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RESEARCH PAPER

Nature-Based Solutions for Urban Climate Risks:

Assessing Local Engagement, Implementation and Scalability in Bharatpur, Chitwan, Nepal

Ravi Mohan Tiwari, *Kathmandu Institute of Applied Sciences*
Susma Giri, *Kathmandu Institute of Applied Sciences*
Jagannath Adhikari, *Birendra Multiple Campus*

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Abstract

As climate change accelerates, urban areas are increasingly exposed to risks such as flooding, heat stress, and environmental degradation, which disproportionately affect marginalized communities. Nature-based Solutions (NbS), including urban forests, wetlands, and green spaces, provide affordable and sustainable strategies to enhance resilience, biodiversity, and community well-being. When integrated into urban planning, NbS can help mitigate climate-related challenges such as flooding, stormwater runoff, and heatwaves. These solutions not only safeguard ecosystems but also provide co-benefits, including cleaner air, safer public spaces, and improved health outcomes. Additionally, NbS foster social cohesion, recreational opportunities, and higher quality of life, making them cost-effective approaches for creating climate-resilient and livable cities. This study, conducted in Bharatpur Metropolitan City, evaluated the ecological, social, and economic impacts of NbS through surveys, interviews, and field observations in climate-vulnerable areas. Findings reveal that socio-economic factors such as age, education, livelihood, and caste significantly shape household vulnerability and adaptive capacity. Agriculture continues to dominate both livelihoods and land use, while extreme heat and drought emerge as the most severe hazards, undermining health, agricultural productivity, and access to green infrastructure. The results demonstrate that NbS represent effective, community-driven strategies for urban climate adaptation. Conclusion**:** Incorporating locally tailored NbS into urban development can strengthen environmental sustainability, enhance resilience, and improve community well-being in rapidly urbanizing Nepali cities.

Keywords: Climate risks, sustainable urban planning, urban resilience, community engagement, climate adaptation

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1. Introduction

As climate change accelerates, it is reshaping the urban landscape, turning cities around the world into hotspots of vulnerability, where extreme weather events and environmental stress are increasingly prevalent. These challenges are amplified in rapidly urbanizing regions, where unplanned expansion, inadequate infrastructure, and environmental degradation heighten the risks, particularly for marginalized communities (Parnell et al., 2007; Putsoane et al., 2024).

In response to these mounting risks, Nature-based Solutions (NbS) offer a promising approach to enhancing urban resilience by leveraging natural processes and ecosystems. These solutions include practices like green infrastructure, urban forestry, wetland restoration, and community-managed green spaces, which help reduce flood risks, enhance biodiversity, and mitigate urban heat islands (Lamsal et al., 2017). Nature-based Solutions offer multiple co-benefits, including improved air quality, enhanced water regulation, and greater social well-being, often providing a more sustainable and cost-effective alternative to traditional engineering approaches (Griscom et al., 2017).

To maximize the effectiveness of NbS, community-based approaches emphasize local engagement, drawing on the knowledge and participation of residents to implement and maintain these interventions. This model fosters a sense of ownership, ensuring that solutions are culturally appropriate and responsive to local needs (Brill et al., 2022; Nunes et al., 2021; Zari et al., 2025). Despite the potential of community-based NbS, their application in urban contexts remains limited, especially in developing countries. Key barriers include lack of awareness, limited technical expertise, and insufficient funding (Ershad Sarabi et al., 2019).

In rapidly urbanizing cities like Bharatpur Metropolitan City in Chitwan, Nepal, these challenges are especially pronounced. The city has experienced significant population growth, leading to substantial land-use changes and increased strain on natural ecosystems, which in turn limits its capacity to mitigate climate impacts such as temperature regulation and water runoff management (Hobbie & Grimm, 2020; Lamichhane, 2022). The lack of climate adaptation strategies tailored to local needs, often relying on costly and unsustainable engineered solutions, further exacerbates the vulnerability of the urban population to risks like flooding and heatwaves. This underscores the urgent need for localized research on NbS, which could effectively address specific urban climate risks and improve resilience in cities like Bharatpur (Frantzeskaki et al., 2019; Majidi et al., 2019).

By focusing on community-based nature-based approaches, this study aims to build an evidence base that supports the implementation of effective, sustainable NbS for enhancing urban climate resilience. To achieve this, NbS must be scalable and adaptable across diverse urban contexts. However, research on scaling community-driven NbS in densely populated areas is still limited, restricting broader implementation. Identifying the factors that enable, or hinder scaling is crucial for developing replicable models for other urban areas in Nepal and beyond. This project aims to investigate these elements, offering practical insights for urban planners and policymakers.

Successful climate adaptation also requires active community participation. Engaging urban residents in NbS initiatives, particularly in areas with diverse populations, can be challenging (Bush & Doyon, 2019). To address this, the research aims to develop culturally tailored strategies that promote local involvement, ensuring better adoption and long-term sustainability of NbS initiatives. Additionally, the integration of NbS into urban planning in Nepal is hindered by a lack of evidence-based policy recommendations. This study aims to inform policy generates actionable insights, offering guidelines to strengthen urban climate resilience in Bharatpur and other similar cities.

1.1 Objectives

Building on this, we investigated the potential of community-based NbS to enhance urban climate resilience, specifically in Bharatpur Metropolitan City, a rapidly urbanizing city in Nepal. The study aimed to tackle climate change challenges, including flooding, heat stress, and water runoff, by assessing how effectively NbS can mitigate these risks. Beyond risk reduction, this project also examined how NbS fostered sustainable urban development and evaluated the potential for scalable implementation in other rapidly urbanizing areas. Specifically, this study focused on:

Assessing the effectiveness of existing community-based NbS in Bharatpur, focusing on their ecological, social, and economic impacts, to evaluate their potential for climate adaptation in the context of urbanization.

Identifying the strategies for successful implementation and community engagement in NbS initiatives, including key factors that influence local participation, adoption, and long-term sustainability.

Developing a tailored framework for expanding NbS in Bharatpur's urban context, taking into account the unique needs, challenges, and resources of local communities, with the goal of creating scalable and adaptable models for other urban areas in Nepal and beyond.

