

Heritage Sites and Climate Resilience: Selected Case Studies of Buddhist Archaeological Sites of Telangana

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Abstract

The historic environment is vulnerable to climate change that is continuous. The loss or degradation of these heritage sites adversely affects physicality, collective memory, identity, and cultural continuity. It is learnt that pose a definite need for policies and strategies to address climate change. Protecting and preserving these sites is particularly challenging because of their diversity in form, location, materials, and cultural meaning. This diversity with increased climatic change illustrates a critical gap in existing heritage management and policy frameworks, emphasizing the need for context-specific approaches for safeguarding historic sites. This paper examines the interrelationship between heritage sites and climate resilience through a case study of Buddhist archaeological sites of Telangana, which hold deep cultural, religious, and historical significance shaped by historical transformation, environmental interaction, and changing cultural meanings. Often located on hillocks, near water bodies, or within ecologically sensitive zones, these sites reveal an inherent sensibility towards the environment around, wisely shaped by Buddhist philosophical ideas of engaging with nature. By conceptualizing Buddhist heritage as a dynamic and relational system, this paper argues for the integration of Buddhist sites of Telangana into sustainable heritage management and climate-adaptive strategies. Drawing upon field observations, archival sources, and secondary literature, this paper assesses the resilience embedded within the material culture, landscape integration, and ritual use of Buddhist archaeological sites of Telangana. The study also evaluates current heritage management approaches of integrating climate resilience into conservation planning.

Keywords: Historic environment, preservation, climate resilience, environmental interaction, Buddhist sites, Telangana.

1. Introduction

Climatic resilience refers to the ability of heritage sites to withstand, adapt to, and recover from climate-related stresses while preserving their cultural significance and physical fabric. The climate change that has been recorded during definite periods of time has revealed that the average global surface temperature has increased by more than 1.1°C during the course of the last ten years, compared to the pre-industrial period (1850-1900). Cultural heritage sites that constitute historic structures, monuments,

and archaeological resources, represent invaluable records of human history embodying artistic, architectural, spiritual, and socio-cultural values accumulated over centuries.

The growing impacts of climate change have significantly influenced the discourse on heritage conservation, prompting scholars and heritage organizations to examine the vulnerability of cultural heritage sites to climatic and environmental stresses. Rising temperatures, changing rainfall patterns, flooding, soil erosion, and biological growth are among the factors that threaten the physical integrity and long-term survival of heritage structures. Studies have found that the impact of changes in temperature and humidity patterns due to climate change has a direct impact on historic materials, resulting in surface loss, degradation, and stress on historic structures and sites (Qiu et al., 2025).

According to academic research, the assessment of climate-related risk factors associated with sites of cultural heritage requires the adoption of methodical approaches that consider the exposure of the site, climate-related hazards, and the vulnerabilities of the materials (Thomas et al., 2025). The necessity of understanding heritage sites as a dynamic cultural landscape has increased due to the increased number of climate-induced challenges, which include heavy rains, temperature changes, erosion, and biological growth. Hence, the Buddhist archaeological landscapes of Telangana have become an important platform for understanding the interaction between settlement patterns and nature.

Telangana, the youngest state of India, whose rich cultural heritage expands across history, contains several significant Buddhist archaeological sites that date back from 4th century BCE to 4th century CE. Some of the notable sites include Phanigiri, Gajulabanda, Nelakondapalli, Dhulikatta, Bavapur Kurru and Karukonda. Despite their archaeological and cultural significance, the climatic vulnerabilities of these Buddhist sites remain relatively under-examined in scholarly research. Many of the structures like stupas, viharas, chaityagrihas, and mandapas, unearthed at these places are found to be constructed primarily of brick masonry with lime mortar, stone components, and earthen structures. The drums of some stupas were embellished with lime stone slabs. Due to their close association with natural environment these Buddhist structures face an increased risk from climate change and are vulnerable to climatic stressors such as monsoonal rainfall, surface runoff, vegetation growth, and temperature fluctuations.

Most of the research has focused on physical monuments and spatial conservation, despite growing literature on climate change and cultural resilience. Early historic Buddhist landscapes show a lack of context-specific studies integrating landscape ecology, material science, philosophical planning, and climate risks highlighting the need for research on Telangana's Buddhist heritage sites. The study focuses on landscape integration, planning patterns, and architectural remains, while also considering Buddhist philosophical and cultural interactions with the environment to provide a broader perspective. This concept aligns with the UNESCO definition of cultural landscapes, which recognizes the interaction between people, belief systems, and the natural environment (UNESCO, 2005).

1.1 Aim and Objectives

This study aims to explore the association between the resilience of Buddhist heritage and climate change in the Telangana region with the following objectives.

1. To identify the climatic and environmental risks affecting the selected Buddhist archaeological sites of Telangana.
2. To assess the vulnerability of these sites based on environmental exposure, material characteristics, and their spatial location within the landscape.

3. To analyze the ecological sensitivity and resilience in the planning and spatial organization of these sites.
4. To propose sustainable, climate-adaptive conservation strategies for Buddhist archaeological sites of Telangana.

1.2 Scope and Limitations of the study

This study examines the climatic resilience of selected Buddhist archaeological sites in Telangana, focusing on their materials, landscape context, and exposure to climatic stressors such as rainfall, temperature variation, erosion, moisture ingress, vegetation growth and extreme events. It adopts an interdisciplinary approach linking heritage conservation with climate and cultural landscape perspective. However, the study is limited to a small number of sites, and its findings may not represent all heritage contexts.

