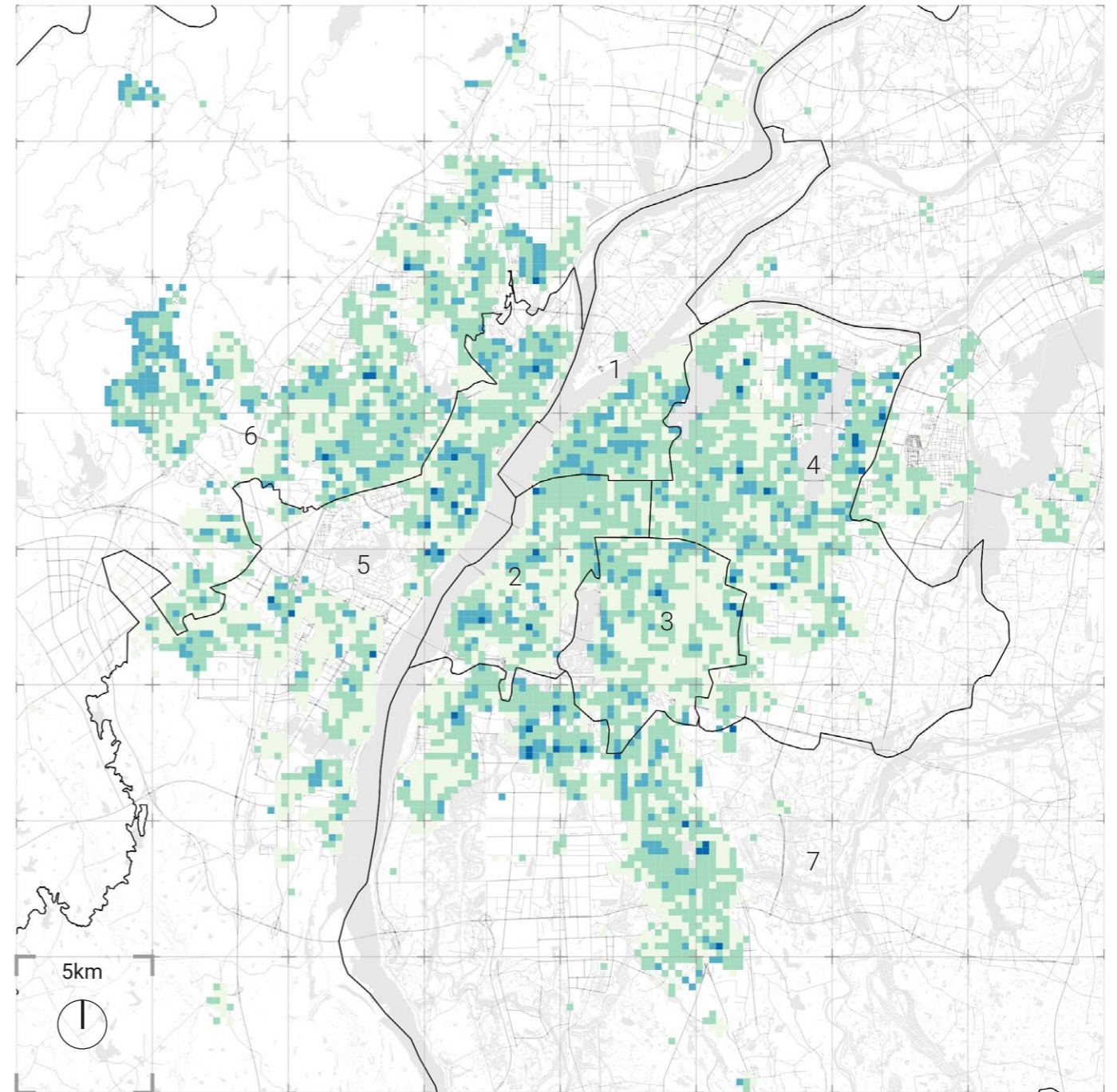
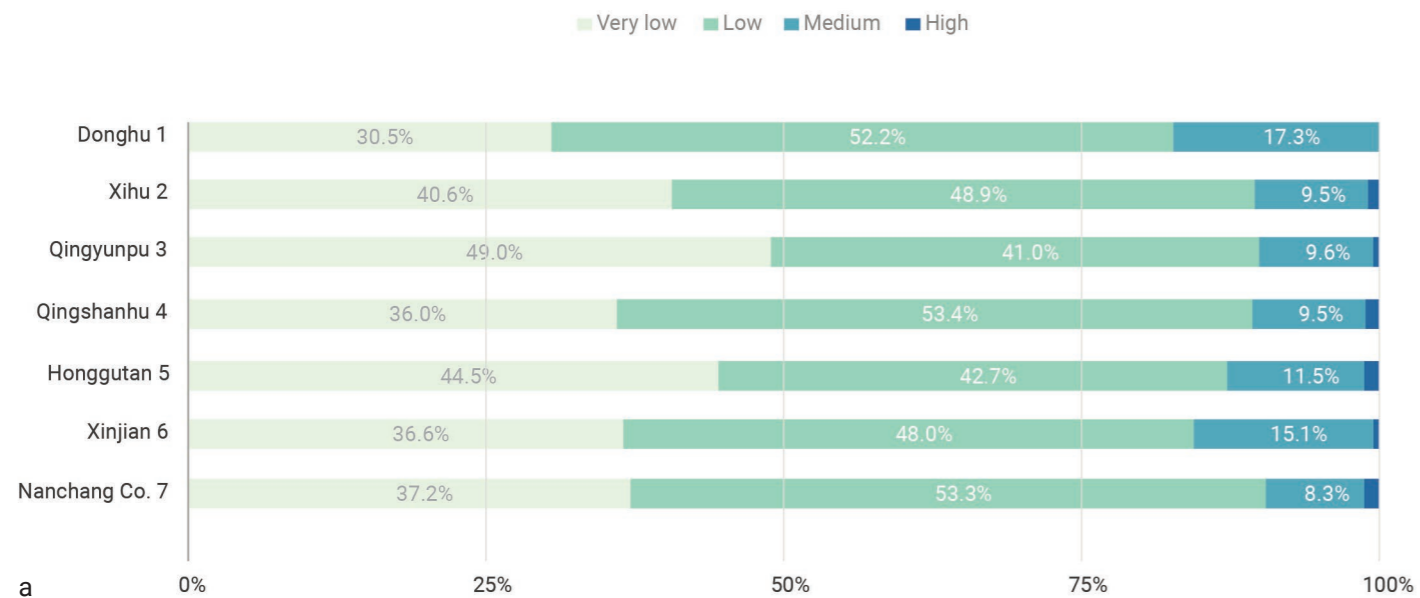
By Author  
Low Accessibility High Accessibility

# Spatial Distribution

The adaptive capacity index across 5,836 grid cells has a mean value of 0.247, indicating that overall cooling resource availability in the study area is low. The distribution is concentrated in the lower half of the scale: the Medium-low class (0.2–0.4) is the largest group at 48.9% (n = 2,853), followed by the Low class (0–0.2) at 38.9% (n = 2,273). Together, these two classes cover nearly 88% of all grid cells. Only 11.3% of cells reach Medium-high levels (0.4–0.6, n = 661), and just 0.8% are classified as High (0.6–1.0, n = 49), indicating that areas with strong access to natural cooling and health infrastructure are rare across Nanchang's residential areas (Fig. 41b).

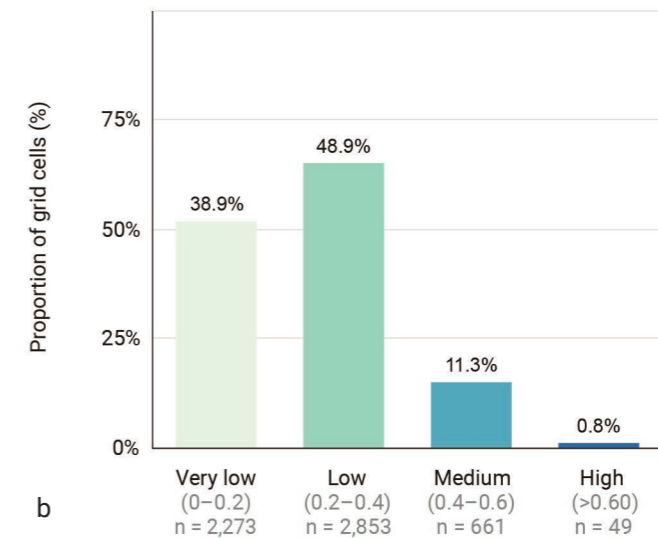
At the district level (Fig. 41a), adaptive capacity remains consistently low across all seven districts, with Low and Medium-low classes jointly accounting for over 80%.

At the district level, adaptive capacity remains consistently low across all seven districts, with Low and Medium-low classes jointly accounting for over 80% of cells everywhere. Qingyunpu shows the weakest profile (49.0% Low, n=240), while Donghu performs relatively better with Medium-low as its dominant class (52.2%, n=154). Xinjian contains the largest absolute number of Medium-high cells (n=214), reflecting its greater spatial extent. High adaptive capacity is negligible citywide ( $\leq 1.3\%$ ).



c

n = 5,836 grid cells · Mean = 0.247



b

Figure 41. Spatial Distribution of Heat Adaptive Capacity(AC) in Nanchang. (a) AC index per district; (b) AC index map by grid cell; (c) AC level distribution across all grid cells *by author*

# Vulnerability: Distributional Inequity of Cooling Resources

Follow the Vulnerability formula:

$$\text{Vulnerability} = \text{Sensitivity} - \text{Adaptive Capacity}$$

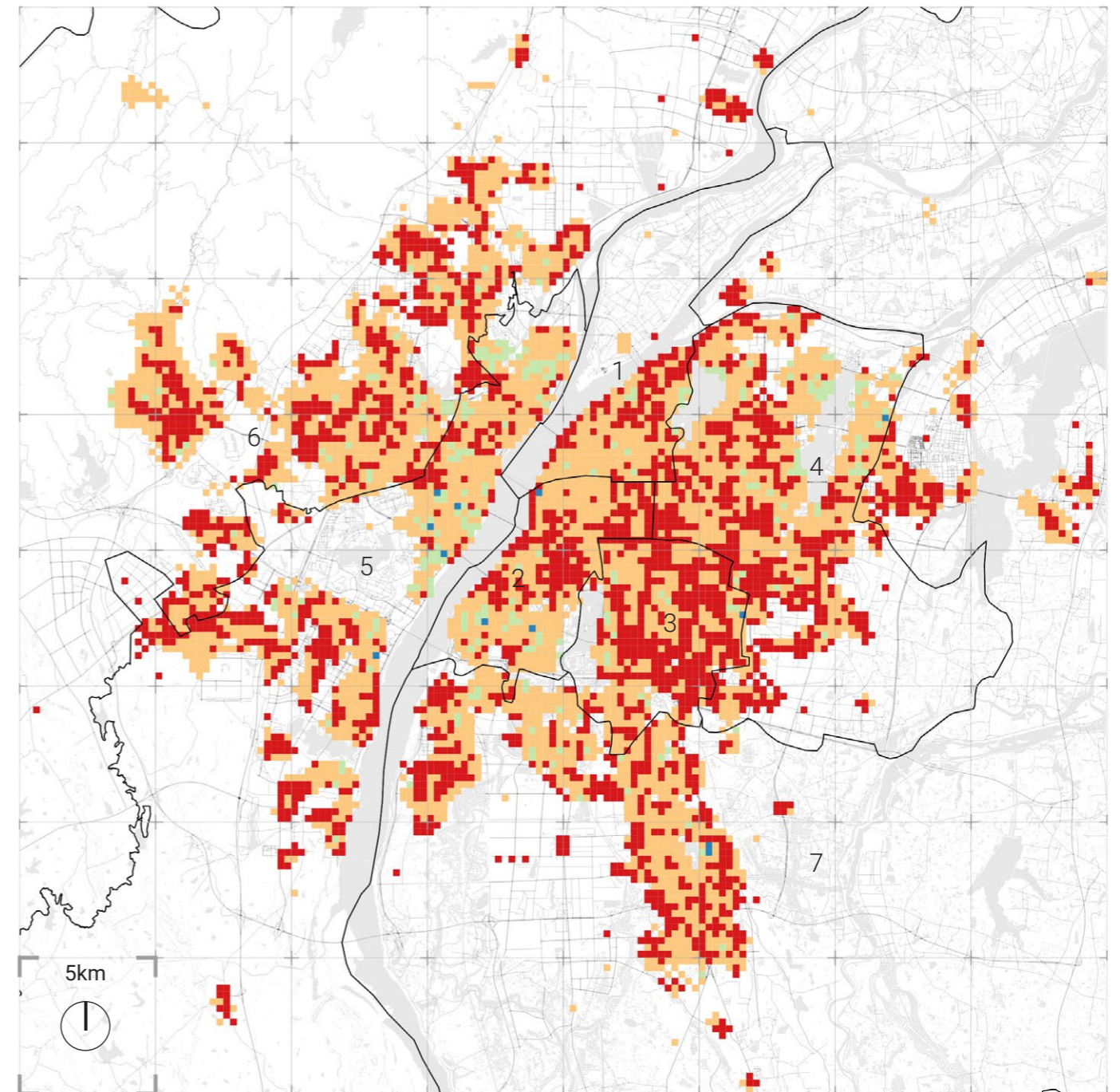
Vulnerability distribution map (Fig. 42c) was generated.

The composite vulnerability index yields a mean value of 0.565, indicating that the study area as a whole tends toward moderate-to-high vulnerability. The Medium class (0.45–0.60) accounts for the largest share of grid cells (49.5%, n = 2,842), followed by the High class (>0.60) at 39.2% (n = 2,247). Together, these two classes represent nearly 90% of all cells, suggesting that a substantial proportion of Nanchang's urban population resides in areas facing considerable heat vulnerability. By contrast, Low (0.25–0.45) and Very low (0–0.25) classifications are limited to 10.8% (n = 620) and 0.5% (n = 29) of cells respectively.

At district level (Fig. 42a), Vulnerability shows the strongest spatial differentiation. Qingyunpu has the highest proportion of High

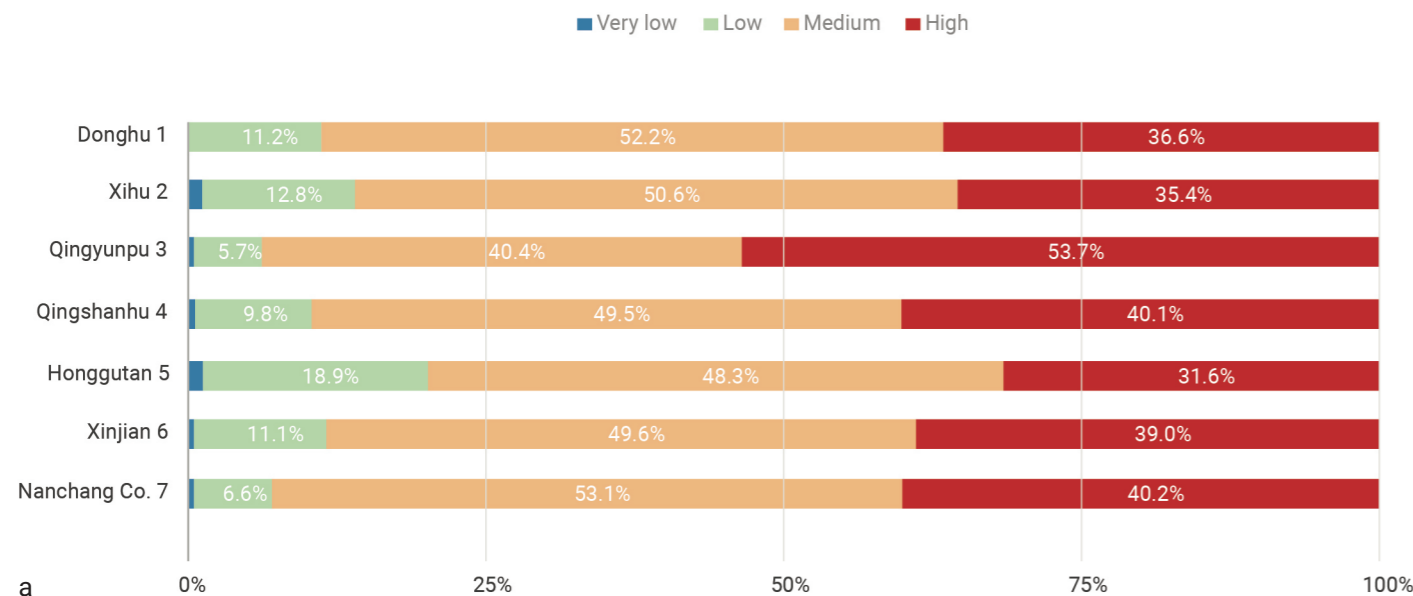
vulnerability cells (53.7%, n=263), driven by its combination of weak adaptive capacity and elevated sensitivity. Honggutan shows the lowest High share (31.6%, n=279). Although Xinjian's High proportion (39.0%) is not the largest, it contains the greatest absolute number of High vulnerability cells (n=553), followed by Nanchang County (n=477), reflecting their larger spatial extents. Medium vulnerability dominates across most districts (40–53%), confirming that moderate heat risk is widespread rather than spatially concentrated.

This map reveals a spatial mismatch between sensitive populations and adaptive capacity: where vulnerability is higher, heat-predisposed residents are less able to cope with thermal stress. **This pattern reflects a distributional inequity in the allocation of cooling resources across Nanchang's residential areas.**

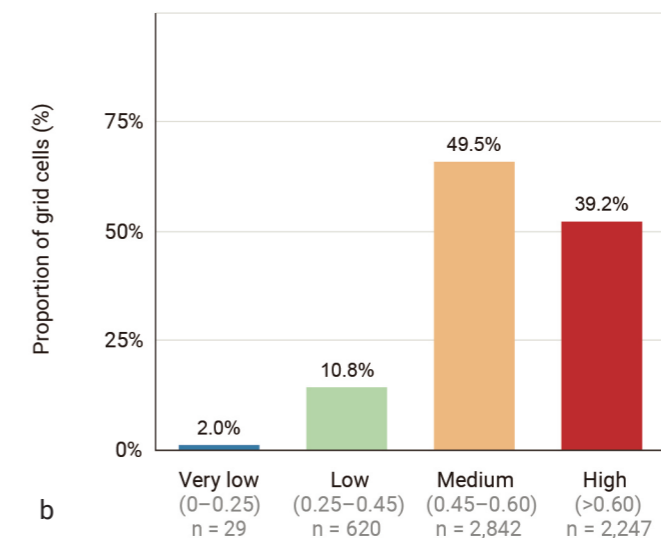


c

n = 5,738 grid cells · Mean = 0.565



a



b

Figure 42. Spatial Distribution of Heat Vulnerability in Nanchang. (a) Vulnerability index per district; (b) Vulnerability index map by grid cell; (c) Vulnerability level distribution across all grid cells *by author*

# Vulnerability Beyond Morphology

By comparing the LCZ map and constructed period with the vulnerability distribution map (Fig. 43 and 44), **the results reveal no consistent correspondence between construction period and vulnerability level.**

In medium vulnerability areas, communities built during 2005–2015 account for the largest share (37.6%), followed by those built after 2015 (25.5%) and before 2005 (25.3%). In high vulnerability areas, the three periods are similarly distributed: 2005–2015 at 28.1%, before 2005 at 24.7%, and after 2015 at 27.3%. Across both vulnerability levels, the three construction periods are represented

in broadly comparable proportions, with no single period dominating or being systematically absent. This pattern holds when examining very low and low vulnerability areas as well, where all three periods co-exist without a clear directional trend. **After all, building age alone does not predict where heat vulnerability is high or low.**

A similar pattern emerges when examining LCZ types. In medium vulnerability areas, open-form typologies – LCZ4 Open high-rise (16.7%), LCZ5 Open midrise (3.7%), and LCZ6 Open low-rise (10.3%) – together account for 30.7% of the area, while compact

typologies – LCZ2 Compact midrise (9.2%) and LCZ3 Compact low-rise (16.7%) – account for 25.9%. In high vulnerability areas, open typologies decline to 23.9% (LCZ4: 13.9%, LCZ5: 2.9%, LCZ6: 7.1%), while compact typologies rise slightly to 24.3% (LCZ2: 7.3%, LCZ3: 17.1%). Although a modest shift is observable – open-form areas decrease and LCZ3 increases as vulnerability rises – neither compact nor open typologies are exclusive to any vulnerability level. Notably, LCZ2 reaches its highest share in the very low vulnerability category (14.2%), contrary to the assumption that compact morphology inherently corresponds to higher heat risk.

**Urban form type alone does not determine vulnerability distribution.**

Overall, neither construction period nor LCZ type shows a consistent relationship with vulnerability level. High vulnerability areas contain a mix of old and new buildings, as well as both compact and open morphologies. **This means that physical form alone cannot identify where heat risk is concentrated – and therefore cannot reliably guide where adaptation interventions should be directed. Consequently, there should be site-specific intervention for each type of neighbourhood.**

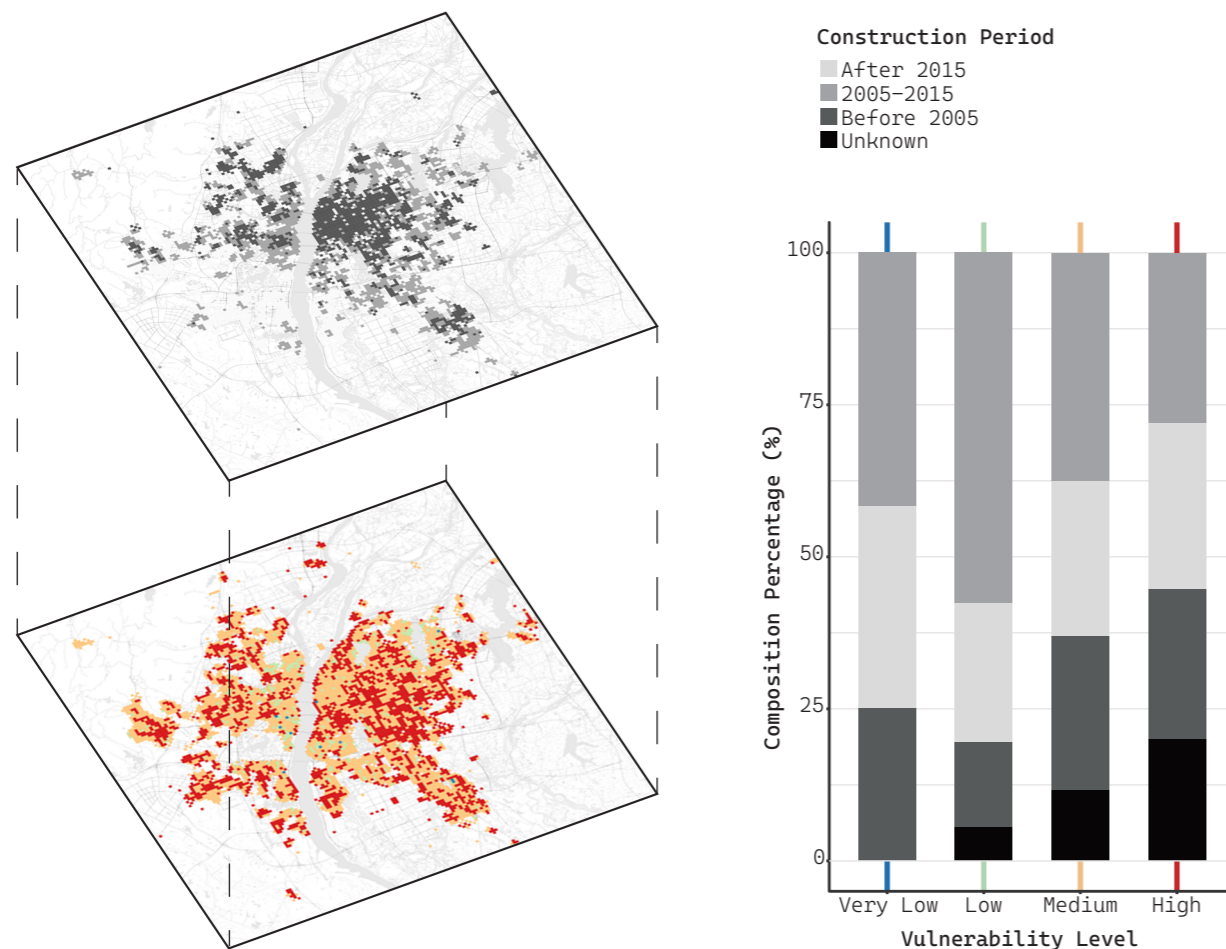


Figure 43. Vulnerability Distribution and Neighbourhood Building Age Comparison  
By Author