2. Literature Review

Urban areas across the globe are facing escalating vulnerabilities due to climate change, manifesting in more frequent flooding, prolonged heat stress, deteriorating air quality, and biodiversity loss. These risks are intensified by the rapid pace of urbanization, often occurring without adequate planning or sustainable infrastructure, which leads to the overexploitation of natural resources, loss of green spaces, and growing pressure on water and energy systems (S. Das et al., 2024). Unplanned urban expansion has also driven widespread environmental degradation, including deforestation, wetland encroachment, and soil erosion, all of which reduce the ability of ecosystems to buffer climatic shocks. Marginalized and low-income communities, often living in hazard-prone areas with limited access to services, bear the greatest burden of these impacts, thereby amplifying existing social and economic inequalities (Parnell et al., 2007).

In response to these challenges, NbS has emerged as a promising and holistic approach to strengthening urban resilience. By harnessing the restorative and adaptive functions of natural systems, such as wetlands for flood control, urban forests for temperature regulation, and green roofs for storm-water management, NbS provide multifunctional benefits that extend beyond climate adaptation. They not only enhance ecosystem services but also promote public health, improve quality of life, and foster social inclusion by creating green jobs and spaces for community interaction. According to the Intergovernmental Panel on Climate Change (IPCC, 2022), NbS are increasingly recognized as cost-effective pathways for achieving both climate change adaptation and mitigation in urban contexts. They not only enhance ecosystem services but also promote public health, improve quality of life, and foster social inclusion by creating green jobs and spaces for community interaction (Griscom et al., 2017; Wolff et al., 2022)

NbS encompasses a range of interventions including green infrastructure, community-managed green spaces, urban forestry, and wetland restoration, which can enhance biodiversity, mitigate urban heat islands, and reduce flood risks (Ferrario et al., 2024; Lamsal et al., 2017; Smith et al., 2021). NbS offer multiple co-benefits, including improved air quality, enhanced water regulation, and greater social well-being, often providing a more sustainable and cost-effective alternative to traditional engineering approaches (Griscom et al., 2017). Importantly, community-based approaches emphasize local engagement, drawing on residents' knowledge and participation to design, implement, and maintain NbS interventions. This participatory model fosters a sense of ownership and helps ensure that solutions are culturally appropriate and responsive to local needs (Wolff et al., 2022).

Despite these benefits, the application of NbS in rapidly urbanizing contexts remains limited, particularly in developing countries where awareness, technical expertise, and funding are often lacking (Ershad Sarabi et al., 2019; Frantzeskaki et al., 2019). Moreover, scholars warn that NbS may inadvertently reinforce inequalities if they are implemented in ways that privilege affluent communities while displacing vulnerable populations, underscoring the importance of equity-sensitive design and governance (Tozer et al., 2020). Evidence from South Asian cities including Dhaka and Nepal demonstrates both the promise and the challenges of NbS, highlighting issues such as weak institutional coordination, competing land uses, and rapid urban expansion (Alam & Rabbani, 2007; Mehta et al., 2023).

In rapidly urbanizing cities like Bharatpur Metropolitan City in Chitwan, Nepal, these challenges are particularly pronounced. The city has experienced significant population growth, leading to substantial land-use changes and increased strain on natural ecosystems (GoN/NSO, 2021). This in turn limits its capacity to mitigate climate impacts such as temperature regulation and water runoff management (Lamichhane, 2022). Reliance on costly and unsustainable engineered solutions, coupled with the lack of climate adaptation strategies tailored to local needs, further exacerbates the vulnerability of the urban population to risks such as flooding and heatwaves. This underscores the urgent need for localized research on NbS to effectively address specific urban climate risks and improve resilience in cities like Bharatpur (Frantzeskaki et al., 2019; Majidi et al., 2019).

To maximize the effectiveness of NbS, it is crucial to identify factors that enable or hinder their scaling in densely populated urban areas. Research indicates that successful NbS implementation requires supportive governance structures, adequate funding, and community involvement (Cook et al., 2025). Moreover, integrating NbS into urban planning necessitates overcoming institutional barriers and aligning policies with sustainability goals.

Reliance on costly engineered solutions, without locally tailored adaptation strategies, further exacerbates vulnerability to flooding and heatwaves. This underscores the urgent need for localized NbS research to identify practical pathways for improving resilience in urban Nepal (Frantzeskaki et al., 2019; Majidi et al., 2019).

3. Methodology

3.1 Study area

The study was conducted in Bharatpur Metropolitan City (BMC), the third most populous city in Nepal (Figure 1). Bharatpur Metropolitan City faces repeated flood risks because it is in a low-lying area near major rivers and wetlands. Many people, homes, roads, services, and markets are directly exposed to these hazards as the city continues to grow. Vulnerability increases where settlements expand into flood-prone areas and drainage systems are weak, making BMC unique not only as Nepal's third-largest city but also as an urban centre closely connected to important natural ecosystems .According to the National Population and Housing Census (GoN/NSO, 2021), the city's population has grown to 369,377, a significant increase from 2011 when it was ranked the fifth most populous city. This rapid urban expansion has made BMC a crucial commercial hub for Chitwan District and central Nepal.

However, this growth has also made BMC highly vulnerable to climate change. The city experiences rising temperatures, contributing to the growing Urban Heat Island (UHI) effect compared to surrounding rural areas, primarily due to increased built-up areas and the reduction of vegetation and agricultural land (Figure 2).

