Atal Mission for Rejuvenation and Urban Transformation

AMRUT Centre of Urban Planning for Capacity Building

A-CUPCB-SPAV

Leveraging A Stepwell - Based Blue Green Infrastructure Framework for Mitigation of Heat and Water Based Risk in Vijayapura, Karnataka

CAR_26_01

PROJECT SUMMARY

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1. BACKGROUND OF THE PROJECT

Rapid urbanization and shifting climatic patterns have placed **unprecedented stress on traditional water and heat management practices**, threatening both ecological balance and public wellbeing. Climate change is expressing itself through several interlinked hazards worldwide like rising temperatures and heatwaves, water stress and droughts, more intense floods and storms, sea-level rise, wildfires, and ocean warming and each carries its own statistical footprint of harm. **Among all of these, heat risk and water risk stand out as the two most prominent** and most directly relevant challenges.

The Intergovernmental Panel on Climate Change (AR6) highlights that cities in semi-arid regions face compound climate risks, where heat stress and water-related hazards interact, amplifying urban vulnerability. **Every 0.5 degree C of global temperature rise** will cause clearly discernible increases in the **frequency and severity of heat extremes, heavy rainfall events and regional droughts**. An additional **350 million** people living in urban areas are estimated to be exposed to water scarcity from severe droughts at **1.5°C of warming**, rising to **410.7 million** people **at 2°C of warming**. AR6 also notes that increasing concurrence of heat and drought events is already causing crop production losses and tree mortality, a direct heat - water compounding effect (*Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report (AR6)).*

In India, these challenges are increasingly visible, with rising temperatures, erratic monsoons, and growing pressure on urban water systems. National initiatives such as the **National Action Plan on Climate Change (NAPCC), the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), and the Smart Cities Mission** emphasize sustainable water management and climate-resilient urban development, yet often rely heavily on centralized, energy-intensive infrastructure. In **2025**, all India **annual mean land surface air temperature was 0.28°C higher than the 1991 - 2020 long-term average**. This made 2025 the eighth warmest year since nationwide temperature records began in 1901. **The warmest year on record was 2024**, when temperatures across India were 0.65°C above the long-term average. **The 2025 annual rainfall over the country as a whole was (1274 mm) 110% of the Long Period Average (LPA) for the period of 1971–2020. Seasonally, winter rainfall was below normal (52% of its LPA)** (*IMD, 2025*). India's cities today sit at the intersection of multiple, mutually reinforcing climatic issues like **flood, drought, water stress, food security, water security, heatwaves, urban heat islands, and heat stress** that no longer arrive one at a time but increasingly strike the same place in the same year.

1.1. The Compounding Heat–Water Nexus

The Central Water Commission recorded **184 extreme and severe floods in 2022** and **145 in 2021**, even as the Karnataka government formally declared **2023 a drought year**, illustrating how flood and drought risk now coexist within the same national water system rather than being opposite extremes. The 2024 floods all over India caused over **1,878 deaths**, displaced more than 3,51,000 people, and forced the evacuation of 65,000 residents. India's water security is now recognised as a frontline climate-resilience issue, the majority of India's climate disasters are water-related, manifesting as floods, droughts and erratic monsoons that threaten agriculture, urban infrastructure and livelihoods, with over 600 million

Indians already facing high-to-extreme water stress (*NITI Aayog's Composite Water Management Index*). A 2024 survey found that **40.9% of marginal Indian farmers** had faced **drought** and **32.6% had suffered crop damage** from **excessive rainfall** in the same period (*Times of India*).

According to the Indian Meteorological Department, heatwave frequency across India's core heat zone **has increased by 0.1 days per decade since 1961**, **and total heatwave duration by 0.44 days per decade**. Average night time temperatures are rising at roughly 0.21 degrees Celsius per decade. Thirty-five of thirty-six Indian states and union territories are getting hotter at night (*Kayly Ober, 2026*). Heat and water risk are tightly coupled as rising temperatures increase evaporative water loss and cooling demand, while water scarcity in turn undermines a city's ability to counter heat through vegetation, evaporative cooling, and groundwater recharge.