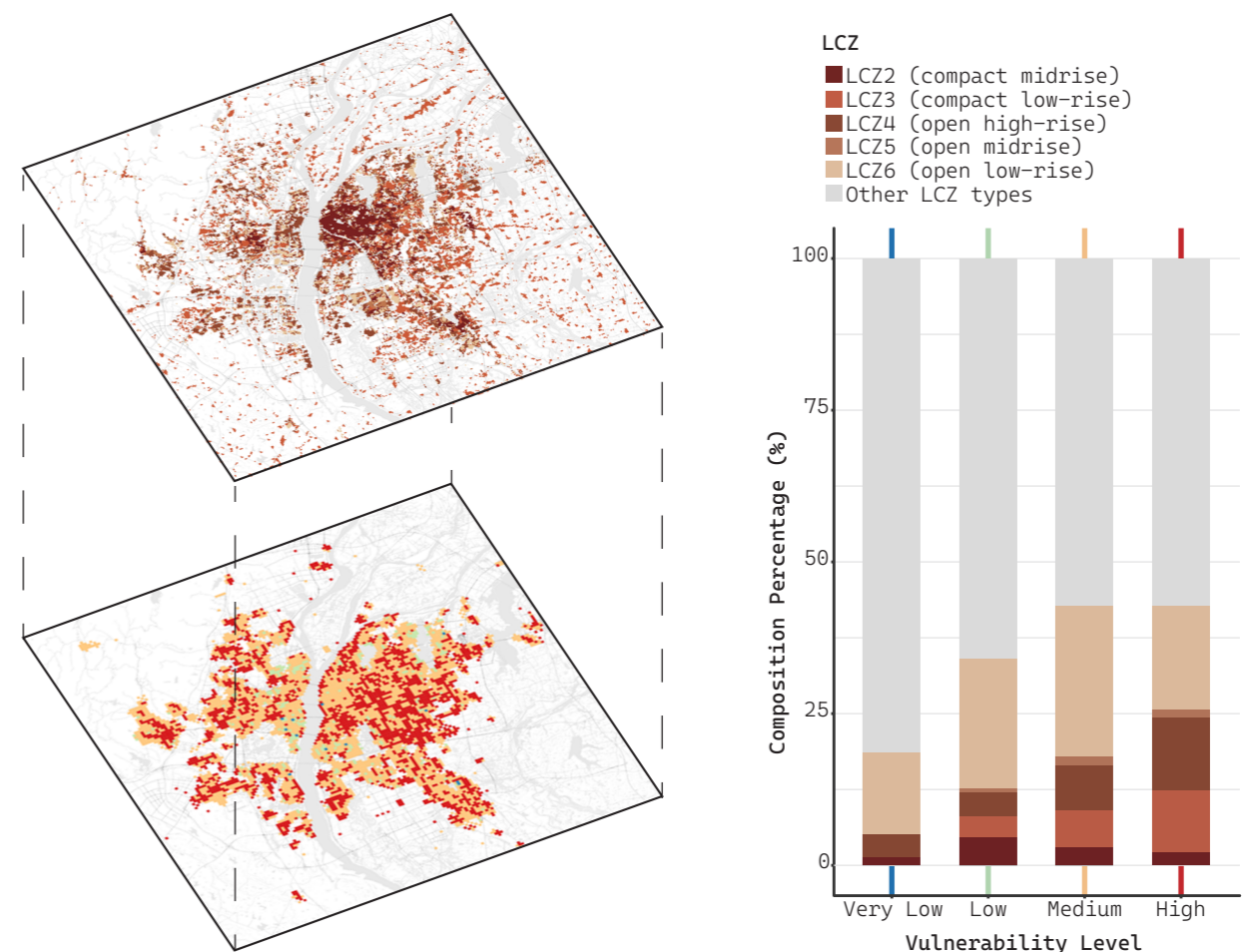
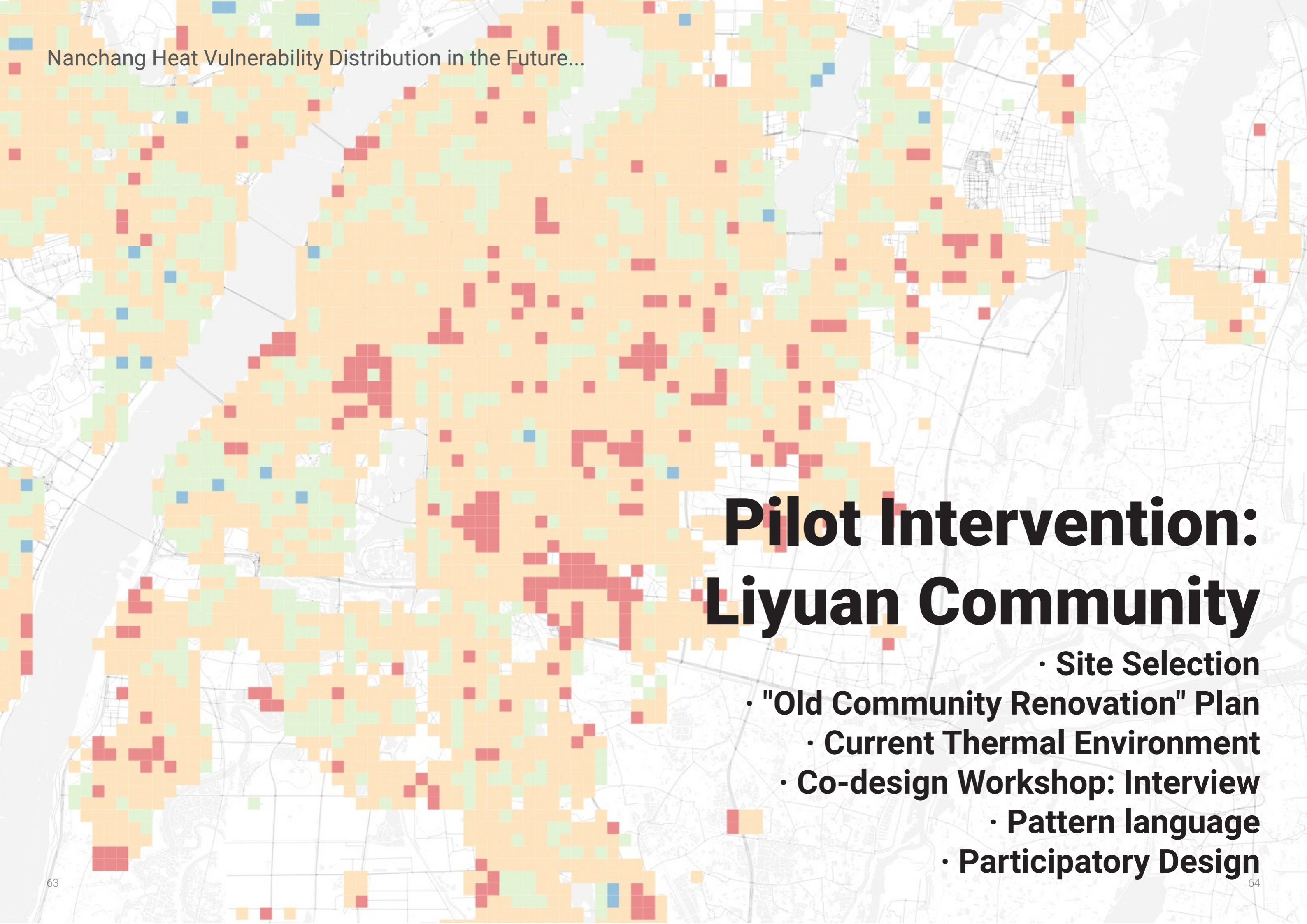


Figure 44. Vulnerability Distribution and LCZ(2-6) Comparison  
By Author



# Pilot Intervention: Liyuan Community

- Site Selection
- "Old Community Renovation" Plan
- Current Thermal Environment
- Co-design Workshop: Interview
  - Pattern language
- Participatory Design

# Site Selection

The spatial analysis reveals no significant relationship between urban morphology typology and composite vulnerability scores, this finding reinforces the need for context-sensitive adaptation strategies rather than morphology-driven generalised interventions.

To demonstrate the applicability of such site-specific approaches, this chapter presents a pilot co-design process developed to explore site-specific heat adaptation strategies for a high-vulnerability neighbourhood in Nanchang. The pilot serves as a proof-of-concept for translating spatial vulnerability findings into participatory planning practice.

The pilot site is selected according to two criteria: vulnerability representativeness and research feasibility. In terms of vulnerability, priority is given to communities that are identified as high vulnerable area according to analysis result from last chapter. In terms of feasibility, the selected site is a neighbourhood where the author previously lived, which facilitates participant recruitment and eases the process of building site familiarity given the constraints of remote fieldwork. In this case, Liyuan Community, located in Qingyunpu District, satisfies both criteria.

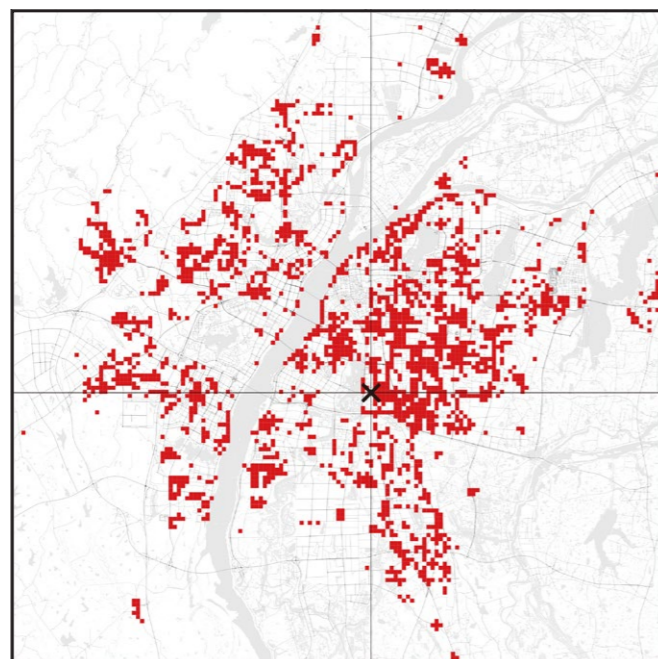


Figure 45. Site Selection within High Vulnerability area  
By Author



a

Commercial	Education	Sport	Business	Multi-function
Recreation	Hospital	Park	Apartment	Outdoor sports field



b

Figure 46. Public Facilities and Community Life in Liyuan Community.  
(a) Public Facilities Distribution, (b) Collage of Community Life  
By Author

Built in the 1990s to house employees of Jiangling Motor Company, Liyuan Community was originally planned with generous public amenities tailored to its employees (Fig. 46a). These include a kindergarten and primary school for employees' children, a swimming pool and medium-sized park for recreation, and an outdoor sports field for exercise. The initial planning also prioritised ecological quality, with substantial vegetation planted throughout the residential blocks. Over time, the neighbourhood transitioned to commercial

housing and was further supplemented with a public reading room and an elderly community centre as part of broader citywide planning improvements. **Together, these facilities and green infrastructure give Liyuan relatively strong baseline conditions in terms of adaptive capacity for heat adaptation.** However, as the original employee residents reach retirement age, **the community is experiencing a pronounced ageing trend in recent years, which contributes to elevated heat sensitivity among its current population.**

# "Old Community Renovation" Plan

Since 2016, Nanchang has been implementing a city-wide renovation programme targeting old residential communities. Supporting policy documents include a renovation item catalogue (Nanchang Municipal People's Government Office [NMPGO], 2022) and technical guidance covering implementation and assessment (Jiangxi Provincial Department of Housing and Urban-Rural Development [JHDURD], 2020). However, heat adaptation is largely absent from both.

NMPGO (2022) contains only two minor items relevant to adaptive capacity, while JHDURD (2020) limits its assessment scope to building energy efficiency retrofits, with no provisions for outdoor thermal environment improvement (Fig. 47). Heat adaptation thus remains unaddressed across the renovation process as a whole even Nanchang has been suffering from severe urban heat problem for quite a long time.

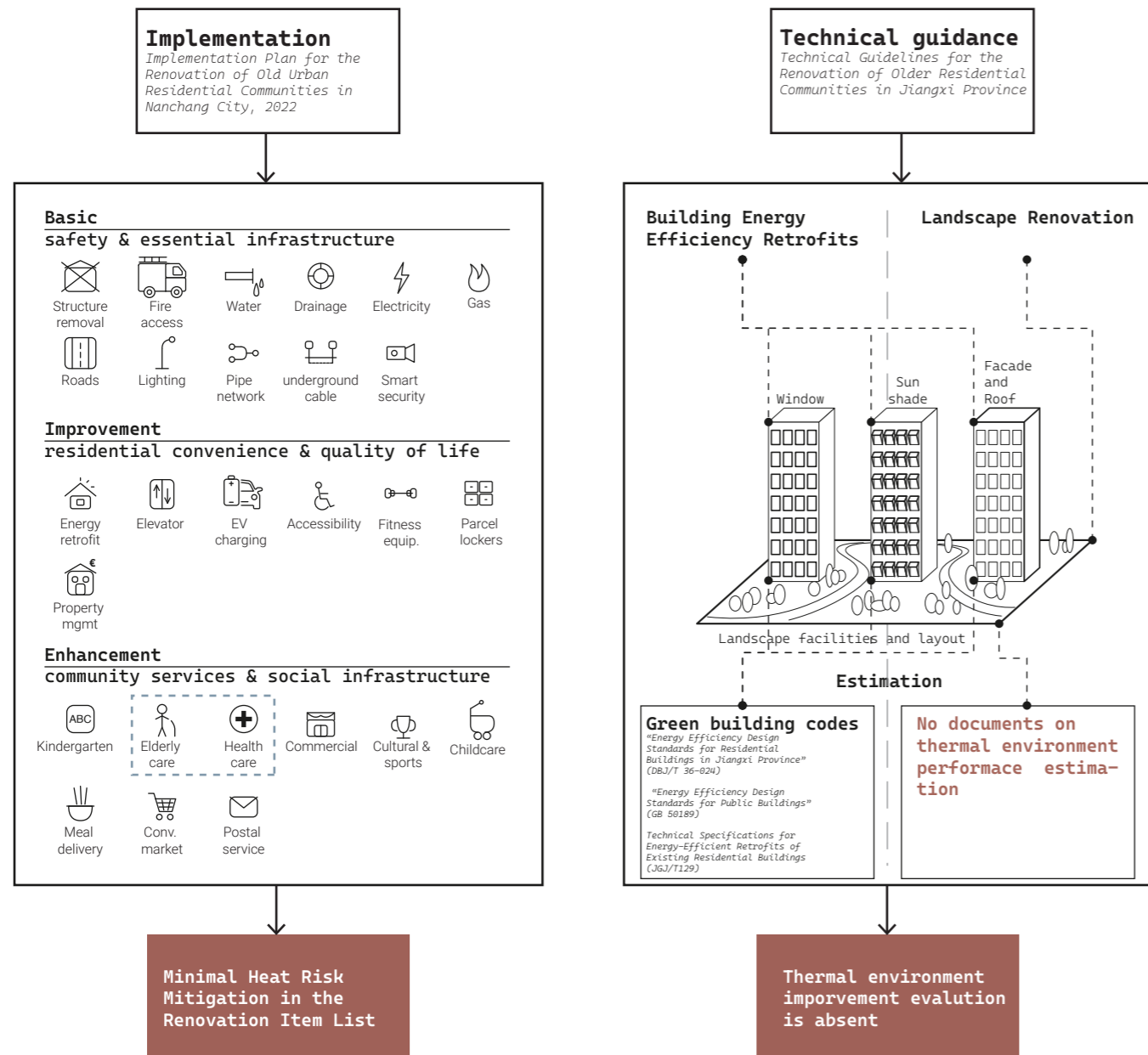


Figure 47. Renovation Plan Audit: A Heat Adaptation Perspective

By Author

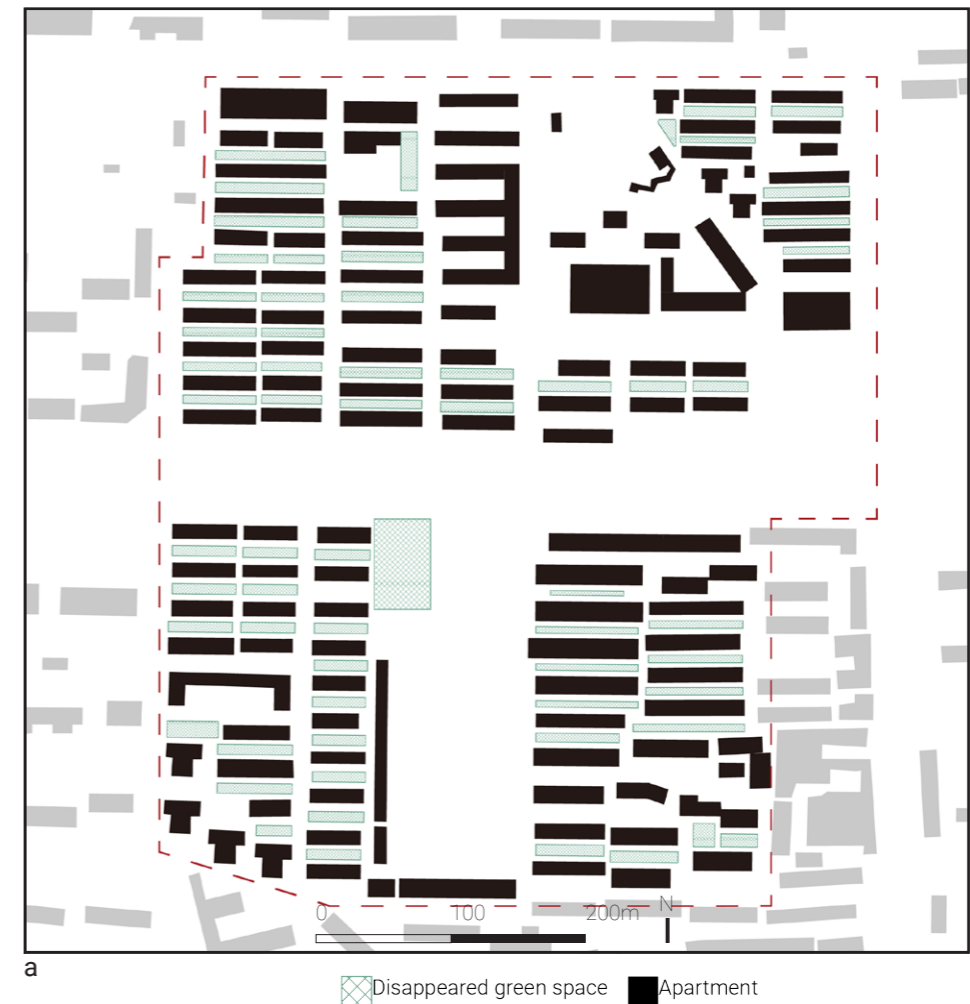


Figure 48. Renovation in Liyuan Community. (a) Map of disappeared green spaces, (b) Street view1 in 2019, (c) Street view1 in 2026, (d) Street view2 in 2019, (e) Street view2 in 2026  
(a), (c), (e) By Author, (b), (d) are images from Baidu Map Street View

Liyuan Community underwent renovation between 2020 and 2022 under the city-wide programme. Works carried out – including underground pipe relocation, facade maintenance, surface material upgrades, elevator installation, and parking expansion – broadly align with the items listed in NMPGO (2022). However, the renovation came at an ecological cost: in a spatially constrained neighbourhood, much of the original green space was replaced to accommodate these interventions. Planted areas between residential buildings were converted into

parking lots and asphalt-paved playgrounds, a pattern that repeated across virtually the entire community (Fig. 48). This reflects not only the physical challenges of retrofitting dense urban fabric, but also a broader absence of ecological awareness among all stakeholders involved. As one resident with a background in urban planning noted, most community members tend to underestimate the value of vegetation relative to other perceived needs without professional training in design or engineering.

# Current Thermal Environment

To assess the current thermal environment of Liyuan Community, an ENVI-met simulation was conducted using 15 July 2025 as the simulation date, representing a typical high-temperature summer day in Nanchang.

The results indicate severe heat stress throughout the community during summer (Fig. 49 and 50). PET rises continuously from 8am to 6pm. At 8am, the lowest recorded PET is 33°C, with only a few areas classified as warm – representing the only period during the day when outdoor thermal conditions remain marginally tolerable. **By 10am, however, all outdoor areas have already transitioned to hot or extreme hot, leaving residents with an extremely narrow window for comfortable outdoor activity confined to the early morning hours.** Conditions peak at 4pm, when PET exceeds 40°C across the entire site, corresponding

to "very hot" thermal sensation and "extreme" heat stress for all outdoor areas.

Examining the 4pm PET distribution map, cooler spots are concentrated beneath tree canopy and in building shadow, while the outdoor sports field and inter-building spaces register as the hottest areas, likely due to direct solar exposure. Wind speed contributes to local variation, though its moderating effect remains limited given the overall severity of conditions. **The comparatively lower PET values beneath existing vegetation and building shade demonstrate a clear cooling effect, suggesting that these elements hold potential as a basis for targeted intervention – their cooling performance could be further enhanced through complementary measures such as additional planting or shading structures.**

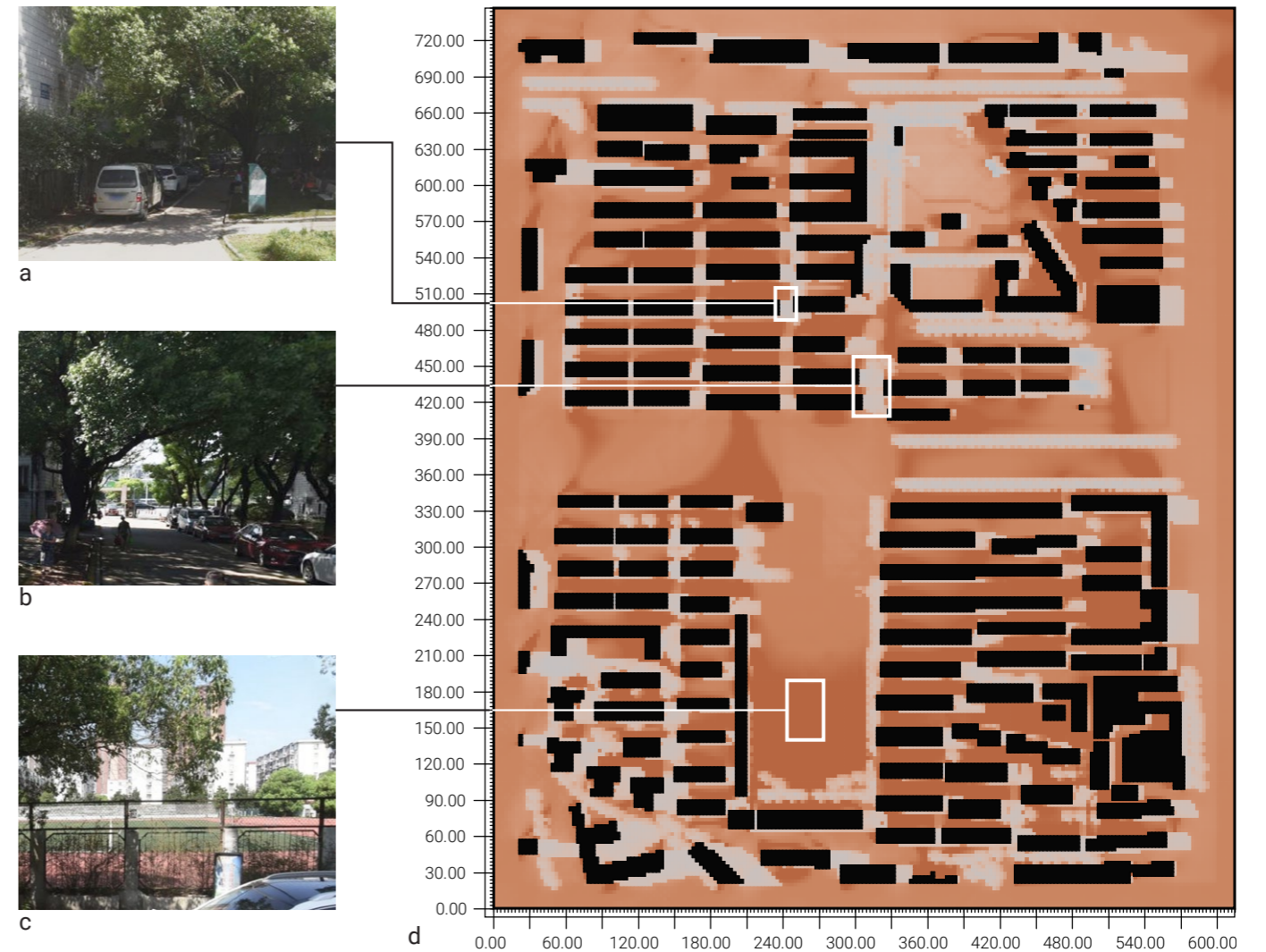


Figure 49. Hot and Cool Spots Identification According to Simulation Result. (a), (b), (c) Street views of Liyuan Community, (d) ENVI-met simulation result at 16:00, July 15, 2025  
(a), (c), (e) Images from Baidu Map Street View, (d) By Author

Thermal Sensation	PET (°C)	Physically stress level
Very cold	4	Extreme
Cold	8	Strong
Cool	13	Moderate
Slightly cool	18	Slight
Neutral	23	NO STRESS
Slightly warm	29	Slight
Warm	35	Moderate
Hot	41	Strong
Very hot		Extreme

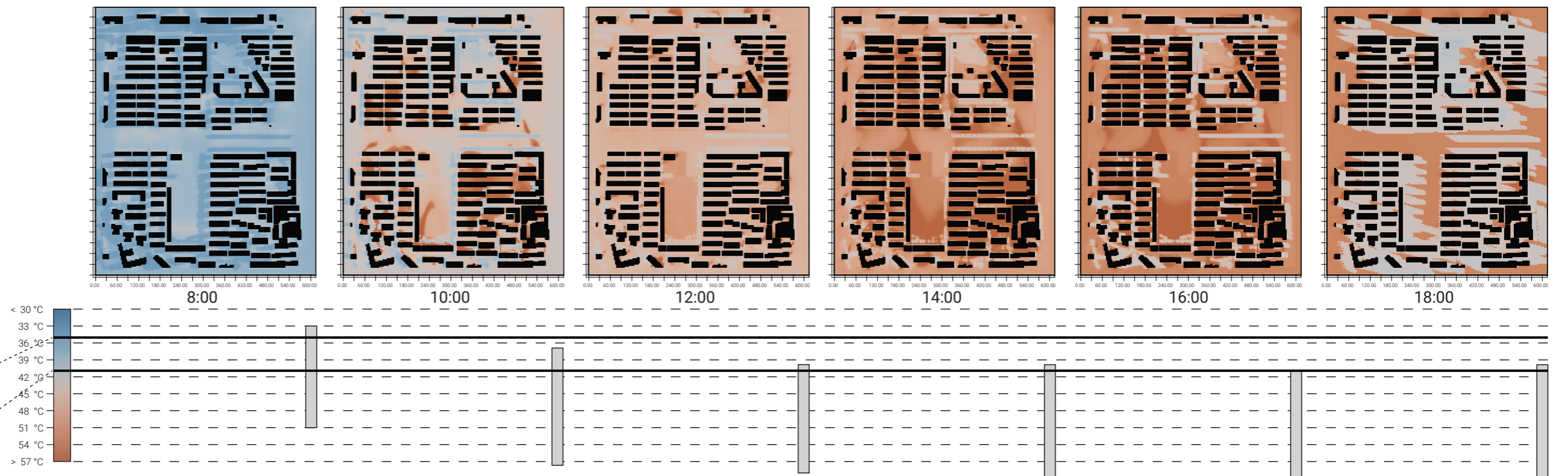


Figure 50. PET Range from 08:00 to 18:00 on 15 July 2025, with Thermal Comfort Threshold References

# Co-design Workshop

Co-design workshop was adopted as the primary methodology for site-specific heat adaptation design in this project for two reasons. First, the vulnerability mapping results demonstrate that heat vulnerability is not concentrated in any single LCZ type – almost all community typologies require intervention. **Designing through resident participation therefore offers an efficient and replicable approach, as the process can be adapted and applied across different neighbourhood contexts.** Second, effective heat adaptation design must respond not only to residents' thermal perceptions and behavioural patterns, but also to the social and political dimensions of their lived experience. **Co-design workshops provide a structured means of surfacing residents' expectations, anxieties towards management, and local knowledge, ensuring that design outcomes are grounded in real conditions rather than purely technical assumptions,** and ultimately more feasible to implement within the local governance and funding context.

The workshop is structured in two parts (Fig. 51). The first part takes the form of a semi-structured interview, through which residents' behavioural patterns and lived experiences during summer are explored. It also shows their understanding of thermal comfort, as well as the needs and obstacles they encounter in adapting to heat. To support this, a base map of the community is prepared alongside a set of guiding questions, enabling systematic data collection. The findings from this part inform adjustments to the design orientation and the tools prepared for the second part.

Before the second part, a pattern language brochure is developed as a design reference tool, adapting the concept of pattern language to the specific context of heat adaptation and refined in light of insights gathered during the first part. Residents receive the brochure in advance and are asked to score the feasibility of each pattern, considering the level of political and financial support it may require as well as their own willingness to adopt it.

In the second part, participants are first introduced to key thermal comfort factors and their relationship with spatial characteristics – the dimensions the pattern language is designed to address. They are then divided into groups of two to three, each tasked with producing a community design proposal using the pattern language. The session concludes with each group presenting their proposal in a short presentation.