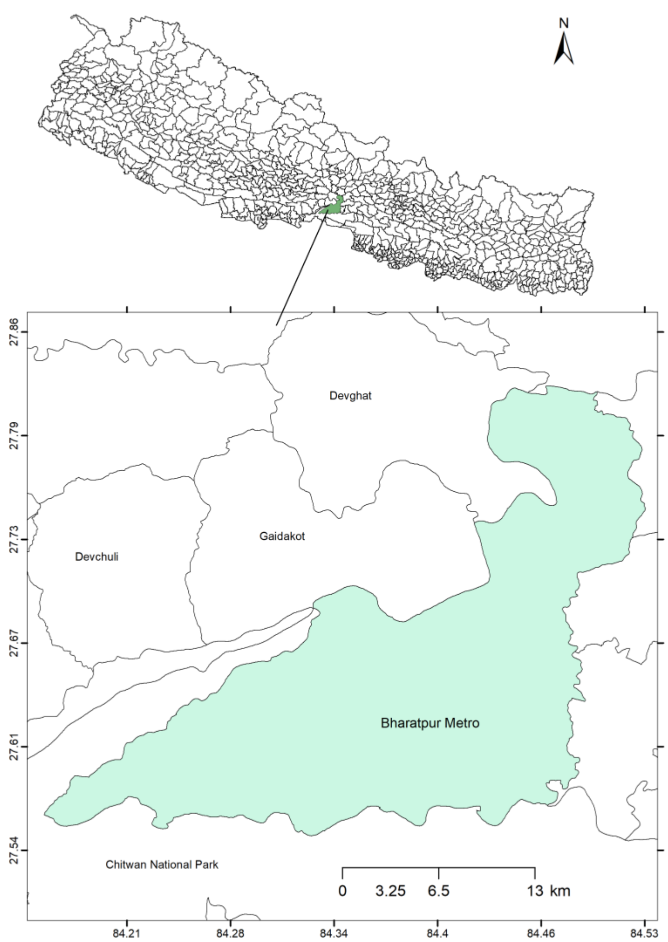


Figure 1: Map of Nepal highlighting Bharatpur Metropolitan City with a zoomed-in view.

In contrast, water bodies and vegetated areas act as cooler zones within the city, helping to mitigate the UHI effect (Paudel, 2024). As the UHI effect intensifies, it contributes to higher energy demands for cooling, increased heat-related health risks, and a decline in overall urban live ability (Jamarkattel et al., 2025).

Erratic rainfall patterns further disrupt crop selection and harvests, threatening food security (Niraula, 2024). Additionally, BMC faces recurrent flooding from the Narayani and East Rapti Rivers, with water levels frequently exceeding danger marks and causing substantial damage to livelihoods and infrastructure (Pandey et al., 2023). These combined challenges—urban heat islands, excessive runoff, and degradation of natural water channels—amplify climate risks, highlighting the urgent need for targeted interventions.

3.2 Data collection

This research utilized a mixed-methods approach, integrating quantitative surveys, qualitative interviews, and spatial analysis to assess the effectiveness, challenges, and scalability of community-based Nature-based Solutions (NbS) in Bharatpur Metropolitan City (BMC), Chitwan, Nepal. The study focused on evaluating how NbS interventions such as urban gardens, green parks, river restoration, and community-led plantation programs—can enhance urban climate resilience, specifically addressing flooding, heat stress, and stormwater management.

3.2.1 Household survey

A household survey was needed to understand how communities in Bharatpur Metropolitan City experience floods and what capacities they have to cope with them. The survey asked households about their past hazard experiences, levels of exposure, preparedness, and access to basic services. Bharatpur faces repeated flood risks due to its low-lying location near major rivers and wetlands, and many people, homes, and services are exposed, with vulnerability increasing where settlements expand into flood-prone areas and drainage systems are weak. The household survey targeted residents of Bharatpur Metropolitan City (BMC), which comprises 96,591 households across 29 administrative wards. The minimum required sample size was calculated using the Raosoft online calculator (Raosoft, 2004) with a 99% confidence level, 5% margin of error, and a proportion estimate of 50% to ensure maximum variability, yielding a minimum of 659 households. Ultimately, 606 households were surveyed, slightly below the ideal sample size but sufficient to capture diverse socio-economic contexts and climate vulnerability profiles across BMC.

Households were selected using a purposive and opportunistic sampling strategy to ensure coverage of different socio-ecological contexts, proximity to various Nature-based Solutions (NbS) interventions, and representation across all 29 wards. Special emphasis was placed on areas identified as highly exposed to climate-induced hazards, such as flood-prone zones that experience recurrent inundation during the monsoon season, as well as vulnerable wards with marginalized and socially disadvantaged populations who often face disproportionate climate impacts and reduced adaptive capacities.

The structured questionnaire, administered using KoboToolbox (A. S. Das, 2024), captured socio-economic information, engagement with NbS, and climate adaptation practices. To complement the household survey, semi-structured interviews were conducted with key stakeholders, including local community members, municipal officials, and environmental organizations, to gather insights on the effectiveness, challenges, and

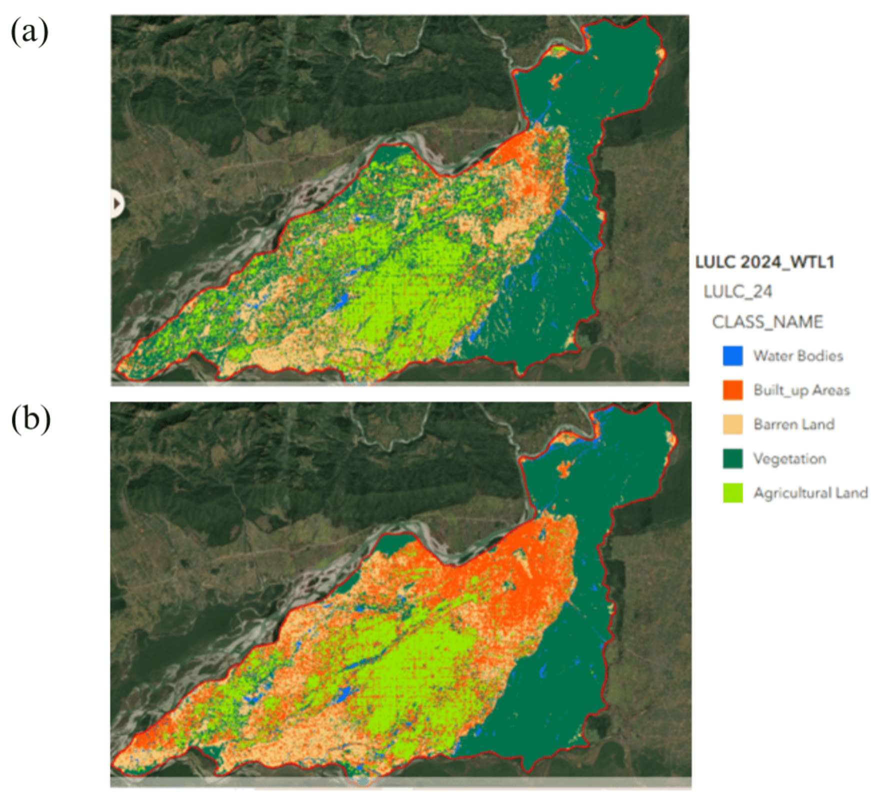


Figure 2: Land Use and Land Cover Map of Bharatpur Metropolitan City for 2014 (a) and 2024 (b) (Source: Paudel, 2024).

perceptions of green infrastructure.