1.2. Challenges Faced to Mitigate the Issues

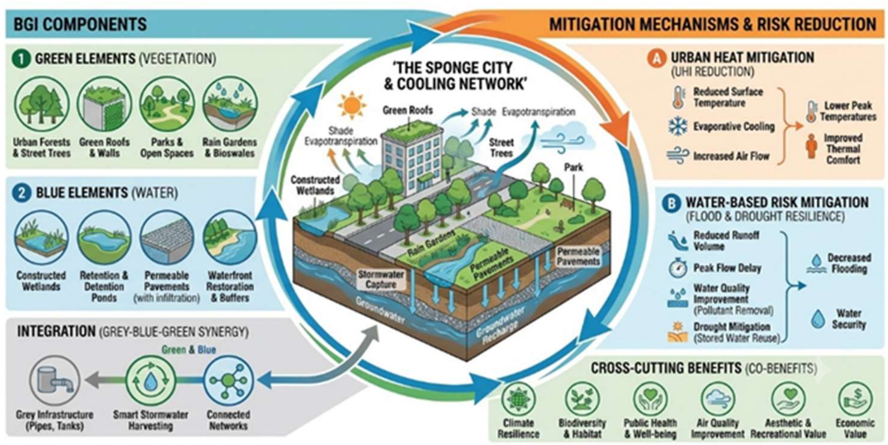

Figure 1 BGI Components

The conventional response to these issues is mostly constructing more concrete drains, more pipelines, more paved surfaces which is increasingly recognised as a **contributing factor to the very heat and hydrological instability it is meant to manage**. **Grey infrastructure** such as **sewage treatment plants and wastewater pumping stations, is itself attributed to large greenhouse gas emissions and high energy utilisation, directly contributing to the local urban heat island effect** it operates within. Rapid population increase and urbanization in India replace open land, vegetation and waterbodies, naturally permeable surfaces with impermeable, dry concrete surfaces, directly forming Urban Heat Islands where cities run measurably warmer than their rural surroundings, adding to social, physical and economic discomfort. Extensive concretization of natural landscapes prevents rainwater percolation, forcing cities to over-extract from aquifers to meet growing water demand which further leads to severe localized aquifer collapse and drought vulnerability.

Recent research increasingly points to **Blue Green Infrastructure** (Figure 1Figure 2) like parks, wetlands, engineered greening, restored water bodies, bioswales, rain garden, permeable pavements as an effective heat and flood mitigation strategy, but consistently flags few structural obstacles. Even where BGI is formally acknowledged in city planning documents, there remains a **significant gap in implementation**. Grey infrastructure keeps expanding because it is easier to fund and monitor at scale, even though it worsens the underlying heat and hydrological problem, while BGI, which addresses root causes, struggles precisely because of planning, coordination and monitoring difficulty.

1.3. Traditional Practices in India

India's historic heat and water-management traditions were diverse, region-specific, and closely tied to social and religious life rather than being purely technical solutions. In cities with hot and arid climate, historical evidences shows use of **passive strategies calibrated to local climate, materials and social life** for cooling. In **Rajasthan**, communities built stepwells (baolis), **johads** (earthen check dams for groundwater recharge), **kunds** and **tankas** (covered underground cisterns) to harvest scarce, seasonal rainfall. **Gujarat** is renowned for its ornate stepwells or **vavs** — such as Rani-ki-Vav and Adalaj Vav — which combined groundwater access with passive cooling architecture. In **Karnataka**, particularly in the semi-arid Deccan cities like Vijayapura and Bidar, **Karez/Kharejari (Qanat-type) systems** used gravity-fed subterranean tunnels to draw groundwater across long distances, supplemented by **Bawdis** (cisterns) and embankment reservoirs (**Talabs/Sarovars**) for surface-water storage and recharge. **Telangana**, under Kakatiya patronage, developed cascading **cheruvu/kunta** tank networks alongside numerous stepwells (bawdis), still numbering over 100 today. **Maharashtra's** semi-arid Deccan belt relied on the **Phad** system, bandharas (check dams) diverting river water through canals into basaltic terrain to recharge aquifers. **Tamil Nadu**, developed the ancient **Eri** cascading-tank network, still irrigating roughly a third of the state.

Of all the above mentioned, research on stepwell provides strong evidences of heat and water stress management. The **stepwell orientation, dimensions, pavilions, sun-shading elements, jaali screens, and the degree of openness to the sky** to achieve passive cooling, with strategies such as **cross-ventilation, shaded courtyards and water reservoirs** were highly effective at preserving thermal comfort. Stone jaali lattices, by narrowing the airflow path, could cool passing air by 1 - 2°C. Elsewhere, a review of passive cooling in medieval stepwells found that combined shading and evaporative cooling techniques could lower surrounding temperatures by as much as 7°C.

By the early 21st century, only a handful of stepwells remained in relatively decent condition mainly those attracting tourists. The rest fell into **deplorable condition** for compounding reasons: many stepwells, deemed unhygienic havens for disease by British colonial administrators, were barricaded, filled in, or destroyed outright, while modern substitutes like village taps, plumbing, water tanks eliminated the physical necessity for them, even as their social and spiritual role faded. Abandoned under British colonial rule on hygiene grounds, many stepwells became outright dumping grounds by the late 20th century. According to the **Stepwell Atlas project** and **INTACH** (Indian National Trust for Art and Cultural Heritage), over **3,000 stepwells survive** across India. Of the thousands of deteriorated stepwells across India, only a **small number have been restored** for their original functional purpose, and fewer still provide usable drinking water. Even celebrated, heavily restored sites like the 9th-century Chand Baori in Rajasthan (3,500 steps) or the UNESCO-listed Rani-ki-Vav in Gujarat now function mainly as tourist and film-shoot destinations rather than active water infrastructure.

Structural and functional revival efforts are almost always **isolated, individual-driven projects** rather than integrated restoration of a whole historic water system. The consequence is that even where restoration succeeds, it treats each stepwell or bawdi as an isolated heritage monument to be preserved as standalone effort. The vernacular strategies embody the core principles of nature-based cooling by drawing on natural systems and local knowledge to build resilience, and contemporary planners need to integrate such heritage-based approaches into city-climate mitigation plans.