The resulting proposals are collected and analysed by the author. Drawing on specialist knowledge, promising ideas from residents are extracted and reorganised into a structured intervention plan, which is subsequently tested through ENVI-met simulation to evaluate the thermal performance of different patterns under Liyuan's specific conditions. Each pattern is then scored for effectiveness based on both simulation results and supporting literature. The process culminates in a feasibility-effectiveness matrix, intended to serve as a practical reference for future heat adaptation management recommendations.

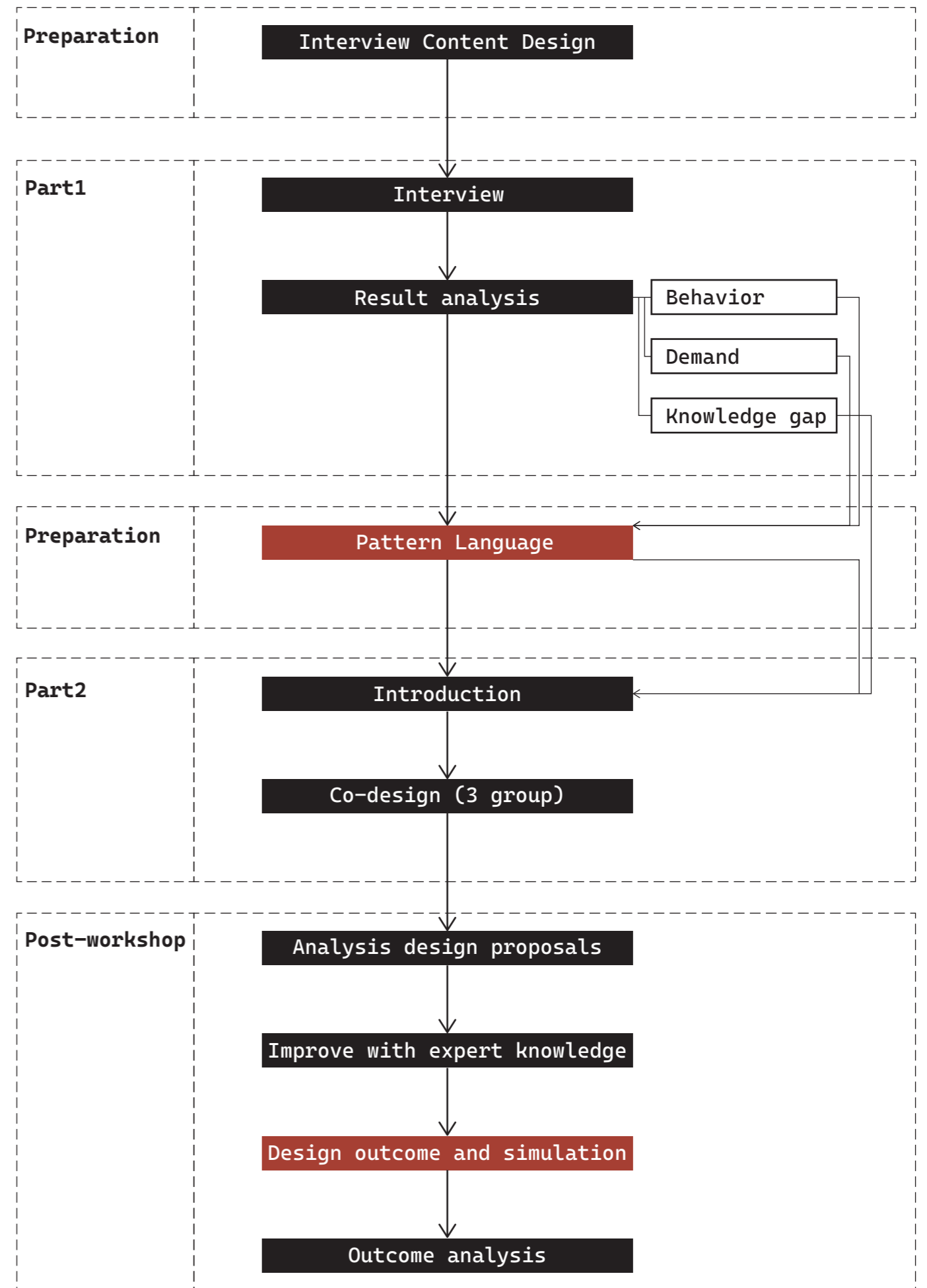


Figure 51. Co-design Workshop Process  
By Author

# Interview

## -Behavior Pattern and Thermal Experience

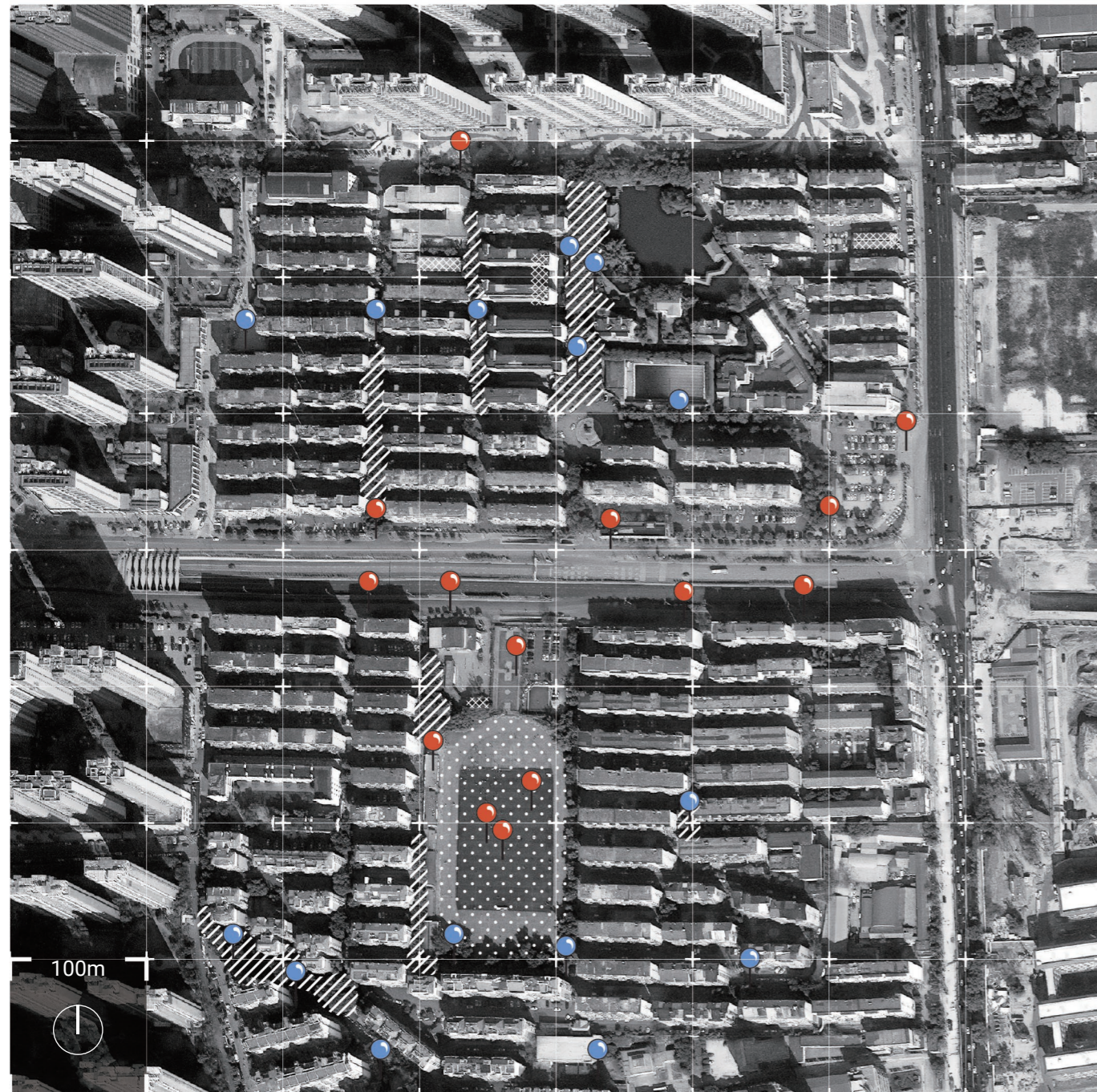


Figure 52. Residents' Self-Identified Activity Spaces and Thermal Hot/Cool Spots in Liyuan Community  
*Drawn by author based on resident interviews*

-  Cool spot identified by residents
-  Hot spot identified by residents
-  Outdoor sports field
-  Spaces under tree canopy
-  Indoor public space with air-conditioning
-  Other outdoor space in the community
-  Wetland park outside the community

Residents' behavioural patterns and thermal experiences were gathered through interviews. Most avoid outdoor spaces from around 9am until sunset, limiting activity to the sports field and a park outside the community. **During hot periods, two types of spaces remain in use: shaded areas beneath tree canopy, favoured particularly by the elderly, and air-conditioned indoor facilities** such as the community centre and reading room. **Residents generally prefer outdoor cool spaces over indoor alternatives for health reasons**, yet they express considerable dissatisfaction with the current thermal environment, as cool spots within the neighbourhood are scarce and difficult to identify. This tension between residents' inclination towards outdoor activity and the unsatisfactory thermal environment further underscores the need for targeted cooling interventions.

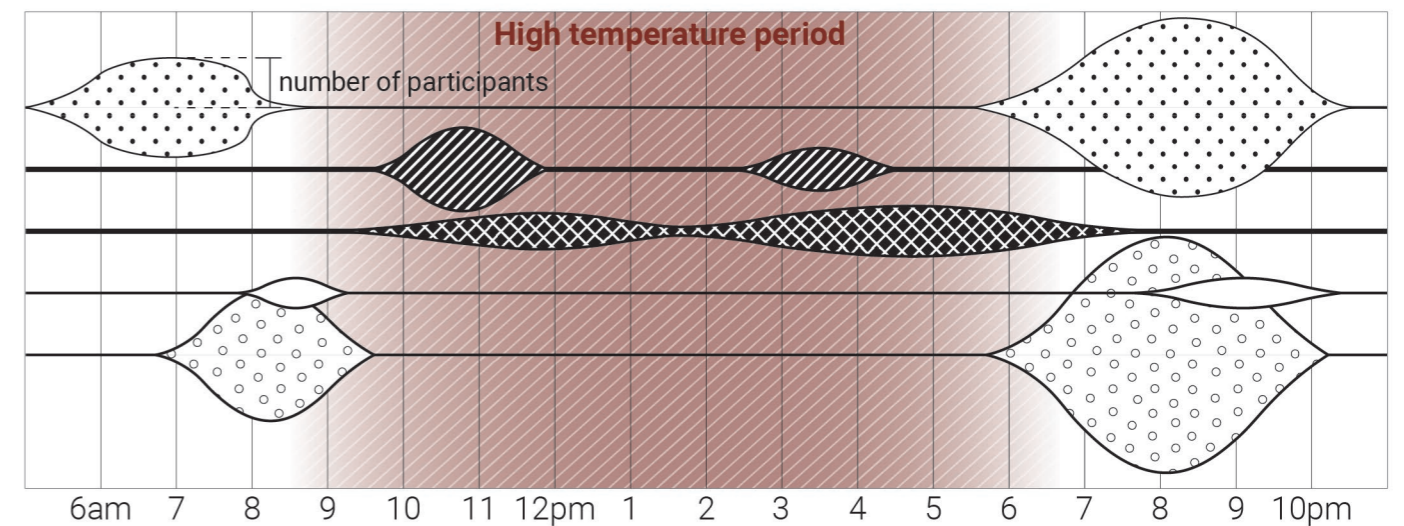
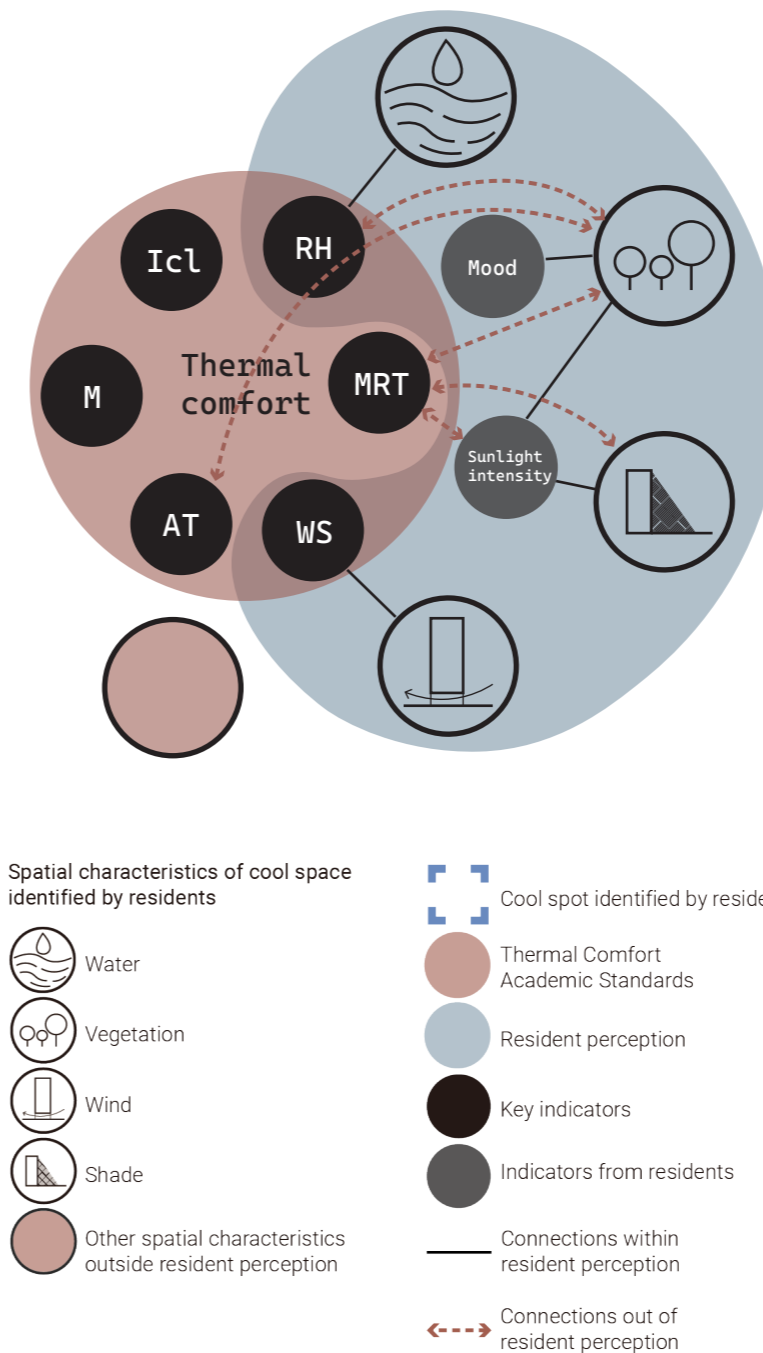


Figure 53. Resident Activity Patterns: Location, Time, and Frequency  
*Drawn by author based on resident interviews*

# Thermal Comfort Perception



Figure 54. Residents' Thermal Comfort Perception Based on Liyuan Community  
*Drawn by author based on resident interviews*



- Water
- Vegetation
- Wind
- Shade
- Other spatial characteristics outside resident perception
- Cool spot identified by residents
- Thermal Comfort Academic Standards
- Resident perception
- Key indicators
- Indicators from residents
- Connections within resident perception
- Connections out of resident perception

Figure 55. Comparison of Residents' Thermal Comfort Perception and Academic Standards  
*Drawn by author based on resident interviews*

The interviews also reveal residents' thermal comfort perception. Although not fully aligned with academic definitions, residents demonstrate an intuitive understanding of key influencing factors – including humidity, wind speed, and sunlight intensity, the latter closely corresponding to mean radiant temperature. They can also identify the spatial characteristics of cool spots they frequent, such as vegetation, building shade, and water. Notably, participants highlighted the role of mood in thermal comfort, recommending more communal activities during summer evenings – **pointing to the importance of social space design alongside physical interventions.**

**However, residents were unable to establish a clear connection between the renovation and changes in the thermal environment, attributing temperature differences to broader climatic variation rather than neighbourhood-scale spatial changes.**

Regarding heat mitigation priorities, residents show a strong preference for vegetation, they also suggest potential in integrating planting with activity spaces and parking lots, noting that the two are currently treated as separate elements in the neighbourhood. More heat shelter is also a way of improvement.

# Stakeholders in Renovation

**Residents' feedback also reveals recognitional inequity throughout the renovation process.** While participants generally hold a positive attitude towards the renovation, they consistently reported their absence from the entire process – not only during initiation and design, but also in decision-making and negotiation. While participatory design practices exist in scattered forms, they remain far from systematic or institutionalised in this context.

When asked about spontaneous self-initiated improvements, residents expressed passive acceptance rather than active agency, as most informal modifications are considered illegal construction. Some expressed hope for policy support that would legitimise resident-led planting or construction, allowing good ideas from the community to be realised. Others, however, raised concerns about management quality under such conditions, suggesting that stronger

oversight mechanisms and detailed design guidelines would be necessary to ensure the quality of resident-oriented interventions.

Finally, participants emphasised the importance of cost control. Cost-effective solutions were considered more feasible for self-implementation, though residents still believe that the primary responsibility for heat adaptation renovation should rest with the government and residents' committee.

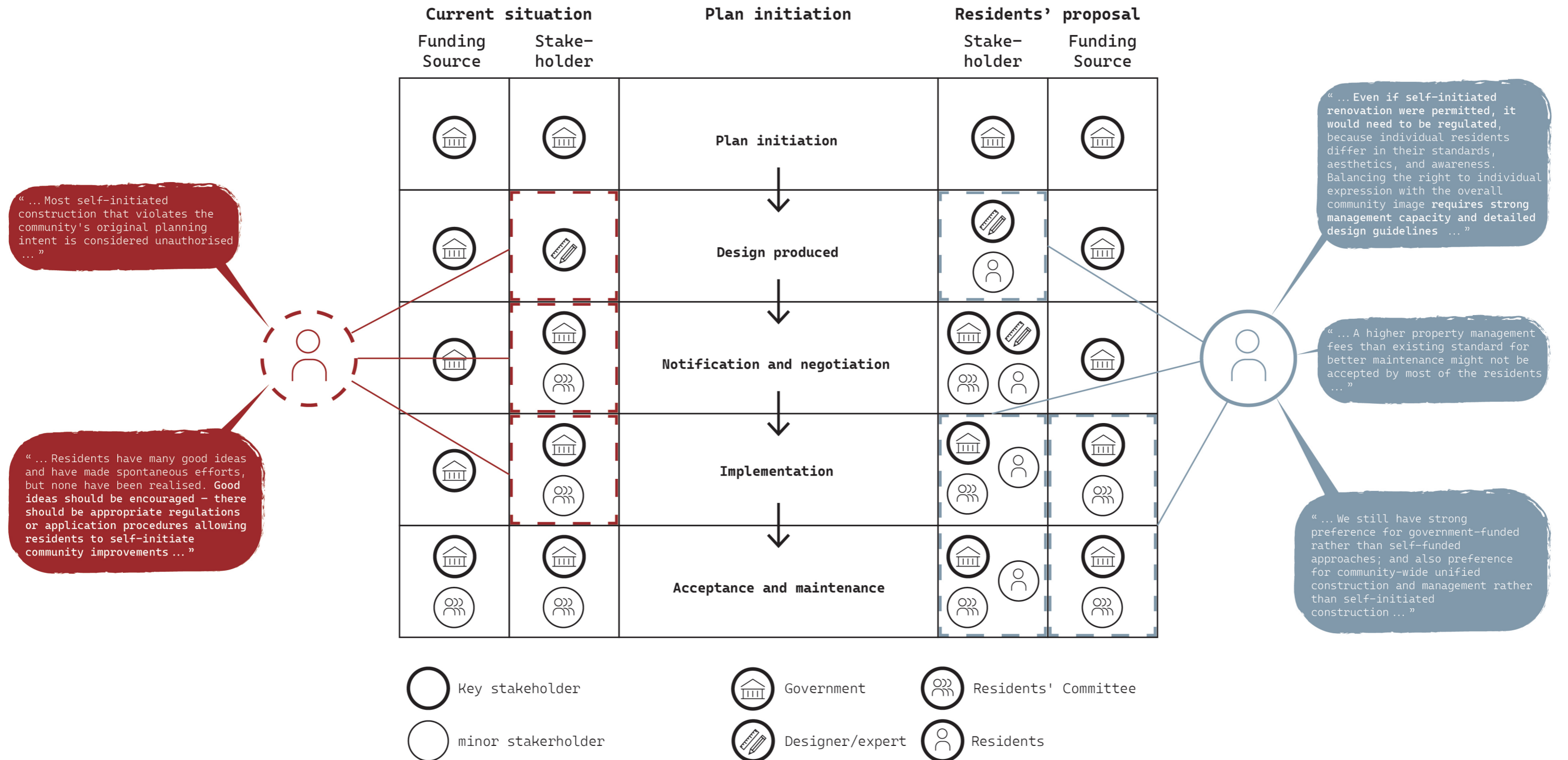


Figure 56. Stakeholder Analysis and Resident Feedback in the Renovation Process

*Drawn by author based on resident interviews and governance audit*

# Pattern Language

## -Design

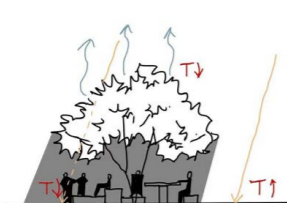
Pattern language, originally developed by Alexander et al. (1977) as a design framework capturing recurring solutions to spatial problems, is here adapted as a structured reference tool for community-scale heat adaptation. Based on the literature review and residents' demands and concerns gathered in the first part of the workshop, a series of patterns is developed for use in the co-design session and as a broader reference for future heat adaptation intervention in Nanchang.

Each pattern consists of five components (Fig. 57). The mechanism drawing presents the concept and its approach to heat mitigation visually, supplemented by a written explanation. Governance support identifies the stakeholders involved and potential funding sources. Limitations and spatial conflicts outline implementation obstacles. Finally, each pattern carries two scores: an effectiveness score (E) assessed by experts based on heat mitigation evidence from the literature, and a feasibility score (F) assigned by workshop participants based on their assessment of responsible stakeholders, funding requirements, and personal acceptance. Both scores are subject

to refinement – E may be updated following post-intervention simulation, and F may be adjusted based on expert experience. **All these patterns will form a recommendation matrix for government and committee** (Fig. 58).

In the matrix, patterns are classified into two priority zones. **Zone 1 covers patterns recommended for prioritised action either through direct government investment or resident self-implementation with guidance these patterns are either with strong resident demand or relatively low implementation costs. Zone 2 represents for secondary action, it covers patterns that are costlier and more complex, requiring government leadership and dedicated funding, but for which residents have expressed clear demand.** Remaining patterns are considered supplementary measures to be adopted when conditions permit. Together with the heat risk and LCZ correlation diagram (Fig. 59), these patterns are intended to serve as a practical recommendation for government and community committees in guiding future heat adaptation interventions across the city.

**S2 Combination of canopy with recreation**



**Explanation:**  
Trees significantly reduce surface temperature, air temperature and PET beneath their canopy. However, existing trees are often treated as purely aesthetic elements without associated seating or activity spaces. Combining rest areas and recreational facilities with existing tree canopy maximises the use of these natural cooling resources, providing accessible cool refuge for residents during hot summer periods.

