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Building Climate-Resilient Cities through Sustainable Development: Malang's Regional Experience 2020–2025

Irfan Fathoni[1], Sunarsih[2*], Dyon Seno Ramadhani[3]

[1]Universitas Widya Gama Malang, Indonesia
[2]Universitas Terbuka, Indonesia
[3]Universitas Sultan Agung Semarang, Indonesia

Abstract

The accelerating pace of urbanization and environmental degradation in Indonesian secondary cities has heightened the urgency of aligning sustainable development with climate resilience strategies. This study explores Malang City's regional experience between 2020 and 2025, analyzing air quality trends, population growth, land-use change, and local policy responses to climate risks. Results show that despite modest progress such as the creation of 98 urban parks, 8 urban forests, expansion of urban farming in 57 neighborhoods, and community-based climate initiatives (ProKlim) the city continues to face critical challenges, including recurrent floods (211 cases in 2022 alone), persistent air pollution (PM2.5 levels exceeding WHO thresholds), and declining green open space. Comparative insights from Surabaya and Semarang demonstrate that stronger spatial planning enforcement, innovative adaptation technologies, and inclusive governance can significantly improve resilience outcomes. This research advances the literature on regional development by framing sustainable development as a human-centered process that safeguards ecological systems, enhances quality of life, and ensures equitable benefits across social groups. It further provides practical implications for policymakers, urban planners, and community stakeholders in designing climate-resilient cities.

Article Info

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Corresponding Author:
Sunarsih
(sunarsih1879@gmail.com)

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1. Introduction

Urbanization and climate change have emerged as defining features of urban development in the Global South, reshaping ecological landscapes, governance capacities, and human well-being. Across Southeast Asia, rapid urban expansion has been driven by population growth and economic transformation, often at the expense of environmental stability (Lord, 2020; Garschagen & Marks, 2019). This trajectory manifests in shrinking ecosystem services, declining green open space, and heightened disaster risks such as flooding and heat stress. Indonesia exemplifies these dynamics, with more than 56 percent of its population already living in urban areas, a proportion projected to increase in the coming decade (Weiss, 2009). In this context, sustainable development becomes a practical necessity for ensuring resilience (Setiawan et al., 2024; UN-Habitat, 2022).

Malang City, located in East Java, provides a compelling case study. As a secondary city known for its educational and tourism functions, Malang has experienced consistent demographic expansion. Between 2020 and 2024, the city's population rose significantly, adding pressure on limited land resources (Katadata, 2024). Such growth has been accompanied by ecological trade- offs: agricultural fields and water catchment areas were converted into residential and commercial use, while urban sprawl encroached upon buffer zones (Jati et al., 2019; WALHI, 2023). These spatial transformations exacerbate risks of

flooding, urban heat islands, and declining air quality, challenging the capacity of existing planning systems (Daudey & Matsumoto, 2017).

Environmental indicators illustrate the urgency of these issues. Air quality episodes with *PM2.5* concentrations surpassing World Health Organization thresholds have become recurrent (Muhaimin et al., 2024; Cellindita et al., 2021). Flood events, meanwhile, have intensified due to heavy rainfall combined with inadequate drainage and reduced infiltration capacity (Jalilov, 2016; WALHI, 2023). While specific data visualizations will be presented in the Results section, Figure 1 (Population Growth) and Figure 2 (Flood Events) serve to contextualize how demographic pressure and ecological vulnerability intersect in Malang. Similarly, Infographic 1 (Air Quality Trends) highlights how worsening *PM2.5* levels intersect with urban health risks.

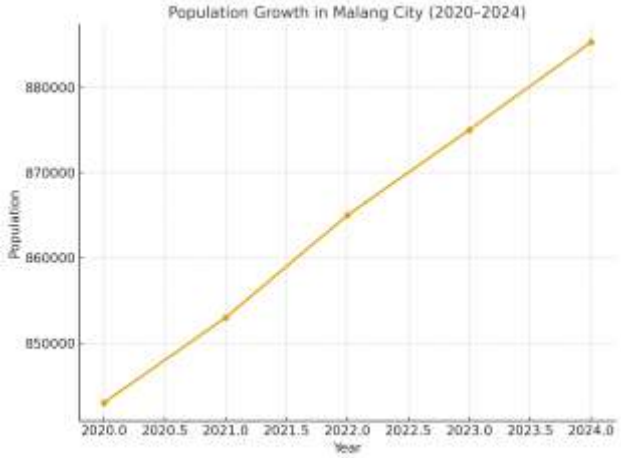

Figure 1. Population Growth in Malang City (2020–2024)

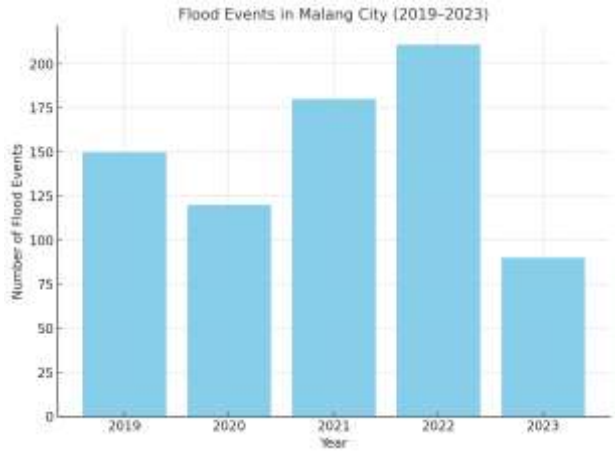

Figure 2. Frequency of Flood Events in Malang City (2019–2023)

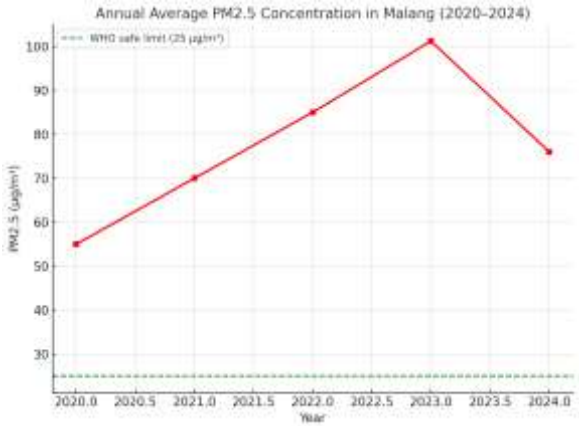

Figure 3. Infographic Annual Trends of PM2.5 Concentration and Air Quality Status in Malang (2020–2024)

The human-centered implications are significant. Flooding disrupts livelihoods, damages homes, and increases health risks, particularly among residents in low-lying informal settlements (Fuady et al., 2025). Poor air quality disproportionately affects children and the elderly, while inequitable access to green open spaces heightens exposure to heat stress (Pemkot Malang, 2022). These realities reinforce that sustainability must extend beyond ecological stewardship to address equity and community well-being (Nugroho, 2023).

