Building Climate Resilience in Kathmandu Valley, Nepal: Learning from Ancient Settlement Planning and Design

Kirti Kusum Joshi
Lumbini Technological University
kirti.joshi@ltu.edu.np

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Keywords	Ancient settlement planning and design, climate change, nature-based solutions
City Population (Metropolitan)	5 million
City Area (Metropolitan)	722 km^2
City GDP	3.5 billion USD
Climate Zone	Cwa (monsoon-influced humid subtropical climate)
ARC3.3 Linkage	Urban Planning, Design, and Architecture

Introduction. Nepal is one of the world's most at-risk countries to climate hazards, and as the country's largest urban region and economic hub with three million inhabitants, the Kathmandu Valley's climate vulnerability is particularly pronounced. The Valley has experienced rapid population growth, especially since the late 1980s, leading to rapid and haphazard conversion of farmlands into built-up areas. Unplanned urban expansion around compact traditional settlements, haphazard construction of buildings, urban sprawl, and intrusion into natural drainage areas—all driven by anthropogenic activities—have collectively led to annual disastrous floods and inundation, causing substantial economic losses. Additionally, the increase in paved surfaces has gradually intensified the urban heat island (UHI) effect in the Valley. Climate change, which has brought about more intense rainfall and increased temperatures, has further exacerbated the challenges faced by the Valley.

Policymakers often lean towards technological or engineering solutions when addressing climate risks. However, the current climate risks facing the Valley can be largely attributed to the disregard for ancient wisdom related to settlement planning and design, which once fostered a harmonious coexistence between humans and nature. The ancient settlements in the Valley, nestled amid farmlands, were strategically positioned on elevated terrains that offered protection against floods. These settlements were characterized by compact layouts, dense populations, and a diverse mix of land uses. Buildings were constructed using locally sourced materials, guided by climate-sensitive design principles. This case study explores how principles derived from ancient settlement planning and design can inform contemporary urban planning and policymaking to build climate resilience.

Urbanization and Climate Change. Comprising 18 municipalities and some rural hinterland, the Kathmandu Valley stands as not only Nepal's largest urban region but also as the political capital and economic hub of the country. Until the late 1980s, the Valley's built-up land use was confined to ancient settlements, with outward expansion commencing in the early 1990s along major roads connecting core cities with the outskirts (Ishtiaque, Shrestha, & Chhetri, 2017). The population of the Valley experienced rapid growth between 2001 and 2011, registering an annual growth rate of approximately 4 percent before slowing down to 2 percent in the subsequent decade (CBS, 2012).

The population growth in the Valley resulted in the conversion of an additional 16 thousand hectares of farmlands into urban use between 2000 and 2020. During this timeframe, the Valley's population surged by 2.5 times, while its total built-up area expanded – at the cost of farmlands – by 4.7 times (Magar and Joshi, 2021). This urban expansion has predominantly taken the form of urban sprawl (Figure 1).

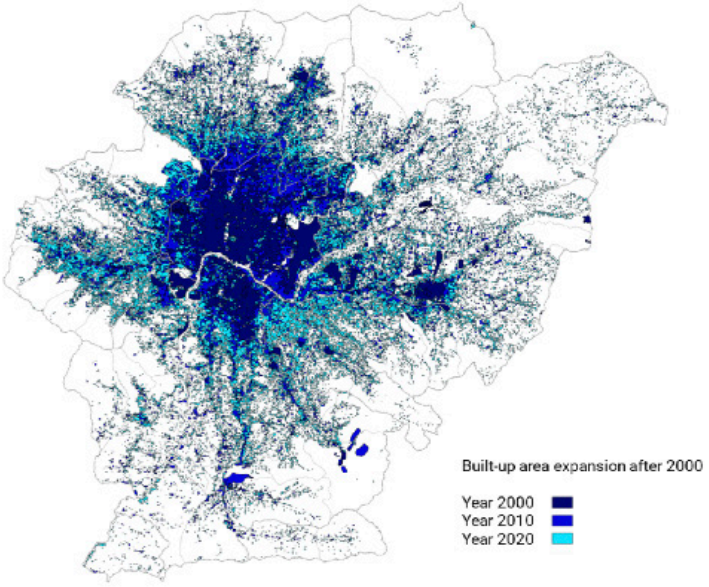

Figure 1. *Built-up area expansion in the Kathmandu Valley after 2000*
Source: Magar and Joshi (2021)

The conversion of farmlands into built-up, haphazard construction of buildings disregarding natural drainage systems, and river encroachment, have resulted in reduced infiltration capacity, severe flood damages, and inundation during monsoons. In 2018, over three thousand people faced temporary displacement due to floods on the Hanumante River following torrential rains (Ojha, 2018). Intriguingly, the affected area had experienced the same volume of precipitation three times previously without significant damage (Robertson, 2021). Moreover, the increase in impervious surfaces has hindered surface runoff from being absorbed into the ground, contributing to severe urban flooding issues even during moderate rainfall. With a changing climate, the situation is likely to exacerbate in the coming days.