**Source:** (Probst et al., 2022), resident demand

**Governance support:**  
**Implementation party:** government-led, community-led  
**Policy support:** revise NODRP and UHAP  
**Funding:** Government-funded, community-funded  
**Maintenance party:** Government, community management

**Limitation:**

**Spatial conflict:**  
Space beneath existing canopy may not be suitable for recreation implementation

**Effectiveness rating (by designer):**  
**Feasibility rating (by resident):**

Figure 57. Example of Pattern Language (For all other patterns, see appendix P.121)

By Author

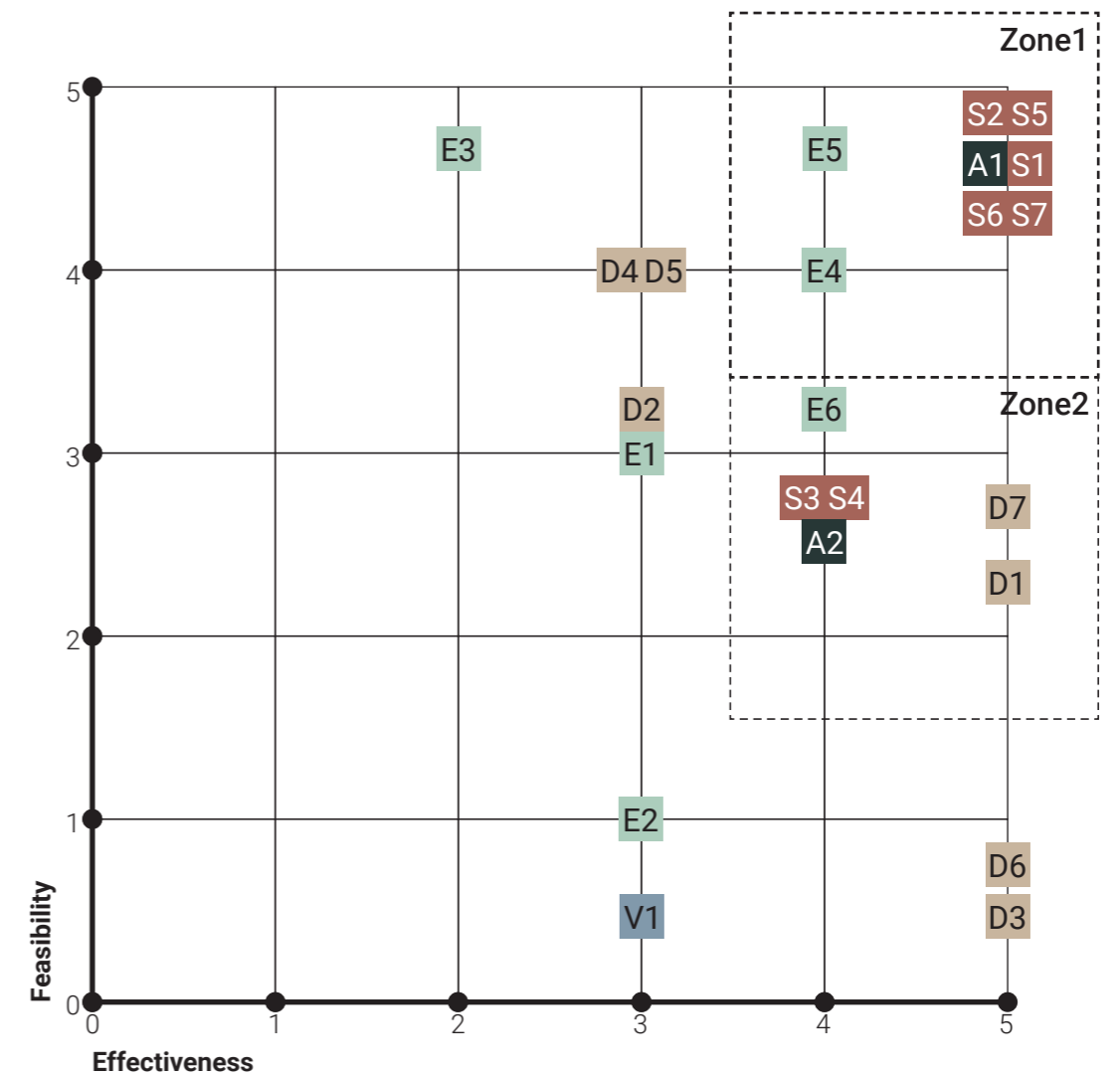


Figure 58. Heat Adaptation Pattern Recommendation Matrix: Effectiveness and Feasibility

By Author

- |   |   |
|---|---|
| <b>S1</b> More canopy between buildings                   | <b>E6</b> Fountain in neighbourhood                   |
| <b>S2</b> Combination of canopy with recreation           | <b>D1</b> Converting Ground-floor Function to Pilotis |
| <b>S3</b> More structural shade between buildings         | <b>D2</b> Optimising Wind Corridors through addition  |
| <b>S4</b> Combination of structural shade with recreation | <b>D3</b> Large community garden                      |
| <b>S5</b> Combination of building shade with recreation   | <b>D4</b> Add pocket park into community              |
| <b>S6</b> More trees than shrubs                          | <b>D5</b> Reflective surface                          |
| <b>S7</b> Parking lot and vegetation combination          | <b>D6</b> Underground parking lot                     |
| <b>E1</b> Green facade                                    | <b>D7</b> Parking garages                             |
| <b>E2</b> Green roof                                      | <b>A1</b> Air-Conditioned Community Cooling Space     |
| <b>E3</b> Permeable pavement                              | <b>A2</b> More Medical Care Spot                      |
| <b>E4</b> Innovative permeable pavement                   | <b>V1</b> Plant trees in downwind area                |
| <b>E5</b> Vegetated balcony                               |   |

# Basis: Heat Risk and LCZ

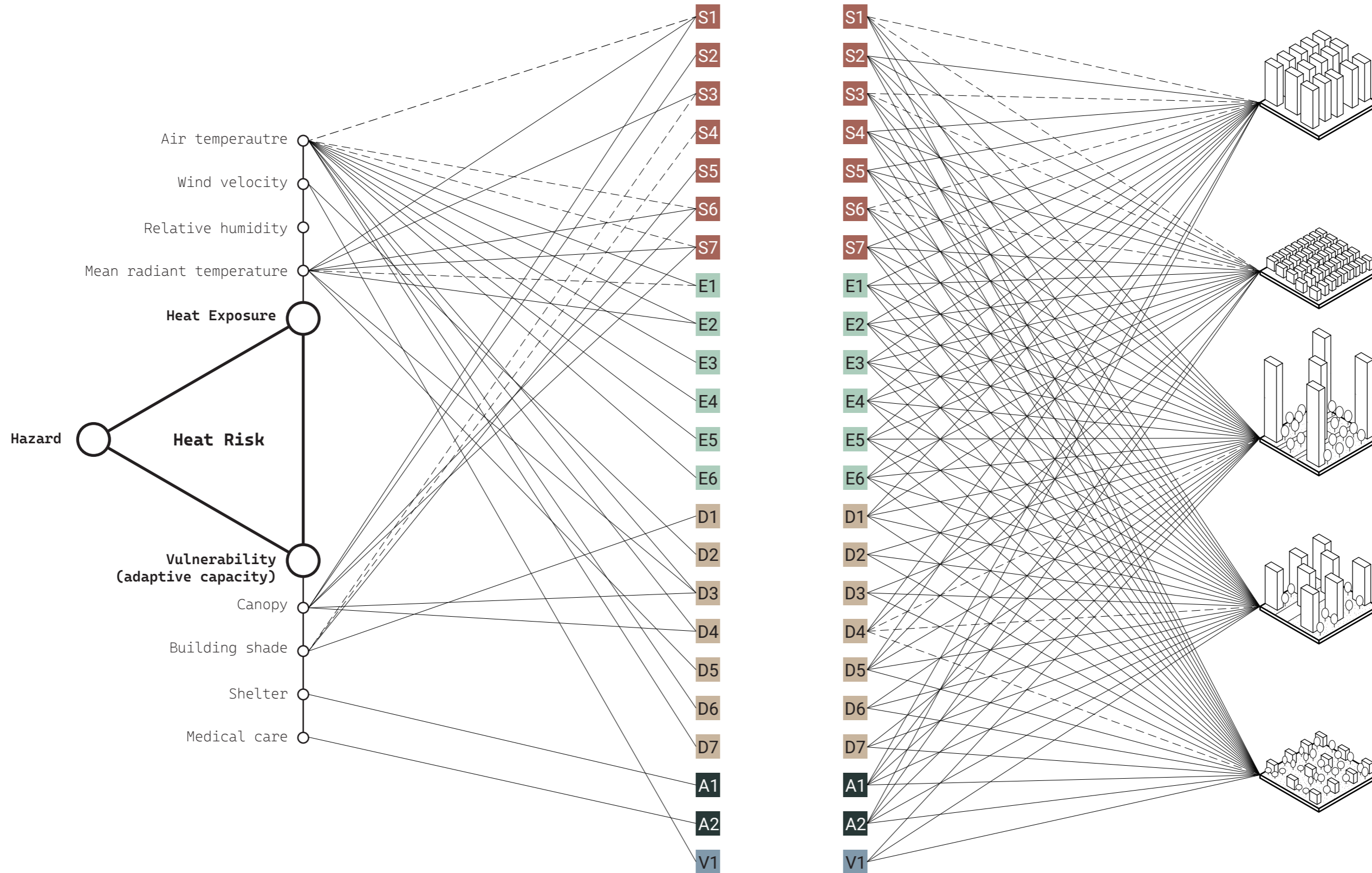
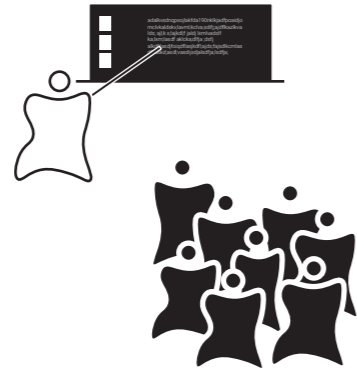


Figure 59. Pattern Language in Relation to Heat Risk Indicators and LCZ Types

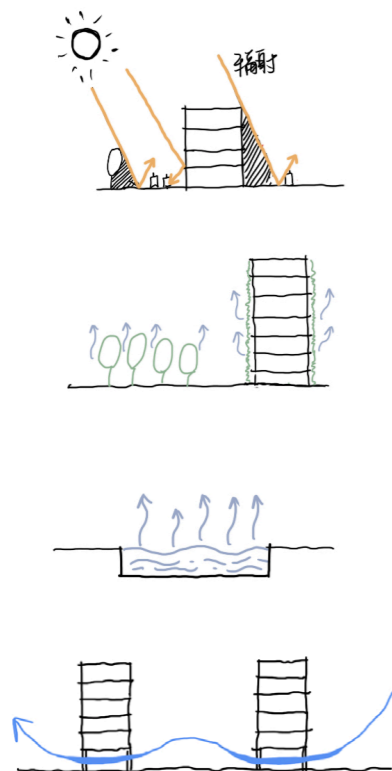
By Author

# Participatory Design -Process Introduction



## STEP1: Concept definition

Using simple diagrams and accessible language, this step introduces the key mechanisms behind human thermal comfort, drawing on the recognition framework and findings from Part 1.

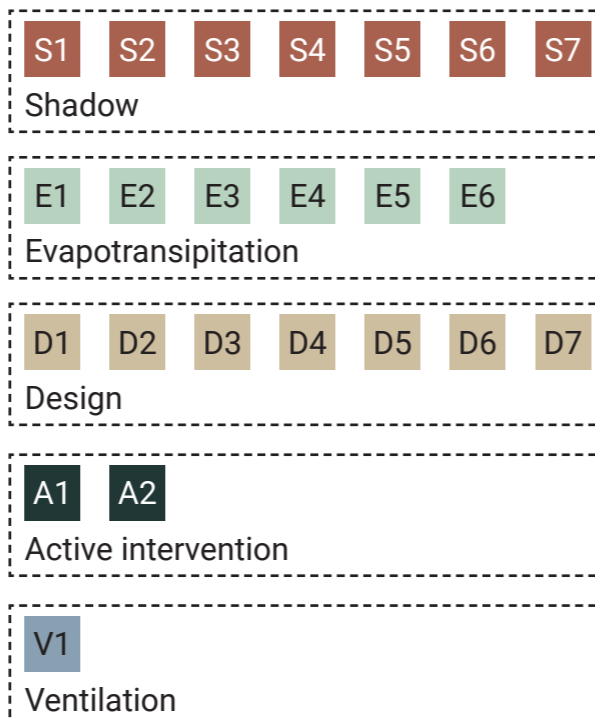


### INTENTION

The intention is to close residents' knowledge gap on heat adaptation, reducing barriers to using the pattern language tool and engaging with heat-related issues more broadly.

## STEP2: Pattern language introduction

Patterns are introduced by category according to their target spatial quality, and each category is explicitly linked to the thermal comfort mechanisms covered in Step 1.

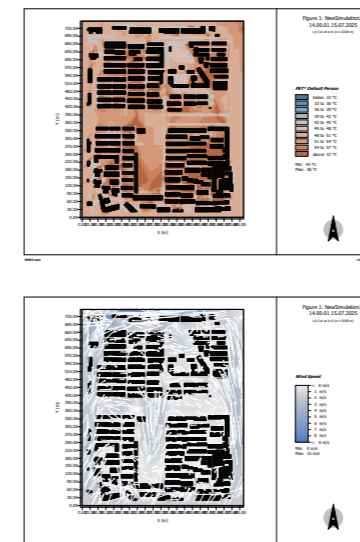


### INTENTION

This structure allows residents without professional design knowledge to more readily understand and apply the patterns.

## STEP3: Design guidance

Participants are provided with the hot and cool spot map from Part 1, the PET simulation map, and a wind direction map as spatial references.

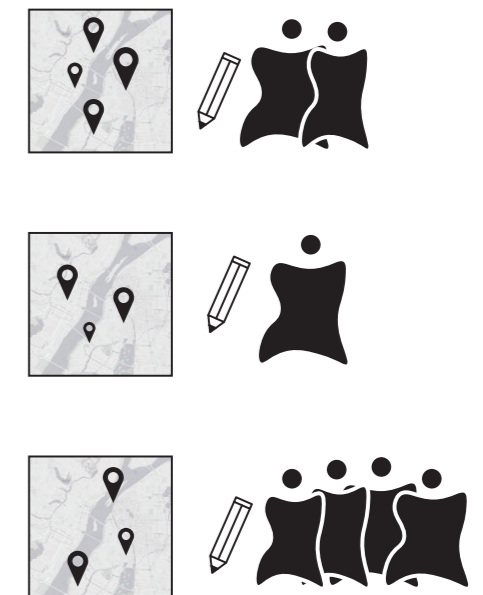


### INTENTION

These materials offer concrete entry points for residents with no design experience, allowing them to begin by focusing on the areas most affected by heat.

## STEP4: Co-design

Participants are divided into three groups. Drawing on the background information from the previous steps and their own spatial preferences, each group applies patterns to a community map to produce a simple planning proposal, concluding with a short group presentation.



### INTENTION

Dividing participants into groups encourages discussion and exchange of ideas while generating a range of diverse proposals for analysis.

Figure 60. Co-design Process Demonstration  
By Author

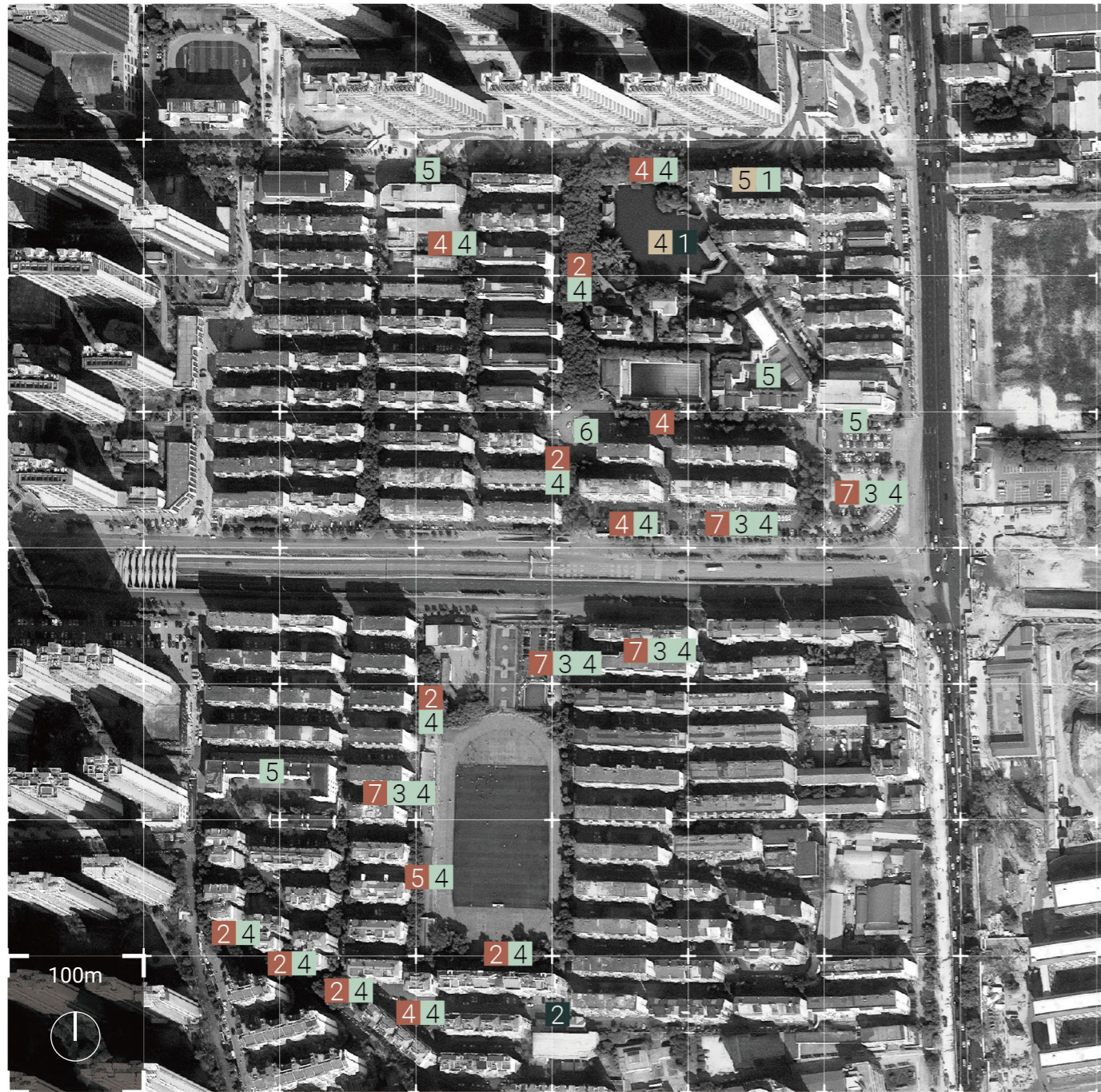


Figure 61. Resident Design Proposal from Group 1

*Redrawn by author based on resident proposal*

- 2** More medical care spot
- 5** Vegetated balcony
- 6** Fountain in neighbourhood
- 4 1** Add pocket park into community  
+Air-conditioned community cooling space
- 2 4** Combination of canopy with recreation  
+innovative permeable pavement
- 4 4** Combination of structure shade with recreation  
+innovative permeable pavement
- 5 4** Combination of building shade with recreation  
+innovative permeable pavement
- 7 3 4** Parking lot and vegetation combination  
+permeable pavement/innovative permeable pavement

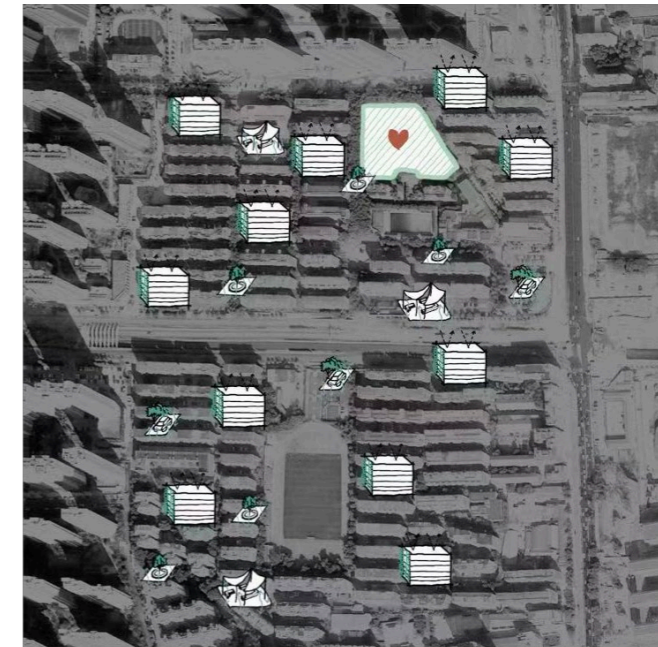


Figure 62. Main Idea of Proposal 1

*Drawn by author based on resident proposal*

### Group1 Proposal

This proposal follows a dispersed renovation logic, focusing on upgrading existing cooling resources across the neighbourhood rather than introducing new structures. Given that PET values across the site exceed 40°C after 12:00, these improvements have the potential to further reduce temperatures at locations that already serve as relative cooling spots.

The residents' proposal to redesign the water park is driven by its outdated condition and lack of activity space. A renewed park could become a more attractive communal space, it may also offering better thermal comfort during summer months.



Figure 63. Resident Design Proposal from Group 2  
 Redrawn by author based on resident proposal

- 1 More canopy between buildings
- 3 Permeable pavement
- 4 Add pocket park into community
- 7 Parking garages

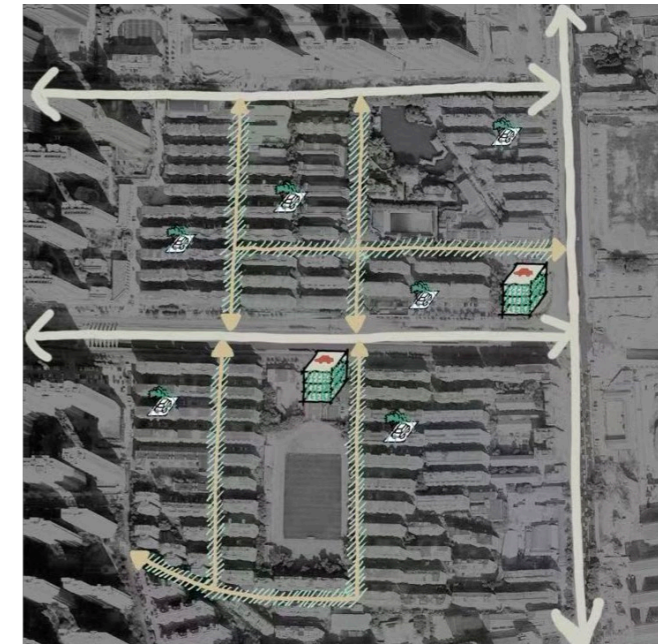


Figure 64. Main Idea of Proposal 2  
 Drawn by author based on resident proposal

### Group2 Proposal

Group 2's proposal focuses on two interconnected interventions that together form a more structured spatial plan. The first is to plant additional trees along the main roads within the community, creating more shade and improving thermal comfort along residents' daily movement routes, particularly for those who commute on foot.

The second intervention addresses parking. Existing parking lots are proposed to be replaced with permeable surfaces, while vertical parking structures would be introduced at available open spaces to compensate for lost capacity. Vehicle circulation routes are also taken into consideration to ensure the overall parking arrangement remains practical for residents.

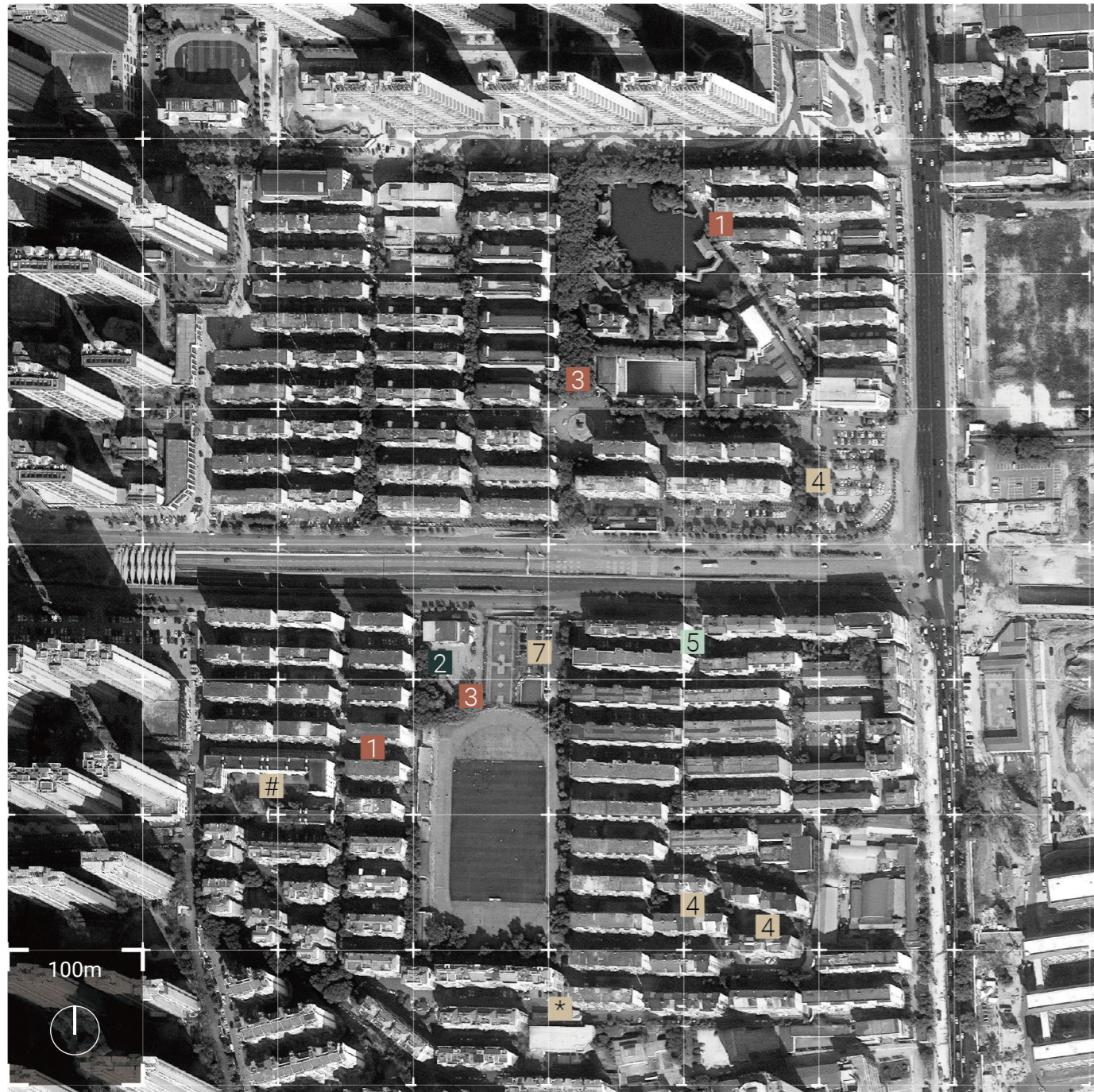


Figure 65. Resident Design Proposal from Group 3  
 Redrawn by author based on resident proposal

- 1 More canopy between buildings
- 3 More structure shade between buildings
- 5 Vegetated balcony
- 4 Add pocket park into community
- 7 Parking garages
- \* Add a community dining hall
- # Change abandoned building into community center

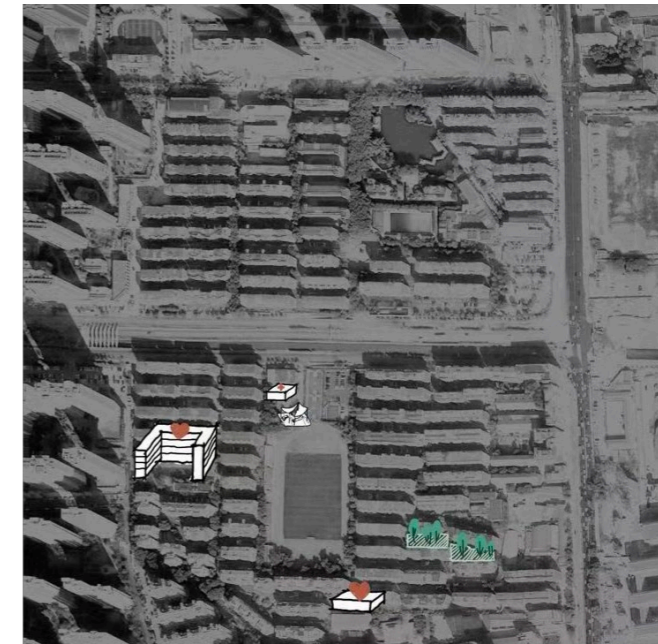


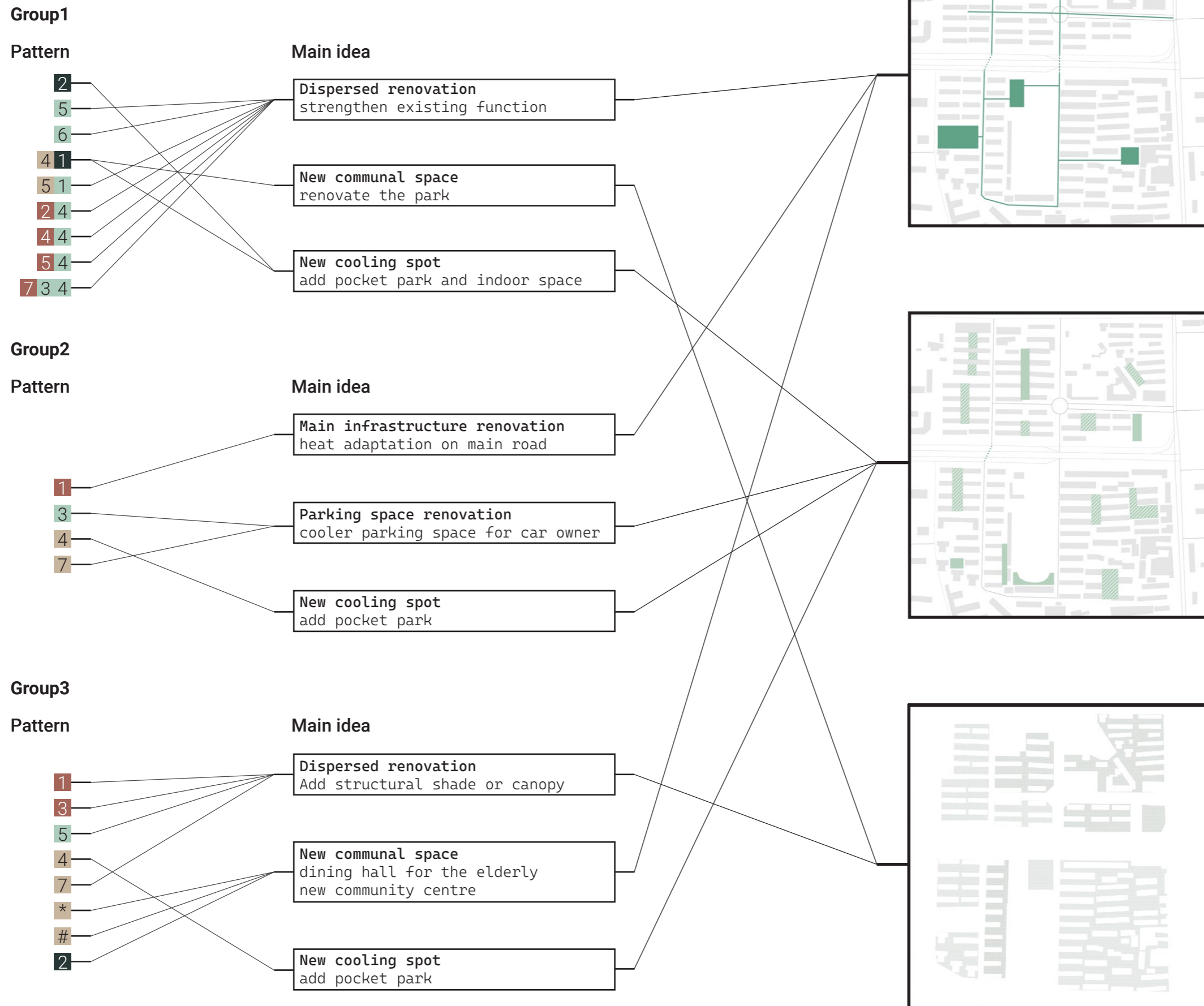
Figure 66. Main Idea of Proposal 3  
 Drawn by author based on resident proposal

### Group3 Proposal

Group 3's proposal focuses on expanding public amenities within the community. One suggestion is to establish a welfare dining hall for elderly residents, reducing the time they spend on grocery shopping and cooking during summer – a practical measure that also limits their heat exposure.