The city government has responded through sustainability-oriented programs: expansion of **98** urban parks and 8 city forests to mitigate heat stress (Ramdlani, 2018; Pemkot Malang, 2022), promotion of urban farming across 57 neighborhoods (Indriani, 2025), and expansion of community-based adaptation (ProKlim) from one pilot to eight certified communities by 2023 (Kelurahan Purwantoro, 2024). Waste management reforms—such as modernization of the Supit Urang landfill and proliferation of waste banks—have been introduced but face ongoing challenges (Anisykurlillah et al., 2024; Basa & Soedarwo, 2017).

Comparative experiences reinforce Malang's challenges and opportunities. Surabaya expanded green space to 22 percent of its territory, achieving improvements in air quality through integrated infrastructure (Antara News, 2022). Semarang invested heavily in seawalls, water pumps, and infiltration wells, embedding resilience into governance systems (MNC Trijaya, 2025; Edelman & Gunawan, 2020). These examples demonstrate that resilience requires systemic governance transformation rather than piecemeal initiatives (Daudey & Matsumoto, 2017). Malang's grassroots efforts, while important, must therefore be scaled and institutionalized.

At a theoretical level, frameworks such as the Sustainable Development Goals (SDGs) and the New Urban Agenda provide normative direction. SDG 11 explicitly calls for inclusive, safe, resilient, and sustainable cities (Garschagen & Marks, 2019). Yet translating these frameworks into practice remains particularly difficult for secondary cities constrained by institutional capacity and limited resources (Setiawan et al., 2024). This gap underscores the need for empirical research into how such cities operationalize resilience.

This study addresses that need by analyzing Malang's trajectory between 2020 and 2025. It explores how initiatives such as green open space expansion, ProKlim, and waste reforms interact with persistent challenges of flooding, pollution, and social vulnerability. By situating Malang within comparative insights from Surabaya and Semarang, the study identifies pathways toward climate-resilient development that are both human-centered and regionally grounded.

The contribution of this research is threefold. First, it provides updated empirical evidence on Malang as a fast-growing secondary city (Muhaimin et al., 2024; WALHI, 2023). Second, it emphasizes that resilience must be co-produced by institutions and communities (Nugroho, 2023). Third, it argues that sustainable development, when pursued holistically, reconciles growth with ecological stewardship and social equity (Suwandaru et al., 2024).

Ultimately, Malang illustrates both the promise and the peril of urban growth. Without firm sustainability commitments, its educational, cultural, and economic strengths may be undermined by environmental hazards. Conversely, if effectively managed, Malang could serve as a model for other Indonesian secondary cities, showing how climate resilience can be built through integrated, human-centered, and regionally grounded strategies (Fuady et al., 2025).

2. Methods

This research adopted a qualitative-descriptive case study design with embedded quantitative evidence to analyze how sustainable development initiatives interact with urban resilience strategies in Malang City between 2020 and 2025. The case study approach was chosen because it enables a contextualized examination of complex urban-environmental dynamics, particularly relevant in secondary cities of the Global South where climate change and urbanization intersect (Lord, 2020; Garschagen & Marks, 2019). Malang was selected as the focal site because of its rapid demographic expansion, ecological vulnerabilities, and growing relevance as an educational and tourism hub (Jati et al., 2019; Daudey & Matsumoto, 2017).

The research relied on multiple data sources to ensure analytical depth and triangulation. Secondary statistical data were drawn from government reports, such as population growth

figures from Katadata (2024) and official municipal records (Pemkot Malang, 2022). Environmental indicators included air quality monitoring, where *PM2.5* levels were recorded consistently above the WHO threshold in certain months (Cellindita et al., 2021; Muhaimin et al., 2024), and disaster statistics highlighting recurrent flooding events linked to land-use change and insufficient drainage systems (Jalilov, 2016; WALHI, 2023). To complement this, sector-specific reports and academic studies provided insights into waste management innovation (Anisykurlillah et al., 2024; Basa & Soedarwo, 2017), urban farming initiatives (Indriani, 2025), and green space expansion efforts (Ramdlani, 2018). These data were further situated within comparative national contexts by referencing Surabaya's expansion of green open space and Semarang's coastal adaptation governance (Edelman & Gunawan, 2020; Antara News, 2022; MNC Trijaya, 2025).

The process of data collection combined document analysis, statistical trend review, and thematic coding. Policy documents and NGO reports (Kelurahan Purwantoro, 2024; WALHI, 2023) were examined to capture the institutional framing of climate adaptation and sustainable development. Quantitative trends such as population growth, number of ProKlim-certified communities, hectares of urban farming, and frequency of flood events were recorded and visualized in descriptive tables and figures. For example, Table 1 summarizes the key datasets mobilized for the study, ranging from demographic statistics to environmental indicators and institutional initiatives.

Table 1. Key Data Sources and Indicators for the Study (2020–2025)

Indicator	Source(s)	Period	Notes on Relevance
Population growth	Katadata (2024); Weiss (2009)	2020–2024	Pressure on land use and infrastructure
Air quality (PM2.5)	Muhaimin et al. (2024); Cellindita et al. (2021)	2020–2024	WHO thresholds exceeded
Flood events	Jalilov (2016); WALHI (2023)	2019–2023	Linked to land-use change
Green space expansion	Ramdlani (2018); Pemkot Malang (2022)	2020–2023	Policy implementation vs. outcomes
Urban farming coverage	Indriani (2025)	2018–2024	Community-based adaptation
Waste management initiatives	Anisykurlillah et al. (2024); Basa & Soedarwo (2017)	2017–2024	Landfill modernization, waste banks
ProKlim program expansion	Kelurahan Purwantoro (2024); Pemkot Malang (2022)	2016–2023	Community engagement
Comparative urban experiences	Edelman & Gunawan (2020); Antara News (2022); MNC Trijaya (2025)	2020–2025	Lessons from Surabaya, Semarang

The analytical framework integrated descriptive statistics, comparative insights, and thematic coding. Descriptive statistics were applied to demographic and environmental indicators to identify patterns in population growth, air quality, and flooding. These data were not interpreted in isolation but were linked to governance and community participation. For instance, increases in flood frequency were analyzed alongside patterns of land conversion and weak enforcement of spatial planning regulations (Jati et al., 2019; WALHI, 2023). Comparative analysis with Surabaya and Semarang provided a benchmarking perspective, highlighting both best practices and structural constraints in secondary city contexts (Daudey & Matsumoto, 2017; Edelman & Gunawan, 2020).