This study primarily focuses on climate-related factors influencing the resilience of Buddhist archaeological sites in Telangana, while giving comparatively less emphasis to anthropogenic influences and heritage management practices. The research adopts a predominantly qualitative approach, drawing upon comparative analysis of secondary literature, archival records, and field observations to examine site-specific climatic vulnerabilities and resilience characteristics. The absence of detailed material characterization, long-term environmental monitoring, and site-specific climatic datasets limits the scope for quantitative assessment and modelling. Consequently, the findings should be interpreted as context-based qualitative insights that contribute to understanding the climate resilience of the selected archaeological sites rather than as definitive quantitative evaluations.

2. Literature review

Research indicates that increased temperatures, changes in precipitation patterns, and more frequent extreme weather events are major manifestations of climate change. These factors contribute to various processes of degradation at cultural heritage sites, including erosion, biological growth, and material decay. (Dimabayao et al., 2025). Archaeological heritage sites have received less attention than built heritage sites in risk assessment models (Sesana et al., 2021; Thomas et al., 2025). Unlike architectural assets and urban environments, archaeological sites still remain peripheral in literature on climate change. Often it is noted that certain frameworks for assessment and management are needed in view of the special vulnerability of archaeological assets such as their exposure, their material vulnerability, and their landscape vulnerability (Paloma & Cathy, 2025). Significant research is available for the evaluation of climate change risks for cultural heritage assets. (Chikodzi et al., 2022). For effective management of risks, especially in contexts where resources are limited, it is considered essential to analyze the risks across multiple factors such as environmental, socioeconomic, and regional factors (Lankester & Knight, 2024).

The policy basis for action can be enhanced by linking heritage resilience to disaster risk reduction and Sustainable Development Goals (Aktürk & Hauser, 2025). The impact of climate change on cultural heritage, which is a relatively newer field of study that emphasizes the importance of risk-informed approaches to the preservation of cultural heritage sites as much as the physical degradation of the site itself. (Sesana et al., 2021). Likewise, (Hollesen, 2022) highlights the impact of environmental risks on archaeological heritage sites and emphasizes the importance of developing monitoring systems that consider climatic changes. Through the use of spatial analysis and GIS to identify vulnerabilities to climatic changes for different qualities of heritage, (Figueiredo et al., 2020), is an improvement on risk

assessment approaches and allows for the prioritization of measures to mitigate the risk. The significance of the use of exposure, sensitivity, and adaptive capacity in the development of resilience indices is further brought out in another study by (Blavier et al., 2023), which proposes a model for assessing resilience, especially for heritage structures that experience extreme weather and service disruptions.

Nevertheless, heritage landscapes and archaeological sites found in rural areas receive less attention compared to built heritage and monument complexes, which form the focus of the majority of the existing studies. Though the studies by (Li et al., 2024; López Sánchez et al., 2020) focus on heritage tourism and the sustainability of the landscape with regards to environmental change, there is no particular discussion regarding archaeological Buddhist sites and their ecological/cultural settings.

In light of the impacts of climate change on cultural heritage sites, there is now the need to assess climate risks. As per recent studies, not only the climate threats but also exposure, sensitivity, and adaptive capacity play a part in heritage risks. (Sesana et al., 2020) used climate exposure, sensitivity, and management capacity to design an integrated vulnerability index for World Heritage Sites. (Adetunji & MacKee, 2026) found that there are certain problems with this approach because specific climate information about sites and adaptation strategies are limited despite the gradual introduction of both qualitative and quantitative measures in climate risk management frameworks. This issue was highlighted even more by (Thomas et al., 2025) who pointed out the need to use multidimensional approaches in order to consider environmental, material, and cultural significance of the area.

Frameworks related to the interaction of culture, ecology, and society within a landscape approach have gradually substituted the monument approach for the preservation of heritage in contemporary times. Cultural landscapes involve a set of conditions whereby cultural values, the environment, and traditions are used to ensure resiliency. As (Moussavi.A & Lak, 2024) state, it is necessary to consider such elements as ecology, history, and communities when adopting strategies for adaptation to climate changes in cultural landscapes. Similarly, research into the landscape approach to conservation emphasizes the need for localized approaches rather than conservation approaches. Such an approach is relevant to archaeological landscapes since the sustainability of sites depends on location, topography, vegetation, and hydrology.

Given changing climatic conditions, heritage vulnerability assessment frameworks provide systematic means for identification of indicators associated with material sensitivity, environmental exposure, structure integrity, and adaptability capabilities that have been often applied within existing frameworks for vulnerability assessment. In order to assist risk-informed decision-making process, (Cacciotti et al., 2024) proposed an approach for vulnerability assessment which combines climate-related risks with heritage characteristics. Importance of factors such as location, drainage situation, construction material, and state of conservation as a determinant of historical sensitivity has been discussed in recent literature on flood and climate risk assessment (Bonazza et al., 2021).