3.2.2 Key Informant Interview

Key informant interviews (n=7) were conducted with a diverse group of stakeholders in Bharatpur Metropolitan City, including municipal officials, government representatives, urban planners, environmental NGOs, and community leaders. These interviews provided qualitative insights into the NbS and their role in climate risk reduction, socio-economic benefits, and policy integration. The semi-structured interviews explored decision-making processes, implementation challenges, community participation, and sustainability of NbS interventions. Importantly, key informants also provided historical context, shared current strategies, and articulated future visions for advancing NbS in the city.

In addition, interviews were conducted (n=5) with social workers, ward chairmen, park chairmen, lake management committee representatives, and members of community forest groups to gather more localized perspectives and quantitative information on climate change and NbS practices applied for its mitigation in BMC. Written consent was obtained from each key informant, and a total of nine interviews were conducted from various parts of the city.

3.2.3 Focus Group Discussion (FGD)

To complement the household surveys and key informant interviews, focus group discussions (FGDs) were held in different locations, including urban, semi-urban, and areas near Chitwan National Park, with groups of more than 10 participants (n = 4). These discussions aimed to understand local perceptions of climate change, its impacts on the area, mitigation measures, community actions, roles of various sectors in addressing climate change, and experiences with Nature-based Solutions (NbS) adaptations. Unlike household surveys and key informant interviews, FGDs brought together local community members and key stakeholders, including representatives from Bharatpur Metropolitan City (BMC), the National Trust for Nature Conservation (NTNC), and local agriculturists, enabling dynamic group discussions that revealed collective perspectives, contested views, and consensus-building processes often missed in individual interviews or surveys. The discussions provided valuable insights into local coping mechanisms and helped refine and improve the quality of the household questionnaire.

3.2.4 Field Visits and Spatial Mapping

Field visits were conducted to systematically document existing NbS interventions, such as urban gardens, green spaces, and riverbank restorations. These visits involved direct on-site observations, photographic documentation, and interactions with local communities to understand the maintenance and functionality of NbS features. Spatial mapping techniques using Geographic Information Systems (GIS) were employed to analyze the distribution of these interventions in relation to climate risk zones.

This process included the collection of georeferenced data using GPS devices. NbS locations were overlaid with multiple environmental and socio-economic datasets such as flood-prone areas, heat-stress zones, land-use patterns, and population density to assess their effectiveness in mitigating climate risks. Spatial interpolation and remote sensing techniques were applied to detect vegetation cover changes and evaluate urban heat island effects. High-resolution satellite imagery and ground-truthing were used to verify the accuracy of spatial data, refine mapping outputs, and identify gaps in NbS coverage. Additionally, participatory mapping exercises (Printed images of hazard-prone sites were used during participatory mapping exercises, allowing community members to overlay their local knowledge directly onto the maps) with local stakeholders were conducted to integrate community knowledge into spatial analysis, ensuring a comprehensive understanding of NbS implementation and its real-world impact.

3.3 Data Analysis

3.3.1 Quantitative and qualitative data analysis

Quantitative data from household surveys and key informant interviews were summarized using frequency tables and percentages. Buffer and non-buffer zone households are the households located either within designated buffer areas surrounding protected or ecologically sensitive sites, where resource use is regulated, or outside these areas, with fewer restrictions on land use and resource access. Comparisons between buffer and non-buffer zone households were primarily conducted using chi-square tests, or Fisher's exact tests when expected cell counts were small. For specific comparisons of park accessibility, a two-proportion z-test was applied, with post-hoc pairwise comparisons adjusted using the Holm method.

Likert-scale responses on climate-related concerns were analyzed using non-parametric methods. A Friedman test evaluated differences across six climate-related issues (flooding, extreme heat, water runoff, landslides, drought, and others), with pairwise Wilcoxon signed-rank tests (Bonferroni-adjusted) for post-hoc comparisons. Mann–Whitney U tests were used to compare concern levels between buffer and non-buffer zone residents.

Qualitative data from KIIs and FGDs were transcribed and systematically analyzed using thematic analysis. Responses were grouped into predefined and emergent themes. Patterns, similarities, and differences across buffer and non-buffer zones were identified to complement quantitative findings. Key quotes and illustrative examples were extracted to provide context and validate survey results. The analysis also highlighted historical knowledge, ongoing initiatives, and community visions for NbS, enabling triangulation with household surveys and KIIs to ensure a comprehensive understanding of local perspectives.

Overall, statistical and qualitative methods were carefully selected based on variable type, sample size, and data characteristics. Adjustments for multiple comparisons were applied to ensure the reliability of statistical results across survey data, while thematic analysis of interviews and FGDs provided detailed insights into community perspectives and practices. All analyses were conducted using R software (R Core Team, 2024).

3.3.2 Geospatial analysis

GIS tools were used to assess spatial correlations between NbS interventions and climate vulnerability hotspots in Bharatpur.

3.3.2.1 Data source

Landsat satellite imagery from the years 2000, 2010, and 2022 was employed to analyze land use and land cover change (LULCC) over a 22-year period in Chitwan District. The datasets included Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for 2000, Landsat 5 Thematic Mapper (TM) for 2010, and Landsat 8 Operational Land Imager (OLI) for 2022, each with a spatial resolution of 30 meters. All images were acquired from the United States Geological Survey (USGS) Earth Explorer portal (U.S. Geological Survey., 2022). To improve the accuracy of classification, supplementary datasets were also incorporated, including topographic maps produced by the Department of Survey (DoS, 2025), high-resolution imagery from Google Earth (https://earth.google.com/), and ArcGIS base maps (https://pro.arcgis.com/).

Preprocessing steps included geometric correction, atmospheric correction, and sub-setting to the study area. All images were projected to the Universal Transverse Mercator (UTM), WGS 84 datum, Zone 44N to ensure spatial comparability. These datasets provided the basis for mapping land cover and analyzing the spatial distribution of NbS relative to climate vulnerability zones (Table 1).