1.4. Grey, Green and Ancestral Blue Heritage Integration

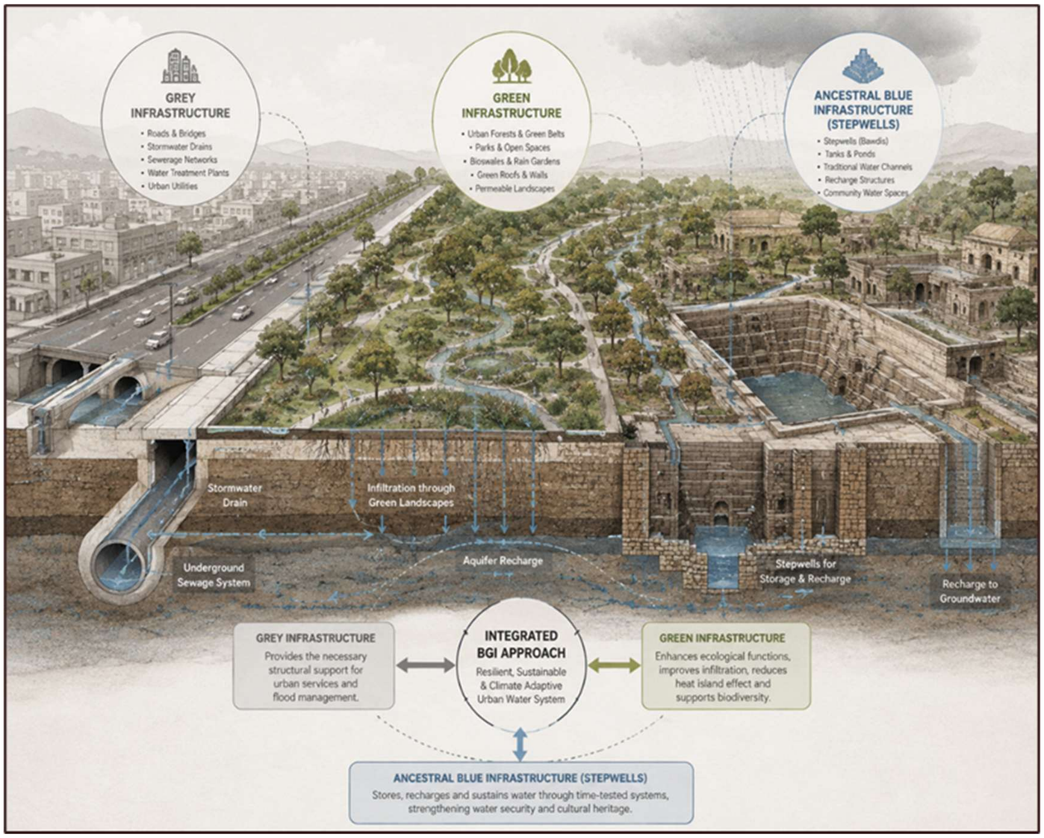

Figure 2 Grey, Green and Blue Integration

Grey, Green and Ancestral Blue needs to be integrated to solve the compound heat-and-water crisis in India, not just for the present issues but also for the future needs and demands (illustrated in Figure 2). Grey infrastructure delivers scale and centralised monitoring but actively worsens local heat islands, **Blue-Green Infrastructure** for heat mitigation, faces real barriers to implementation and monitoring, Ancestral blue heritage like stepwells, bawdis, karez systems had already solved the combined heat, water-harvesting, and community-resilience problem centuries ago, but survives today only in isolated, individually revived fragments rather than as the interconnected, watershed-scale systems. This project therefore attempts to **reintegrate stepwell systems into contemporary urban planning** by evaluating their role as stepwell-based blue - green infrastructure for climate mitigation. By bridging traditional knowledge with modern spatial and climatic analysis, the research aims to provide a scalable, evidence-based framework that enhances urban resilience while supporting national and global climate goals. This multi-scalar approach ensures that both heritage-rich and rapidly urbanizing areas are captured, allowing for a comprehensive assessment of climate risks and adaptation potential. The research adopts a two-stage, mixed-method approach combining spatial analysis, field-based measurements, and scenario modelling to evaluate and integrate stepwell systems into a blue–green infrastructure (BGI) framework for climate mitigation.

2. INTRODUCTION TO THE CITY AND STUDY AREA

Vijayapura district (formerly Bijapur) is located in northwestern Karnataka, India, spanning the northern Karnataka Plateau with an area of 10,541 sq km at an average elevation of 606 meters (Figure 3). It is bordered by Maharashtra's Solapur and Sangli districts to the north/north-west, Belgaum to the west, Bagalkot to the south, Gulbarga to the east, and Raichur to the south-east. It is drained by the Krishna, Bhima, and Doni rivers.

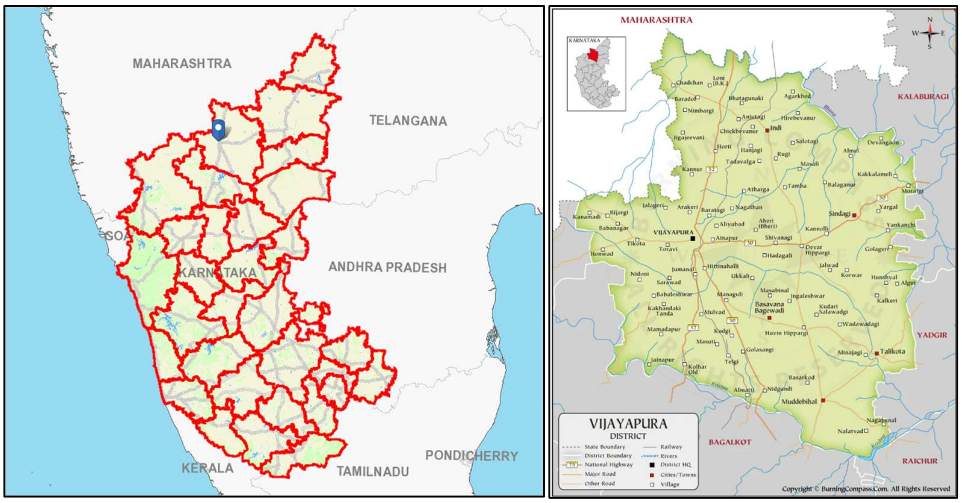

Figure 3 Karnataka State Map(left) and Vijayapura District Map (right)
Source: K-Gis Portal, https://www.burningcompass.com/

