Impacts of Urban Renewal on Urban Climate in Shanghai

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Keywords	Urban renewal, urban climate science, UHI
City Population	24,890,000
City Area	6,340.50 km^2
City GDP	669.8 billion USD
Climate Zone	Cfa (humid subtropical)
ARC3.3 Linkage	Urban Climate Science Element

Introduction. Urbanization, driven by both expansion and renewal, significantly alters local climates. Urban expansion, marked by increased man-made structures and population density, intensifies extreme weather events such as flooding, heatwaves and urban heat islands (Zhou et al., 2004; Dewan et al., 2021). In contrast, urban renewal, spurred by large-scale urban transformations and ecological environment reconstruction, embodies the vision of sustainable development (Zheng et al., 2014). This process necessitates the closure and relocation of numerous urban factories and the migration of millions of people, often leading to conflicts between modern living concepts and entrenched customs. These challenges include the economic burdens associated with relocation and the financial resources required for constructing new buildings, all of which directly affect the well-being of the general public and present formidable obstacles.

Shanghai, which experienced the world's fastest urbanization from 1979 to 2020, has been actively renewing its urban landscape since 2005 (Wang and Shu, 2020). In this urban renewal process, the city has had to navigate the challenges of shutting down and relocating a significant number of urban factories, managing the migration of millions of residents, and reconciling conflicts between modern lifestyles and outdated practices. This endeavor also involves addressing economic interests and financial burdens during the population relocations and securing land resources and funding for new construction. However, as urban renewal initiatives have gradually unfolded and objectives have been met, the anticipation of creating a sustainable, climate-resilient city capable of disaster prevention and mitigation has become a driving force in the aspirations and ongoing efforts of the city's residents. Fortunately, these efforts have enhanced the city's ability to combat climate-related disasters, improved the urban climate and ecological environment, and turned Shanghai into an ideal laboratory for exploring both successful and unsuccessful experiences and lessons (Lim, 2013; Wang and Shu, 2020).

Brief History. In the 1980s, the Chinese government elevated Shanghai's strategic significance, and the Shanghai municipal government established ten major projects, including the construction of Pudong International Airport, the Shanghai Outer Ring Road, elevated highways, Metro Line 2, wastewater treatment facilities, deep-water ports, Pudong communications infrastructure, and the expansion of the Pujiang Tunnel. These projects marked a significant step in Shanghai's urban development (Wan, 2022). To secure urban development funding, batch land leasing was introduced, departing from the traditional land-use model and transitioning to compensated use of state-owned land. This method accelerated the revitalization of old urban areas through domestic and foreign capital.

In the 1990s, the plan was set to construct 80 million square meters of new residential space, completing the renovation of 650,000 square meters of shanties, simple housing, and unsafe buildings citywide. Municipal development initiatives facilitated the relocation of millions of residents into new homes, resulting in an average living space of 13.1 square meters per urban resident (Zhang, 2004; Wan, 2022). Subsequently, the Shanghai Municipal People's Government issued the "Suggestions on Further Promoting the Work of Old Area Renovation in This Municipality" in 2009 to further advance this work. In addition to residential area renovation, the transformation and revitalization of existing industrial land is also one of the key focuses of urban renewal. The Shanghai Municipal People's Government has successively introduced related policies, such as the 2013 "Trial Opinions on Increasing Research and Development Headquarters-Type Land-related Work" and, in 2014 and 2016, the "Implementation Measures for Revitalizing Existing Industrial Land in this Municipality," which clarified that the original right holders of industrial land in Shanghai can implement the transformation of existing industrial land through the dual assessment method of "incremental land value."

Furthermore, in 2015, policies such as the "Shanghai Urban Renewal Implementation Measures," "Shanghai Urban Renewal Planning Land Implementation Rules (Trial)," and "Several Opinions on Deepening Urban Organic Renewal to Promote the Protection of Historical Features" were successively issued. Recently, Shanghai has established a Municipal Urban Renewal Center and is advancing the compilation of corresponding urban renewal regulations, further enriching and improving the operational model and policy system of urban renewal in Shanghai. Urban renewal is gradually recognized as an important path for future urban development in Shanghai (Lim, 2013).