Table 1: Datasets that were applied during land use and land cover analysis (USGS, 2022)

Scene	Acquisition date	Landsat Scene ID	Spacecraft ID	Spatial resolution	WRS Path/Row	UTM Zone
A	3-Apr-00	LE71420402000094SGS00	L7_ETM	30 m	142/41	45
A	18-Feb-10	LT51420412010049KHC00	L5_TM	30 m	142/41	45

A	17-Mar-22	LC81420402020077LGN00	LANDSAT_8	30 m	142/41	45

The satellite images were first georeferenced to the WGS 84 datum, then aligned to UTM Zone 45N coordinate system using associated metadata. Landsat 5 TM, 7 ETM, and 8 OLI images contain seven, eight, and eleven spectral bands, respectively (USGS, 2022) (Table 2).

Table 2: Landsat images such as Landsat 5 (TM), Landsat 7 (ETM) and Landsat 8 (OLI) with different bans that were used for band combination

Landsat 5 TM			**Landsat 7 ETM**			**Landsat 8 OLI**		
Bands	Wave length (µm)	Resolution	Bands	Wave length (µm)	Resolution	Bands	Wave length (µm)	Resolution
Band 1- Blue	0.45-0.52	30	Band 1- Blue	0.45-0.52	30	Band 1- Coastal aerosol	0.43 - 0.45	30
Band 2- Green	0.52-0.60	30	Band 2- Green	0.52-0.60	30	Band 2- Blue	0.45 - 0.51	30
Band 3- Red	0.63-0.69	30	Band 3- Red	0.63-0.69	30	Band 3- Green	0.53 - 0.59	30
Band 4- Near Infrared Red (NIR)	0.77-0.90	30	Band 4- Near Infrared Red (NIR)	0.77-0.90	30	Band 4- Red	0.64 - 0.67	30
Band 5- SWIR1	1.55-1.75	30	Band 5- SWIR1	1.55-1.75	30	Band 5- Near Infrared Red (NIR)	0.85 - 0.88	30
Band 6- Thermal infrared (TIR)	10.40-12.50	120	Band 6- Thermal infrared (TIR)	10.40-12.50	30/60	Band 6-SWIR1	1.57 - 1.65	30
Band 7- SWIR2	2.08-2.35	30	Band 7- SWIR2	2.09-2.35	30	Band 7- SWIR2	2.11 - 2.29	30
			Band 8- Panchromatic (Pan)	0.52-0.90	15	Band 8- Panchromatic (Pan)	0.50 - 0.68	15

				Band 9- Cirrus	1.36 - 1.38	30
				Band 10- Thermal infrared (TIRS1)	10.6 - 11.19	100
				Band 11- Thermal infrared (TIRS2)	11.5 - 12.51	100

3.3.2.2 Image classification

Landcover classes were established using published and unpublished literature (Adhikari et al., 2024; Adhikari et al., 2022), reports (WWF, 2013, 2025) and field observations. For this study, landcover types were grouped into seven categories based on forest types (categorized on the basis of dominant plant species), Build-up area (human settlements and developed areas), landscape features, water bodies, and agricultural land (Table 3).

Table 3: *Seven land use and landcover types found in Chitwan, Nepal*

SN	Land cover types	Description
1	Water bodies	All types of wetlands
2	Riverbed	Catchment areas of rivers having Sand, gravel, flood plains
3	Grassland	Grasslands, scattered shrub
4	Forest	Sal (*Shorea robusta*), Saaj (*Terminalia alata*), Karma (*Adina cordifolia)* and associates plants including riverine forest
5	Other wooded lands	Jamuno (*Syzygium cumini*), Amaro (*Spondaic pinnata*), along with fruiting tress. Fodder plants and public forest area
6	Cropland	Paddy field, vegetables garden, other crops such as maize, mustard, wheat etc.) cultivated lands
7	Buildup area	City area, developed area and rural settlements, roads, industries, airport

Two primary techniques were applied: unsupervised (automated by software) and supervised (guided by human input) classification (Adhikari et al., 2022). Unsupervised classification relies exclusively on software algorithms, producing spectral classes without field guidance (Adhikari et al., 2022). In contrast, supervised classification uses human-defined training data to guide the categorization of land-cover classes ensuring accurate classification (Adhikari et al., 2022).

3.3.2.3 Image analysis

All Landsat images were processed and analyzed using *ERDAS IMAGINE 15* (OSME, 2015).

An unsupervised classification approach was first applied to the multi-temporal Landsat datasets from 2000, 2010, and 2022. Specifically, K-means clustering algorithm was employed with 10 iterations, using the nearest-likelihood criterion as described by Duda & Canty (2002). The initial classification produced 40 spectral classes (convergence threshold = 0.90), which consolidated into ecologically meaningful categories. The outputs of this unsupervised classification served two important purposes: (i) guiding the collection of ground-truth points, and (ii) providing a baseline framework for subsequent supervised classification.

For the supervised classification, the parametric Maximum Likelihood Classification (MLC) algorithm was employed, following the approaches of Poudel & Rawat (2023) and Adhikari et al. (2022) Training signatures were generated using field observations and ground-truth data for the 2022 imagery. For the 2010 imagery, Google Earth data and the classified map developed by ICIMOD were used, whereas for the 2000 imagery, Google Earth and topographic maps prepared by the Department of Survey served as reference materials. To reduce noise and minimize misclassification, a 3×3 majority filter was applied to the classified images. Furthermore, classification results were refined through recoding with the aid of field-verified data, thereby improving thematic accuracy.

Finally, spatial change detection was performed to identify areas that experienced substantial land cover transitions (i.e., >50% change) over the 22-year study period. These zones were subjected to further detailed analysis in order to better understand the magnitude, spatial distribution, and ecological implications of land use and land cover change in Chitwan.

The GIS and LULCC analyses complement the household surveys, KII, and FGDs by providing a spatial perspective on the distribution and effectiveness of NbS interventions relative to climate vulnerability zones. While survey and interview data capture local perceptions, experiences, and historical knowledge, the spatial mapping enabled the objective assessment of NbS coverage, proximity to vulnerable communities, and potential ecological impact. Integrating these methods provides a holistic understanding of NbS performance, informs adaptive planning, and supports evidence-based recommendations for enhancing climate resilience in Bharatpur Metropolitan City and Chitwan District.

In addition to the satellite-based land cover analyses, GPS coordinates were collected for major NbS intervention sites, including recharged lakes and ponds, playgrounds, roadside plantations, riverbank management areas, and recreational parks. These locations were mapped in ArcGIS 10.8 (Esri, 2020) and integrated with the classified land cover datasets. This allowed for spatial overlay and comparison of NbS distribution with identified vulnerability zones, ensuring that ground-level interventions could be analyzed in relation to broader land cover dynamics. By combining remote sensing outputs with field-based GPS mapping, the study provides a more comprehensive spatial perspective on the placement, extent, and potential ecological role of NbS interventions in Bharatpur Metropolitan City and Chitwan District.