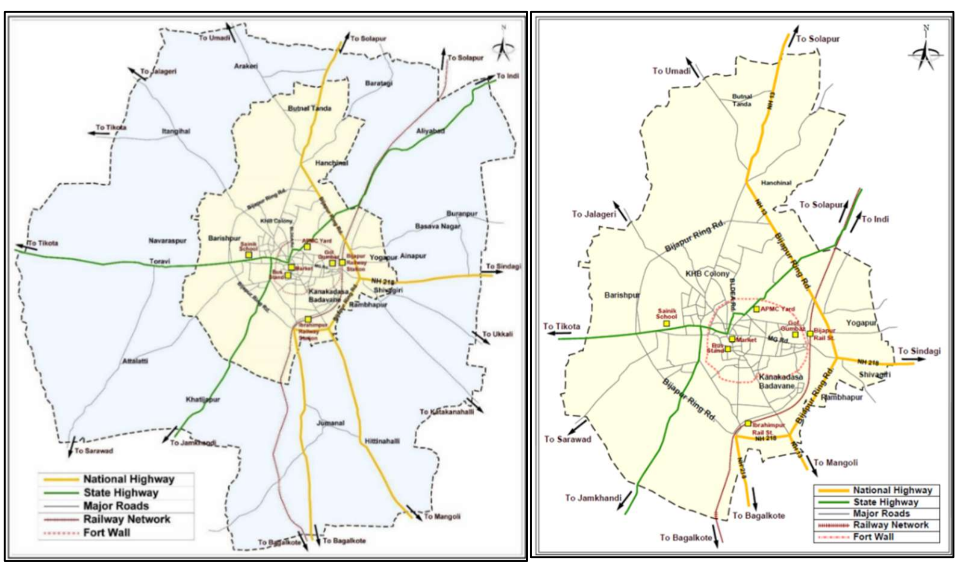

Figure 4 Vijayapura Planning Area(left) and Vijayapura Municipal Corporation(right)
Source: https://dult.karnataka.gov.in/

Vijayapura City Area: 97.5 Sq Kms	Population (2011): 3,27,427	Pop Density: 33.58 person/hectare

The city of Vijayapura is characterized by a hot semi-arid climate, the city experiences intense summer temperatures, declining groundwater levels, and increasing urban heat stress, compounded by unplanned urban expansion. Despite possessing a rich network of traditional stepwells and underground water systems, many are neglected or underutilized, limiting their potential contribution to climate resilience. The foundations for the city of Bijapur were laid by Chalukyas of Kalyani during the 10th Century ACE and was called Vijayapura, which was later passed on to the hands of Yadavas in the 11th Century ACE and further to the Bahmani's in 1347 (*Nazim, 1836; Sathyan, 1966*). The city prospered under the governorship of Yusuf entitled Adil Khan a Turk who had entered the service of Bahmani during the early part of 15th Century ACE (*Sherwani, 1985*). The city sits in a sink with a highly dissected and undulating topography of the Deccan Plateau. The plateau soils are shallow along the slopes and uplands while the valleys with thicker layers are extensively cultivated. Below the fine clayey soil on the surface is the weathered basaltic layer (vesicular basalt) and further below the harder Deccan Trap as bedrock. The vesicular basalt layer forms a fairly good aquifer (*Govindankutty Valliyil, 2022*).

2.1. Water and Heat Stress

Vijayapura falls within Karnataka's Kalyana Karnataka (north-interior) region, which regularly records the state's most severe pre-monsoon heat. Local temperature records for Vijayapura show a consistent pattern of severe **pre-monsoon heat** over the past 15 years and readings of **40.2 - 41.1°C recorded on successive days** in early May 2026. In 2024, Vijayapura district was placed under **IMD heatwave red alert** alongside Raichur, Kalaburgi, Yadgir and Bellary, with maximum temperatures forecast to reach 40 - 46°C. In 2026, Vijayapura, along with Bidar, Raichur and Kalburgi, was again flagged for heatwave conditions through April, disrupting daily life. This near-annual recurrence of 40°C+ peak temperatures for over a decade confirms Vijayapura as a chronic, escalating urban heat-risk zone.