Another suggestion takes advantage of the vacancy left by a relocated primary school, proposing that the abandoned building be converted into a community centre. These new communal spaces, combined with the interventions proposed by the other two groups, have the potential to form a more coherent spatial structure. By shaping where residents go and when, they could meaningfully influence daily routines – particularly for retired residents who spend most of their time within the neighbourhood.

# Proposal Synthesis



**Level1 Main Cooling Infrastructure**  
Key communal spaces proposed by residents, together with existing cooling spots, are connected by shaded pathways along the main roads within the community. The primary purpose of these pathways is to minimise heat exposure when residents travel between destinations. Beyond circulation, the pathways can also serve as informal rest areas, combining shade with opportunities for recreation.

**Level2 Pocket Park**  
Since residents tend to seek the nearest available cooling spot rather than travelling far, pocket parks are introduced as localised cooling spaces distributed across the neighbourhood. Sites are selected in two ways: first, locations with existing good canopy cover are prioritised; second, additional sites are identified to fill gaps in coverage not reached by existing pocket parks or Level 1 cooling infrastructure.


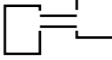




**Level3 General renovation**  
The remaining spaces – including outdoor parking lots and open areas between buildings – are addressed in this final phase. As these spaces do not require changes to their functional layout, renovation focuses on adding canopy cover and replacing hard surfaces with heat-mitigating materials across the wider neighbourhood.

Figure 67. Proposal Synthesis: Towards a Final Proposal  
By Author



Figure 68. General Plan of Final Proposal

By Author

-  Indoor public facility
-  Cooling infrastructure
-  Pocket park
-  Large canopy trees (Camphor tree)
-  Medium canopy trees (Japanese Maple)
-  Structural shade

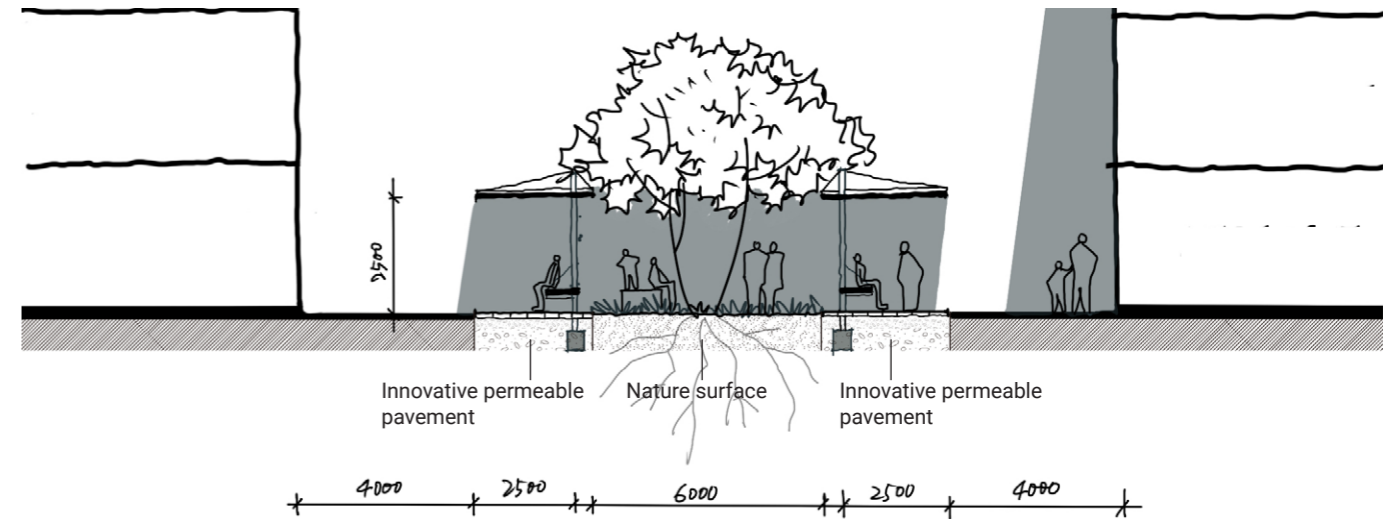
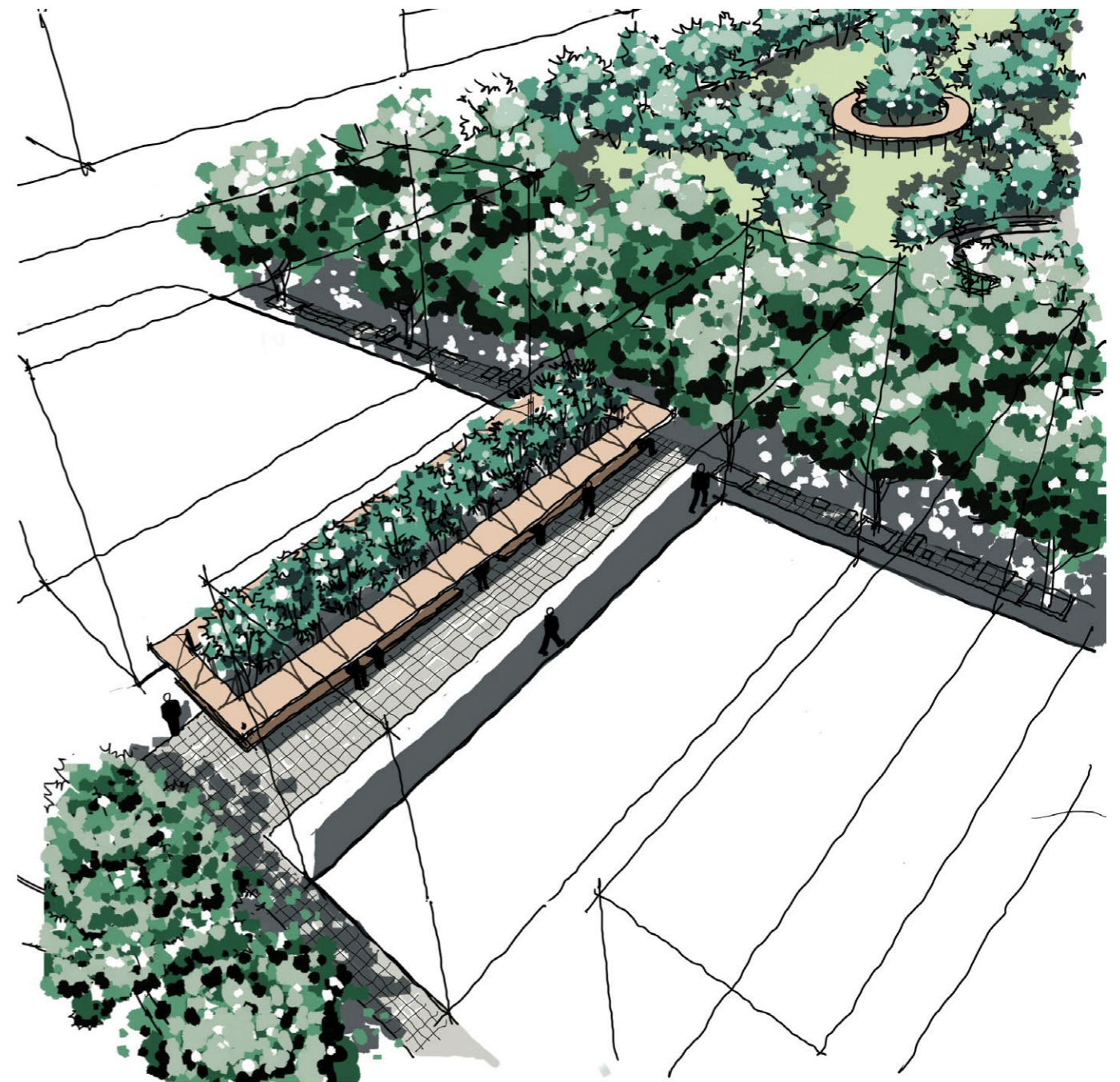
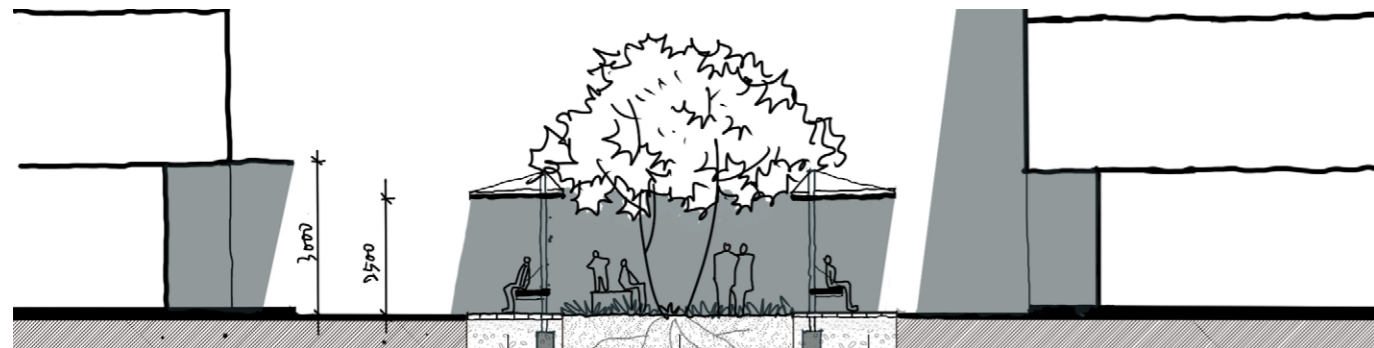
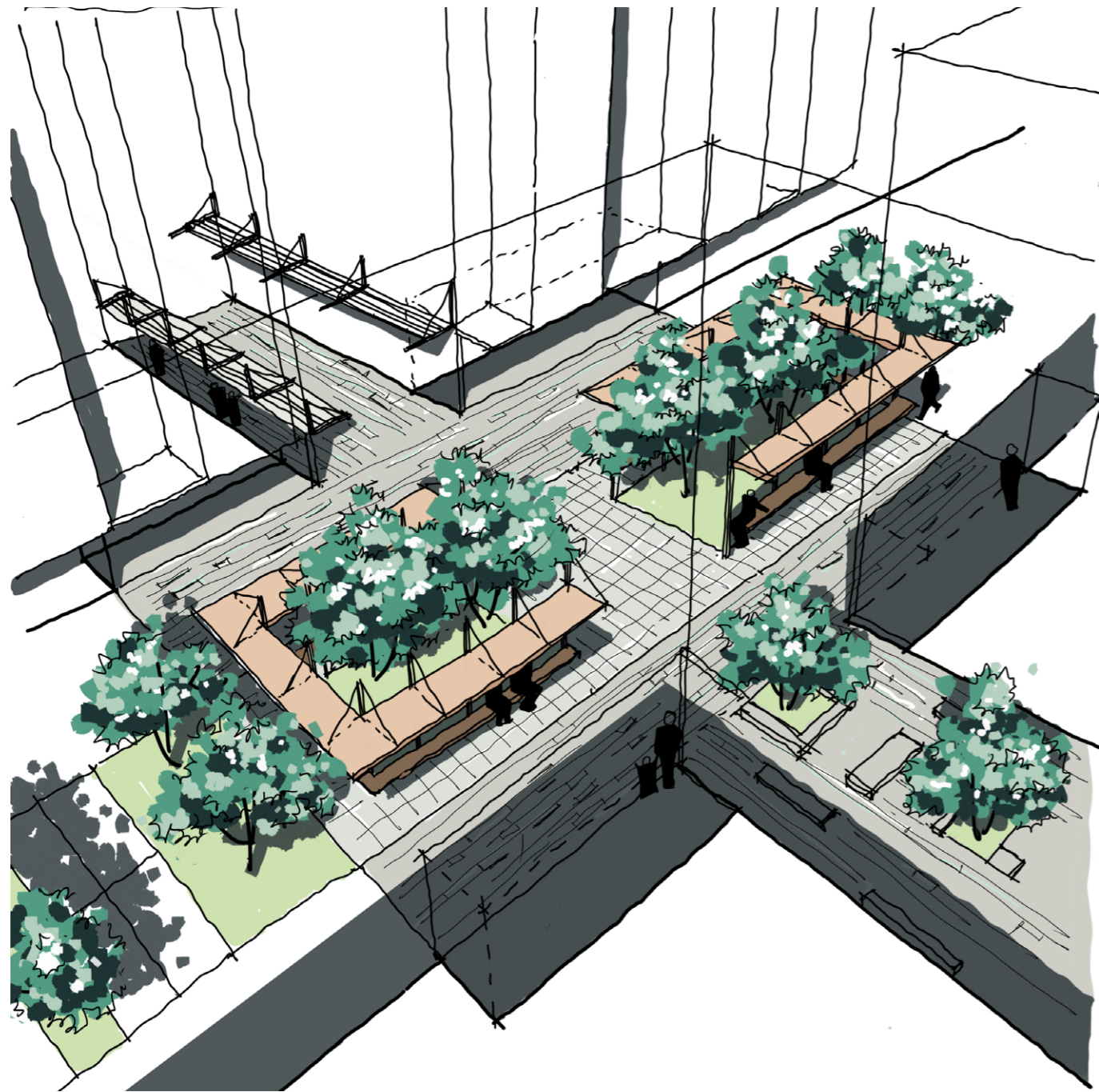


Figure 69. Scenario and Section of Level 1

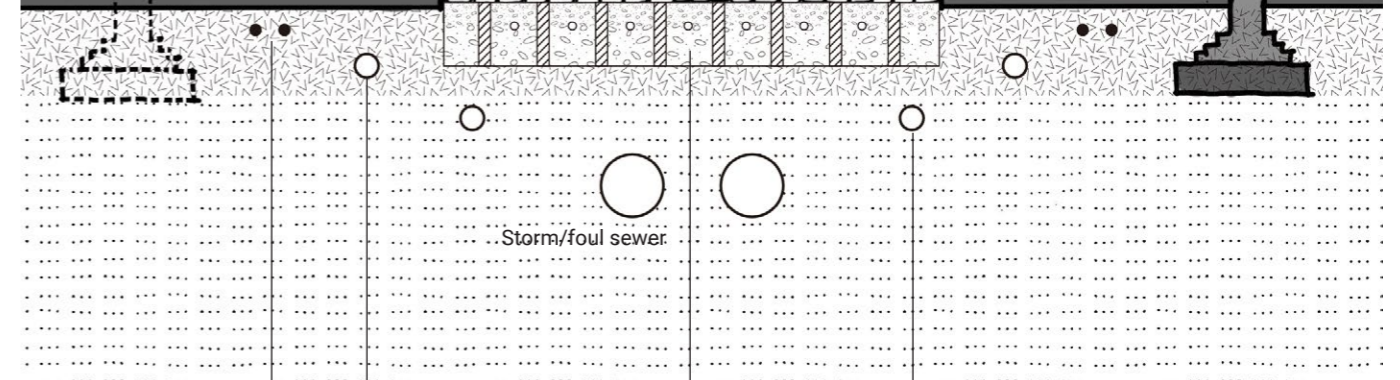
By Author



Innovative permeable pavement Nature surface Innovative permeable pavement

1500 1500 4000 2000 6000 2000 3000 1500

Figure 70. Scenario and Section of Level 2  
By Author



Electrical/telecom cables Water supply pipe Storm/foul sewer Innovative permeable pavement Gas pipe

Figure 71. Scenario and Section of Level 3  
By Author

# Simulation Result of Intervention

The post-intervention simulation results show a moderate but limited cooling effect overall (Fig. 72). Looking at the diurnal trend, **the most visible improvement occurs at 8am, where the lowest PET drops from 33°C to 28°C.** However, the maximum PET at the same hour also increases significantly, seemingly driven by an anomalous spike at a single point in the sports field – possibly a simulation artefact, though this remains unconfirmed. **While the lowest PET values across all time periods show a reduction following the interventions, most areas remain extremely hot throughout the period. Cool spots become more numerous and visible across the site, and combined pattern applications – such as tree canopy paired with permeable paving – demonstrate a measurable though modest cooling effect.** Notably, the coolest spots are concentrated in the narrow gaps between gable walls of buildings, though the underlying cause remains unclear and warrants further investigation. This spatial pattern was not explicitly anticipated in the existing pattern language, suggesting that building gap microclimates deserve greater attention in future iterations of the framework.

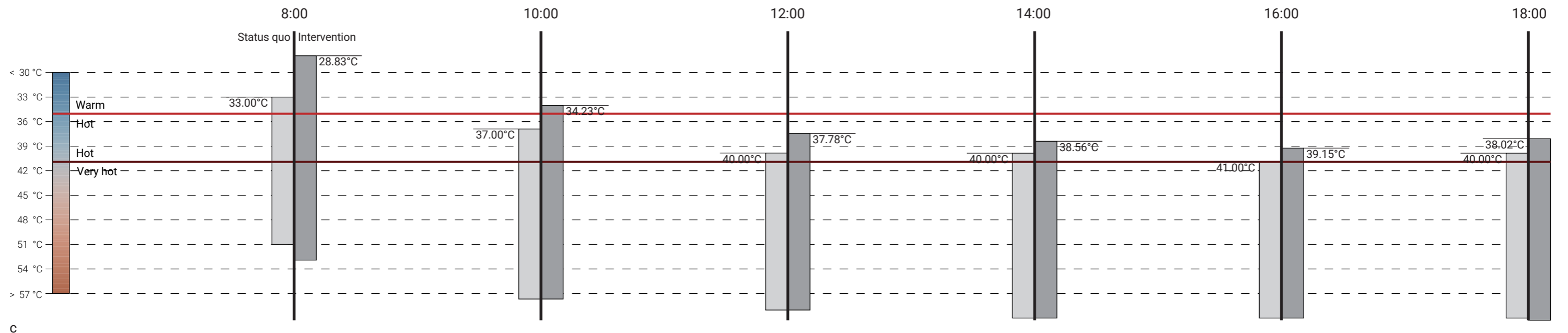
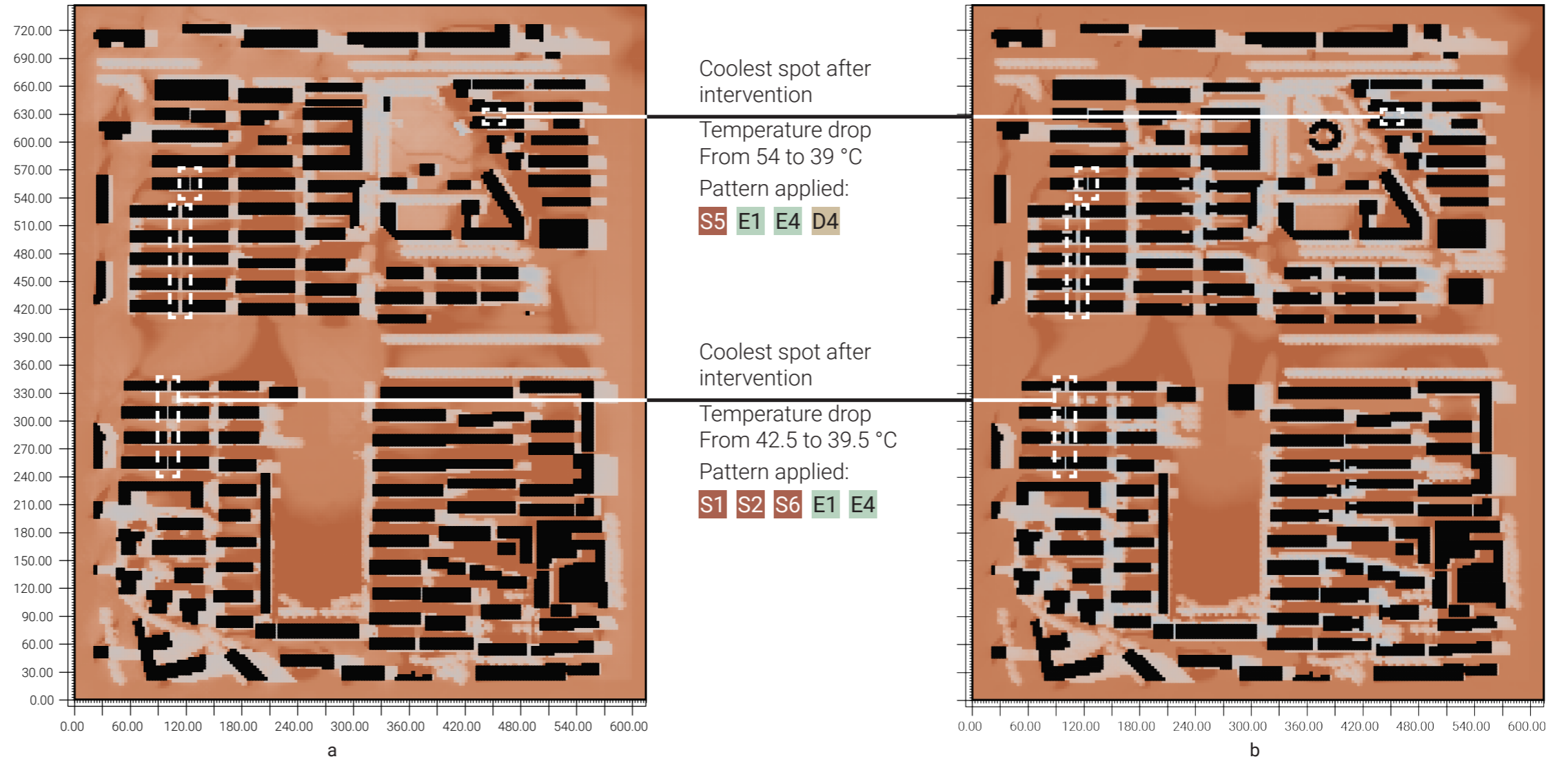


Figure 72. Thermal Environment Simulation: Status Quo vs. Post-Intervention Comparison. (a) current PET map of Liyuan Community at 16:00; (b) PET map after intervention at 16:00; (c) Comparison of PET range from 8:00 to 18:00

By Author

# Recommendation Matrix Iteration

Based on the simulation results, the recommendation matrix has been partially updated. Cooling effects are most concentrated around the newly added pocket park(D4), **indicating that pattern D4 performs better than initially expected**. Within these cooler zones, **innovative permeable surfacing (E4) also proves effective** – notably in the narrow gaps between building gable walls, where it is the only intervention applied yet produces a visible improvement. For the remaining patterns, changes are modest. This may reflect genuinely limited thermal impact, or simply that the

effect of individual patterns is harder to isolate within a multi-pattern environment. Ideally, further rounds of co-design and simulation would allow both residents and experts to refine the patterns and test different configurations at varying scales. If adopted by government, effectiveness would benefit from more rigorous expert evaluation, and feasibility scores may need reassessment when applied to other neighbourhoods in Nanchang. **The matrix is therefore best understood as a living document – one that should continue to evolve alongside each new round of implementation and feedback.**

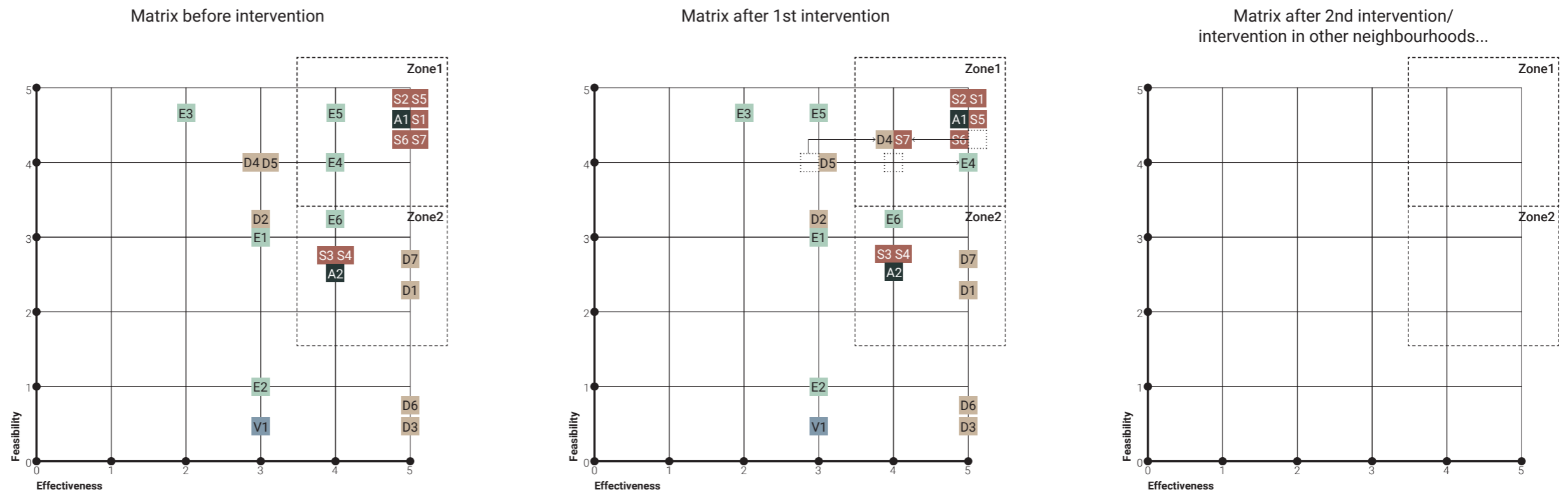
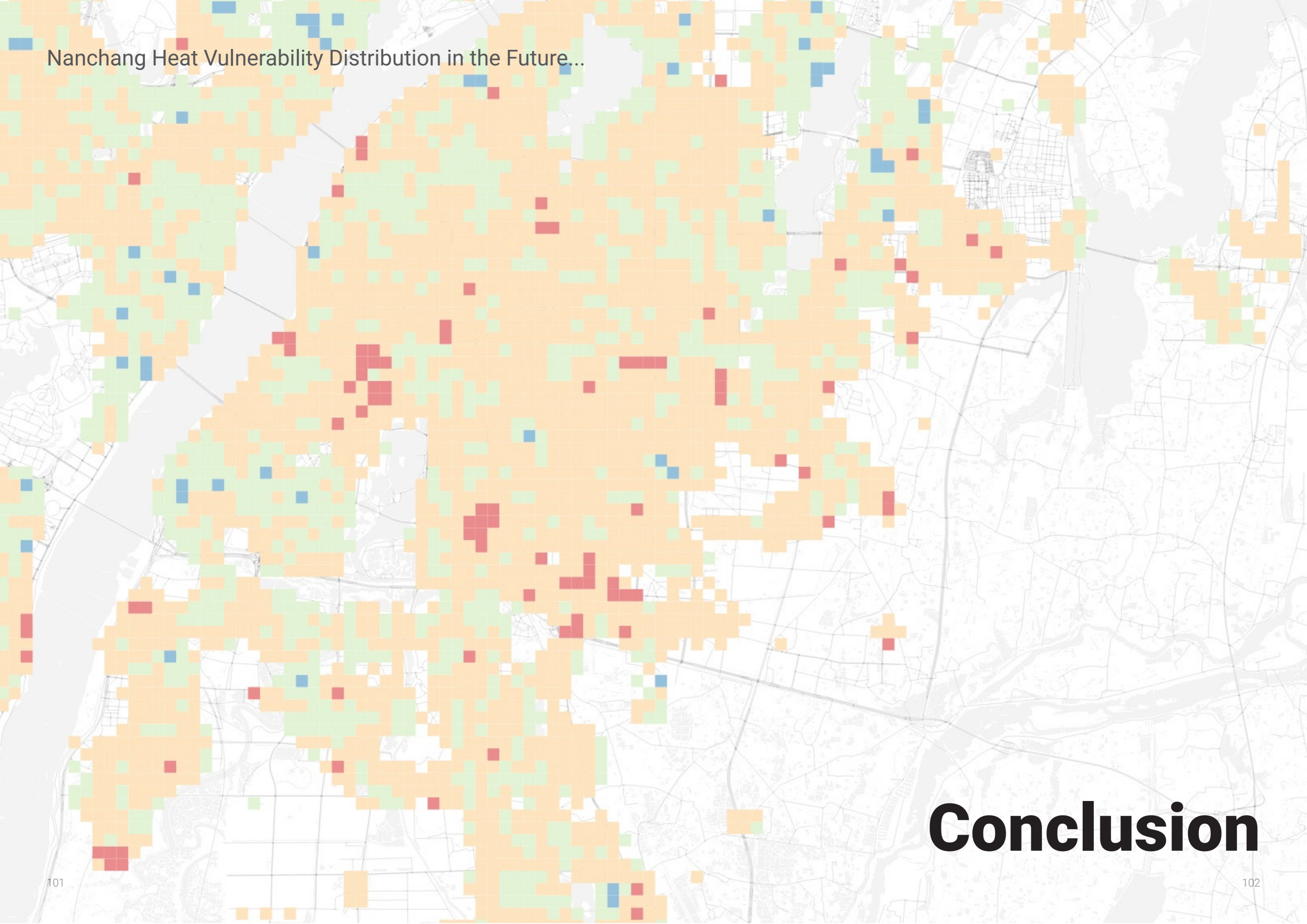


Figure 73. Demonstration of Recommendation Matrix Iteration  
By Author

# Nanchang Heat Vulnerability Distribution in the Future...



**Conclusion**

### Sub-research Question 1:

What are the differences in spatial characteristics and heat exposure among different neighborhoods in Nanchang, China?