Potential limitations

Several limitations should be acknowledged. First, the household survey relied on purposive and opportunistic sampling, which, although diverse, may not fully represent the entire socio-economic profile of Bharatpur. Second, the cross-sectional nature of the study limits the ability to assess long-term impacts of NbS, particularly for interventions that require years to mature (e.g., forest plantations, wetland restoration). Third, perceptions of effectiveness may be influenced by awareness levels rather than measurable outcomes, potentially biasing responses toward visible interventions. Finally, while spatial analysis captured land-cover change and NbS distribution, higher-resolution or longitudinal data would be necessary to quantify ecosystem service impacts more precisely.

4. Results and Findings

4.1 Household Survey

A total of 606 household interviews were conducted across 29 wards, with between 5 and 27 households sampled per ward.

4.1.1 Socioeconomic profile of the respondents

The majority of respondents were female (59%), and the age of participants ranged from 16 to 88 years.

4.1.1.1 Ethnicity

The majority of respondents belonged to the Brahmin/Chhetri/Thakuri/Dasnami (BCTD) group (n = 337; 55.6%), followed by Indigenous groups (n = 177; 29.2%) and Dalits (n = 79; 13.0%). A small proportion of respondents were categorized as others (n = 13; 2.1%). This distribution reflects the demographic composition of the study area, with BCTD households representing the largest share of the surveyed population, while Indigenous and Dalit communities also constituted substantial proportions.

4.1.1.2 Education

The largest share of respondents, 31.4% (n = 190), had completed only basic education (grades 1–8), followed by 23.4% (n = 142) who had attained secondary education (grades 9–10). Illiteracy was reported among 19.3% (n = 117), while 18.5% (n = 112) had completed higher secondary education (grades 11–12). Only 7.4% (n = 45), had obtained a university degree. These results indicate that while access to primary and secondary education is relatively widespread, opportunities for higher education remain limited, and illiteracy continues to be a challenge.

Education levels also varied across age groups. Respondents younger than 40 years exhibited higher attainment (notably higher secondary and university education), whereas older age groups (41 years and above) showed lower completion rates and higher illiteracy, reflecting improvements in access to education over time (Figure 3).

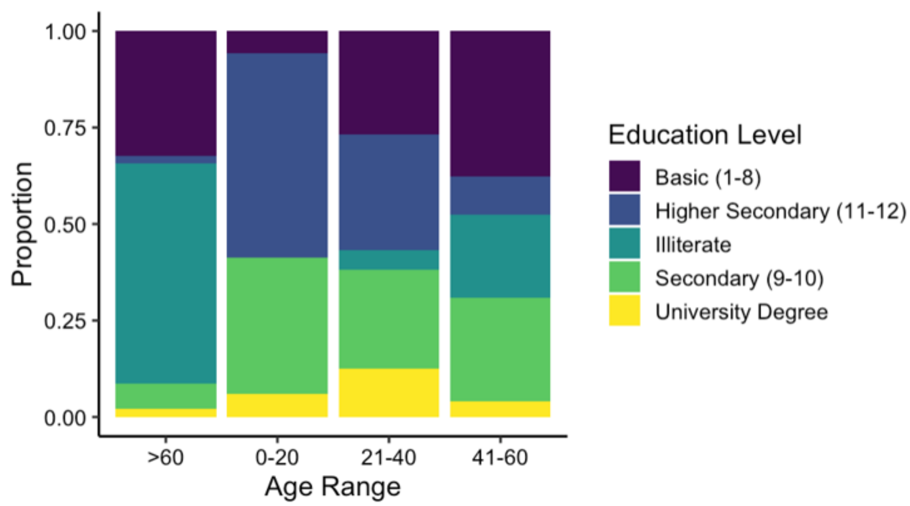


Figure 3: Educational attainment across age groups

4.1.1.3 Occupation

Agriculture remained the primary livelihood source, engaging 37.6% of households (n=242). Business and other informal occupations each accounted for 27.1% (n=174), while smaller shares relied on private jobs (4.8%), remittance-based work (2.5%), daily wage labor (2.2%), and government employment (1.4%).

Overall, the socioeconomic profile highlights continued dependence on farming, alongside diversification into small-scale business and informal sectors. Formal wage employment and external income sources remain limited. The sample further reflects a gender balance skewed toward women, educational improvements among younger cohorts, moderately sized households, and ethnically diverse representation, with BCTD households forming the majority alongside Indigenous and Dalit communities.

4.1.1.4 Household size

The average household size did not differ significantly across wards (Kruskal–Wallis, p = 0.32) or ethnic groups (Kruskal–Wallis, p = 0.35). However, Dalit households had the largest mean size (5.39 members), followed by Others (5.00), Indigenous groups (4.96), and Brahmin/Chhetri/Thakuri/Dashnami (BCTD) households, which had the smallest average size (4.78).

4.1.1.5 Health status

Among the 606 households surveyed, the majority (67.5%, n = 409) reported being generally healthy, indicating that most families did not experience immediate or recurring health problems. Nevertheless, a substantial proportion (32.3%, n = 196) reported living with chronic diseases, highlighting the presence of a long-term health burden within the community. Frequent illness was reported in 7.1% of households (n = 43), suggesting a subgroup particularly vulnerable to recurrent or seasonal health challenges. A small fraction of families (0.8%, n = 5) reported having a member with a disability, representing a relatively low but important subgroup that may require targeted health and social support interventions.

Analysis of overlapping health conditions revealed that most families (92.6%, n = 561) reported a single health condition at a time, suggesting that households generally experienced either good health or a single type of health challenge. Meanwhile, 7.1% of households (n = 43) reported two concurrent health conditions, and 0.3% (n = 2) reported three overlapping conditions, indicating the presence of comorbidities and multiple health challenges within a minority of households. Further breakdown shows that 374 households were classified as healthy, 155 had chronic disease, and 30 experienced frequent illness, while the remaining households reported overlapping conditions (Table 4). These findings suggest that while most households face singular health status, a notable minority experience chronic or multiple health burdens. This highlights the need for integrated health care strategies and targeted interventions to address both chronic disease management and the specific needs of households experiencing frequent illness or chronic conditions.