Vijayapura district is one of Karnataka's most chronically **drought-affected** districts, sitting in the rain-shadow interior of the Deccan. The district's annual rainfall averages only about 400 mm against a gross annual water deficit of roughly 1,500 - 1,600 mm, meaning the region experiences severe drought conditions through most of the year, with crop growth restricted to only about 90 days annually. Karnataka faced **drought for a third successive year** in 2015-16, with rainfall deficient since 2012-13; by August 2015 the Almatti dam in Vijayapura district was only half full and by March 2016, Vijayapura faced an acute water crisis as Maharashtra delayed release of Karnataka's share of Krishna River water. Karnataka received its **lowest rainfall in 123 years** in 2023-24 and declared **195 of its 236 taluks drought-hit,** with a statewide rainfall deficit of around 40%. Vijayapura, historically among the state's driest districts, was again affected as part of this widespread declaration. The district experiences **recurring drought conditions nearly every year due to erratic rainfall and low humidity** *(Times of India).*

Although Vijayapura district itself is drought-prone in its interior, its position on the Krishna and Bhima River basins and its hosting of the **Almatti (Lal Bahadur Shastri) Dam** make it periodically vulnerable to **reservoir-linked and riverine flooding**. The 2019 Krishna basin floods, recognised as a major flood event causing extensive damage to Krishna basin districts across both Maharashtra and Karnataka, prompting a joint technical study into the impact of Almatti backwaters. Multiple documented episodes in 2020, where heavy inflow from Maharashtra's catchments forced large-scale releases from Almatti with Vijayapura battling deluge, and Sindagi taluk in Vijayapura district cut off from Kalaburagi district after a bridge over the Bhima was submerged. Vijayapura district administration also issued flood alerts for the Krishna River basin due to Almatti dam discharge levels during 2024 floods. Even while the Krishna River threatened flooding along its banks, the Bhima River within Vijayapura district itself had scanty local rains leaving the district anxiously awaiting rainfall for drinking water. In **September 2025**, Vijayapura district faced severe flooding as the Seena River overflowing forced closure of the Vijayapura-Solapur national highway, stranding thousands of vehicles, while the Krishna River was simultaneously in spate, driven by heavy monsoon rains and dam releases from upstream Maharashtra reservoirs in the Krishna basin as in Figure 5, Figure 6.

Figure 5 Waterlogging near Badi Kaman, Vijayapura due to heavy rainfall. August 2026
Source: Bijapur Exppress

Figure 6 Waterlogging near Kori Chowk, Vijayapura due to heavy rainfall. August 2025

Table 1 Water and Water Risk

Indicator	Details	Source
City population; Area; Density (2011)	327,427 persons; 97.5 sq.km ; 33.58 person/hectare	Census of India, 2011
District drought vulnerability rank (India)	Rank 7 of all Indian districts	Govt. of Karnataka, Drought Vulnerability Assessment
Karnataka rainfall deficit (2026 June-July)	~35% deficit; 24 districts rain-deficient	KSNDMC / Deccan Chronicle
Severely drought-hit taluks (undivided Vijayapura–Bagalkot–Belagavi)	34 of 40 taluks	Deccan Herald
Borewells run dry in worst-hit regions (2019 drought)	~25%	KSNDMC, cited in ReliefWeb
India's mean temperature rise (1901–2015)	+0.85°C	Basha et al. 2017, cited in Sci. lit.
Peak recorded max. temperature (1988)	45.1°C (heatwave red alert)	Weather Blaze
State-wide flood-vulnerable villages, Krishna Basin	1,478 of 1,698 total (643 very high-risk)	Karnataka Revenue Dept., cited in Deccan Herald
Flood recurrence interval Vijayapura District in Karnataka river basins	1-4 years (2005–2021)	Flood Vulnerability of Karnataka study
2019 Karnataka floods (statewide, Vijayapura affected)	61 deaths, 40,000+ houses damaged, 2,000+ villages hit	KSNDMC / Wikipedia (MHA data)
Oct 2020 flood relief, 7 North Karnataka districts including Vijayapura	7,776 relocated to 54 camps; 799 houses damaged	Karnataka SDMA, cited in The News Minute
Almatti Dam inflow during Aug 2021 Krishna flood	~5 lakh cusecs	Deccan Herald
Sept 2025 flood, Kalaburagi–Bidar–Vijayapura region	~157 houses damaged	Deccan Chronicle

DROUGHT   HEAT STRESS   FLOOD

Note: There is a research gap in city-level, actionable, spatially resolved evidence which needs to be addressed. the available literature and datasets are almost entirely district- or state-level.

2.2. Natural and Heritage Assets of Vijayapura

Vijayapura is drained by the **Krishna** and **Bhima** rivers and their tributaries, the Ghataprabha, Malaprabha and Doni, with the non-perennial **Torwi stream** feeding the Kharejari headworks directly (Govindankutty, 2022). Ramling Talab (Chalukya-era), Begum Talab, Torwi Sarovar, Ibrahim Sarovar, Afsal Khan Sarovar, and Muhammed Sarovar are man-made embankment reservoirs that also function as groundwater recharge structures and remain part of the district's natural hydrology today (Govindankutty, 2022). Historically, tamarind and mango tree cover dominated the slopes and valleys, though this natural cover is rapidly giving way to unplanned urbanization (Govindankutty, 2022). Vijayapura's heritage falls into two closely linked categories as **monumental architecture** and **historic water heritage**.