At the neighbourhood scale, heat exposure manifests primarily through its effect on residents' thermal comfort rather than ambient temperature alone. At this local scale where heat directly affects human physiology, a comfort-oriented index is more appropriate for capturing actual heat exposure experienced by residents.

Based on LCZ classification, residential neighbourhoods in Nanchang can be categorised into five types: compact mid-rise, compact low-rise, open high-rise, open mid-rise, and open low-rise. These types differ systematically in building density,

height, sky view factor (SVF), and green coverage. Drawing on existing literature, these morphological differences translate into differentiated heat exposure levels – SVF in particular has been identified as a dominant parameter explaining variation in mean outdoor thermal comfort across LCZ types.

In sum, LCZ classification provides a meaningful framework for understanding spatial variation in heat exposure across Nanchang's residential neighbourhoods, forming the basis for the vulnerability assessment developed in subsequent steps.

### Sub-research Question 2:

What cause the inequity of urban heat adaptation in Nanchang?

Inequity appears in three aspects within current situation of Nanchang heat adaptation.

#### Spatial mismatch of sensitive people and cooling resource

The vulnerability assessment reveals a spatial mismatch between the distribution of cooling resources and the populations most in need, as shown in the vulnerability map (Fig. 42c). Areas of high vulnerability – where sensitivity markedly exceeds adaptive capacity – are unevenly distributed across the city, indicating that heat adaptation support is not reaching those who need it most.

#### Heat adaptation overlooked in renovation planning

An analysis of Nanchang's old community renovation plan reveals that only two minor items are related to heat risk reduction, while

the technical guidance overlooks outdoor thermal environment improvement entirely during the acceptance phase. Heat adaptation is therefore not equitably integrated into the renovation process, representing a systematic procedural omission.

#### Residents excluded from renovation process

Residents' feedback from the co-design workshop indicates that they were neither informed nor involved in negotiation throughout the renovation process. While residents express a desire for their ideas to be recognised and supported, spontaneous improvements are largely treated as illegal construction, leaving residents with no choice but to passively seek cooling resources. The exclusion of residents' voices and the procedural denial of their initiatives constitute a form of recognitional inequity in heat adaptation governance.

### Sub-research Question 3:

What kind of site-specific design can reduce heat risk in Nanchang?

Addressing heat risk in Nanchang requires both technical and participatory dimensions.

**First, pattern language provides a structured framework for spatial intervention, consolidating effective solutions for exposure reduction and adaptive capacity enhancement.** As each pattern carries specific spatial requirements and limitations, pattern selection should be informed by neighbourhood morphology to ensure compatibility with the existing built environment.

**Second, resident participation is essential for effective implementation.** Demands and lived experiences vary across neighbourhoods, and engaging residents ensures that interventions are grounded in local knowledge and more likely to gain acceptance and uptake. Furthermore, design proposals refined on the basis of residents' input are more efficient, as they prioritise interventions that are both spatially feasible and community-endorsed.

Together, pattern-based participatory design is proposed as an effective site-specific strategy for heat risk reduction in Nanchang.

### Sub-research Question 4:

How can governance support an equal heat adaptation in site-specific design strategies?

Governance plays a central role in enabling equitable heat adaptation at the neighbourhood scale, and the following recommendations are proposed.

First, when identifying sites for renovation, high-vulnerability areas identified in the composite vulnerability map should be prioritised, ensuring that resources are directed towards communities most in need.

Second, heat adaptation should be systematically integrated into the existing renovation process – incorporating heat mitigation patterns into renovation plans, establishing outdoor thermal environment regulations, and applying simulation tools to iteratively assess and improve heat adaptive strategies.

Third, co-design should be institutionalised

as a standard component of the renovation process, with policy mechanisms established to formally recognise and support resident-initiated improvements.

The feasibility-effectiveness matrix (Fig. 58) provides a prioritised implementation reference. High-effectiveness and high-feasibility patterns should be actioned first, either through direct investment or guided self-implementation. High-effectiveness but medium-feasibility patterns involve greater costs and should be government-led, potentially phased into existing renovation programmes. Remaining patterns serve as supplementary measures when conditions permit.

The design guideline presented in the conclusion consolidates these principles into a practical reference for future implementation.

**Main Research Question:**

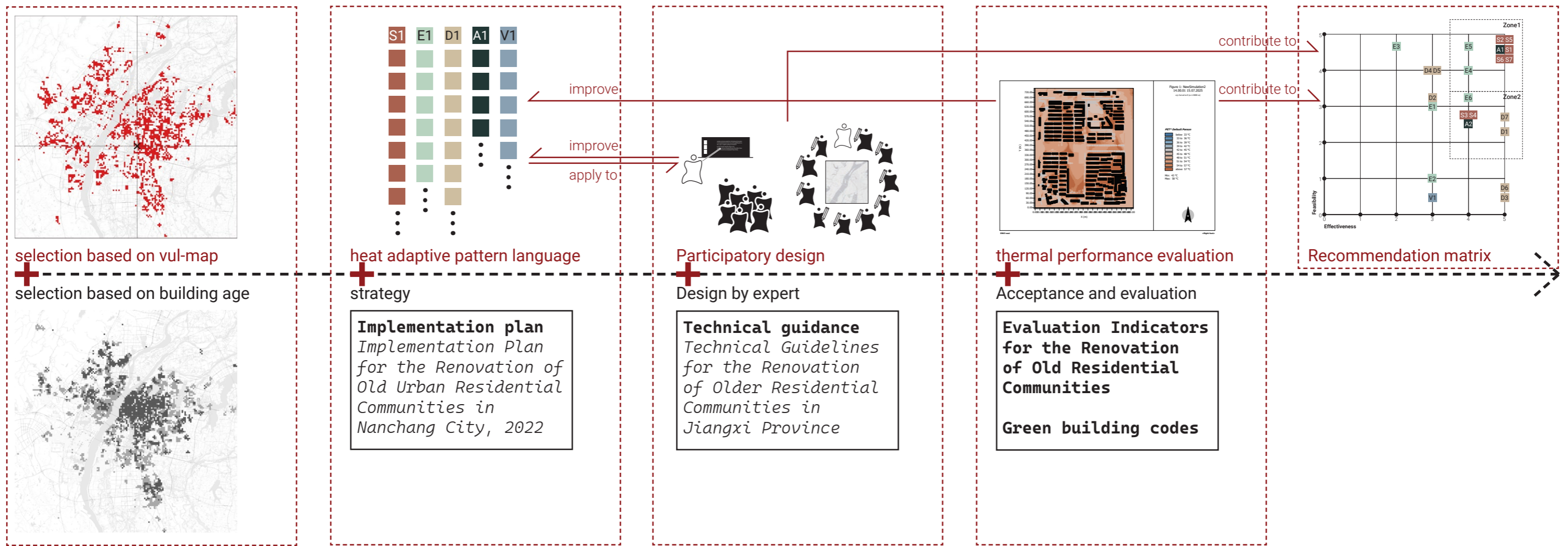
How can site-specific design reduce heat risk at local scale, promoting equity in urban heat adaptation in Nanchang, China?

Site-specific design can reduce heat risk and promote equity in urban heat adaptation through a government-led, participatory process operating at the neighbourhood scale. Rather than applying uniform solutions across the city, each neighbourhood should be approached individually, with intervention strategies informed by its specific vulnerability profile, morphological characteristics, and residents' lived experience.

Pattern language provides the technical backbone of this process, offering a curated set of heat risk mitigation strategies that can be selectively applied according to neighbourhood conditions. Crucially, this pattern library should not be treated as static – new expert knowledge, resident proposals gathered through co-design, combined with post-design simulation outcomes, should feed back into iterative refinement of the patterns, improving both their practical relevance and demonstrated effectiveness over time.

Government plays an enabling role throughout: prioritising high-vulnerability areas for intervention, integrating heat adaptation into existing renovation frameworks, and institutionalising co-design as a legitimate and recurring component of the planning process. This governance structure ensures that adaptation is not only technically effective but procedurally and recognitionally equitable – reaching those most in need and incorporating the voices of those most affected.

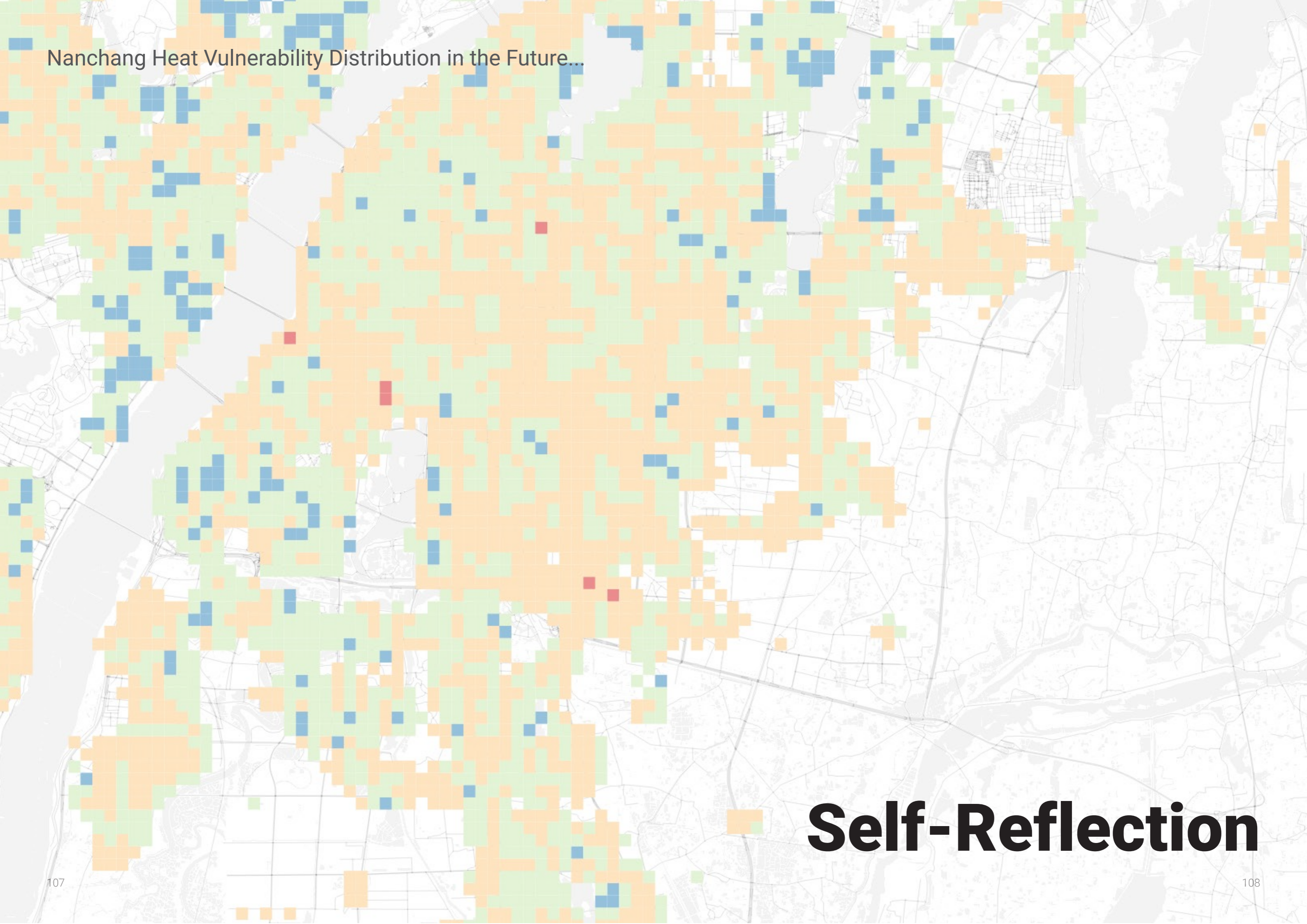
**heat adaptive renovation guideline**



Old renovation process

Figure 74. Heat Adaptation Guideline  
By Author

# Nanchang Heat Vulnerability Distribution in the Future...



**Self-Reflection**

## 1. Where it began

This graduation project stems from a personal concern that developed during the second quarter of the master programme, when questions of climate change in the built environment began to feel both intellectually urgent and personally relevant. Growing up in Nanchang – a city long exposed to severe summer heat – gave this concern a concrete human dimension that shaped the direction of the research from the outset. An encounter with urban climate scholarship through ICUC further sharpened my interest into a more specific focus on heat vulnerability and equitable adaptation. The methodological toolkit I employed – ENVI-met simulation, MCDA-based vulnerability assessment, and pattern language – draws directly on skills and frameworks acquired during the first year of the programme, giving the project a sense of accumulated purpose.

At the start, my research agenda felt clear and my ambitions were high. A structured analytical framework was in place, outcomes were anticipated, and the path from vulnerability mapping to design recommendation seemed, if challenging, at least legible. This confidence, as the research would soon reveal, was both a necessary starting point and a somewhat fragile one.

## 2. Learn to work in uncertainty

The analysis phase was defined by the difficulty of data collection and processing. Training the LCZ map independently proved unfeasible, and I eventually had to request data from another research team. Population income data, being privately held, was inaccessible directly and had to be approximated through housing price maps. The selection of indicators for MCDA and the distribution of weights presented their own challenges – without a sufficiently objective basis, I settled on an equal weighting, a decision I remained uncertain about. Beyond these specific obstacles, recurring issues of data accuracy and resolution accumulated into a broader self-doubt: with each compromise, I found myself questioning the reliability of the analysis as a whole.

## 3. Difficulty in remote participatory design

Participant recruitment presented its own complexity. While conventional participatory design guidance cautions against over-reliance on existing social networks to avoid social pressure, I found that in practice, participatory design is met with considerable reluctance in China – most people were hesitant and disinclined to engage. Existing social connections were, frankly, a very effective means of reducing this resistance. This required a careful and conscious balance: leveraging personal networks just enough to lower the threshold for participation, while remaining attentive to the social obligations and pressure that such networks inevitably carry.

Yet this phase also brought unexpected rewards. Through residents' feedback, I encountered a wealth of everyday knowledge and lived experience that no amount of remote data analysis could have surfaced – local patterns of behaviour, spatial preferences, and practical concerns that were invisible from a distance. This was humbling, and genuinely enlarging: even having grown up in Nanchang myself, there was a great deal I simply did not know.

## 4. When my research holds myself accountable

The most profound shift in this project concerned my understanding of my own role as a designer. Initially, the plan was to develop two parallel proposals – one from myself as a designer, one from residents – for comparison. This changed after the first part of the workshop. Hearing residents speak at length about their concerns around funding, management responsibility, and implementation feasibility made it impossible for me to proceed with an independent design agenda. These were not minor concerns – they were central to whether any intervention could ever be realised. To ignore them would have been to betray the very equity principles my research was built on. At this point, I became deliberately passive, stepping back from any design authority and deferring almost entirely to residents' expressed wishes.

It was through conversations with my supervisors that I began to question whether this passivity was itself a problem. Bottom-up design, I came to understand, does not mean the uncritical acceptance of every idea that emerges from the community. Residents, however perceptive and knowledgeable about their own lives, had not received professional design training and did not have access to the technical knowledge around heat adaptation that the research had assembled. The designer's role, then, is not to impose nor to disappear – it is to organise, to filter, to translate. To take residents' ideas seriously enough to refine them into something that can actually be built and evaluated.

This realisation reframed my understanding of equity itself. Equity does not require the expert's absence; it requires that expertise be exercised in service of those most affected, rather than over them. In a quiet way, this was the most important thing I learned from the entire project – and it came not from the literature, but from the experience of nearly getting it wrong.

## 5. Value and transferability

The project addresses a real and pressing urban heat problem in Nanchang, while introducing resident participation into a governance culture that has traditionally operated top-down – not to dismantle existing structures, but to work within them differently.

Academically, the project combines LCZ-based morphological classification, MCDA vulnerability assessment, and participatory co-design in a way that remains relatively uncommon in the Chinese urban context. Applying a three-dimensional equity lens – distributional, procedural, and recognitional – to heat adaptation also offers a more specific diagnosis than vulnerability mapping alone. The adaptation of pattern language as a participatory tool for local-scale heat adaptation adds a modest methodological contribution to both design practice and climate adaptation research.

The transferability lies in the process rather than the outcomes. The vulnerability-co-design-simulation framework is replicable, and its tools are designed to iterate – the pattern language can be enriched through successive rounds of engagement, and the feasibility-effectiveness matrix can be recalibrated according to simulation results and each community's specific needs. This project offers not a finished answer, but a working process intended to improve with use.

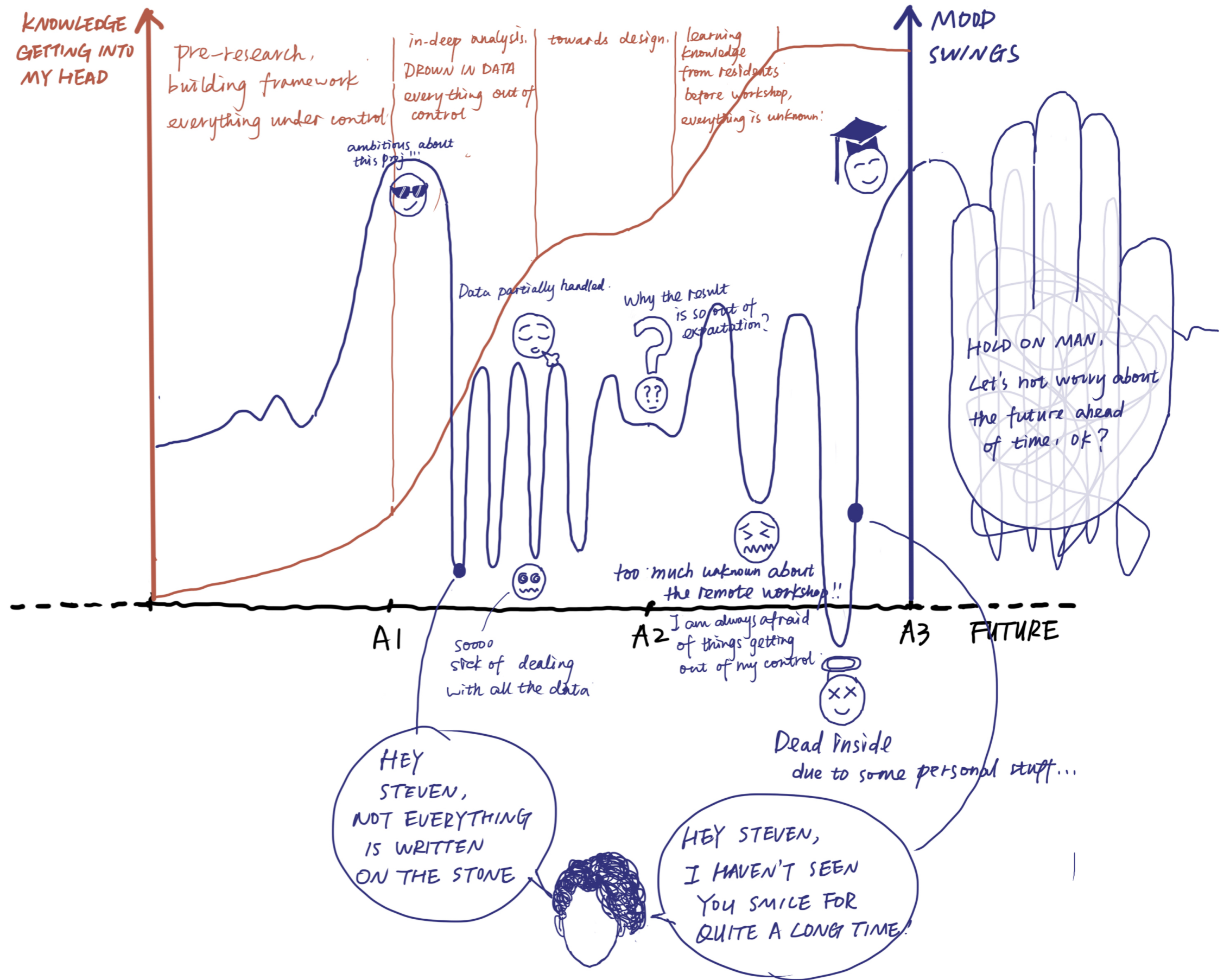
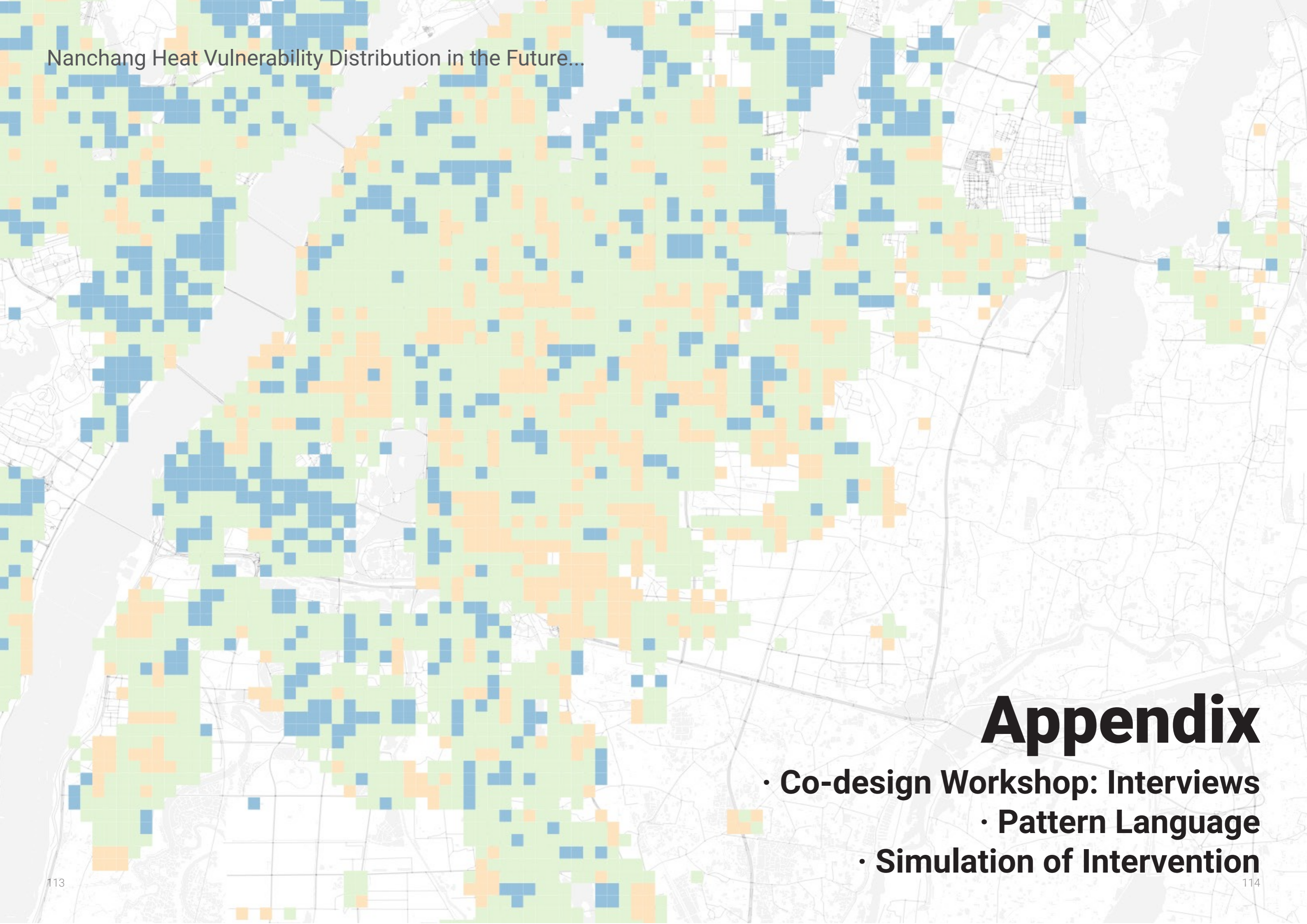


Figure 75. My Growth during This Project  
vBy Author



# Appendix

- Co-design Workshop: Interviews
- Pattern Language
- Simulation of Intervention

# Co-design Workshop: Interviews

## Topic 1: Heat Environment Experience Survey

1. During summer daytime, do you stay outdoors in the community for extended periods (more than 30 minutes)? What activities do you mainly engage in? How long do you typically stay, and during which time periods?