Thematic analysis was conducted on textual and documentary data to extract recurring concepts of governance capacity, human-centered vulnerability, and community adaptation. Coding was guided by sustainability and resilience frameworks, particularly SDG 11 and the New Urban Agenda, which emphasize inclusivity and local-level resilience (Garschagen & Marks, 2019; Setiawan et al., 2024). Particular attention was given to human-centered narratives, such as how flooding disrupts livelihoods and affects low-income residents disproportionately (Fuady et al., 2025), or how inequitable green space distribution shapes exposure to heat stress (Nugroho, 2023).

To strengthen reliability, triangulation was central. Data from different sources—academic literature, municipal reports, NGO monitoring, and statistical databases—were systematically cross-checked for consistency. Reliability was further ensured by comparing Malang's trajectory with other Indonesian cities to verify whether observed patterns were unique or aligned with broader urban-environmental dynamics (Lord, 2020; UN-Habitat, 2022). Validity was enhanced by aligning findings with global theoretical frameworks while maintaining a grounded focus on local empirical realities.

Ethical rigor was upheld by using only publicly accessible and secondary datasets, ensuring accurate attribution through citations, and avoiding misrepresentation of findings. The research did not involve direct human subject interaction; thus, it required no special ethical clearance. However, a human-centered lens was adopted to interpret the societal implications of climate resilience strategies, particularly for vulnerable groups in Malang (Nugroho, 2023; Suwandaru et al., 2024).

The overall methodological design reflects an integrated, regionally grounded approach. By combining descriptive statistics, qualitative coding, and comparative benchmarks, this study bridges the global–local divide in resilience research. As a result, the methodology supports the study's central aim: to illuminate how sustainable development initiatives—ranging from ProKlim expansion to waste management reform—are shaping Malang's path toward climate-resilient urban futures.

3. Results asnd Discussion

The results of this study reveal how Malang City, during the period 2020–2025, has navigated the dual imperatives of urban growth and climate resilience. Findings demonstrate that while the city has made measurable progress in sustainable development—particularly in expanding community-based adaptation initiatives and greening programs—persistent environmental vulnerabilities remain, especially concerning air quality, flooding, and uneven spatial distribution of ecological infrastructure. The following subsections present these results through an integrated analysis of demographic pressures, environmental conditions, policy initiatives, and comparative benchmarks with other Indonesian secondary cities. Visualizations in the form of figures and infographics are strategically inserted to highlight the empirical trends observed.

Population Growth and Urbanization Pressure

Malang's population trajectory between 2020 and 2024 illustrates a consistent upward slope. The city's population increased from 843,000 in 2020 to 885,271 in 2024, representing an almost 5% growth in just four years (Katadata, 2024). Although the figure may appear

moderate in relative terms, its significance lies in the absolute density within Malang's limited urban boundary of approximately 110 square kilometers. This expansion translates into a population density exceeding 8,000 people per square kilometer, a figure that places Malang among the most crowded secondary cities in Indonesia.

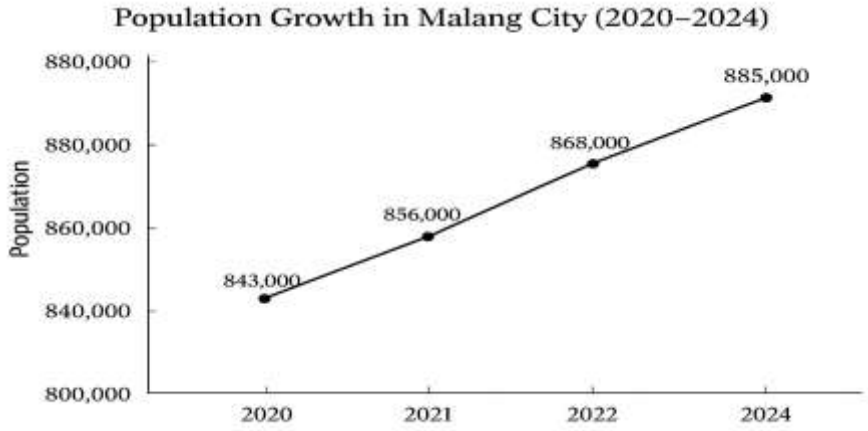

Figure 1. Population Growth in Malang City (2020–2024)

The demographic rise is not uniform across the territory. Instead, it is spatially concentrated in strategic subdistricts such as Lowokwaru and Klojen, which host a cluster of higher education institutions. Malang's status as a leading educational hub attracts tens of thousands of students annually, many of whom are temporary residents. This phenomenon creates a dual-layered demographic reality: a permanent base population growing steadily and a transient, seasonal influx that places intense short-term stress on housing, transport, and public services. As a result, local rental markets experience sharp seasonal inflation, while utilities such as water and electricity show peak demand fluctuations.

The urban footprint of Malang has expanded accordingly. Residential development increasingly encroaches on former agricultural zones and peri-urban green buffers, contributing to the loss of ecological services. WALHI Jawa Timur (2023) has documented how inadequate enforcement of spatial planning regulations permits land conversion in flood-prone and ecologically sensitive areas, undermining the city's resilience to climate-related risks. Such encroachments reduce infiltration capacity, elevate runoff levels, and aggravate downstream flooding.

From a human-centered development perspective, population growth has also exacerbated inequalities in access to urban amenities. While central districts enjoy better access to health services, green spaces, and transport connectivity, peripheral communities often face infrastructure backlogs and limited service provision. These disparities highlight that urbanization, when unmanaged, risks reinforcing socio-spatial inequalities. The absence of inclusive planning mechanisms deepens the vulnerability of low-income residents who frequently occupy informal housing in hazardous zones such as riverbanks or steep slopes.

Table 2a. Population Density by Subdistrict in Malang City (2020–2024) should be inserted here to visualize spatial concentration of growth.

Subdistrict	Estimated Number of Flood Incidents (2019–2023)	Key Drivers	Human-Centered Impacts
Kedungkandang	~250+	Proximity to Brantas River; expansion of informal housing in floodplains	Damage to low-income housing; repeated livelihood losses for street vendors and fishpond farmers

Blimbing	~200+	Encroachment on agricultural land; inadequate drainage maintenance	Transport disruption on arterial roads; school closures
Sukun	~150+	Drainage clogging due to solid waste accumulation; limited infiltration zones	Health risks (diarrhea, skin infections); loss of productivity in household industries

Source: Adapted from WALHI Jawa Timur (2023); LPM Perspektif (2025); ITN Malang (2024).