Due to climate variability, extreme weather conditions, and lack of integration of climate adaptation measures in conservation planning, the ancient heritage of South Asia is now at risk. This is because most of the archaeology sites in the region are located in fragile ecosystems, river valleys, and semi-arid regions, making them vulnerable to erosion, flooding, temperature changes, and biological growth. From various studies on this matter, it can be noted that heritage management in South Asia requires context-specific measures that consider the region's resources and environment, among other things. The limited resources and lack of collaboration between climate scientists and heritage managers increase the

challenges linked to climate adaptation measures. In this case, landscape approach and multidisciplinary perspective are critical in ensuring the safety of the archaeological heritage in South Asia (Adetunji & MacKee, 2026; Sesana et al., 2020; Wijesuriya, 2021). Indicator based assessment frameworks are particularly suitable for cultural heritage because they help assess the combined effects of cultural and climatic factors.

2.1 Research Gap:

Although a large amount of work has been conducted in regard to how climate hazards affect cultural resources, it is mostly site-specific in nature and concentrates on degradation rather than viewing archaeological landscapes as an ecological-cultural system. Climate change resilience that may result from the traditions of culture, integration of the landscape, and historical settlement patterns has not been explored much. Moreover, although vulnerable to various environmental factors, the South Asian archaeological heritage has not been much represented in international climate adaptation studies yet. In order to take into account specific characteristics of archaeological sites, it is necessary to further adjust the existing frameworks for risk assessments. This research will fill the identified gap by evaluating the Buddhist archaeological sites of Telangana through a landscape approach to resilience.

2.2 Conceptual Framework:

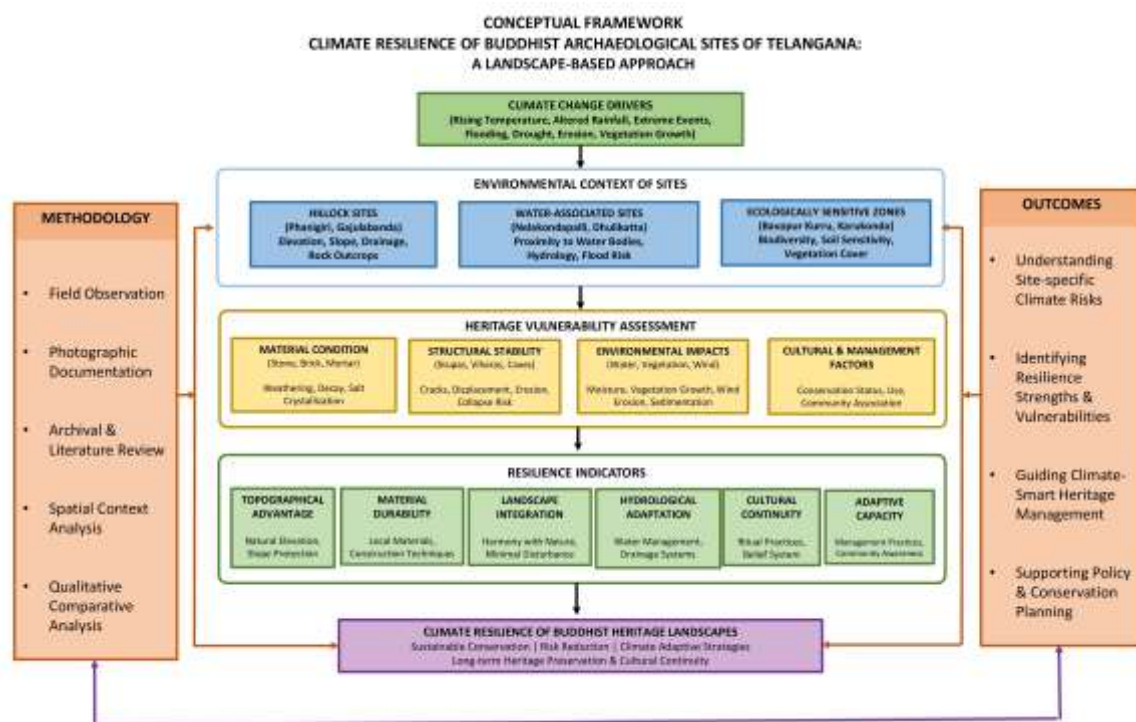


Figure 1: Conceptual framework . Source : Author(s), 2026

Figure 1 shows the conceptual framework that helps in understanding the interaction between the environment, vulnerability of the heritage, impacts of climate change, and resilience at the Buddhist archaeological sites of Telangana. The framework takes into account the characteristics of the sites, like hills, water bodies, and ecological zones, along with climatic impacts like changes in temperatures, precipitation, erosion, and floods. The material aspect, structural aspect, impact of the environment, and management of the sites are some of the factors taken into account while considering the vulnerability of the heritage sites. Topography, material longevity, landscape adaptation, hydrological adaptability,

cultural sustainability, and adaptive capacity are some of the factors considered for evaluating the resilience of the heritage sites.

3. Methodology

This study adopts a multiple case study design to examine climatic resilience in archaeological heritage sites of Telangana. Six significant Buddhist sites were selected across varied environmental contexts to enable comparative analysis. Sites on hillocks include Phanigiri and Gajulabanda; those near water bodies include Nelakondapalli and Dhulikatta; and sites in ecologically sensitive zones include Bavapur Kurru and Karukonda. These locations feature remains such as stupas, chaityas, viharas, rock-cut caves, and monastic complexes.