Analysis, Evaluation, and Implementation. Over the past 30 years, Shanghai's urban renewal efforts have been comprehensively and systematically advancing, gradually adapting to the demands of high-quality development, and establishing a sound urban renewal system and policy framework. Specifically, the renovation of the old city has gone through several key stages, starting with the initial implementation of "365 dangerous shanties into simple housing" and "demolish old, build new" for shanty-town transformation (Wan, 2022). In 2000, a "new round of old district renovation" was initiated, emphasizing a combination of demolition and renovation, especially the transformation of houses in entire secondary old neighborhoods. Subsequently, from 2016, the urban renewal strategy shifted towards "retaining, renovating, and demolishing together, with preservation as the primary focus," with particular attention to the renovation of historic neighborhoods. Iconic successful cases such as Shanghai Xintiandi, Hongqiao Old Street, Laoxiantang area, and Zhang Garden area's urban renewal transformations fully showcase the remarkable effects and achievements of Shanghai's urban renewal strategy.

Shanghai's urban green construction has witnessed a significant leap to address multiple challenges posed by the rapid urbanization, including diminishing natural ecological spaces, land use conflicts, resource limitations, environmental crises, and climate change (Wu et al., 2019). The "Shanghai Urban Green Space System Planning (1994-2010)" achieved a balanced distribution of various green spaces, breaking the urban-rural binary structure, emphasizing extensive urban environmental greening, and expanded greenbelts, wedge-shaped and patchy green areas around the city. In 2002, Shanghai further formulated the 'Shanghai Urban Green Space System Planning (2002-2020)' with the aim of creating a harmonious ecological environment for both humans and nature. The plan revolved around public green spaces at all levels, with suburban large ecological forests as the core, and green areas in riversides, lakes, seas, and roads forming a network and connection. It constructed a five-level structure system, including "ring, wedge, corridor, garden, and forest." This structure promoted a large-scale cycle of urban greening, achieving comprehensive development through the interaction of green spaces at various levels. By 2020, Shanghai has achieved significant milestones in green space development, with a total of 90,000 mu (approximately 60 square kilometers) of afforestation completed, and the city's forest coverage rate reaching 18.49%.

In the realm of carbon emissions reduction, Shanghai has taken a series of proactive measures aimed at gradually reducing overall coal consumption and mitigating environmental pollution (Wang and Shu, 2020). These actions include prohibiting the construction of new coal-fired facilities, implementing clean energy to replace traditional coal boilers, phasing out low-efficiency coal-fired units, and promoting natural gas and external electricity supply. Simultaneously, Shanghai has completed over 4,000 industrial restructuring projects, conducted extensive upgrades in chemical industrial zones, pursued comprehensive ultra-low emission transformations for coal-fired power plants, replaced coal boilers and kilns with clean energy sources, eliminated decentralized coal burning, and advanced a special initiative for the comprehensive management of industrial furnaces and kilns. Significantly, in the transportation sector, Shanghai has actively accelerated the phase-out of old vehicles and machinery, increased the proportion of new energy and electrification, and elevated emissions control requirements for shipping areas (Zhang et al., 2020). These comprehensive measures underscore Shanghai's resolute commitment to carbon emissions reduction, aiming to improve environmental quality, reduce carbon emissions, and make an outstanding contribution to the sustainable development of urban renewal.

These urban renewal measures have not only significantly improved the living conditions of citizens and raised their living standards but have also driven the upgrading of the urban climate. A detailed analysis of Shanghai's daily average and maximum temperatures since 1960 has been conducted, along with the statistical assessment of the changes in the urban heat islands and the intensity of cumulative heatwaves from 1960 to 2020. In this study, Xujiahui Station was selected as the urban site, and Fengxian Station as the suburban site. These choices were made based on previous research findings, considering the degree of urbanization around the sites and the same amplitude of temperature fluctuations (Wang and Shu, 2020). As evident from Figure 1a, the annual average temperature trends at both Xujiahui and Fengxian stations have been generally consistent. Under the combined influence of global climate change and urbanization, temperatures have gradually risen since 1990. However, after 2005, this rapid upward trend was curtailed, and the urban heat island intensity (Figure 1b) showed a significant decline from 2005 to 2020.