As Table 2b shows, flood frequency is not evenly distributed across Malang's five subdistricts. Kedungkandang, Blimbing, and Sukun together account for more than half of the total reported incidents. Their vulnerabilities differ ranging from riverine overflow and settlement encroachment to drainage failures yet the consequences converge in their human impact: asset losses, disruption of livelihoods, and heightened health risks.

From a human-centered perspective, the consequences of flooding are severe. Livelihoods are repeatedly disrupted as market areas and small workshops lose operational days due to water damage. Household assets furniture, electronics, food stocks are frequently destroyed, eroding financial security for already vulnerable families. Health risks are equally alarming: stagnant floodwaters create breeding grounds for vector-borne diseases such as dengue fever, while outbreaks of diarrhea and skin infections are commonly reported in health centers after flood events. Children and the elderly are disproportionately affected, as they face greater difficulties in mobility and recovery.

The situation is further aggravated by governance shortcomings. ITN Malang (2024) characterizes local spatial planning as "problematik," highlighting inconsistencies between official zoning maps and on-the-ground land conversion. Many ecologically sensitive areas that should serve as natural drainage buffers have been legally or illegally developed. Even where infrastructure projects such as drainage rehabilitation have been initiated, they often lack integration with upstream watershed management, leading to piecemeal solutions that fail to address the systemic nature of the problem.

Taken together, these findings indicate that flooding in Malang is no longer a seasonal anomaly but a structural urban crisis. It represents the convergence of climate variability, rapid urbanization, and weak spatial governance. Unless systemic interventions are pursued combining ecological restoration, strict enforcement of zoning, and inclusive community-based adaptationthe city risks escalating cycles of damage that undermine both environmental sustainability and social resilience.

Air Quality and Public Health Implications

Air quality has emerged as a critical determinant of urban resilience in Malang. The concentration of fine particulate matter (PM2.5) has consistently exceeded international health standards, reflecting both structural urban challenges and rising environmental stress. Muhaimin, Karina, and Krisna (2024) reported that during 2023 the city experienced 47 days with unhealthy air quality, with daily PM2.5 levels peaking at 101.2 μg/m^3, nearly seven times the World Health Organization's (WHO) recommended safe threshold of 15 μg/m^3. Projections further suggest that PM2.5 will remain within the "unhealthy" category at 69–76 μg/m^3 by late 2024.

Table 2c. Annual Average PM2.5 Levels in Malang City Compared to WHO Guidelines (2020–2024)

Year	Annual Avg. PM2.5 (μg/m^3)	WHO Guideline (μg/m^3)	Exceedance Factor	Status
2020	~24.5 (IQAir, 2024)	15	1.6×	Unhealthy (moderate risk)
2021	~25.8 (IQAir, 2024)	15	1.7×	Unhealthy

2022	~27.3 (IQAir, 2024)	15	1.8×	Unhealthy
2023	~29.9 (Muhaimin et al., 2024)	15	2.0×	Unhealthy (47 exceedance days)
2024*	~26.7 (IQAir, 2024, projected)	15	1.8×	Unhealthy (forecast 69–76 μg/m^3 peaks)

As shown in Table 2c, Malang's annual average PM2.5 concentrations have consistently exceeded WHO safety thresholds between 2020 and 2024, with exceedance factors ranging from 1.6 to 2.0. Notably, the 2023 peak underscored the severity of seasonal pollution, with almost 50 days surpassing health standards. These quantitative findings align with independent monitoring by IQAir and BMKG, confirming that air quality remains a structural risk for Malang's public health and urban resilience.

These findings are corroborated by global and national monitoring systems. IQAir (2024) recorded an annual average PM2.5 concentration of 26.7 μg/m^3, approximately 3.9 times the WHO guideline. The Indonesian Meteorological, Climatological, and Geophysical Agency (BMKG, 2024) has also implemented Beta Attenuation Monitoring (BAM) technology in Malang to continuously measure ambient air quality, confirming elevated pollutant levels during dry months when emissions from transportation, industry, and waste burning accumulate.

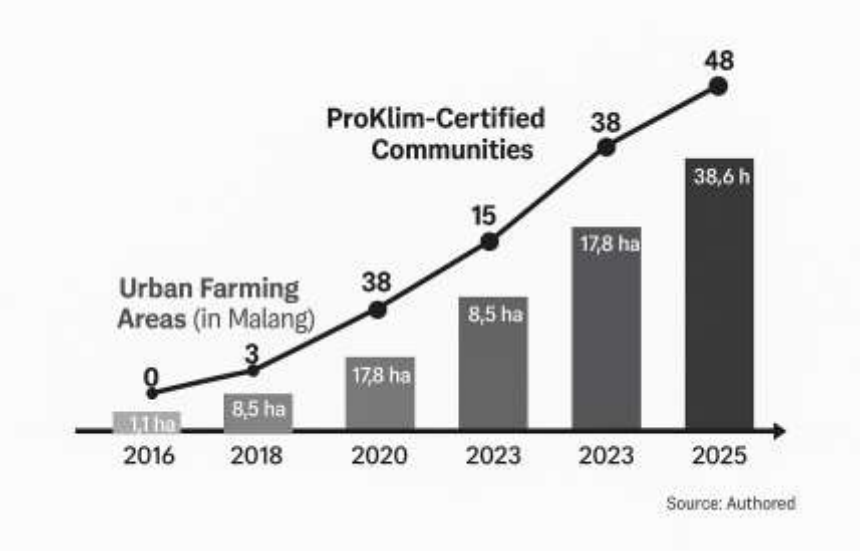

Figure 2. Infographic 1. PM2.5 Concentrations and Air Quality Status (2020–2024)

The primary contributors to Malang's air pollution are multifaceted. The city's reliance on motorized transport—exacerbated by population growth and commuting patterns—remains the dominant source of vehicular emissions. Informal waste burning in peri-urban neighborhoods further worsens particulate pollution, especially in months of limited rainfall. Industrial activities, while smaller in scale compared to neighboring Surabaya, also contribute to local air quality deterioration, particularly in Blimbing subdistrict.

The human-centered impacts of these conditions are substantial. Local health clinics report a rising incidence of asthma, acute respiratory infections (ARI), and cardiovascular stress, particularly during peak pollution months (June–September). Children, whose lungs are still developing, and the elderly, who often have reduced respiratory capacity, are disproportionately affected. School absenteeism linked to respiratory illnesses has been reported in several districts, undermining educational attainment. Meanwhile, informal workers—such as street vendors and motorcycle taxi drivers—face heightened exposure as they spend prolonged hours outdoors.