The research primarily relies on qualitative methods, with systematic field observation as the core approach. Physical observation was conducted to document topography and environmental settings, while the material condition of structural remains was assessed to understand durability and weathering processes. Indicators such as erosion, vegetation growth, and water-induced deterioration were examined. Photographic documentation was used to record site conditions and deterioration patterns for comparative analysis. In addition, secondary data from archival sources, academic publications, and heritage studies were reviewed to contextualize findings and incorporate existing scholarly perspectives, ensuring a comprehensive and well-grounded analysis. The research uses an interdisciplinary approach that includes knowledge of archaeology, environmental evaluation, cultural landscape interpretation, and conservation planning approaches.

The environmental setting of each site has been examined through a spatial context analysis. A qualitative comparison framework with spatial and environmental interpretations was utilized to analyze the collected data. The data collected was arranged according to the main parameters of climatic resilience and structural stability, landscape integration and cultural continuity. In order to illustrate the similarities and differences in the techniques of adaptation that have been included in the process of site planning and architecture, a cross-case analysis has been conducted. To put the climatic exposure into context, an interpretive analysis has been conducted using basic environmental data. The selected locations include hilltop sites (Phanigiri and Gajulabanda), water-based sites (Dhulikatta and Nelakondapalli), and ecologically sensitive regions (Bavapur Kurru and Karukonda). This classification enables comparison of the influence of geographical conditions on climate exposure, adaptability, and conservation problems.

Cultural continuity as a resilience indicator through consideration of continued cultural connections, ritual importance, community connections, and the importance of heritage sites to collective memory. The site factors were documented using photographic recordings and a systematic assessment of the erosion patterns, vegetative growth, material degradation, and drainage and landscape connectivity at the sites. The resilience indicators were used to categorize the observed information, and comparisons between the selected cases were made.

Table 1: Parameters for climate resilience

Parameter	Indicators
Topographical Advantage	Elevation, slope condition, natural drainage
Material Durability	Construction material, weathering, deterioration

Landscape Integration	Terrain adaptation, vegetation relationship, orientation
Hydrological Adaptation	Water proximity, flood exposure, drainage pattern
Cultural Continuity	Ritual practices, belief systems, community association

Source: Author(s), 2026

4. Data (Case study) Analysis and Findings

The criteria for climate resilience, which include topographical advantage, physical durability, landscape integration, hydrological adaptability, and cultural continuity, are used to conduct the case analysis. Evaluation of flood protection and runoff efficiency was carried out by studying topography and natural drainage patterns. Evaluation of durability against climatic stress was carried out by studying the resistance to weathering and materials used for construction. Evaluation of integration with the landscape was carried out by studying environmental factors, interaction with vegetation, and alignment with natural slopes. Evaluation of flood vulnerability and proximity to water bodies was carried out to assess hydrological risks.

4.1 Sites on Hills/Hillocks

Hill sites in Buddhism were deliberately selected for their seclusion and tranquillity, supporting meditation and ascetic practices (Lars Fogelin, 2006). Monasteries (viharas) and stupas were often located on hilltops to create spiritually conducive environments, where elevation symbolized spiritual ascent (Mircea Eliade, 1959). Their visual prominence across landscapes helped establish them as important pilgrimage landmarks (Himanshu Prabha Ray, 2004). Hill environments also provided climatic advantages, such as improved ventilation and reduced humidity, aiding both habitation and structural preservation (D. Mitra, 1971). Architecturally, these sites reflect landscape-sensitive planning, with features like rock-cut caves and terraced construction adapting to topography (A. Ghosh, 1989). Many such sites were earlier sacred landscapes, later integrated into Buddhist traditions, demonstrating cultural continuity (Romila Thapar, 2002).

4.1.1 The Monastic establishment of Phanigiri



Figure 1: Ariel view of Phanigiri Buddhist site,
(Source: Google Earth, 2024)



Figure 2: Remains of Buddhist site on Phanigiri

Source : Author(s) ,2024

4.1.1.1 Climatic Resilience and Structural Stability

The archeologically remains at the Phanigiri Buddhist Site demonstrate a significant degree of structural stability and environmental adaptability, reflecting the construction knowledge and planning strategies employed in early Buddhist architecture. Located in the Deccan plateau region of Telangana, the site primarily dates to 2nd c. BCE – 3rd c. CE. Locally available limestone was used for its durability and compressive strength. Rubble masonry techniques wherein irregular stone blocks were arranged in thick load-bearing walls with smaller stones filling the interstitial gaps were adopted. In addition to stone masonry, burnt bricks often larger than modern bricks, some of them measuring 22”x11”x3”, were employed in construction of stupa, chaityas, viharas and other structural elements. They were bonded with lime mortar, which served as a flexible and durable binding material capable of accommodating minor structural movements. Thick masonry walls help moderate internal temperatures by reducing heat penetration during hot summers, while lime mortar joints allow moisture evaporation, thereby preventing long-term deterioration of masonry.

The topographical context of the site also played a crucial role in ensuring structural stability. The monuments were constructed on naturally elevated rock surfaces of the hill, providing a firm foundation capable of supporting masonry loads. Terraced construction across the hill slopes created stable platforms contributing to slope stabilization. The circular plan of the stupa further enhanced structural stability by allowing uniform distribution of loads along the circumference of the structure. The elevated hilltop location promotes natural ventilation and reduces moisture accumulation around the foundations. The sloping terrain facilitates effective surface drainage during monsoon seasons, thereby minimizing water infiltration into masonry joints.