Further analysis gave the five-year moving average of heatwave intensity during summer days from 1960 to 2020. Here, we use urban stations with temperatures exceeding 35°C in summer as a basis, calculating the the value of the highest daily temperature reaching or exceeding 35 °C to determine the heatwave intensity in this high-temperature weather process, with reference to previous studies (Robinson, 2001; Tan et al., 2010; Yi-Ling et al., 2013; Xu et al., 2016). Figure 2a shows the cumulative values of heatwave intensity for urban and suburban stations during summer days exceeding 35°C from 1960 to 2020. It demonstrates a trend of increasing heatwave intensity followed by a decrease in both urban and suburban sites because of the synoptic patterns and other reasons that remain to be analyzed. Additionally, we computed the difference in heatwave intensity between urban and suburban stations (Δheatwave intensity),

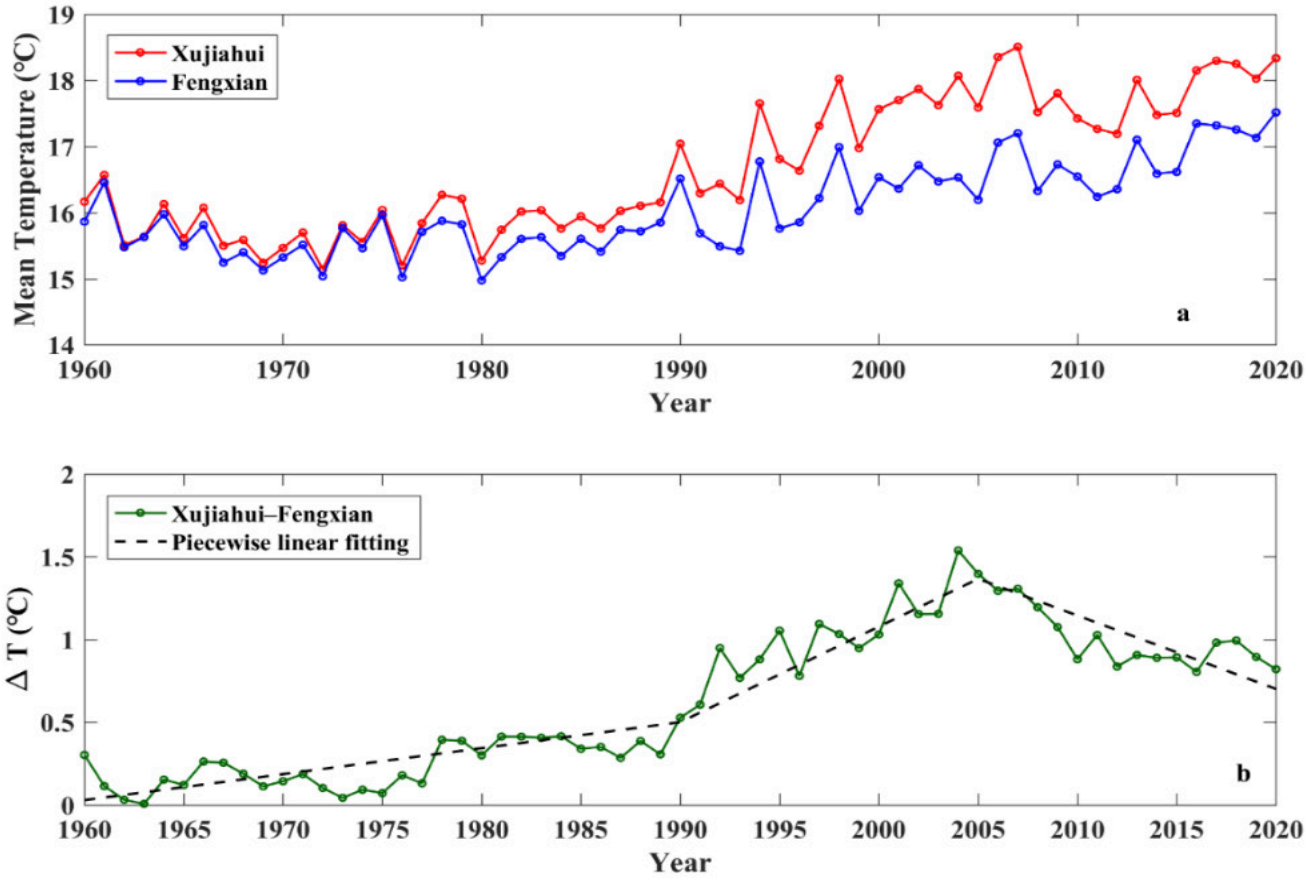

Figure 1. *Annual average temperature variations of urban (Xujiahui) and rural(Fengxian) stations (a) and their trends in urban heat island intensity (b).*