Vijayapura City has **more than 50 heritage** structures. Vijayapura's monumental heritage is anchored by several major Adil Shahi-era structures: the **Gol Gumbaz**, a 17th-century mausoleum housing the remains of Muhammad Adil Shah, seventh sultan of the Adil Shahi dynasty, famed for one of the largest unsupported domes in the world; the **Ibrahim Rauza**, a tomb complex dedicated to Ibrahim Adil Shah II, commissioned in 1627 by Queen Taj Sultana and completed in 1633 under Persian architect Malik Sandal, considered one of the finest examples of Deccan architecture; and the **Jama Masjid**, the largest mosque in the city, commissioned in 1537 by Ali Adil Shah I and known for its gilded mihrab inscribed with Persian verses. Beyond these three, the city holds a wide array of further monuments, including Bara Kaman, Malik-e-Maidan (a giant medieval cannon), Gagan Mahal, Anand Mahal, Mithari Mahal, Asar Mahal, the Citadel/Bijapur Fort walls and gates, Upli Buruj, and dozens of smaller mosques, tombs and gateways, while the Archaeological Survey of India's centrally protected list for Vijayapura additionally includes structures such as the Kamarkhi Gumbaz, Karim-Uddin's Mosque, Makka Masjid, the **Moats of the City wall**, and numerous other named mosques and dargahs.

Vijaypura's historic water infrastructure developed under the Bahmani and later, the Adil Shahi dynasty (1490–1686), whose rulers commissioned Persian engineers, under the supervision of court nobles (Amirs), to design and build the city's water supply. The system combined three distinct networks, spatially arranged so that both rich and poor citizens had access to water. An 1850s British survey recorded around **~700 stepless wells and 340 stepped bawdis** in Vijayapura (*The Hindu, 2017*).

3. ABOUT THE PROJECT

Considering the heritage asset and the growing climatic challenges, this project titled "Leveraging A Stepwell - Based Blue Green Infrastructure Framework for Mitigation of Heat and Water Based Risk in Vijayapura, Karnataka" attempts to reintegrate stepwell systems into contemporary urban planning by evaluating their role as stepwell-based blue–green infrastructure for climate-centric multi-hazard mitigation through City Specific Applied Research Project (CAR) under AMRUT Centre of Urban Planning for Capacity Building at SPA Vijayawada (ACUPCB-SPAV) funded by the MoHUA, Government of India. By bridging traditional knowledge with modern spatial and climatic analysis, the research aims to provide a scalable, evidence-based framework that enhances urban resilience while supporting national and global climate goals.

The project adopts a multi-scalar approach to ensure that both heritage-rich and rapidly urbanizing areas are captured, allowing for a comprehensive assessment of climate risks and adaptation potential.

It aims to address the following questions:

- Can traditional water systems reduce combined hazard exposure (heat + flood)?
- How integrated spatial planning of blue–green networks, including existing stepwells, can provide maximum benefit in mitigation?

3.1. Objectives

To address the above questions, the project lays four-point objective as follows:

- To identify heat extreme events and water-related risk exposure within the city at a local scale.
- To conduct baseline assessment of existing stepwells and blue-green infrastructure (BGI) elements based on literature review and site investigations.
- To evaluate spatial integration of stepwells and BGI for mitigation of heat extreme events.
- To propose Blue Green Infrastructure Framework leveraging stepwells for mitigation of Heat and Water Based Risk.

3.2. Scope of the Project

The scope of the project includes:

- The study will examine Vijayapura's urban water and heat landscape holistically, mapping the spatial distribution of historic hydraulic assets alongside present-day urban growth patterns in a City Level.
- For water stress investigations, the study will examine the watershed limits concerning the city.
- The study will integrate Indigenous Knowledge Systems (IKS) into climate-resilient urban planning, rather than treating them as isolated heritage restoration efforts.

3.3. Methodology

The research adopts a two-stage, mixed-method approach combining spatial analysis, field-based measurements, and scenario modelling to evaluate and integrate stepwell systems into a blue - green infrastructure (BGI) framework for multi-hazard climate mitigation strategies. Stage 1 is ‘Literature Review and Baseline Assessment’ and Stage 2 is “Integration, Modelling, and Planning Framework” as shown in Figure 7.