Table 4: Household health status and combinations

Health Status Combination	Frequency

Healthy	374
Chronic Disease	155
Frequent Illness	30
Healthy + Chronic Disease	30
Frequent Illness + Chronic Disease	8
Healthy + Frequent Illness	3
Disabled	2
Chronic Disease + Disabled	1
Frequent Illness + Disabled	1
Healthy + Chronic Disease + Disabled	1
Healthy + Frequent Illness + Chronic Disease	1

4.1.1.6 Land holding, livestock and income

Among the 606 households, 87% reported holding registered land while the remaining 13% had unregistered land.

Livestock rearing varies among households. Cattle were maintained by 21 households, buffaloes by 115, goats by 122, and poultry by 119 households. A larger number of households (341) reported keeping other types of livestock not listed in the main categories. This suggests that small ruminants and poultry are common livelihood assets, while larger livestock such as cattle are less prevalent.

Household income varied across the sample. A total of 208 households (34.3%) reported a monthly income of less than NRs. 10,000. The largest proportion of households (240; 39.6%) fell within the NRs. 10,000–30,000 range. Fewer households reported higher income levels, with 106 (17.2%) earning NRs. 30,001–60,000, and 53 (8.7%) earning above NRs. 60,000. These results indicate that most households earn below or around the middle-income range, with relatively few in the higher-income bracket.

4.1.2 Spatial and locational context

Out of the surveyed households, 164 reported being located in a buffer zone area (areas that are less than 5 km from the buffer zone), while 442 households were outside the buffer zone. The buffer zone includes areas surrounding Chitwan National Park, indicating that approximately one-quarter of the households are situated within these protected areas. This may have implications for land use, resource management, and conservation policies in these communities.

The majority of households (n = 403) reported immediate walking (≤ 250 m) access to a park or green space, while smaller proportions indicated short (251 – 500 m; n = 138), moderate (501 – 1000 m; n = 41), or long (> 1000) walking distances (n = 24), suggesting that although overall access is relatively high, a subset of households still experiences limited proximity to recreational areas.

Comparative analysis between buffer zone and non-buffer zone households using a two-proportion z-test revealed notable differences in park accessibility. Non-buffer zone households were more likely to be within immediate walking distance (69%) than buffer zone households (59%), whereas buffer zone households were overrepresented in the moderate (12% vs. 5%) and long walking distance categories (11% vs. 1%). A chi-squared test confirmed that these differences were statistically significant ($\chi^2 = 39.47$, df = 3, $p < 0.001$).

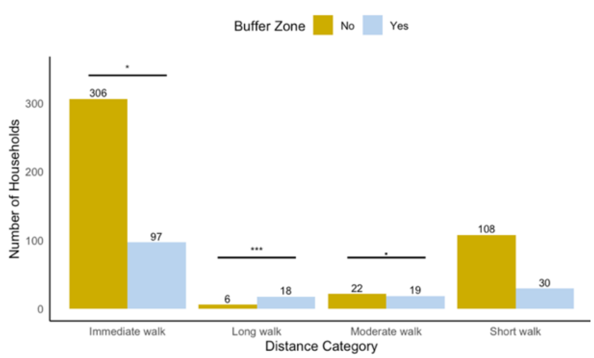


*Figure 4. Household counts by walking distance to the nearest park within and outside the buffer zone. Lines with asterisks indicate significant differences (*p < 0.05, **p < 0.01***, p<0.001, = marginal, p < 0.1).*

Post-hoc pairwise comparisons with Holm adjustment indicated that the long walking distance category primarily contributed to the observed differences, with buffer zone households (residential areas which are located less than 5 km from the buffer zone areas) significantly more likely to report long walking distances compared to immediate or short distances (adjusted $p < 0.001$). Moderate walking distances also differed significantly between groups (adjusted $p = 0.015$), whereas short walking distances did not show a statistically significant difference ($p = 0.136$).

These results suggest that households situated within buffer zones including areas adjacent to Chitwan National Park experience relatively reduced accessibility to parks and green spaces compared to households outside buffer zones, highlighting potential spatial inequalities in recreational infrastructure (Figure 4).

4.1.3 Perceptions of climate change

4.1.3.1 Climate Issues Experienced

The survey revealed that extreme heat was the most commonly reported climate-related issue, experienced by 94.1% (n=570) of respondents, highlighting widespread concern over rising temperatures. Other notable issues include drought (27.1%, n=164), and water runoff (10.9%, n=66). Flooding (6.8%, n=41) and landslides (1.7%, n=10) were mentioned less frequently, while 5.0% (n=30) identified other climate-related issues. These results suggest that heat and drought are the most pressing stressors, with potential impacts on health, livelihoods, and water availability.

Significant differences emerged between buffer and non-buffer zone residents. Drought was reported more frequently outside the buffer zone (30.8%) compared to inside (17.1%, p = 0.001). Extreme heat (93.0% outside vs. 97.0% inside; p = 0.101) and flooding (6.6% outside vs. 7.3% inside; p = 0.88) showed no meaningful variation.

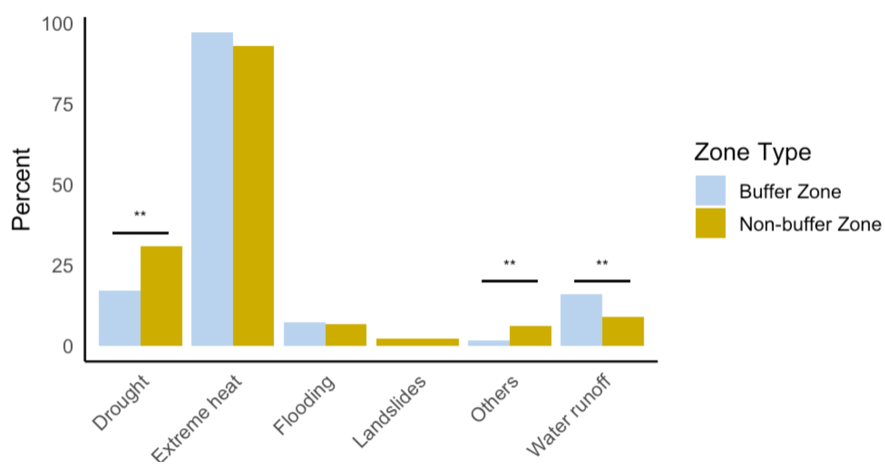


*Figure 5: Perceived climate issues among respondents in buffer and non-buffer zones. Lines with asterisks indicate significant differences (*p < 0.05, **p < 0.01,***p<0.001, . = marginal, p < 0.1).*

Landslides were slightly higher among non-buffer zone respondents (2.3% vs 0%; p = 0.07), though this difference was only marginally significant obviously given no landslide experience was reported within the buffer zone. Other climate-related issues were more commonly reported outside the buffer zone ((6.1% vs. 1.8%; p = 0.034). Water runoff was also significantly higher outside the buffer zone (15.9% vs. 9.0%; p = 0.025) (Figure 5).