Location	Activity	Time Period
Sports court	Exercise	6:00–8:00am, 7:00–9:00pm (after sunset)
Tree shade	Cooling down	10:00–11:00am, 3:00–4:00pm
Ruzi Bookstore (air-conditioned indoor space)	Reading, cooling down	No fixed time
Elderly Activity Centre (air-conditioned indoor space)	Chess, table tennis, recreational activities	No fixed time
Market (outside community)	Grocery shopping	7:00–9:00am
Within community	Walking dogs, strolling	8:00–9:00am, 8:00–10:00pm

Note: Cannot stay in air-conditioned rooms for extended periods — need fresh air.

2. During summer daytime (10:00–16:00), which outdoor spaces in the community feel relatively cool, and which feel particularly hot? (Please mark on the map as instructed)

Notes:

- In Nanchang, there are no genuinely cool outdoor spaces
- Relatively cool spots: shaded areas cast by buildings and surrounding walls
- Storage room entrances (frequented by elderly residents)

3. In the coming hot summer, will you go to the cool areas you selected to escape

the heat? (Please give reasons)

- During the most extreme heat, no — residents only stay outdoors briefly and do not remain for extended periods

4. Around 2021, Liyuan Community underwent a renovation. Many spaces changed — for example, grassland was converted into parking lots and activity plazas, and the park at the sports centre became a car culture plaza. How do you evaluate this renovation? (Who led it? Were residents consulted? Are you satisfied with the results?)

Party involved	Renovation content	Evaluation
Government-led renovation (Nanchang Old Residential District Renovation Programme)	Urban infrastructure and pipeline upgrades	Parking became more convenient; community became tidier and more orderly
Residents' committee	Aesthetic improvements (no resident participation)	Strengthened existing functions (parking, elevator installation, etc.)

5. From a thermal comfort perspective, did this renovation make you feel like the community got hotter (higher perceived temperature, more sun-exposed areas, etc.) or cooler?

- Residents do not feel a significant change in temperature and are uncertain whether any change is due to climate fluctuation or the renovation itself

6. Compared to other communities (if you have lived elsewhere), is Liyuan Community a more liveable community during hot summers? Why?

- Not particularly — the community lacks greenery and there are relatively few large trees providing shade
- The sports court is a valued community asset, but facilities are ageing and lack timely maintenance

## Topic 2: Thermal Comfort Awareness Survey

### 6. What factors do you think affect "perceived temperature" (causing it to differ from actual air temperature)?

- Humidity, solar radiation intensity, wind
- 

### 7. In the cool spots you marked in the community, what makes those places feel cooler?

- Duration and coverage of shading (shadow coverage area and time)
  - Ventilation conditions
  - Presence of water
  - Vegetation (areas with more greenery feel more comfortable)
- 

### 8. Do you feel the community needs more of these elements? What do you think is currently most lacking?

- Social environment: lack of community collective activities (e.g., evening cool-down gatherings)
- Community renovation feels uniform and lacks character
- Could add small air-conditioned reading rooms — not necessarily large, but small and distributed throughout the community
- More trees in the community
- Greening integrated with activity spaces and facilities
- Greening integrated with parking spaces
- Pet-friendly areas

*Note: A good mood is also a way of coping with the heat*

---

### 9. Apart from what already exists in this community, have you seen any particularly effective cooling methods elsewhere (e.g., other residential communities, parks, near shopping centres)?

- Shaded canopy structures

- Covered walkways/corridors (e.g., Xianghu Park)
- Vegetation (e.g., Xianghu Park)

*Note: Residents are more willing to travel to Xianghu Park for heat relief during summer, even if it requires walking some distance*

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## Topic 3: Participation in Decision-Making and Implementation During Renovation

### 10. Do you think it is necessary to consider "reducing perceived temperature during hot weather" in community renovation planning?

- Multiple participants expressed that it is necessary: "Should be considered", "Necessary", "Very necessary"
- 

### 11. Compared to other renovation demands (such as adding parking spaces or activity plazas), how important do you consider "reducing perceived temperature"?

- Can be included as one component, but is not considered the most essential or indispensable priority
- 

### 12. Do you think renovation aimed at "reducing perceived temperature" is practically feasible in this community? What concerns do you have?

- **Lack of ecological awareness among participants (residents and policy implementers)** Current greenery, activity spaces, and parking are treated as separate and disconnected elements. Neither residents nor management officials have developed an ecological consciousness — they do not recognise the importance of the ecological environment or the value of integrating ecology into design. For example, greening integrated with parking design can help cool parked vehicles, but most people only think about needing more parking spaces.
  - **Cost determines feasibility**
  - **Parking is a basic necessity.** Underground parking would be the most effective solution, but building density is too high to accommodate it, and costs are prohibitive. Current parking fees in the community are relatively low, and residents resist any increase.
-

**13. Have you ever spontaneously attempted any cooling methods (e.g., building a shade canopy in a communal open space)? What obstacles prevent you from taking action?**

- **Lack of spontaneous construction behaviour** Most self-initiated construction is considered unauthorised and violates the community's original planning intent. Some residents previously planted banana trees and other vegetation between buildings, but these were treated as prohibited individual actions.

Residents have many good ideas and have made spontaneous efforts, but none have been realised. Good ideas should be encouraged — there should be appropriate regulations or application procedures allowing residents to self-initiate community improvements.

However, such spontaneous actions are very difficult to manage. Even if self-initiated renovation were permitted, it would need to be regulated, because individual residents differ in their standards, aesthetics, and awareness. Balancing the right to individual expression with the overall community image requires strong management capacity and detailed design guidelines covering materials, colours, and forms.

Residents approve of growing plants on balconies, viewing it as environmentally beneficial and personally enjoyable — but this remains individual behaviour without a systematic framework.

- **Passively seeking suitable environments** Elderly residents do not frequently use air conditioning — partly to save electricity, and partly due to the belief that natural ventilation is healthier. If cool outdoor spaces were available, most elderly residents would prefer to find cool spots outdoors rather than staying inside.
- **Technical issues** Taking facade greening as an example: on south-facing facades, climbing plants conflict with natural lighting — how to balance both is a challenge. On gable walls, the root systems of climbing plants may damage the building facade (though they could address overheating issues for end-unit residents), requiring more careful maintenance and management.

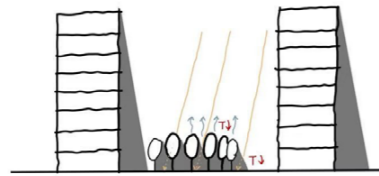
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**15. If the residents' committee or government organises a unified cooling renovation, what form would you prefer? (e.g., direct construction on residents' behalf, professional advice for self-build, etc.) Regarding costs, what do you consider reasonable — fully funded, a nominal property management fee, or other arrangements?**

- Strong preference for government-funded rather than self-funded approaches (very low proportion willing to contribute personally); preference for community-wide unified construction and management (not accepting higher property management fees or increases to existing fees) rather than self-initiated construction

# Pattern Language

## S1 More canopy between buildings



### Limitation:

May conflict with underground infrastructure  
Dense canopy in narrow street canyons may block ventilation and trap heat at night

### Spatial conflict:

South-facing placement may reduce ground-floor sun light  
May conflict with parking demand or drive way

### Explanation:

Canopy between buildings blocks direct solar radiation, significantly reducing mean radiant temperature (MRT) at pedestrian height. Evidence shows that smaller spaces between buildings consistently record lower PMV than large open areas, making them priority locations for shade intervention. Tree canopy additionally lowers air temperature through evapotranspiration, making it more effective than structural shade alone.

**Source:** (Wang & Luan, 2016), resident demand

### Governance support:

**Implementation party:** government-led

**Policy support:** revise Nanchang Old Residential District Renovation Programme (NODRP) and urban heat adaptation planning (UHAP)

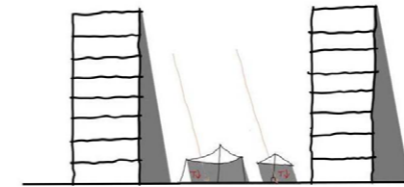
**Funding:** Government-funded

**Maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

## S3 More structural shade between buildings



### Limitation:

Structure in narrow street canyons may block ventilation and trap heat at night

### Spatial conflict:

May conflict with parking demand or drive way

### Explanation:

Structural shade between buildings blocks direct solar radiation, significantly reducing mean radiant temperature (MRT) at pedestrian height. Evidence shows that smaller spaces between buildings consistently record lower PMV than large open areas, making them priority locations for shade intervention.

**Source:** (Wang & Luan, 2016), resident demand

### Governance support:

**Implementation party:** government-led, community-led, resident-initiated

**Policy support:** revise NODRP and UHAP; Improve the reporting system, provide design guidelines

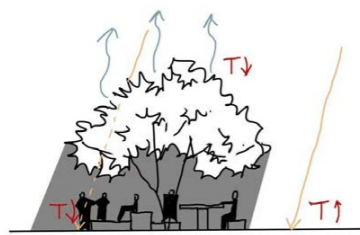
**Funding:** Government-funded, community-funded, self-funded

**Maintenance party:** Government, community, resident

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

## S2 Combination of canopy with recreation



### Limitation:

### Spatial conflict:

Space beneath existing canopy may not be suitable for recreation implementation

### Explanation:

Trees significantly reduce surface temperature, air temperature and PET beneath their canopy. However, existing trees are often treated as purely aesthetic elements without associated seating or activity spaces. Combining rest areas and recreational facilities with existing tree canopy maximises the use of these natural cooling resources, providing accessible cool refuge for residents during hot summer periods.

**Source:** (Probst et al., 2022), resident demand

### Governance support:

**Implementation party:** government-led, community-led

**Policy support:** revise NODRP and UHAP

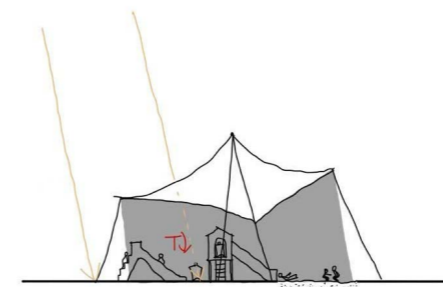
**Funding:** Government-funded, community-funded

**Maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

## S4 Combination of structural shade with recreation



### Limitation:

Structure in narrow street canyons may block ventilation and trap heat at night

### Spatial conflict:

No specific conflict

### Explanation:

Structural shade combined with recreational facilities creates shaded activity spaces, reducing MRT at pedestrian height and extending comfortable outdoor time. This encourages social interaction and community wellbeing, particularly beneficial for elderly residents and children who spend more time outdoors.

**Source:** resident demand

### Governance support:

**Implementation party:** government-led, community-led

**Policy support:** revise NODRP and UHAP

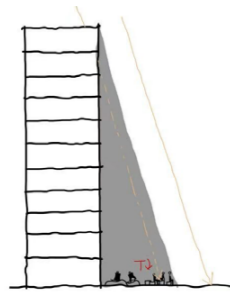
**Funding:** government-funded, , community-funded

**Maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

### S5 Combination of building shade with recreation



#### Limitation:

Cooling effect is time-dependent — building shade shifts throughout the day, meaning the shaded zone may not consistently cover the rest area

#### Spatial conflict:

May conflict with existing informal storage or parking uses at ground level

#### Explanation:

Building shade consistently demonstrates the strongest PET reduction effect compared to other shade types. Combining rest areas and recreational facilities with these existing building shade zones maximises their cooling potential and provides accessible outdoor refuge during peak heat hours.

Source: (Middel et al., 2021), resident demand

#### Governance support:

Implementation party: government-led, community-led

Policy support: revise NODRP and UHAP

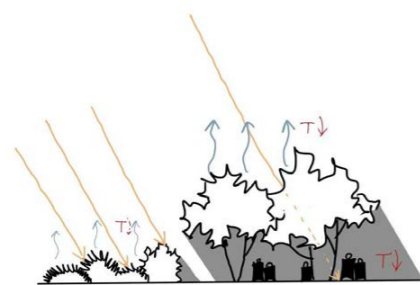
Funding: Government-funded, community-funded

Maintenance party: Government, community management

#### Effectiveness rating(by designer):

Feasibility rating(by resident):

### S6 More trees than shrubs



#### Limitation:

Large trees require greater soil depth and planting space compared to shrubs;  
May conflict with underground infrastructure due to root systems

#### Spatial conflict:

Large canopy trees may reduce natural lighting for ground-floor residents on south-facing sides

#### Explanation:

Trees outperform shrubs in cooling effectiveness due to their ability to provide larger canopy shade, directly reducing mean radiant temperature at pedestrian height. Shrubs offer limited shading capacity and rely primarily on evapotranspiration for cooling, which is less effective in humid subtropical climates where evaporative cooling potential is constrained.

Source: (Wang & Luan, 2016)

#### Governance support:

Implementation party: government-led

Policy support: revise NODRP and UHAP

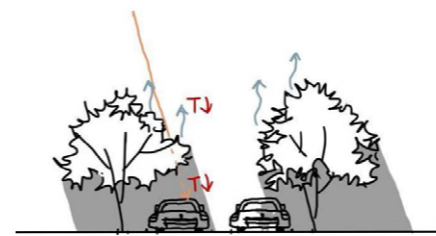
Funding: Government-funded

Maintenance party: Government, community management

#### Effectiveness rating(by designer):

Feasibility rating(by resident):

### S7 Parking lot and vegetation combination



#### Limitation:

No specific limitation

#### Spatial conflict:

May conflict with parking demand if more parking space is required

#### Explanation:

Replacing impervious asphalt parking surfaces with grass grid pavers offers limited but measurable cooling benefits through increased evapotranspiration and reduced heat absorption. The primary cooling intervention in this pattern is tree canopy, which significantly reduces MRT and pedestrian-level thermal stress. Residents also noted that tree canopy over parking spaces helps reduce vehicle interior temperatures, addressing a practical everyday heat concern beyond outdoor thermal comfort.

Source: (Li et al., 2022), resident demand

#### Governance support:

Implementation party: government-led

Policy support: revise NODRP and UHAP

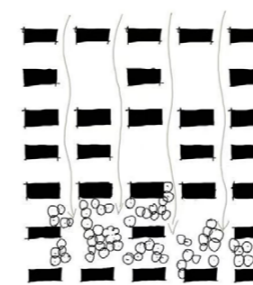
Funding: Government-funded

Maintenance party: Government, community management

#### Effectiveness rating(by designer):

Feasibility rating(by resident):

### V1 Plant trees in downwind area



#### Limitation:

Requires prior analysis of prevailing wind direction;  
Effectiveness depends on seasonal wind pattern consistency

#### Spatial conflict:

Limited planting space in high-density old residential districts may restrict optimal placement relative to wind direction

#### Explanation:

Trees planted in the downwind direction of prevailing winds maintain neighbourhood ventilation while still providing cooling through evapotranspiration. Research shows that scattered tree planting does not significantly increase effective canopy coverage compared to centralised plantation, and reduces windspeed within the neighbourhood. Concentrating tree planting in downwind areas preserves airflow while maximising cooling benefits.

Source: (Wang & Luan, 2016)

#### Governance support:

Implementation party: government-led

Policy support: revise NODRP and UHAP

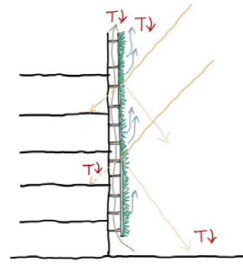
Funding: Government-funded

Maintenance party: Government, community management

#### Effectiveness rating(by designer):

Feasibility rating(by resident):

### E1 Green facade



#### Limitation:

South-facing facades may conflict with sunlight requirements; climbing support structure installation may cause damage to facade and building structure

#### Spatial conflict:

May conflict with facade-mounted equipment commonly found in old residential buildings

#### Explanation:

Vertical greenery systems absorb incident solar radiation and convert it into evapotranspiration, reducing air temperature and improving outdoor thermal comfort. Additionally, green facades enhance building insulation and reduce solar heat gain for indoor spaces, offering dual benefits for both outdoor and indoor thermal environments. To facilitate plant growth, climbing support structures such as wire mesh or trellis systems can be mounted onto building facades, providing a low-cost and adaptable framework for various climbing species.

**Source:** (Probst et al., 2022)

#### Governance support:

**Implementation party:** government-led, community-led, resident-initiated

**Policy support:** revise NODRP and UHAP, green facade manual

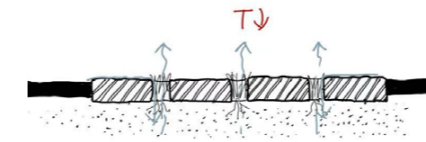
**Funding:** Government-funded, community-funded, self-funded

**Maintenance party:** Government, community management, resident

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

### E3 Permeable pavement



#### Limitation:

Cooling effect is limited and is highly dependent on moisture availability.

#### Spatial conflict:

No specific conflict

#### Explanation:

Permeable brick pavement reduces pedestrian-level heat stress by up to 3.0°C UTCI compared to impervious surfaces under dry conditions, with further improvement following irrigation. Despite absorbing more solar radiation at the ground surface, its evaporative cooling effect benefits thermal comfort at human height, particularly within enclosed street canyon environments. It also provides stormwater management co-benefits by increasing water infiltration and reducing surface runoff.

**Source:** (Zhao et al., 2026)

#### Governance support:

**Implementation party:** government-led

**Policy support:** revise NODRP and UHAP

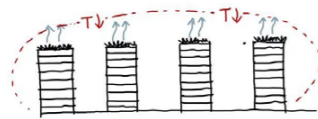
**Funding:** Government-funded

**Maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

### E2 Green roof



#### Limitation:

Cooling effect at pedestrian level is negligible in medium- to high-rise buildings; Existing roof structure may require reinforcement to support additional load.

#### Spatial conflict:

May conflict with existing rooftop equipment; Irrigation requirements may conflict with water supply capacity

#### Explanation:

Green roofs reduce sensible heat fluxes through increased solar reflection and evapotranspiration. However, cooling effect at pedestrian level is negligible in medium- to high-rise buildings, with only limited air temperature reduction achievable in low-rise neighbourhoods below 30 metres. Their adoption is better justified by multifunctional co-benefits including stormwater management, biodiversity enhancement, and solar panel integration.

**Source:** Probst et al., 2022

#### Governance support:

**Implementation party:** government-led

**Policy support:** revise NODRP and UHAP

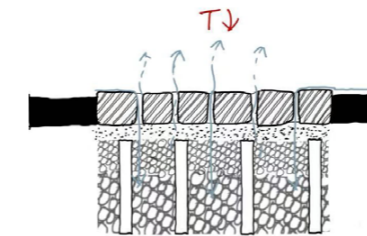
**Funding:** Government-funded

**Maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

### E4 Innovative permeable pavement



#### Limitation:

Higher installation cost compared to conventional permeable pavement; Requires specialist installation and maintenance

#### Spatial conflict:

May conflict with existing underground system; May conflict with building structures besides

#### Explanation:

Innovative Permeable Pavement (IPP) consists of capillary columns and an internal water storage zone formed by a high-density polyethylene liner. IPP demonstrates significantly stronger cooling performance – surface temperature during hot summer periods is around 15°C lower than traditional pavement. The cooling effect persists as long as stormwater remains stored in the internal water storage zone, making it particularly effective following rainfall events.

**Source:** (Liu et al., 2020)

#### Governance support:

**Implementation party:** government-led

**Policy support:** revise NODRP and UHAP

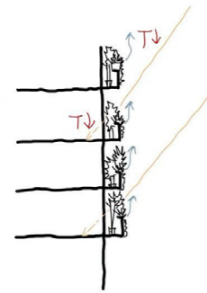
**Funding:** Government-funded

**Maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

### E5 Vegetated balcony



#### Limitation:

Vegetated balcony's cooling effect and mechanism on outdoor pedestrian-level space remains unclear; South-facing facades may conflict with sunlight requirements

#### Spatial conflict:

No specific conflict

#### Explanation:

Vegetated balconies reduce indoor thermal stress through shading of the building facade and plant evapotranspiration. Research in tropical climates demonstrates indoor temperature reductions of up to 2.5°C under real conditions (Priya & Senthil, 2025), while Kumar et al. (2024) report an average air temperature reduction of 3.8°C associated with vegetated balconies across monitoring studies.

**Source:** (Priya & Senthil, 2025), (Kumar et al. 2024)

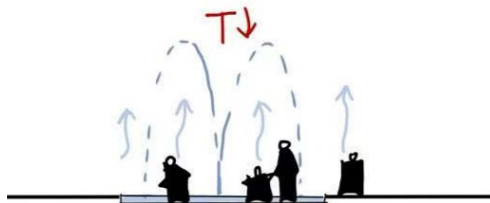
#### Governance support:

**Implementation party:** community-led, resident-initiated  
**policy support:** revise NODRP and UHAP, green facade manual  
**Funding:** community-funded, self-funded  
**maintenance party:** community management, resident

#### Effectiveness rating(by designer):

**Feasibility rating(by resident):**

### E6 Fountain in neighbourhood



#### Limitation:

Requires water supply and regular maintenance; May increase local humidity

#### Spatial conflict:

Requires available open space within the community; May conflict with existing underground system

#### Explanation:

Fountains and water features enhance cooling through rapid evaporation of dispersed water droplets, reducing air temperature by up to 2°C within a radius of up to 35 metres downwind. The cooling effect is most pronounced in confined spaces such as courtyards, making them well-suited to the enclosed spaces between residential buildings. Cooling persists even after the spray is turned off, offering sustained relief during peak heat periods.

**Source:** (Probst et al., 2022)

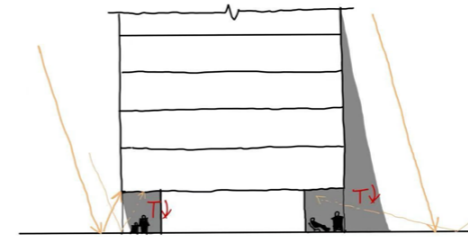
#### Governance support:

**Implementation party:** community-led  
**policy support:** revise NODRP and UHAP  
**Funding:** community-funded  
**maintenance party:** community management

#### Effectiveness rating(by designer):

**Feasibility rating(by resident):**

### D1 Converting Ground-floor Function to Pilotis



#### Limitation:

Requires structural assessment to ensure building integrity before partial demolition  
Not applicable to load-bearing ground-floor walls

#### Spatial conflict:

Relocation of stored items requires coordination; May reduce available ground-floor parking or utility space

#### Explanation:

Partial demolition of ground-floor storage spaces creates pilotis that improve neighbourhood ventilation and provide shaded semi-outdoor spaces. Increasing the shape coefficient of open space during demolition maximises airflow through the building complex, reducing air temperature and improving pedestrian thermal comfort. This approach repurposes underutilised storage areas without affecting residential functions.

**Source:** (Huang & Zhao, 2020)

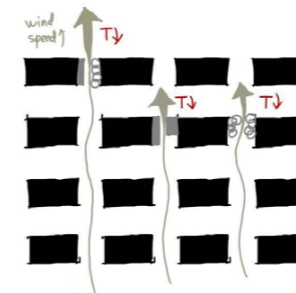
#### Governance support:

**Implementation party:** government-led  
**Policy support:** revise NODRP and UHAP  
**Funding:** Government-funded  
**Maintenance party:** Government, community management

#### Effectiveness rating(by designer):

**Feasibility rating(by resident):**

### D2 Optimising Wind Corridors through addition



#### Limitation:

Requires prior wind environment analysis; Incorrect placement may obstruct rather than enhance airflow, potentially worsening thermal comfort

#### Spatial conflict:

May conflict with existing parking spaces or driveways; Only applicable in communities with sufficient open space

#### Explanation:

By strategically placing small additions or vegetation beside existing buildings, wind corridor patterns can be redirected and localised windspeed increased. This approach is particularly suitable for communities with sufficient open space but lacking outdoor facilities, as the additions can serve dual functions of wind guidance and recreational or aesthetic improvement.

**Source:** (Huang & Zhao, 2020)

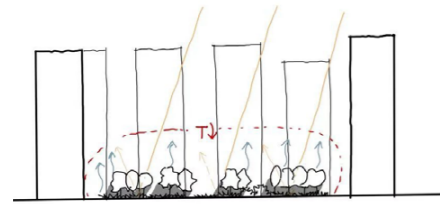
#### Governance support:

**Implementation party:** government-led  
**Policy support:** revise NODRP and UHAP  
**Funding:** Government-funded  
**Maintenance party:** Government, community management

#### Effectiveness rating(by designer):

**Feasibility rating(by resident):**

### D3 Relatively large community garden



**Limitation:**  
No specific limitation

**Spatial conflict:**  
Not suitable for high-density old residential district;  
May conflict with other function and demand.

#### Explanation:

Urban parks generate a park cooling island effect, with internal air temperatures averaging 0.94–5.7°C lower than surrounding areas. The cooling effect frequently extends beyond park boundaries, with an influence radius of approximately 100 metres. Newly constructed community may consider

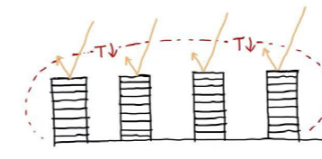
**Source:** Probst et al., 2022

#### Governance support:

**Implementation party:** government-led  
**Policy support:** revise UHAP, enhance minimum community garden size requirements into future planning  
**Funding:** Developer-funded  
**Maintenance party:** Government, community management

**Effectiveness rating(by designer):**  
**Feasibility rating(by resident):**

### D5 Reflective surface



**Limitation:**  
Higher installation cost compared to conventional permeable pavement;  
Requires specialist installation and maintenance

**Spatial conflict:**  
No specific conflict

#### Explanation:

Reflective surfaces absorb less solar radiation, reducing surface temperature and heat storage. Reflective paint offers a cost-effective implementation option but may cause unintended cooling in winter. Due to limited cooling effect when used alone, reflective pavement is recommended as a supplementary strategy combined with blue-green infrastructure.

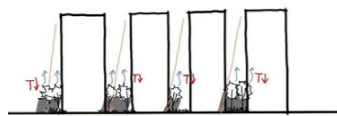
**Source:** (Probst et al., 2022)

#### Governance support:

**Implementation party:** government-led  
**Policy support:** revise NODRP and UHAP  
**Funding:** Government-funded  
**maintenance party:** Government, community management

**Effectiveness rating(by designer):**  
**Feasibility rating(by resident):**

### D4 Add pocket park into community



**Limitation:**  
Cooling effect is localised — limited influence beyond immediate park boundaries

**Spatial conflict:**  
May conflict with other demand if existing open space is repurposed

#### Explanation:

Pocket parks provide a practical solution for introducing green space in high-density urban areas. Their cooling effect is ranked as medium class, offering air temperature reductions of 1.4–3.07°C. Cooling performance is maximised when trees are concentrated at the centre with a tall, single-layer canopy structure, and when the park is located adjacent to buildings to benefit from combined shading effects.