4.1.1.2 Landscape Integration

The Phanigiri Buddhist Site demonstrates a strong integration between architecture and the natural landscape, which is a characteristic feature of many early Buddhist monastic complexes. Hill which resembles the hood of a serpent influenced the name “Phanigiri” that also contributed to the spatial organization of the monastic settlement. One of the primary aspects of landscape integration at Phanigiri is the adaptation of architectural structures to the natural topography of the hill. Terraced platforms along the slopes were created to accommodate major architectural components. This terraced arrangement allowed the structures to be anchored directly onto stable rock surfaces, thereby enhancing structural stability while maintaining harmony with the natural landform. The elevated setting allowed for natural ventilation and panoramic views of the surrounding plains, which likely contributed to the contemplative environment associated with Buddhist monastic life.

4.1.1.3 Cultural Continuity

Historically, Phanigiri flourished as a prominent Buddhist monastic centre during the period of the Satavahana Dynasty and later under the Ikshvaku Dynasty. The site functioned as an important centre for Buddhist religious practice, learning, and pilgrimage. The presence of sculptural fragments, inscriptions, and relic stupas further suggests that ritual activities and monastic life were sustained here for several centuries. Although active Buddhist monastic traditions at the site gradually declined after the early medieval period, the sacred character of the landscape appears to have persisted in local cultural memory. The hill on which the site is located continues to hold cultural significance for nearby communities, reflecting a form of continuity in the perception of the landscape as a place of spiritual importance. In recent decades, archaeological investigations and conservation initiatives by the Department of Heritage Telangana, (erstwhile State Archaeology and Museums), have contributed to the revival of interest in Phanigiri as an important cultural heritage site which also increased public awareness and scholarly attention.. Additionally, the establishment of Site Museum and heritage awareness programs has increased public engagement with the site's historical legacy.

4.1.2 Gajulabanda:



Figure 3: Plan of Buddhist site at Ganjulabanda
(Source: Department of Heritage, Telangana)



Figure 4: Stupa and surrounding environment of Gajulabanda Buddhist site, Source : Author(s), 2024)

4.1.2.1 Climatic Resilience and Structural Stability

The Gajulabanda Buddhist Site represents an important early historic Buddhist settlement in Telangana. The site which flourished during 1st c. CE- 2nd c. CE, particularly under the influence of the Satavahana Dynasty, reflects a well-planned integration of materials, construction techniques, and topographical advantages. Archaeological evidence suggests that stone masonry and burnt brick were the primary construction materials used for building stupas, viharas and other monastic structures. In structural remains, rubble masonry techniques were employed, where irregular stone blocks were assembled with smaller stones filling the voids, thereby enhancing the cohesion and mass stability. Brick masonry, often bonded with lime mortar, was also used. The topographical context of Gajulabanda, a slightly elevated

terrain or hillock, where structures were often built directly on stable rock surfaces enhanced the stability of monuments. In addition to structural considerations, the planning and construction of the site reveal adaptation to regional climatic conditions similar to the Phanigiri site. The elevated terrain facilitates natural drainage during monsoon seasons, preventing water stagnation around structural foundations.

4.1.2.2. Landscape Integration

Like Phanigiri site, Gajulabanda Buddhist Site also illustrates a close relationship between the built environment and the natural landscape.. Located in the semi-arid plateau landscape of Telangana, it provided both environmental advantages and symbolic significance, reflecting the Buddhist preference for establishing monastic complexes in tranquil and elevated settings conducive to meditation and monastic life. The spatial organization of the site further reflects a deliberate relationship with the surrounding environment. Stupa was constructed at an elevated point, making it visually prominent within the landscape. The surrounding natural environment, including rocky outcrops, vegetation cover and Bikkeru river one of the tributaries of Godavari, to the east of the site, contributes to the overall character of the site and reinforces its integration within the broader cultural landscape. Additionally, the elevated setting allows for improved air circulation and exposure to natural light, which would have contributed to comfortable living conditions for the monastic community.

4.1.2.3 Cultural Continuity

Archaeological findings suggest that Gajulabanda functioned as a Buddhist monastic centre during the early historic period. The remains of stupas, viharas, and associated architectural fragments indicate that the site once supported an organized monastic community. The spatial arrangement of the structures suggests that the site served as a place of worship as well as a centre for the dissemination of Buddhist teachings within the region. The hill and surrounding area continue to be recognized by nearby communities as a historically important place, indicating the survival of cultural memory associated with the site. In recent years, archaeological documentation and heritage conservation initiatives by Department of Heritage, Telangana, have contributed to awareness of the site's historical importance.

4.2 Sites near Water Bodies

Buddhist sites were frequently established near water bodies to ensure water availability for monastic life, ritual use, and agrarian support. Proximity to water also enhanced microclimatic comfort and facilitated trade routes, aiding the spread of Buddhism. Buddhism emphasizes monks to inhabit tranquil, resource-sufficient landscapes conducive to meditation. (Fogelin, 2006; Schopen, 1997; Cunningham, 2015; Shaw, 2007).