as shown in Figure 2b. Figure 2b illustrates the annual trends in the cumulative values of Δheatwave intensity throughout the summer, indicating a decline in cumulative values around 2005. This trend is closely linked to urban development and the effectiveness of urban renewal measures (Wang and Shu, 2020). Moreover, in recent years, Shanghai has experienced year-after-year improvements in environmental air quality. From 2013 to 2020, the Air Quality Index (AQI) in Shanghai showed a continuous increase in the proportion of excellent and good air quality, reaching a historical high of 87.2% by the end of 2020. Compared to 2013, this marked an increase of 21 percentage points, and an 18-point increase compared to 2015. This indicates that Shanghai has made significant progress in improving air quality, providing residents with fresher air and a more habitable living environment.

Currently, although Shanghai has achieved initial successes in urban renewal, there are still some issues and challenges that Shanghai will face in future urban renewal (Wang, 2010):

1) Land Use Concerns: Urban renewal often demands a significant amount of land, while land resources are limited. Therefore, efficiently managing land use and allocation to ensure the sustainability of urban renewal projects and the efficient use of land resources is a critical issue.

2) Historic and Cultural Preservation: Shanghai boasts a rich historical and cultural heritage. However, during the urban renewal process, there is a possibility of demolition or destruction of historical and cultural buildings and areas. This raises concerns about the preservation of historical and cultural heritage, necessitating a better balance between modernization and historical preservation in urban renewal.

3) Urban Planning and Design: Urban renewal requires clear planning and design to ensure that new projects align with the city's overall development and environment. Poor planning and design can lead to an incoherent urban landscape, potentially undermining the city's sustainability and livability (Wang et al., 2020; Wang and Shu, 2022).

Future Implementation and Concluding Thoughts. While Shanghai has achieved some successes in urban renewal and improved its urban climate and environment, as a highly urbanized mega-city, it has shifted its urban development model from outward expansion to internal enhancement and from large-scale incremental construction to focusing on existing assets. A significant challenge for the future of urban renewal in a city with limited land resources is how to use urban renewal methods like old city transformation, greening, and carbon emissions reduction to further enhance the urban climate. It's crucial to explore how to implement, promote, and utilize resources within the context of organic urban renewal, creating replicable models for urban renewal actions. In July 2020, the Shanghai Urban Renewal Center was established, serving as a unified functional platform for old area revitalization in Shanghai. Additionally, in August 2021, Shanghai introduced the 'Shanghai Urban Renewal Regulations', providing robust institutional support for advancing urban renewal.