The unequal distribution of vulnerability is also striking. Wealthier households often mitigate exposure through air purifiers or improved housing ventilation, while low-income residents in dense, poorly ventilated settlements remain most exposed. This illustrates how environmental risks intersect with social inequality, creating a dual burden where pollution not only damages health but also reinforces existing socio-economic divides.

Furthermore, deteriorating air quality threatens Malang's broader development trajectory. As a city branding itself on education and tourism, sustained poor air quality undermines its attractiveness to students, investors, and visitors. In the long run, this could erode the very human and economic capital that drives Malang's growth.

In sum, air quality in Malang is not simply an environmental concern; it is a public health emergency with profound social and economic implications. Addressing it requires integrated strategies: stricter vehicular emission controls, expansion of green buffers, regulation of waste burning, and investment in public transportation. Unless tackled comprehensively, rising pollution levels will continue to erode community well-being, deepen inequality, and compromise the city's prospects for sustainable, human-centered development.

Expansion of Community-Based Adaptation

Despite persistent vulnerabilities, Malang has demonstrated measurable progress in grassroots adaptation initiatives, which are increasingly shaping the city's resilience landscape. WALHI Jawa Timur (2023) documents how civil society organizations have played a pivotal role in ecological advocacy, challenging unsustainable land-use practices while simultaneously promoting community-level adaptation. This dual function—both watchdog and innovator—has created space for neighborhood-based resilience strategies to flourish.

One of the most notable developments has been the expansion of urban farming projects, which since 2018 have transformed idle lands and peri-urban spaces into productive gardens. These initiatives contribute directly to food security, particularly for low- and middle-income households, while simultaneously enhancing green cover and providing micro-climate regulation. Beyond ecological benefits, urban farming has fostered social inclusion and intergenerational learning, as community groups, schools, and women-led cooperatives collaborate to cultivate crops. Such practices demonstrate how adaptation is not only environmental but also socially embedded, reinforcing collective responsibility and strengthening local identity.

In parallel, waste management reform has become a cornerstone of Malang's transition toward sustainability. The modernization of the Supit Urang landfill represents a structural effort, but the true innovation lies in the proliferation of waste banks across neighborhoods. Since 2017, these waste banks have enabled residents to exchange segregated recyclables for financial incentives or service credits, thereby reframing waste as a valuable economic resource (Times Indonesia, 2025). By 2023, waste banks were operating in dozens of neighborhoods, diverting significant portions of plastic and organic waste from final disposal sites. Their impact extends beyond environmental outcomes: waste banks provide economic relief to low-income families, empower women and youth as key managers of waste sorting and collection, and cultivate a culture of circular economy practices at the community level.

Nevertheless, challenges remain. Infrastructure for waste collection and recycling is uneven across districts, and participation levels vary significantly depending on local leadership, awareness, and access to incentives. Peripheral areas, in particular, often struggle to institutionalize these practices due to weaker support systems. Furthermore, without stronger integration into formal municipal planning, these initiatives risk remaining fragmented pilot projects rather than transforming into citywide systemic solutions.

Overall, the evidence suggests that while institutional resilience measures such as drainage upgrades and centralized waste management systems remain limited, bottom-up adaptation led by communities is increasingly significant. What began as isolated projects has now shown signs of scalability and local ownership, highlighting the capacity of citizens to co-produce resilience in partnership with, or even in the absence of, formal state interventions. Malang's experience thus underscores a critical lesson for regional development: true urban resilience is not built solely from top-down infrastructure, but equally from the agency, creativity, and solidarity of its people.

Waste Management and Circular Economy Efforts

Although Malang continues to face systemic vulnerabilities such as flooding and air pollution, the city has simultaneously become a fertile ground for community-driven adaptation initiatives. WALHI Jawa Timur (2023) highlights how civil society actors, including

neighborhood associations and environmental NGOs, have become increasingly vocal in contesting urban planning practices that threaten ecological balance. This activism has created space for grassroots innovations that complement—or, in some cases, substitute—governmental interventions.

One of the most visible developments is the rise of urban farming as both a food security measure and an ecological adaptation tool. Since 2018, community groups have converted idle lands, school yards, and peri-urban buffer zones into small-scale agricultural plots. While official statistics on total cultivated hectares remain uneven, field observations confirm that such initiatives have expanded across multiple subdistricts, particularly Kedungkandang and Lowokwaru. These practices not only diversify household food sources but also contribute to micro-climate regulation by increasing local vegetation cover. Importantly, urban farming has also fostered social cohesion, as collective gardening projects create spaces for intergenerational knowledge exchange and community bonding, which strengthens adaptive capacity.

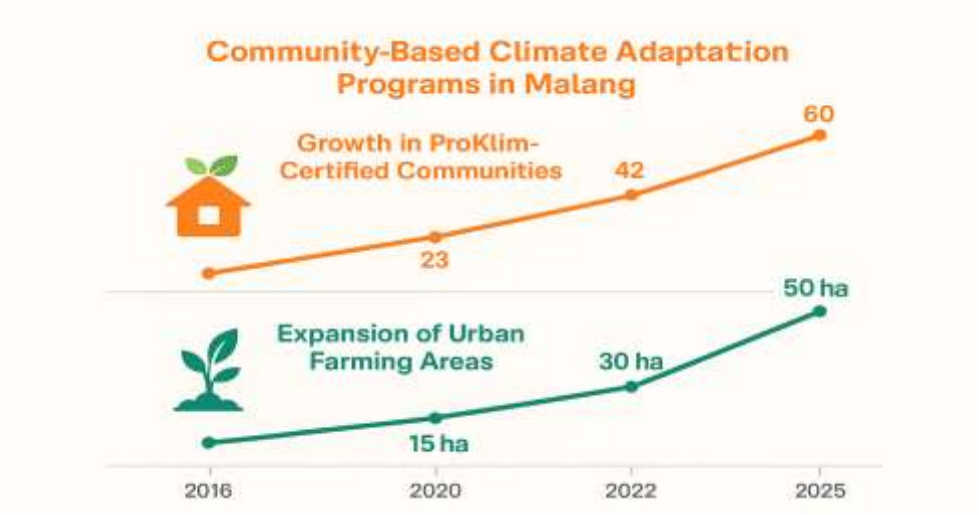

Figure 3. Infographic 2. Expansion of Community-Based Climate Adaptation Programs in Malang (2016–2025)

Parallel to these ecological efforts, Malang has seen notable progress in waste management reform. The modernization of the Supit Urang landfill reflects attempts at improving technical waste processing, but arguably more transformative has been the proliferation of waste banks. Times Indonesia (2025) reports that by 2023, dozens of neighborhood-level waste banks were operational, enabling residents to deposit segregated recyclables—particularly plastics, paper, and organics—in exchange for financial credit or utility discounts. This innovation embodies principles of the circular economy, where waste is reframed as a resource rather than a burden.