4.2.1 Nelakondapalli



Figure 5: Stupa at Nelakondapalli Buddhist site, Source : Author(s), 2024

4.2.1.1 Climatic Resilience and Structural Stability

The Nelakondapalli Buddhist Site represents one of the most significant Buddhist archaeological sites in Telangana associated with early Buddhist monastic architecture that dates back to 1st c. BCE to 6th c. CE. The surviving structural remains demonstrate the use of durable materials, stable construction techniques, and site planning strategies that contributed to both structural stability and climatic resilience. Nelakondapalli is well known for mahastupa which is considered largest in South India. The massive construction with bricks of size 22"x11"x3" laid in systematic courses ensured structural strength. Bonding with lime mortar provided cohesion and flexibility within the masonry.

The circular drum base and hemispherical dome with recessed terraces enhanced long term stability protecting the structure from soil erosion and moisture infiltration. The region experiences high temperatures and seasonal monsoon rainfall, thick brick masonry walls provide thermal mass and the use of lime mortar allows the masonry to breathe by permitting moisture evaporation. The slightly elevated terrain of the settlement helps prevent water stagnation during monsoon seasons, while the layout of the structures allows for adequate air circulation across the complex. The integration of durable materials, effective masonry techniques, and environmentally responsive design illustrates the sophisticated construction knowledge applied in the development of this major Buddhist centre.

4.2.1.2 Landscape Integration

Situated in the plains of Telangana, the site developed within a landscape characterized by gently undulating terrain, fertile agricultural fields, and nearby water sources. This setting provided both environmental advantages and accessibility, making it suitable for the establishment of a large monastic and religious centre. Unlike many Buddhist sites located on hilltops, Nelakondapalli was developed primarily on relatively level terrain. by creating raised platforms and plinths for Mahastupa. These elevated platforms helped establish visual prominence within the landscape while also protecting the structures from seasonal water accumulation and soil moisture.

The surrounding natural environment also contributed to the functional and symbolic character of the site. The open plains allowed the monumental stupa to be visible from considerable distances, reinforcing its significance as a religious landmark within the regional landscape. Additionally, the availability of nearby water resources from now the Balasamudram lake, would have supported the daily needs of the monastic community and facilitated agricultural activities that sustained the settlement. The relatively open terrain enabled natural air circulation, which helped moderate the effects of the region's hot climatic conditions.

4.2.1.3 Cultural Continuity

Archaeological excavations indicate that Nelakondapalli flourished as a major Buddhist settlement during the early historic period, particularly under the influence of the Satavahana Dynasty. The site functioned as an important centre for Buddhist religious practices, learning, and pilgrimage. The remains indicate that monastic activities, ritual practices, and the dissemination of Buddhist teachings were sustained at the site for several centuries. Over time, the site became integrated into the broader cultural and historical identity of the region, reflecting a form of cultural continuity through the preservation of place-based memory and local awareness of the ancient remains. In recent decades, archaeological investigations and conservation initiatives by the Department of Heritage Telangana, have strengthened the cultural relevance of the site.

4.2.2 Dhulikatta



Figure 6: Stupa and surroundings at Dhulikatta Buddhist site, Source: Author(s), 2024)

4.2.2.1 Climatic Resilience and Structural Stability.

The Dhulikatta Buddhist Site represents an important early historic archaeological site in Telangana that flourished between 2nd c. BCE to 1st c. BCE. Particularly during the period of the Satavahana Dynasty, when Buddhist monastic establishments expanded across the Deccan plateau. Similar to the Nelakondapalli site, Structural stability at Dhulikatta is largely attributed to the use of robust construction materials and well-developed masonry techniques by burnt bricks and stone masonry. The bricks used were arranged in systematic courses and bonded with lime mortar. The circular plan of the stupa facilitates an even distribution of loads around the structure, reducing the concentration of stress at specific points. In addition, the embellishments in lime stone cladding to the base reflect the symbolism and iconography of Buddhist teachings.

4.2.2.2 Landscape Integration

Situated in the plains of Telangana, the site developed within a landscape influenced by nearby Hussainmiya Vagu, a rivulet of Godavari, fertile agricultural lands, and gently undulating terrain. This environmental setting provided favorable conditions for the establishment of a Buddhist monastic complex and associated habitation areas. Access to water resources would have been essential for sustaining the monastic community and supporting agricultural activities in the surrounding region. The riverine landscape also facilitated trade and communication networks, which likely contributed to the growth and prominence of the settlement. Environmental factors such as open plains allow for natural air circulation, which helps mitigate the effects of high temperatures typical of the region.

4.2.2.3 Cultural Continuity

Archaeological excavations at Dhulikatta reveal that the site flourished as a Buddhist centre during the early historic period; the settlement functioned as both a religious and urban centre. The stupa served as the primary focal point for ritual activities, pilgrimage, and the veneration of relics of the monastic community. The strategic location of Dhulikatta within the broader trade and communication networks of the Deccan region may have facilitated cultural interactions and the dissemination of Buddhist teachings.

The presence of fortifications and habitation remains suggests that the site also functioned as a settlement that supported economic and social activities alongside religious practices. Such integration of religious and urban functions reflects the broader cultural landscape in which Buddhist monastic establishments operated during the early historic period. The Department of Heritage Telangana has undertaken documentation and preservation initiatives that have enhanced public awareness of the site's historical importance.