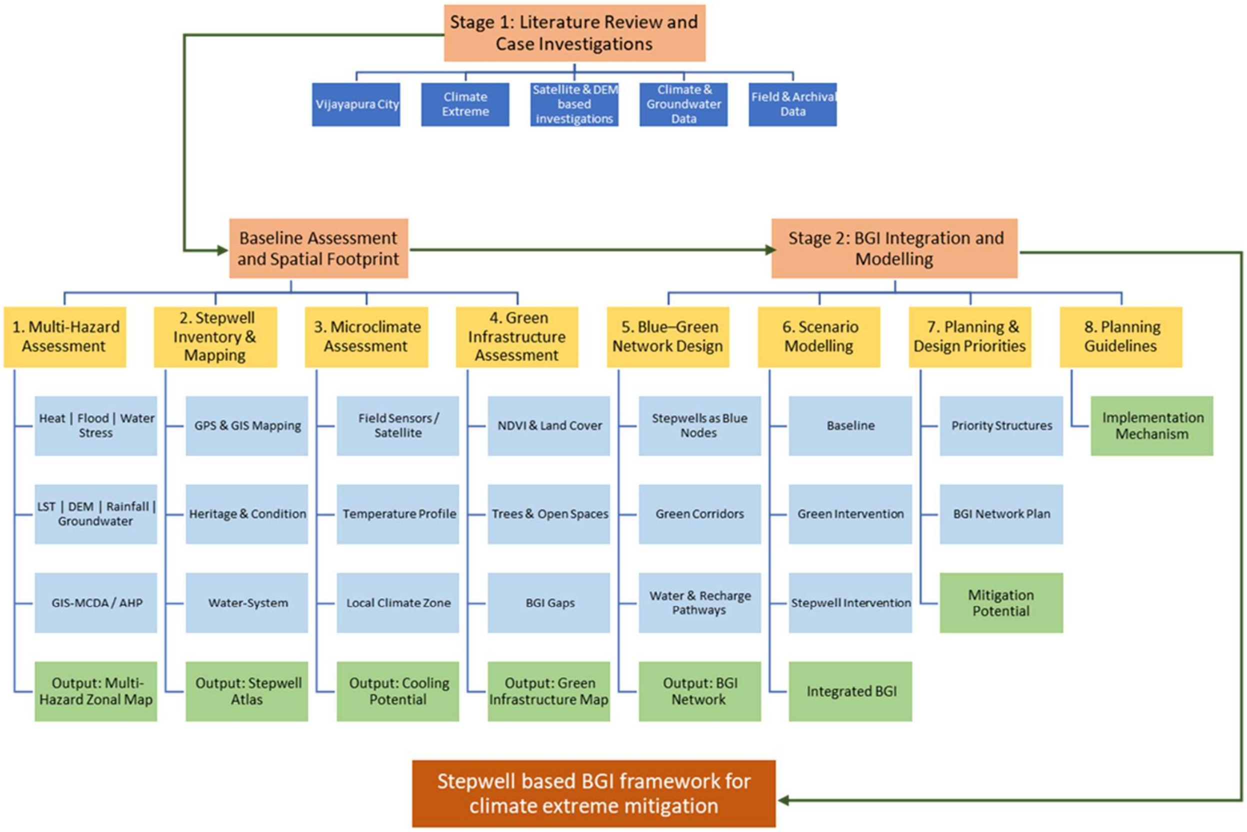

Figure 7 Methodology

STAGE 1: LITERATURE INVESTIGATION AND BASELINE ASSESSMENT

1. Risk Assessment: The first step involves literature review and data collection for identifying and mapping climate-related hazards, traditional water systems and its conditions. Satellite-derived data (e.g., Landsat, Sentinel) will be used to compute Land Surface Temperature (LST) and identify heat hotspots. Digital Elevation Models (DEM), drainage patterns, and rainfall data will be analysed to map flood-prone zones, while groundwater data from secondary sources will be collected to identify water stress areas. These layers will be integrated using GIS-based multi-criteria analysis to develop a Multi-Hazard Zonal Map (MHZM) for the city.

2. Stepwell Inventory and Spatial Mapping: A comprehensive geospatial inventory of stepwells will be developed. This includes location mapping using GPS and GIS, classification based on heritage status, condition, depth, and accessibility; Documentation of associated systems (tanks, channels, recharge zones). Field surveys and secondary archival sources will be used to validate and enrich the dataset. The output will be a Stepwell Atlas, forming the core blue infrastructure layer.

3. Microclimate Measurement and Analysis: To establish the cooling potential of stepwells, detailed field measurements will be conducted at selected representative sites: Portable environmental sensors will be used for data collection. The aim is to quantify temperature differentials (°C reduction); Thermal comfort improvement evidence. The parameters will include air temperature (inside vs outside stepwell), surface temperature, relative humidity, diurnal variation (morning, afternoon, evening).

4. Green Infrastructure Assessment: To identify areas lacking green cover and assess opportunities for integrating stepwells with urban greenery to enhance cooling and infiltration, vegetation cover and green infrastructure will be mapped using GIS and remote sensing tools.

STAGE 2: INTEGRATION, MODELLING, AND PLANNING FRAMEWORK

5. Blue - Green Infrastructure Network Design: Based on Stage 1 findings, stepwells will be conceptualized as nodes within a broader blue–green infrastructure network. Spatial analysis tools will be used to: Connect stepwells via green corridors, identify potential recharge zones and water pathways and optimize BGI spatial distribution for maximum climate benefit.

6. Scenario Development and Simulation: Microclimate simulation tools (e.g., ENVI-met) and hydrological models (e.g., SWMM) to assess temperature reduction, runoff reduction and groundwater recharge potential. Scenarios will be developed and evaluated which will include the following: Baseline scenario (current conditions), Green-only intervention (enhanced vegetation), Stepwell revival scenario, Integrated BGI scenario (stepwells + green infrastructure)

7. Urban Design and Planning Priorities: The study, in consultation with the stakeholders, will identify priority area and aid to develop site-specific and city-level design strategies which may include spaces for conversion of stepwells into public cooling spaces (heat refuges), creation of water plazas and permeable surfaces, integration with stormwater drainage systems and, development of shaded pedestrian corridors

8. Actionable planning guidelines: The final step involves translating findings into actionable Multi-Hazard Climate Mitigation Plan, including scope to integrate Heat Action Plans and/or inclusion in Development Control Regulations (DCRs) and Heritage-sensitive strategies

4. DELIVERABLES

- **Heat and Flood Zone Map:** A GIS-based spatial map overlaying Land Surface Temperature (heat hotspots), flood-prone areas (from DEM, drainage, and rainfall analysis), and groundwater stress zones, providing a consolidated view of where climate hazards are most concentrated across the city.
- **Blue-Green Infrastructure Priority Zones:** A prioritized spatial layer identifying where stepwells, green corridors, and other blue-green interventions would deliver the greatest cooling, groundwater recharge, and flood-mitigation benefit, based on the overlap between hazard zones and existing/potential heritage water assets.
- **Heat and Water Risk Mitigation Plan:** Combining the design strategies like repurposing stepwells as public cooling refuges, introducing water plazas and permeable surfaces, linking them into

stormwater drainage networks, and building shaded pedestrian corridors into an actionable Multi-Hazard Climate Mitigation Plan.