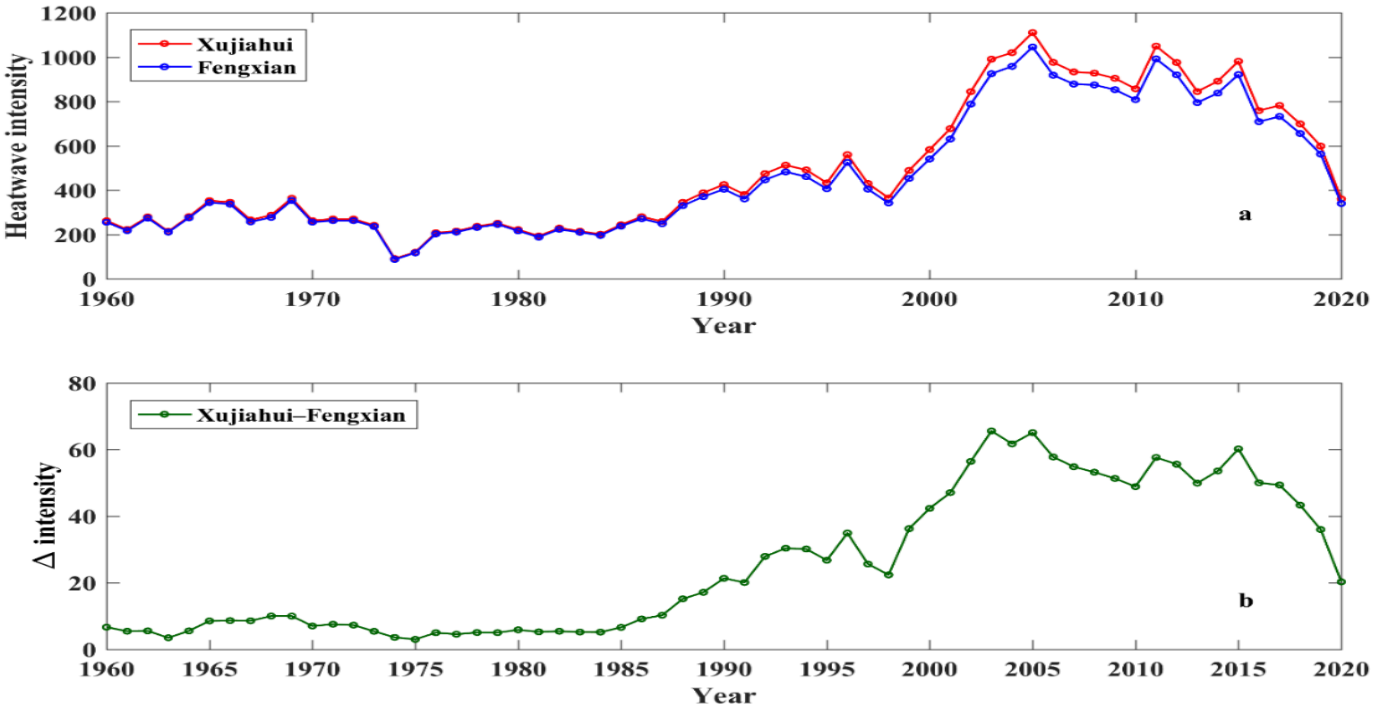

Figure 2. *Variations in five-year moving averaged heatwave intensity for urban (Xujiahui) and rural (Fengxian) stations (a), along with the trends in their difference (b).*

The regulations also specify the need to raise standards for urban planning and design to ensure that urban renewal projects harmonize with the city's overall development and environment. Furthermore, they encourage green construction and the environmentally friendly retrofitting of existing buildings, harnessing the intensification benefits of green architecture and creating eco-friendly urban districts.

Urban renewal brings advantages to the nation and its citizens, yet it is frequently impeded by financial constraints, resulting in the inefficacy of urban renewal measures (Nesticò and Sica, 2017). Therefore, there arises a necessity for more all-encompassing safeguards for urban renewal in the future, including administrative legislation, financial support, tax incentives, land use policies, land policy support, and public housing tenancy rights. This will promote the well-ordered and thriving advancement of urban renewal projects. The municipal and district governments, along with their relevant departments, should enhance urban renewal policies and measures, deepen institutional innovation, intensify resource coordination efforts, and provide support and assurance for urban renewal. Financial institutions are encouraged to lawfully engage in diversified financial product and service innovations to meet the financing requirements of urban renewal. Furthermore, they should support eligible enterprises in conducting financing activities on various capital markets, harnessing the role of finance in promoting urban renewal. In urban planning, there is a need to explore the potential for increasing urban green spaces, enhancing the temperature regulation effect of existing urban green areas. Simultaneously, the construction of regulation gates that can obstruct storm surge intrusion and discharge accumulated floodwater is essential. The evaluation of the effectiveness of existing sponge city rainwater collection systems is necessary, aiming to improve the efficient collection and utilization of rainwater resources, which can enhance water storage capacity and strengthen the city's flood resilience. Additionally, there is a requirement for awareness of the participation of climate scientists in the construction planning of coastal cities, making full use of sea breeze effects to improve local climate conditions (Wang and Shu, 2022).

The urban renewal initiatives in Shanghai, including old city redevelopment, green infrastructure development, and energy reduction efforts, align with global climate action goals and indicators. These actions play a crucial role in reducing carbon emissions, enhancing urban environmental quality, and improving urban sustainability. Shanghai's efforts serve as a valuable example of the exchange of urban climate experiences among cities worldwide and demonstrate the importance of local actions in addressing climate change and promoting sustainable urban development.

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Additional Data

- **Population Density:** 3,900 people/km^2
- **Gross National Income (GNI):** 13,400 USD (High Income)
- **Gini Coefficient:** 35.7
- **Human Development Index (HDI):** 0.788 (High)
- **Type of Climate Intervention:** Hybrid