4.3 Sites in Ecological Sensitive areas:

Buddhism presents a simple and practical approach to living in harmony with nature. Its teachings are based on ideas like interdependence, non-violence, and moderation in the use of resources. These principles encourage respect for all living beings and discourage overuse or harm to the environment. Buddhist practices were often carried out in natural settings such as forests and near water bodies, showing a close relationship with the environment. Today, scholars connect these ideas with sustainability and environmental conservation (Harris, 2000; Tucker & Williams, 1997; Schmithausen, 1991; Chapple, 2000).

4.3.1 Bavapur Kurru :



Figure 7: Surroundings of Bavapur Kurru

Source: Author(s), 2024



Figure 8 : Ariel view of Bavapur Kurru Buddhist site
(Source: Google Earth, 2024)

4.3.1.1 Climatic Resilience and Structural Stability.

The Bavapur Kurru is an important Buddhist archaeological site that flourished during 3rd c. BCE to 3rd c. CE. Located on an island formed by bifurcation of Godavari River in present day Nirmal district of Telangana, preliminary investigations have documented a brick-built stupa, and viharas, indicating the presence of an organized monastic establishment. The structural remains at the site reflect construction practices that ensured durability and stability while responding to the tropical semi arid climatic region of present Nirmal district of Telangana.

The elevated mound setting and durable brick construction would have provided protection against seasonal flooding and moisture-related deterioration, while the island context ensured relative isolation and reduced anthropogenic pressures. Excavations and preliminary surveys revealed that the structural stability of the monuments at Bavapur Kurru is largely attributed to the use of brick masonry and carefully prepared foundation systems suited to the soft alluvial soils of the Godavari region. As it

experiences high humidity, heavy monsoon rainfall, and seasonal flooding, elevated platforms and raised plinths may have protected the structures from water accumulation and surface runoff.

4.3.1.2 Landscape Integration

Located in the fertile plains of Telangana the site developed within the alluvial terrain influenced by the distributaries of Godavari River. This geographical setting played a crucial role in shaping the spatial organisation, environmental adaption and functional character of the Buddhist settlement. One of the key aspects of landscape integration at Bavapur Kurru is the adaptation of architectural structures to the low-lying and flood-prone environment. The builders appear to have carefully selected slightly elevated ground within the alluvial plains for the construction of religious monuments such as stupa and monastic structures that reflects an understanding of the hydrological conditions typical of island landscapes.

The proximity of the site to the Godavari river system also contributed to its strategic and cultural significance. Riverine networks historically served as important routes for trade, communication, and the movement of religious ideas. The location of Bavapur Kurru within this riverine landscape may have facilitated interactions between monastic communities and trading groups, thereby supporting the spread of Buddhism across coastal Andhra regions through the riverine networks of the Godavari. The open plains and agricultural lands surrounding the site would have also provided resources necessary for sustaining the resident monastic population.

4.3.1.3 Cultural Continuity

Archaeological investigations indicate that Bavapur Kurru flourished as a Buddhist settlement during the early historic period. The discovery of stupa remains, brick structural foundations, and associated artifacts suggests that the site functioned as a religious centre where ritual practices, monastic activities. The landscape surrounding Bavapur Kurru continues to preserve traces of this historical past, linking the present-day environment with its earlier Buddhist heritage. Through archaeological research, conservation efforts, and heritage awareness, the site continues to maintain relevance in understanding the historical development of Buddhism and the cultural heritage of the region.

4.3.2 Karukonda



Figure 9: Hill and Buddhist Structures of Karukonda, Source: Author(s), 2024

4.3.2.1 Climatic Resilience and Structural Stability.

Located within the hilly terrain of Karukonda Ramavaram in Telangana the site belongs to 3rd c. CE to 4th c. CE, experiences a tropical climate characterized by high temperatures, seasonal monsoon rainfall, and varying humidity levels. Two rock-cut caves and a rock-cut stupa are found in the footing of the hill. The caves were carved into hard, weather-resistant rock, sedimentary rock formations, primarily sandstone and lateritic formations typical of the Godavari valley region which naturally withstands

erosion, heat, and rainfall better than built structures. Rock-cut caves are carved into the hillside rather than built outward, reducing direct exposure to wind, rain, and temperature fluctuations. The natural vegetation on the hill also protected the caves and stupa from high temperatures. Despite centuries of exposure to climatic stresses such as rainfall, temperature variation, and vegetation growth, the rock cut caves survived, demonstrating considerable durability. Yet a part of the rock cut stupa is damaged because of a thunderbolt creating a crack in the boulder.

4.3.2.2 Landscape Integration

The Buddhist site of Karukonda occupies an elevated terrain that offers both environmental advantages and symbolic significance. The secluded hill setting also reinforced the contemplative and spiritual atmosphere associated with Buddhist monastic establishments..The sloping terrain facilitates natural drainage during the monsoon season, preventing water accumulation around the stupa and caves.. The forested environment and vegetation cover contribute to microclimatic moderation by reducing direct solar exposure and promoting natural air circulation.

4.3.2.3 Cultural Continuity

The rock-cut stupas served as ritual and commemorative centres of worship, while the associated caves functioned as monastic dwellings, collectively supporting both the spiritual and residential needs of the Buddhist community. In recent decades, archaeological documentation and conservation initiatives of the Department of Heritage Telangana, helped preserve the Stupa and Caves promoting research and tourism on the Buddhist heritage of the region.