The rise in the number of buildings and paved surfaces in the Valley has also intensified the UHI effect. As temperatures increase due to climate change, the UHI effect is poised to become a significant hazard in the near future. This is especially concerning considering the bowl-shaped topography of the Valley, which creates conditions for the trapping of heat and air pollution.

The contemporary urbanization trend in the Valley stands in stark contrast to its traditional settlement planning and socio-cultural practices that once fostered harmonious coexistence between humans and nature. Many of these traditional techniques still retain their relevance, particularly in the context of climate change.

Climate Resilience in Ancient Settlement Planning and Design

Settlement Planning and Design. Ancient towns in the Kathmandu Valley were strategically positioned on elevated lands, leaving fertile plains along riverbanks preserved for agriculture (Tiwari, 2007). This approach not only safeguarded residents from monsoon floods by allowing vast farmlands to absorb rainfall and river overflo , but also delineated a clear human domain within the town boundary, beyond which lay the domain of nature (Tiwari, 2002). Infill development was employed to accommodate population growth. When existing towns reached their carrying capacity, the creation of new towns followed a pattern similar to the existing ones.

Today, climate-friendly cities are characterized by high density, walkability, car-free urban designs, and mixed-use compact development, as exemplified by concepts like 15-minute cities. The ancient settlements of the Kathmandu Valley were compactly built, with houses constructed back-to-back on either side of narrow streets. Since walking was the primary mode of commuting, connectivity held greater importance than street width. Streets and courtyards not only linked different places but also served as an extension of residential space, fostering social interactions, festivals, ritual processions, and trade (Korn, 1998).

The dual use of buildings as both residences and workplaces played a significant role in the compactness of ancient settlements. Ground floors were typically designated for commercial activities or workshops, or served as storage spaces for farm instruments, depending on the household occupation. These practices can be considered early examples of running a home-based office. Embracing home-based offices in contemporary settings can contribute to reducing commuting requirements, which can also minimize vehicular emissions.

Traditional Buildings. The vernacular architecture of a place is a testament to centuries of resource optimization, social organization, and climate adaptation. In the Kathmandu Valley, the traditional residential buildings – those belonging to the indigenous Newar community – seamlessly integrate aesthetics with climate responsiveness and energy efficiency (see Korn, 1998; Gutschow, et al., 1987). Typically three or three-and-a-half stories tall, these buildings make use of locally sourced materials such as wood, mud, bricks, and tiles (Figure 2). The construction ingenuity allows for the repair or replacement of elements without dismantling the entire structure. Even in the event of dismantling, bricks and timber elements can be easily recovered for reuse. The uniform building heights in these neighborhoods facilitate air circulation and sunlight, mitigating the challenges posed by dense urban environments.

Figure 2: Sectional view of a typical Newar house
Source: Korn (1988)

Most of these traditional buildings are constructed with three parallel load-bearing walls, with the middle wall serving as the structural backbone. Fire-burnt bricks, known for their resistance to weathering, are utilized in the outer walls, while sun-dried bricks compose the inner walls. With a total thickness ranging from 400 to 450 mm, these walls provide low thermal transmittance, offering effective insulation. These walls serve as heat reservoirs, storing warmth during the day and releasing it at night. The walls help traditional buildings maintain a warm interior in winter and a cool one in summer, exemplifying their effective climate adaptability.

Owing to the rainy climate in the Kathmandu Valley, traditional buildings typically feature roofs pitched at around a 30-degree angle with overhangs and eaves supported by wooden struts projecting obliquely from the walls at right angles to the roof edge. These overhangs serve a dual purpose: shielding walls from rain while also blocking di-

rect sunlight in summer but allowing it in during winter.

Currently, reinforced cement concrete frame structures dominate building construction practices. Unlike their traditional counterparts, modern buildings often lack energy efficiency and climate adaptability. Additionally, concrete structures have large carbon footprints and are less reusable.