5. PROJECT TIMELINE

The project timeline spans a total of **32 weeks (8 months)**, structured to reflect the two-stage methodology including **12 tasks** as in Figure 8. It begins with **Project Initiation and Literature Review** in the first weeks, followed closely by **Data Collection and Hazard Mapping**, which slightly overlaps into the **Stepwell Inventory and BGI Survey**, allowing field data collection to run in parallel with hazard analysis. This is followed sequentially by **Microclimate Measurement** and the development of the **Multi-Hazard Zone Map**, marking the transition from Stage 1 (Baseline Assessment) into Stage 2 (Integration and Planning). A **Stakeholder Meeting** midway through the timeline validates the baseline findings before the project moves into **BGI Network Design**, **Scenario Development**, and **Simulation and Modelling**, which run in close succession to translate the mapped evidence into design options. The final phase consolidates these outputs into **Planning Priorities and Strategies**, followed by a second **Stakeholder Meeting** to review recommendations, before concluding with the compilation of the **Final Report** in the last two weeks, reflecting a logically sequenced, iterative workflow that builds from evidence generation through to actionable, stakeholder-validated planning outputs.

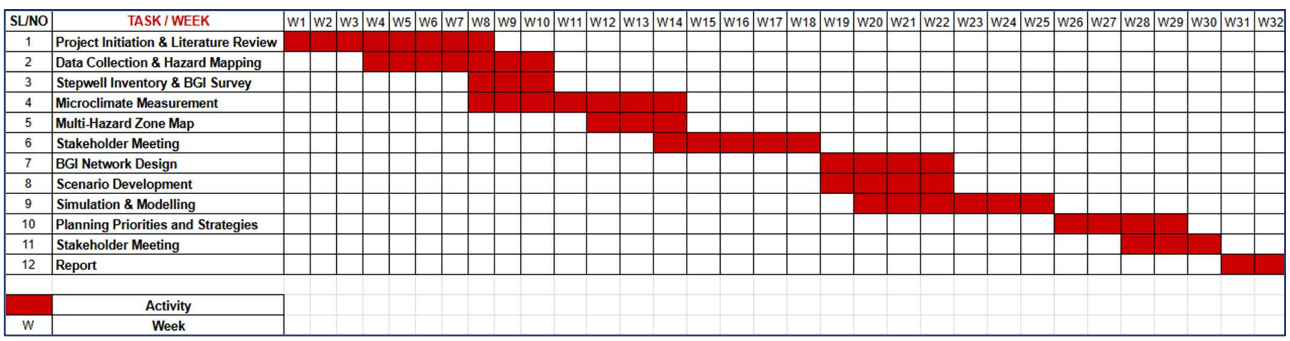

Figure 8 Project Timeline

6. HIGHLIGHTS

The project outcome would aid the local bodies in developing city as climate responsive. It connects the heritage assets and sustainable urban growth through the following: -

- **Evidence-based heat mitigation planning**: Provides ULBs with mapped heat hotspots and cooling zones, enabling targeted interventions such as stepwell-based cooling hubs and shaded corridors.
- **Strengthening Heat Action Plans (HAPs)**: Supports integration of stepwells as decentralized cooling shelters within city-level emergency response strategies.

- **Water-sensitive urban planning**: Helps municipalities enhance stormwater management, groundwater recharge, and drought resilience using existing stepwell systems.
- **Cost-effective infrastructure approach**: Promotes low-energy, decentralized solutions compared to expensive grey infrastructure, reducing long-term operational costs.
- **Heritage-linked urban development**: Enables ULBs to revive and repurpose stepwells as functional assets, aligning conservation with climate adaptation.
- **Improved spatial decision-making**: Provides GIS-based tools and vulnerability maps to prioritize investments in high-risk zones.
- **Integration into planning regulations**: Offers inputs for Development Control Regulations (DCRs) and local plans to protect and utilize water structures.
- **Climate-resilient urban design guidelines**: Assists in designing blue–green corridors, permeable surfaces, and public cooling spaces.
- **Community engagement and inclusivity**: Encourages public use of stepwells as accessible thermal refuges, especially for vulnerable populations.
- **Alignment with national missions**: Supports implementation of programs like the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and Smart Cities Mission, enhancing funding and policy convergence.

7. PROJECT TEAM

Dr. Anurag Bagade, Assistant Professor (Dept of Planning) – Principal Investigator

Prof. Dr. Ayon Tarafdar, Professor (Dept of Planning) – Co-Principal Investigator

Dr. Prasanth Vardhan, Associate Professor, (Dept of Planning) – Team Member

Prof. Dr. Shanmuga Priya G, (Department of Architecture) – Team Member

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Atal Mission for Rejuvenation and Urban Transformation

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