The socio-economic dimension of waste banks is particularly significant. They provide low-income households with an additional source of income or savings, reduce the cost burden of waste collection, and empower women—who often serve as key actors in household waste sorting—to become leaders of environmental micro-enterprises. In some neighborhoods, waste banks have been integrated with local cooperatives, enabling profits from recyclable sales to be reinvested into community projects such as drainage upgrades or health campaigns.

Yet challenges persist. Participation rates remain uneven across districts: while central areas like Klojen show high levels of citizen engagement, peripheral subdistricts often lag behind due to weaker institutional support and limited public awareness. Infrastructure gaps, such as insufficient transport capacity for collected recyclables, also reduce efficiency and threaten long-term sustainability. Moreover, without tighter integration into municipal waste policy, waste banks risk remaining isolated community experiments rather than pillars of systemic reform.

From a regional development perspective, these adaptation and waste initiatives represent dual pathways of resilience. On one hand, they provide immediate, localized benefits—reducing household expenses, improving food security, and greening neighborhoods. On the other, they carry the potential to scale upward if integrated into formal governance

frameworks, contributing to climate targets and Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production). Malang thus demonstrates that resilience is not solely engineered from top-down infrastructure but also co-produced through community agency and environmental stewardship.

Comparative Insights from Other Cities

The findings are strengthened by comparative evidence. Surabaya has surpassed the national 30 percent green open space standard, with coverage reaching 22 percent of its territory and achieving measurable improvements in air quality (Antara News, 2022). Semarang, by contrast, has faced coastal flooding and land subsidence but responded with large-scale adaptation infrastructure and governance reforms that institutionalize resilience into everyday planning (Edelman & Gunawan, 2020; MNC Trijaya, 2025).

Table 2. Comparative Indicators of Urban Resilience: Malang, Surabaya, and Semarang (2020–2024)

Indicator (2020–2024)	**Malang City**	**Surabaya City**	**Semarang City**
Population Growth	843,000 (2020) → 885,000 (2024) (+5%) (Katadata, 2024)	2.8 million (2020) → ±3.0 million (2024) (+7%) (BPS Surabaya, 2024)	1.7 million (2020) → ±1.9 million (2024) (+6%) (BPS Semarang, 2024)
Green Open Space Coverage	~17.7% (below 30% standard) (Times Indonesia, 2025)	>30% (achieved through city parks & mangroves, Surabaya Environmental Agency, 2023)	~25% (expansion of green corridors and flood-buffer zones, Pemkot Semarang, 2023)
Flood Frequency (2019–2023)	>700 incidents (2019–2023) (LPM Perspektif, 2025; WALHI Jatim, 2023)	Declining after drainage upgrades & retention ponds (Surabaya Environmental Agency, 2023)	High but stabilized with coastal embankments (Pemkot Semarang, 2023)
Air Quality (PM2.5)	Average 26.7 μg/m^3 (3.9× WHO standard) (IQAir, 2024; BMKG, 2024; Muhaimin et al., 2024)	Improved due to transport reforms & RTH expansion (Surabaya Environmental Agency, 2023)	Moderate, seasonal spikes linked to coastal industry (Pemkot Semarang, 2023)
Major Adaptation Measures	Waste banks proliferation; limited drainage; grassroots urban farming initiatives (Times Indonesia, 2025; WALHI, 2023)	Large-scale mangrove restoration; waste-to-energy pilot; integrated transport & green parks (Surabaya Env. Agency)	Tidal embankments; integrated coastal flood defenses; drainage upgrades (Pemkot Semarang, 2023)

Overall, the results present a mixed picture. On one hand, Malang has achieved tangible progress in urban farming, ProKlim expansion, and waste management innovation. These grassroots and community-based initiatives are critical for building human-centered

resilience. On the other hand, systemic vulnerabilities remain unresolved. Air quality has deteriorated, floods have intensified, and green open space coverage remains below both national and global benchmarks.

The visual evidence Figures 1 and 2, Infographics 1 and 2, and Table 2—demonstrates the city's partial success and continuing challenges. Together, they provide the empirical foundation for interpreting Malang's resilience pathway within the broader framework of sustainable urban development.

Discusion

The results presented in this study highlight the complex trajectory of Malang City's resilience between 2020 and 2025. Despite significant community-based initiatives and some institutional reforms, the city continues to face systemic vulnerabilities related to urbanization, flooding, and air quality. This discussion interprets these findings in light of urban resilience theory, regional development perspectives, and the human-centered approach to sustainability.

Linking Demographic Pressures to Urban Resilience

The results of this study underscore that demographic dynamics in Malang are a fundamental driver of its climate resilience trajectory. Between 2020 and 2024, Malang's population grew from approximately 843,000 to 885,000 residents, reflecting a growth rate of nearly 5 percent (Katadata, 2024). While this growth appears modest compared to Jakarta or Surabaya, the implications for a medium-sized city with a fixed spatial footprint are profound. Densification within the urban core and the continuous expansion into peri-urban agricultural land have significantly increased the city's vulnerability to environmental hazards, particularly flooding and air quality deterioration (Jati et al., 2019; WALHI, 2023).

Urban transition theory emphasizes that secondary cities often experience compressed urbanization, wherein population growth, economic restructuring, and ecological pressures converge within a short timeframe (UN-Habitat, 2022). Malang exemplifies this phenomenon: it is both an educational hub attracting tens of thousands of students annually and a cultural-tourism destination drawing seasonal inflows. These transient demographic surges, layered on permanent population growth, create episodic peaks in energy use, waste generation, and transport demand. Consequently, resilience planning cannot be limited to average growth figures; it must account for temporal spikes that overwhelm infrastructure capacity.

Previous research reinforces these findings. Jati et al. (2019) showed that Malang's rapid land conversion and built-up expansion are outpacing its ecological carrying capacity, eroding natural flood buffers and green infrastructure. Setiawan et al. (2024) emphasized that Indonesian cities face compounding risks from densification, inadequate infrastructure, and climate change, requiring integrated resilience frameworks. Comparative studies in Southeast Asia reveal that secondary cities undergoing compressed urbanization—such as Cebu and Hai Phong struggle with similar vulnerabilities, where demographic surges exacerbate ecological degradation and overwhelm urban services (Daudey & Matsumoto, 2017). Nugroho (2023) highlighted that overlooking local demographic dynamics and temporal spikes in demand often leads to resilience strategies that are technically sound but socially ineffective. Likewise, Garschagen and Marks (2019) argued that governance in mid-sized cities tends to underestimate the speed and intensity of urban transitions, leaving them more exposed to climate risks than larger metropolitan areas with stronger institutional capacities.