5.1 Table 2: Comparative study on selected Buddhist sites

Site	Environmental Context	Resilience Characteristics	Major Climate Concerns
Phanigiri	Hillock landscape	Elevated location, rock bed, natural drainage, landscape adaptation	Soil erosion, weathering, moisture ingress
Gajulabanda	Hillock landscape	Terrain integration, natural ventilation, landscape compatibility	Material deterioration, vegetation growth
Nelakondapalli	Water-associated landscape	Hydrological awareness, settlement planning	Moisture exposure, flooding risk
Dhulikatta	Water-associated landscape	Resource accessibility, spatial organization	Water damage, vegetation intrusion
Bavapur Kurru	Eco sensitive area	River landscape integration	Erosion and environmental changes
Karukonda	Eco sensitive area	Ecological buffering, stable rocky, foundation	Ecological disturbance

Source: Author(s), 2025.

5.2 Results and Discussion

The selected sites for study together reveal the strong connection between heritage and climate resilience. Instead of random planning, the geographical spread of the selected sites across varied topography reveals an intentional environmental participation. The hillocks of Phanigiri and

Gajulabanda reveal an intensive understanding of topographical advantage. The elevated ground enabled natural draining, ventilation, and protection from floods. These sites reveal the symbiotic connection between spiritual solitude and environmental safety. The ecological awareness of the monastery planning is revealed by the architectural assimilation with the slopes, indicating minimal disturbance to the natural terrain. Being close to water bodies, Nelakondapalli and Dhulikatta present an alternative adaptable model. These sites were part of the larger socioeconomic systems through their proximity to rivers. This proximity made one vulnerable to the instability of the earth's surface, dampness, and floods. The mitigating strategies are evident in the drainage systems and the elevated position. By managing the environment's risk, these sites have shown resilience.

The analysis suggests that resilience attributes vary depending on the geographical context. Water-related settlements have an adaptive response to hydrology while hillocks exhibit resilience by elevation and natural drainage. The resilience of these sites to environmental stress has been additionally made possible by the layout of habitation and material selection. Relational settlement patterns are evident in the sites like Bavapur Kurru and Karukonda, which are placed in ecologically vulnerable areas. However, the vulnerabilities of erosion, flooding, and climatic change are areas of weakness. The sites should not be considered only as archaeological in their character but also as relational landscapes where ecological, architectural, and cultural processes that continue to influence resilience.

The material culture of bricks and stones demonstrates varying levels of resilience to environmental exposure at all six locations. However, the more pertinent fact is that resilience does not extend to structures alone. These locations are nurtured as religious landscapes that are based on ritualistic significance, cultural continuity, and community memory. The comparative analysis indicates that environmental intelligence and philosophical interactions with nature were the creators of historical Buddhist settlements in Telangana. However, the environmental risks that are associated with the landscape level are not taken into consideration within the dominant strategies of conservation. It is imperative to recognize that these areas are dynamic systems characterized by continuous interrelations between the environment, culture, and architecture, which would provide a platform for the incorporation of the location within a sustainable paradigm of conservation.

The results of comparative study indicate that there were different adaptive features according to the geography of these Buddhist communities. There was adaptation due to hydrology in the water-based communities and elevation in the hillock communities. They do interact with nature but those fragile biological regions require more climate-sensitive management techniques. Unlike the previous approach that focused on monuments only, this study recognizes the Buddhist archaeological sites as cultural landscapes wherein the elements of environment, construction, and culture all work toward resilience. This perspective provides a better understanding of heritage conservation under changing climate conditions. In the course of future investigation, laboratory testing of material, microclimate analysis and GIS vulnerability modelling could be considered.

5. Conclusions and Recommendations

The Buddhist heritage sites at Phanigiri, Gajulabanda, Nelakondapalli, Dhulikatta, Bavapur Kurru and Karukonda are located across the hillocks, riverine plains, and environmentally sensitive areas, creating an eclectic environmental scenario to understand the resilience of past human settlements to climatic and topographical changes. The present study aims to find the inherent resilience present within the

geography, material culture, and cultural continuity by considering the Buddhist heritage sites as an interlinked phenomenon.

The findings indicate that hillocks with elevation and natural drainage, such as Phanigiri and Gajulabanda possess high topographical resilience. Dhulikatta and Nelakondapalli, which are two sites near water resources, illustrate negotiated adaptation that balances risks and resource accessibility. Hillocks that are ecologically vulnerable, like Bavapur Kurru and Karukonda, possess low-impact landscape integration and are becoming more vulnerable due to vegetation growth and erosion. In all cases, resilience includes cultural continuity and group association in addition to physical fabric. However, comprehensive climate-responsiveness is not always included in heritage management strategies.

The study arrives at a conclusion that says that environmental intelligence based on the historical landscape of interaction is reflected in the Buddhist heritage sites of Telangana. For the incorporation of Buddhist heritage sites into a framework of climate adaptation and sustainable heritage management, it is necessary to recognize them as a cultural-ecological system. For better evaluation of the future study, vulnerability indexing, microclimatic studies, and GIS techniques of geographical analysis can be employed. More beneficial may be a multidisciplinary study that incorporates a framework of community involvement, climatic modelling, and conservation science. In the context of rapid changes in the climatic scenario, long-term studies of heritage sites may prove beneficial for developing policies of preservation through digital heritage site mapping.

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