Lessons for Climate Resilient Urban Development. Current urban policymakers often favor technological or engineering solutions to urban problems, which can lead to unintended consequences. For example, 'river training' compromises natural river cross-sections, worsening flood impacts downstream. Similarly, recent modifications to building codes mandate larger structural elements, leading to increased costs and carbon footprints. In contrast, the ancient settlement planning and design of the Kathmandu Valley embodied principles of harmonious coexistence between nature and humans, now recognized as nature-based solutions. Drawing on such ancient wisdom, strategies can be informed to enhance climate resilience in the Valley.

The government's recent attempt to prevent the conversion of farmlands into urban use through the 2019 Land Use Act may be arriving almost too late for the Valley. Nevertheless, leveraging the constitutional rights granted to local governments by the 2015 Constitution of Nepal, municipalities in the Valley can play a pivotal role in safeguarding remaining farmlands, preventing river encroachment, and reclaiming encroached public lands for transformation into urban parks. These measures can address floods and inundation problems and also mitigate the UHI effect.

Some Valley municipalities have recently undertaken efforts to revive old ponds to store rainwater and capture surface runoff. However, the growing trend of constructing concrete beds poses a challenge as it contradicts the original purpose of these ponds – to recharge groundwater. On a positive note, some historic ponds have been successfully restored using traditional technology (Nepali Times, 2019).

In the aftermath of the 2015 Gorkha Earthquakes, the government implemented fundamental building bylaws—applicable throughout the country—that included regulations on building setbacks, heights, and ground coverage for earthquake safety. Instead of a one-size-fits-all approach, these bylaws should be contextualized according to local situations and modified to integrate climate considerations. Municipal governments have constitutional rights to define more detailed regulations. Recommended measures include setting setbacks from rivers based on hydrological studies rather than setting a uniform setback, defining height restrictions to allow air circulation and sunlight in dense neighborhoods, and requiring a certain share of private open spaces to be either unpaved or paved with pervious materials as part of the ground coverage regulation.

Lot sizes in the Valley have historically been relatively small, with the minimum allowable size being 80 square meters. Small lots contribute to high density, resulting in a low ecological footprint per capita. However, the increasing number of vehicles has exacerbated traffic congestion problems in densely populated neighborhoods. Government agencies have primarily promoted road widening as the solution to ease congestion. However, with a diameter of approximately 25 km, the circular bowl-shaped Valley does not warrant car-centric development; rather, it requires investments in enhancing public transportation and creating pedestrian-friendly neighborhoods. While some previous pedestrianization initiatives did not meet expectations (Pradhan, 2022), municipalities should learn from these experiences and enhance their strategies. This also presents an opportunity to involve municipalities in fulfilling Nepal's commitment to climate change mitigation, as outlined in the country's Nationally Determined Contributions (NDC).

Modern buildings can be made more climate-friendly by encouraging rooftop gardening and rainwater harvesting. Additionally, sloped roofs can be utilized to install solar panels for solar energy capture. Some municipalities offer subsidies for constructing buildings based on traditional architecture, promoting the use of locally sourced and climate-friendly building materials. Such initiatives should be scaled up. Moreover, municipalities should discourage the growing use of glazing materials in building facades, as they reflect light and heat, amplifying the UHI effect.

Conclusion. The Kathmandu Valley serves as a stark reminder of the dual challenges posed by rapid urbanization and climate change in a large urban region. The Valley's transformation from a cluster of ancient settlements to haphazard urban sprawl, guided by anthropogenic activities, has eroded the foundational elements of traditional settlement planning that endowed ancient settlements with climate resilience, resulting in disastrous floods and an intensified Urban Heat Island effect.

Urban policymakers often tend to address these challenges through technological or engineering interventions, without a comprehensive understanding of the root causes. However, there is an opportunity to harmoniously integrate traditional knowledge with contemporary technologies and engineering expertise to devise sustainable measures for addressing urban climate risks. This imperative applies not only to the Kathmandu Valley but also to any urban region with a historical legacy of nature-based planning.

Implementing nature-based solutions, following traditional settlement planning practices, in current times poses a challenge. One potential approach is to initiate implementation on a small scale within a municipality or ward and evaluate its effectiveness before considering further upscaling.

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Acknowledgments

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Additional Data

- **Population Density:** 4,155 people/km^2
- **Gross National Income (GNI):** 1,370 USD (Lower-Middle Income)
- **Gini Coefficient:** 32.8
- **Human Development Index (HDI):** 0.601 (Medium)
- **Type of Climate Intervention:** Adaptation