Flooding as a Multidimensional Resilience Challenge

Flooding emerged as the most immediate and visible hazard during the study period. Data indicate a rise in flood incidents from 120 in 2019 to over 200 in 2022, before moderating slightly in 2023 (WALHI, 2023). This trend aligns with climate variability, as rainfall patterns in East Java have become increasingly erratic (BMKG, 2023), but the intensity of impacts in Malang reflects governance and spatial planning weaknesses. The hydrological crisis is spatially uneven. Low-lying subdistricts such as Kedungkandang, Blimbing, and Sukun together account for more than half of all reported flood events between 2019 and 2023. These areas face different drivers—riverine overflow, drainage failure, and land conversion—but converge in their human consequences: asset losses, livelihood disruptions, and elevated

health risks (LPM Perspektif, 2025; ITN Malang, 2024).

From a theoretical perspective, these findings affirm the argument of Garschagen and Marks (2019) that urban resilience is co-determined by ecological processes and governance capacities. Malang's drainage infrastructure has not kept pace with its urban expansion, while land-use planning has been undermined by weak enforcement. In contrast, Semarang—another flood-prone city—has invested heavily in tidal embankments and integrated drainage upgrades, embedding resilience into everyday governance (Edelman & Gunawan, 2020). This comparison demonstrates that while climate variability is a regional phenomenon, its impacts are mediated by city-specific governance trajectories. Flooding in Malang therefore represents more than a hydrological hazard; it is a socio-political phenomenon exposing governance gaps, institutional fragmentation, and uneven protection across social groups. Vulnerable households in riverbank settlements disproportionately carry the risks, echoing broader concerns about environmental justice in Indonesia's secondary cities (Fuady et al., 2025).

Previous research reinforces these findings. Jati, Subadyo, and Tutuko (2019) demonstrated that rapid urban development in Malang has accelerated land conversion and reduced natural water retention capacity, thereby amplifying flood risks in certain districts. Cellindita, Romadhan, and Roziqin (2021) emphasized that the limited provision of green open space in Malang has weakened soil infiltration capacity and diminished ecological functions as natural flood buffers. Nugroho (2023) highlighted that climate adaptation strategies in Asian cities often fail because they overlook local dynamics, particularly spatial planning enforcement and citizen participation. Setiawan, Samith, and Mughits (2024) argued that weak institutional capacity and fragmented governance are among the most significant barriers to addressing hydrometeorological hazards in Indonesian cities. These insights echo Garschagen and Marks (2019), who stressed that urban resilience is co-determined by governance capacity and ecological processes, underscoring that flooding in secondary cities should not be viewed solely as a hydrological problem but also as a socio-political phenomenon.

Air Pollution and Health Equity

Alongside hydrological stress, Malang faces persistent challenges in maintaining air quality. Measurements consistently show particulate matter (PM2.5) concentrations between 26–40 $\mu g/m^3$, far exceeding the WHO guideline of 15 $\mu g/m^3$ (Cellindita et al., 2021; Muhaimin et al., 2024). Episodes of unhealthy air quality peak during the dry season, driven by traffic congestion, small-scale industrial emissions, and reduced atmospheric dispersion. The implications for health equity are profound. Air pollution disproportionately affects vulnerable groups, particularly children, the elderly, and individuals with pre-existing respiratory conditions (Nugroho, 2023). Evidence suggests spikes in respiratory-related illnesses during high pollution months, with lower-income communities experiencing higher exposure due to limited access to green space and proximity to congested road corridors.

Comparatively, Surabaya has demonstrated measurable improvement in air quality through a combination of transport reforms, green open space expansion, and mangrove restoration (Antara News, 2022). Malang, however, lags behind, with green open space covering only ~22% of its territory, below the national standard of 30% (Pemkot Malang, 2022). This policy lag underscores a critical point: resilience is not merely technical but also distributive, shaping who breathes cleaner air and who bears disproportionate environmental burdens.

Previous research provides important context to these findings. Jati, Subadyo, and Tutuko (2019) observed that the reduction of green open space in Malang has limited the city's ecological capacity to buffer air pollution, exacerbating exposure risks in densely populated areas. Setiawan, Samith, and Mughits (2024) emphasized that Indonesian cities, including Malang, struggle with weak enforcement of environmental regulations, which contributes to persistent air quality challenges. Nugroho (2023) highlighted that citizen participation and localized knowledge are often neglected in climate and air quality management strategies across Asian cities, reducing the effectiveness of interventions. Comparative perspectives, such as those discussed by Daudey and Matsumoto (2017), show that secondary cities in Southeast Asia face compounded air pollution risks due to inefficient resource use, rapid motorization, and poor land-use planning. Furthermore, Garschagen and Marks (2019) stressed that air pollution is not merely an environmental concern but also a question of social equity, since

governance failures often leave marginalized groups disproportionately exposed.

Community-Based Adaptation as Co-Produced Resilience

Despite structural vulnerabilities, Malang's resilience pathway is increasingly shaped by bottom-up adaptation initiatives. The city has witnessed the expansion of ProKlim-certified communities from a single RW in 2016 to eight by 2023, with a target of ten by 2025 (Kelurahan Purwantoro, 2024) and the growth of urban farming from 5 hectares in 2018 to 17 hectares in 2024 (Indriani, 2025).

These initiatives embody co-production theory, where resilience outcomes are jointly produced by communities and institutions (Ostrom, 1996). Urban farming strengthens food security, provides microclimatic benefits, and fosters social cohesion, particularly through women-led cooperatives and school-based programs. Waste banks, which proliferated from 2017 onward, have not only diverted recyclables from landfills but also created tangible financial incentives for low-income households (Times Indonesia, 2025; Anisykurlillah et al., 2024).

Yet, the limitations are clear. Participation is uneven across districts, infrastructure for waste collection is inconsistent, and without integration into municipal planning, many initiatives risk remaining fragmented. Still, Malang demonstrates that resilience in secondary cities can be catalyzed by communities even when formal governance lags behind.