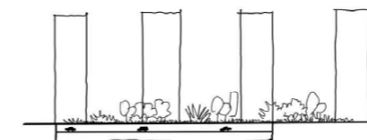
**Source:** Kumar et al., 2024

#### Governance support:

**Implementation party:** government-led  
**Policy support:** revise NODRP and UHAP  
**Funding:** Government-funded  
**Maintenance party:** Government, community management

**Effectiveness rating(by designer):**  
**Feasibility rating(by resident):**

### D6 Underground parking lot



**Limitation:**  
Extremely high construction cost;  
Technically unfeasible in high-density old residential districts;  
May increase community-management cost

**Spatial conflict:**  
May conflict with existing underground infrastructure including pipelines and drainage systems

#### Explanation:

Vehicles parked on surface lots are a significant source of anthropogenic heat through engine heat emission and solar heat absorption by car surfaces. Relocating surface parking underground frees ground-level space for green infrastructure, significantly increasing potential canopy coverage and reducing overall community heat load.

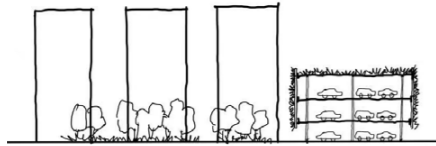
**Source:**

#### Governance support:

**Implementation party:** government-led  
**Policy support:** revise NODRP and UHAP  
**Funding:** Government-funded  
**maintenance party:** Government, community management

**Effectiveness rating(by designer):**  
**Feasibility rating(by resident):**

### D7 Parking garages



#### Limitation:

Requires sufficient adjacent land for garage footprint  
High construction cost, though significantly lower than underground parking

#### Spatial conflict:

Requires available land adjacent to or within the community

#### Explanation:

Multi-storey parking garages consolidate surface parking into a vertical structure, freeing ground-level space for green infrastructure and reducing the heat-absorbing impervious surface area. Unlike underground parking, above-ground parking garages are technically more feasible in existing communities. The garage structure itself can also incorporate green facades or rooftop greening to partially mitigate its own heat contribution.

#### Source:

#### Governance support:

**Implementation party:** government-led

**policy support:** revise NODRP and UHAP

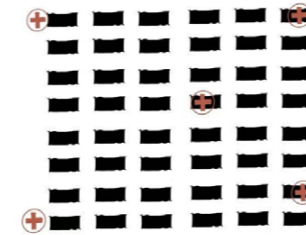
**Funding:** Government-funded

**maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

### A2 More Medical Care Spot



#### Limitation:

High construction and management cost

#### Spatial conflict:

Requires available indoor space within the community, which is scarce in high-density old community

#### Explanation:

Extreme heat significantly increases health risks for elderly residents and those with pre-existing conditions, raising the incidence of heat exhaustion, heat stroke, and cardiovascular complications. Adequate community-level medical facilities within walking distance are therefore critical. Communities with higher concentrations of vulnerable residents require strengthened emergency response capacity and regular heat-related health training to enhance adaptive capacity during heatwaves.

**Source:** (Wu et al., 2025)

#### Governance support:

**Implementation party:** government-led, community-led  
**policy support:** Enhance "15-minute medical service circle" policy framework, integrate heat emergency protocols into existing community health planning standards

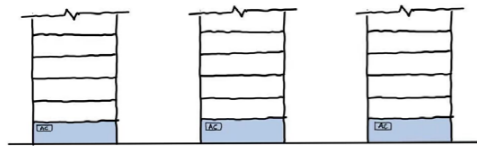
**Funding:** Government-funded

**maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

### A1 Air-Conditioned Community Cooling Space



#### Limitation:

High construction and management cost

#### Spatial conflict:

Requires available indoor space within the community, which is scarce in high-density old community

#### Explanation:

Air-conditioned community spaces provide critical heat refuge for residents who cannot afford to operate it during extreme heat periods. Small, distributed cooling spaces within walking distance are preferred over single large facilities, as distance is the primary barrier to access for elderly and mobility-limited residents. Beyond thermal relief, such spaces encourage social interaction and reduce isolation among vulnerable populations.

**Source:** Resident demand

#### Governance support:

**Implementation party:** government-led, community-led

**policy support:** revise NODRP and UHAP

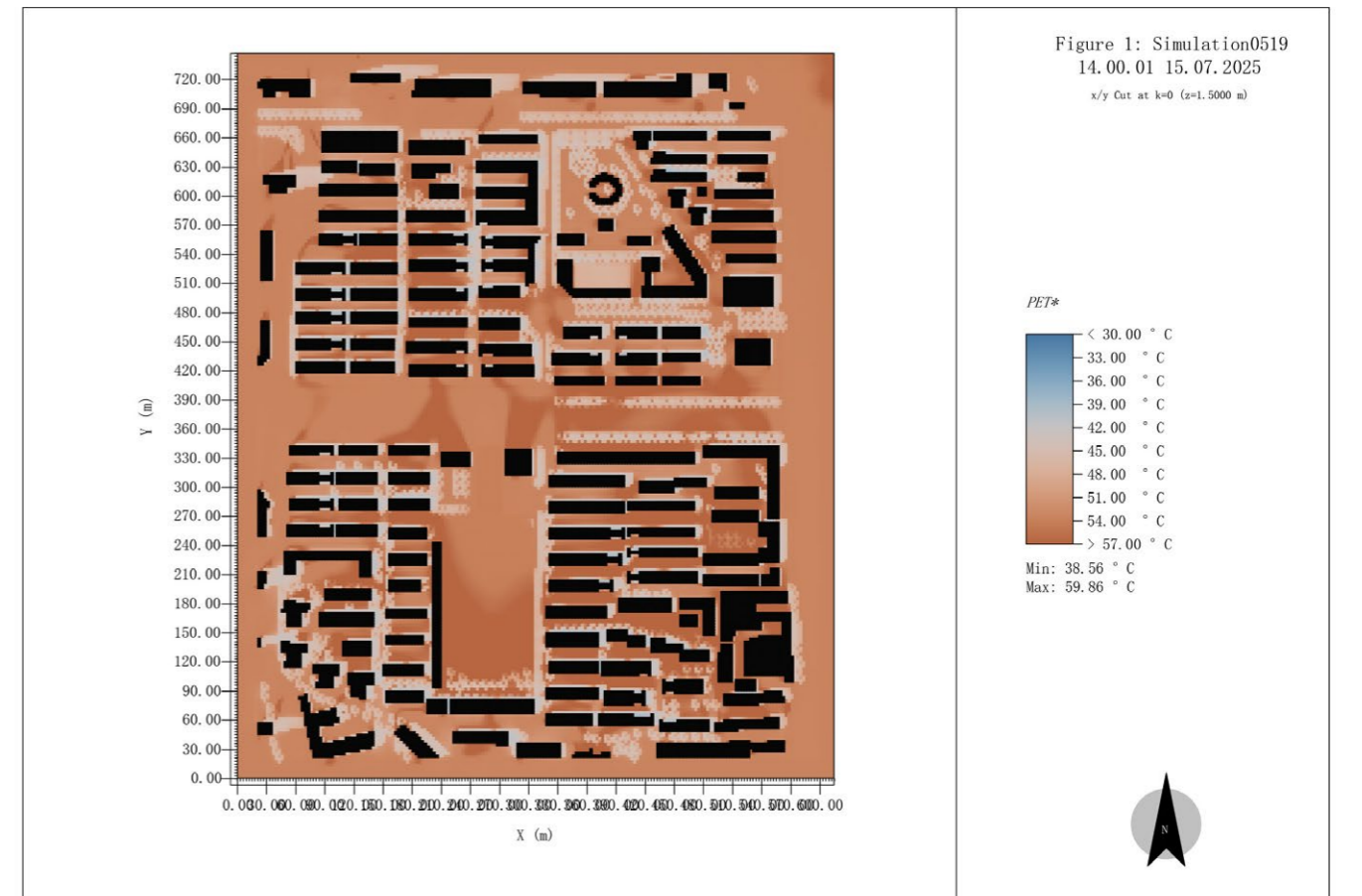
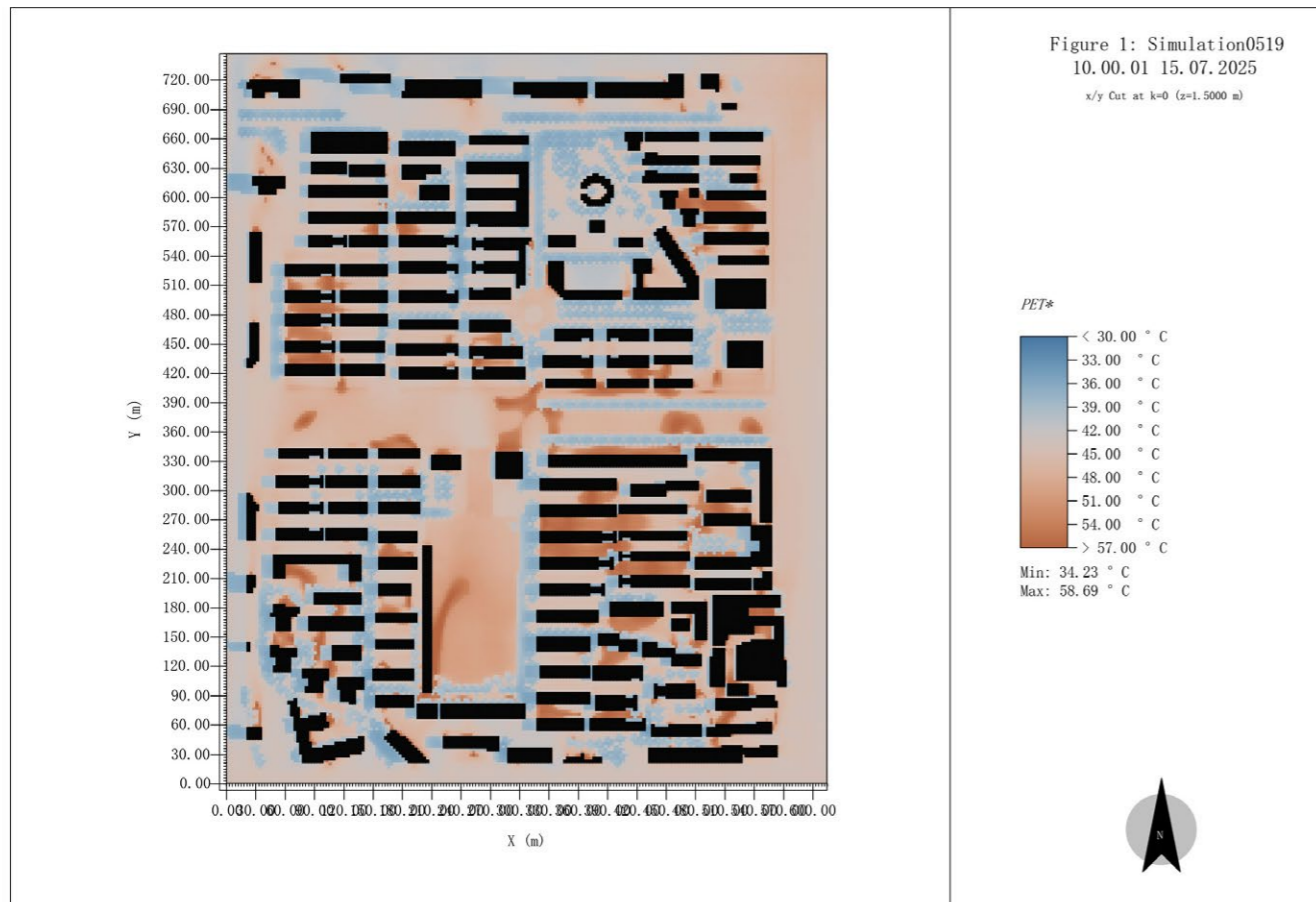
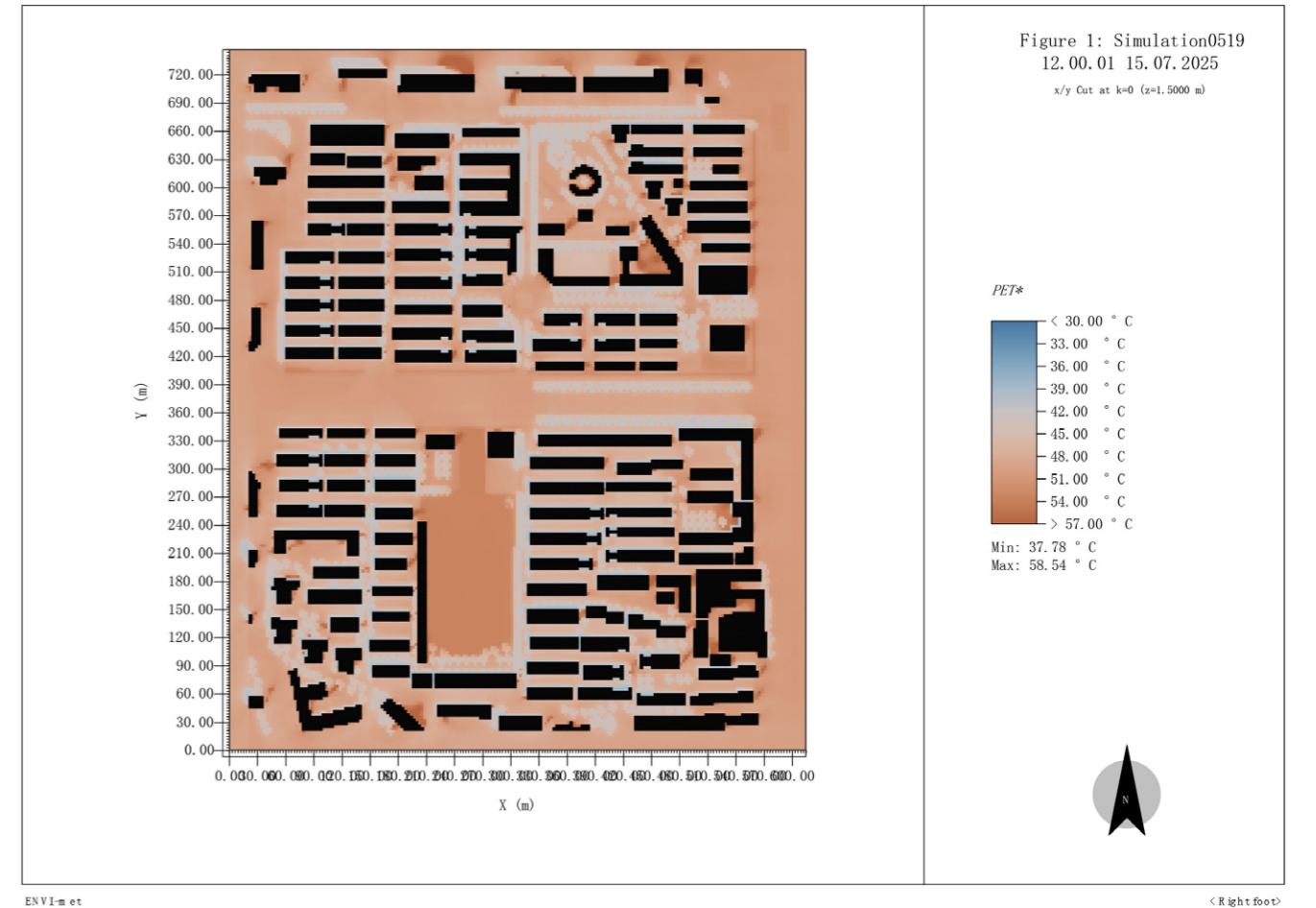
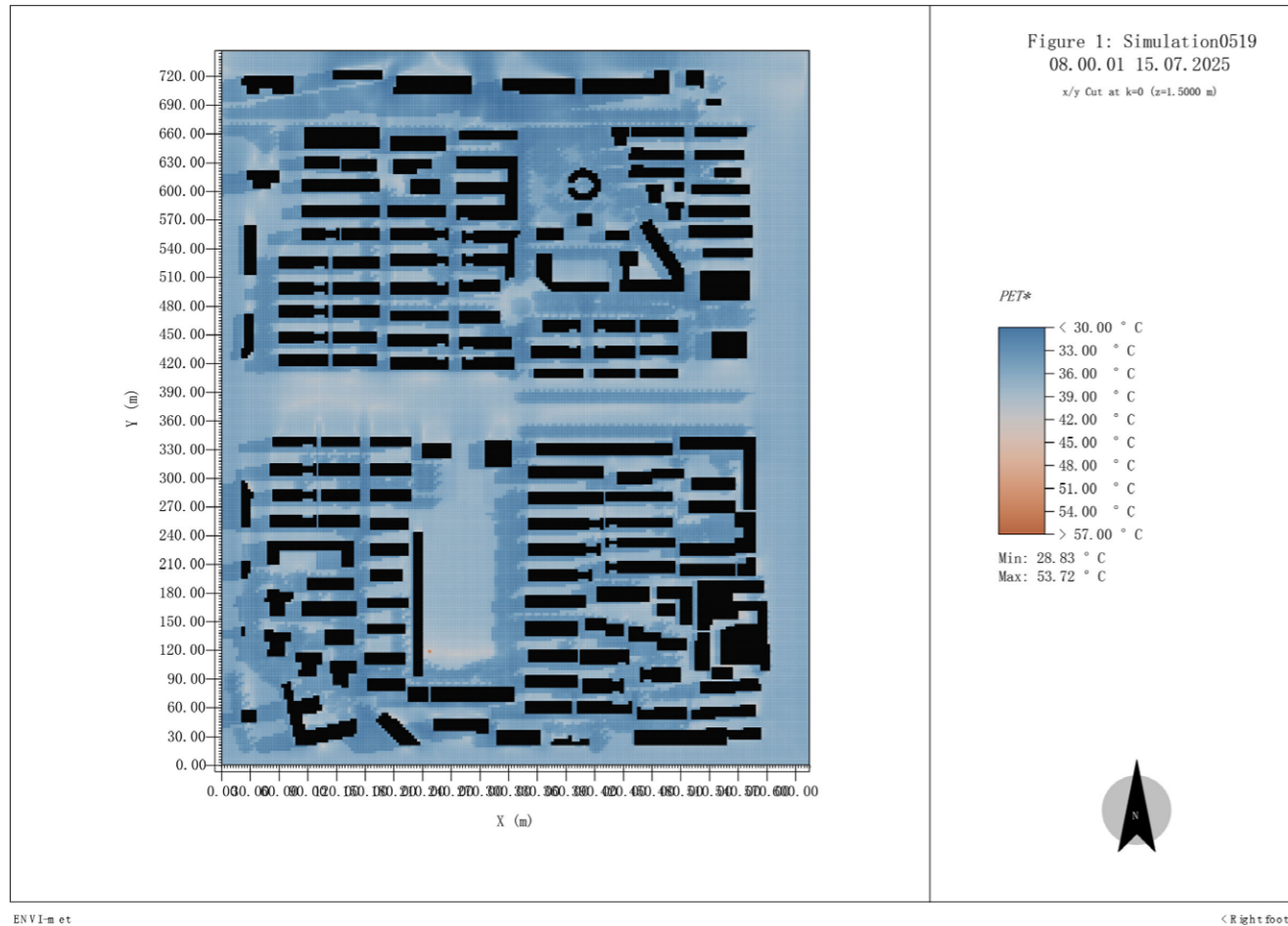
**Funding:** Government-funded,

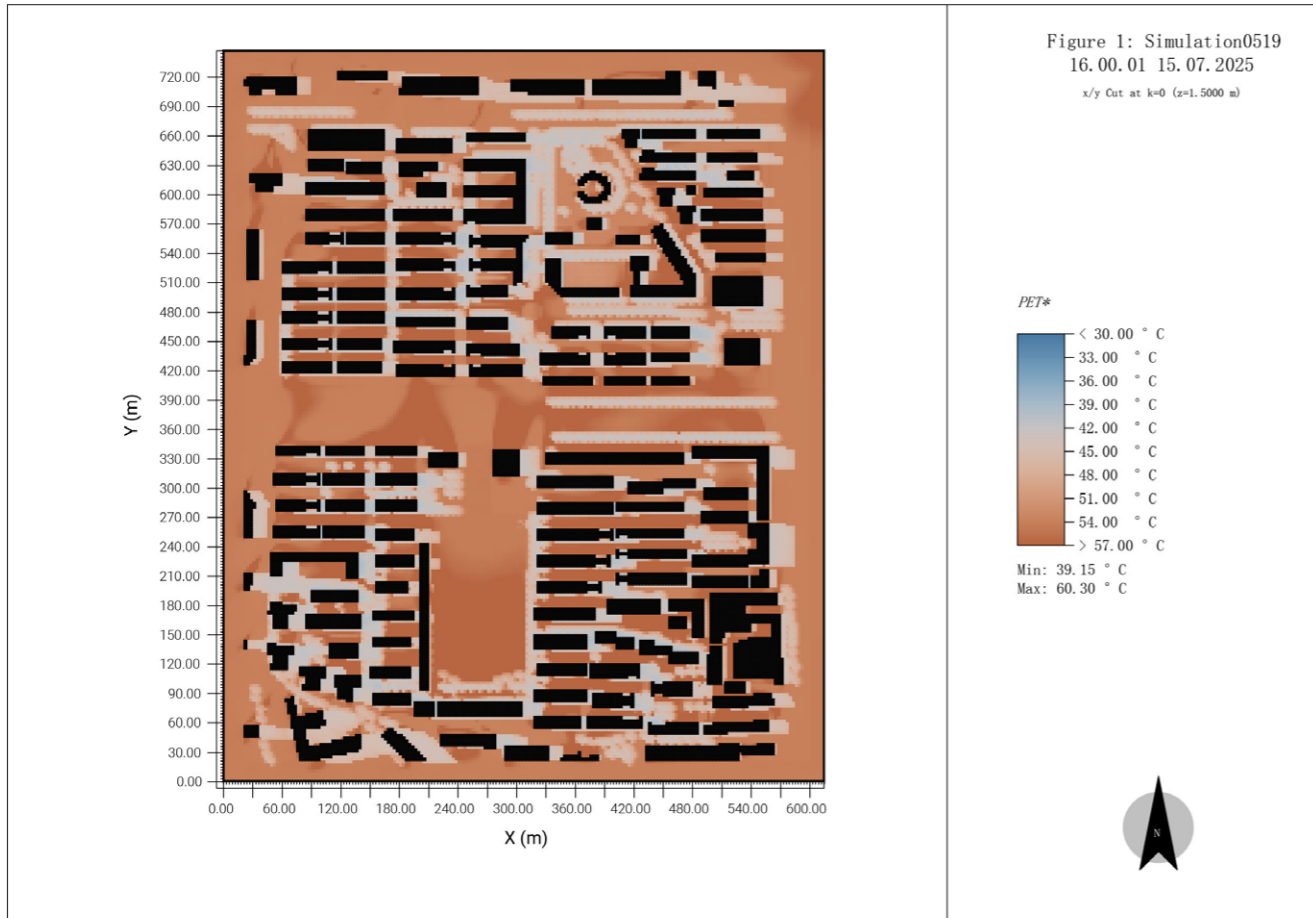
**maintenance party:** Government, community management

**Effectiveness rating(by designer):**

**Feasibility rating(by resident):**

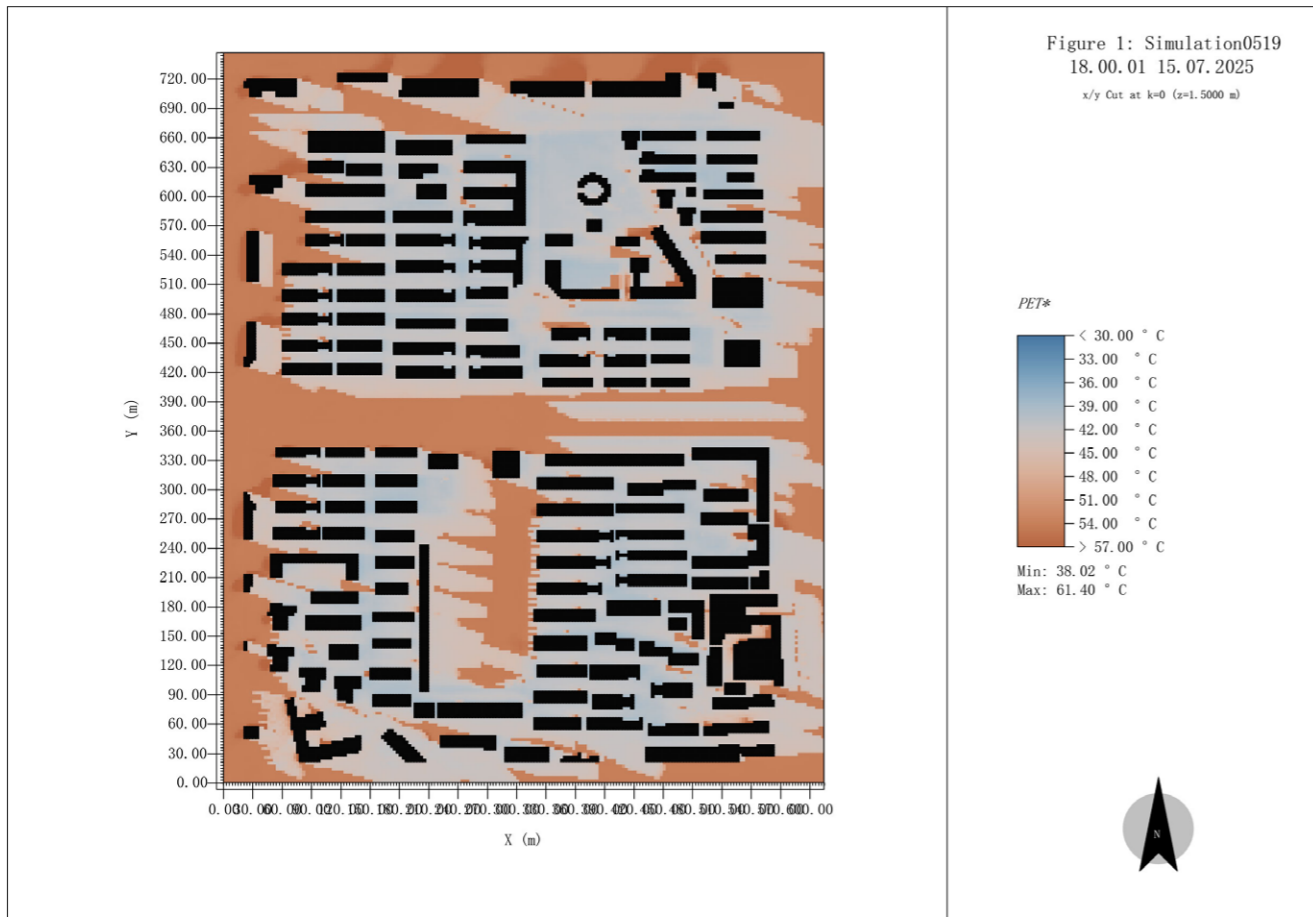
# Simulation of Intervention





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