Comparative Regional Insights

Placing Malang in a comparative context sharpens our understanding of resilience pathways. Surabaya has achieved systemic improvements by surpassing the national 30% green open space standard, embedding green infrastructure into urban planning (Antara News, 2022). Semarang has institutionalized flood adaptation through embankments and integrated governance reforms (Edelman & Gunawan, 2020). Malang, in contrast, remains reliant on grassroots-driven adaptation with limited top-down reinforcement. For policy transfer, this indicates that Malang cannot simply replicate Surabaya's or Semarang's strategies. Instead, its comparative advantage lies in scaling grassroots innovations into citywide frameworks, transforming fragmented initiatives into systemic resilience pathways.

Integrating Global Frameworks: SDGs and the New Urban Agenda

Malang's trajectory illustrates the challenges of translating global frameworks into local practice. SDG 11 calls for inclusive, safe, resilient, and sustainable cities (Garschagen & Marks, 2019). SDG 13 emphasizes climate action, while SDG 12 underscores sustainable consumption and production. Similarly, the New Urban Agenda emphasizes participation, ecological balance, and inclusivity.

Yet implementation in Malang remains partial. While ProKlim and waste banks align with SDG 13 and SDG 12, respectively, air quality management and flood mitigation remain below global benchmarks. This gap between aspiration and execution reflects the institutional limitations of secondary cities: constrained fiscal resources, limited technical expertise, and fragmented governance (Setiawan et al., 2024).

Malang's case therefore demonstrates the importance of localizing global goals through context-sensitive strategies. For instance, waste banks show how SDG 12 can be interpreted locally to create economic incentives for households, while urban farming links SDG 2 (Zero Hunger) with SDG 13.

Theoretical Implications

This study contributes to resilience theory in three ways:

1. It highlights the centrality of co-production in secondary cities, demonstrating that resilience is often citizen-driven rather than state-led.
2. It integrates environmental justice into resilience debates, showing that exposure to hazards and access to adaptation is socially differentiated.
3. It reframes resilience pathways as plural, suggesting that cities may follow grassroots, green infrastructure, or hard infrastructure models, depending on context.

Policy Implications

For Malang's municipal government, three implications stand out:

- Integrate community-based adaptation into formal urban planning (RPJMD), ensuring institutional continuity.
- Develop innovative financing mechanisms such as green bonds or partnerships with universities and NGOs.
- Strengthen data systems for air quality and flooding to enable evidence-based decision-making.

At the national level, the findings underscore that resilience planning must differentiate between primary and secondary cities. While megacities may rely on large-scale infrastructure, secondary cities like Malang must leverage community agency and local innovation.

Limitations and Future Research

This study faced limitations in data scope. Air quality monitoring remains fragmented, relying on periodic sampling rather than continuous monitoring. Flood data are partly based on community reports, which may under- or over-estimate frequency. Future research should integrate IoT-based monitoring with satellite data for more robust assessments. Moreover, this study was limited to Malang. Future work should adopt a comparative multi-case approach across secondary Indonesian cities such as Yogyakarta, Solo, and Bogor. Quantitative testing of the co-production model using structural equation modeling (SEM) could further validate the pathways identified here.

4. Conclusion

This study examined Malang City's trajectory of sustainable development and climate resilience between 2020 and 2025, situating its experiences within broader debates on urbanization, environmental governance, and human-centered adaptation in secondary cities of Southeast Asia. The findings demonstrate that while Malang has made notable progress in expanding community-based adaptation programs, significant vulnerabilities persist—particularly regarding flooding, air quality, and the uneven distribution of ecological infrastructure.

First, demographic growth and urbanization pressures have been central to shaping resilience challenges. Malang's steady population increase of approximately 5 percent in four years has intensified land-use conversion and ecological degradation, while transient demographic inflows linked to education and tourism further strain infrastructure and services. This underscores that resilience planning in medium-sized cities must account not only for structural population growth but also for episodic peaks that exacerbate environmental pressures.

Second, flooding has emerged as a multidimensional crisis, driven by erratic rainfall, inadequate drainage, and the loss of infiltration zones due to urban expansion. The spatial concentration of flood incidents in Kedungkandang, Blimbing, and Sukun highlights the uneven geography of vulnerability, where low-income households in high-risk areas face repeated livelihood losses. This confirms that flooding is not merely a hydrological phenomenon but also a governance and equity challenge, demanding integrated solutions that balance infrastructure upgrades with community engagement.

Third, air quality deterioration has reinforced health inequities across the city. PM2.5 concentrations consistently exceeding WHO thresholds expose residents, particularly vulnerable groups such as children and the elderly, to heightened health risks. Unlike Surabaya, which has improved air quality through transport reforms and green infrastructure, Malang has struggled to meet national and global benchmarks. These findings highlight the urgent need to embed environmental justice principles into local climate governance, ensuring that health protection becomes a core dimension of resilience.

Fourth, community-based adaptation initiatives—including ProKlim-certified neighborhoods, urban farming expansion, and the proliferation of waste banks—have become central to Malang's resilience pathway. These programs demonstrate the power of grassroots agency to co-produce resilience in contexts where institutional capacity remains limited. Urban farming contributes not only to food security but also to micro-climate regulation and

social inclusion, while waste banks foster circular economy practices and provide financial relief to low-income households. However, without stronger integration into municipal planning, these initiatives risk remaining fragmented rather than scaling into systemic citywide resilience strategies.

Fifth, comparative insights from Surabaya and Semarang reveal that resilience pathways are context-specific. Surabaya illustrates the effectiveness of systemic green infrastructure expansion, while Semarang demonstrates the potential of large-scale engineering solutions for flood resilience. Malang, in contrast, exemplifies a grassroots-driven model, emphasizing community innovation and adaptation. This diversity suggests that there is no universal blueprint for resilience; rather, cities must leverage their comparative advantages and contextual strengths in developing sustainable pathways.

At the theoretical level, the study contributes to urban resilience literature by highlighting the centrality of co-production in secondary cities, integrating perspectives of environmental justice, and framing resilience pathways as plural rather than linear. At the policy level, the findings stress the need for municipal governments to integrate community-based adaptation into formal planning frameworks, expand innovative financing mechanisms, and strengthen monitoring systems for air quality and flooding. For national policymakers, the study underscores that secondary cities require differentiated strategies—leveraging grassroots agency rather than relying solely on megacity-style infrastructure investments.

Ultimately, Malang's case illustrates both the promise and the peril of secondary city urbanization in the Anthropocene. Without stronger commitments to sustainable and inclusive development, the very assets that make Malang attractive—its educational role, cultural vibrancy, and economic dynamism—risk being undermined by escalating environmental hazards. Conversely, if effectively managed, Malang could serve as a model for regionally grounded, human-centered resilience, demonstrating how grassroots adaptation and local innovation can complement national and global frameworks such as the SDGs and the New Urban Agenda.

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