4.1.3.2 Frequency of occurrence

Among respondents reporting climate-related hazards, the frequency of occurrence varied by type of event. Drought was most commonly experienced ‘sometimes’ (once a year) by 76.2% of respondents, whereas only 1.8% reported never experiencing it. Extreme heat was reported sometimes by 56.8% of respondents, frequently by 34.0%, rarely by 5.4%, and never by 3.7%. Flooding primarily occurred sometimes (53.7%) or rarely (43.9%), with a minimal proportion indicating not applicable (2.4%). Landslides were infrequent, with 70% of affected respondents experiencing them sometimes and 30% rarely. For other climate-related events, 73.3% reported experiencing them sometimes, 13.3% never, 10%

rarely, and 3.3% frequently. Water runoff was reported as occurring sometimes by 74.2% of respondents, rarely by 15.2%, and never by 10.6%.

Comparison between buffer zone and non-buffer zone households revealed spatial differences in hazard frequency. For drought, 77.9% of non-buffer zone respondents reported experiencing it sometimes, with 21.3% rarely and 0.7% never, whereas in buffer zones, 67.9% experienced it sometimes, 25.0% rarely, and 7.1% never. Extreme heat was more pronounced in buffer zones, with 47.2% experiencing it frequently, 39.0% sometimes, 10.1% rarely, and 3.8% never, compared to non-buffer zones where 29.0% experienced it frequently, 63.7% sometimes, 3.6% rarely, and 3.6% never. Flooding occurrence differed markedly, with non-buffer zones reporting it mostly sometimes (69.0%) and buffer zones primarily rarely (83.3%). Landslides were reported only in non-buffer zones, with 70% sometimes and 30% rarely, and no cases recorded in buffer zones. For other climate-related issues, 81.5% of non-buffer zone respondents experienced them sometimes, whereas buffer zones reported these events rarely (66.7%) or never (33.3%). Water runoff was experienced sometimes by 67.5% of non-buffer zone respondents and 84.6% of buffer zone respondents, with smaller proportions indicating rarely or never.

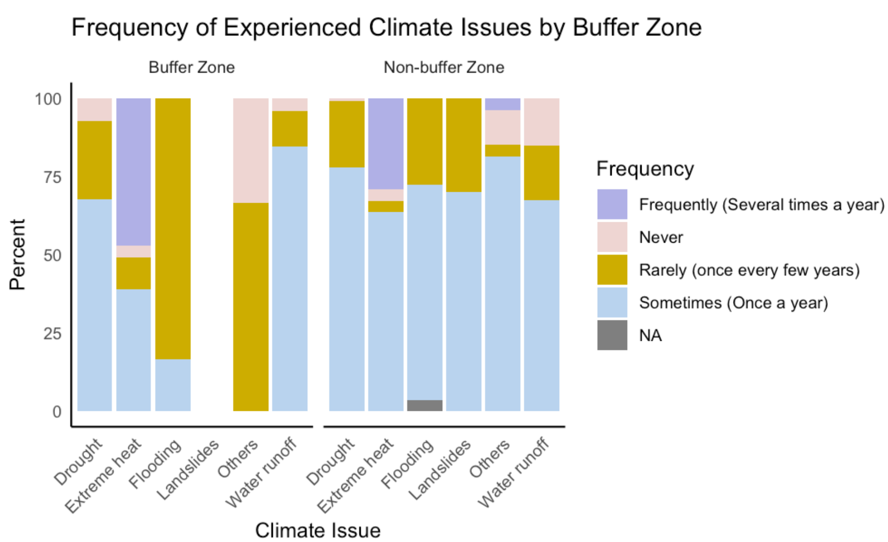


Figure 6: Climate issues experienced by households in buffer and non-buffer zones. Bars represent different climate issues, and colors indicate

Overall, ‘sometimes’ (once a year) was the most reported frequency across most hazards. However, extreme heat and water runoff exhibited higher frequent occurrences in buffer zones, while drought and flooding were more evenly distributed between buffer and non-buffer areas. These patterns suggest that the intensity and recurrence of specific climate hazards varies spatially, highlighting the importance of context-specific risk assessments and targeted adaptation strategies (Figure 6).

4.1.3.3 Concern for each climate issue

Community concern regarding climate-related hazards exhibited notable variation across different types of events. Extreme heat was consistently perceived as the most critical issue, with the majority of respondents reporting high levels of concern. This reflects the direct and observable impacts of heat on daily life, livelihoods, and well-being, making it a primary environmental stressor for the local population. Drought and other climate-related issues elicited moderate concern, indicating that while these events are recognized as impactful, they are not viewed as immediate threats on the same scale as extreme heat. In contrast, hazards such as flooding, water runoff, and landslides were associated with comparatively low levels of concern, suggesting that their occurrence is less frequent, their impacts are less visible, or households have developed coping mechanisms that reduce perceived risk.

Overall, these results indicate that the community prioritizes concern for heat-related hazards over other environmental risks. This pattern highlights the importance of aligning adaptation strategies and resource allocation with the perceptions and experiences of local populations, ensuring that interventions address both the hazards perceived as most significant and those that may have longer-term cumulative impacts. These results provide insight into local risk perception and can guide policymakers, planners, and disaster management practitioners in designing context specific adaptation measures that reflect community priorities (Figure 7).

Quantitative analysis further supported these observations. Respondents rated concern levels for six climate-related issues flooding, extreme heat, water runoff, landslides, drought, and other hazards on a 5-point Likert scale (1 = “Not concerned at all,” 5 = “Extremely concerned”). Mean, median, and standard deviation values indicated that extreme heat (mean = 3.75, median = 4) elicited the highest concern, followed by other

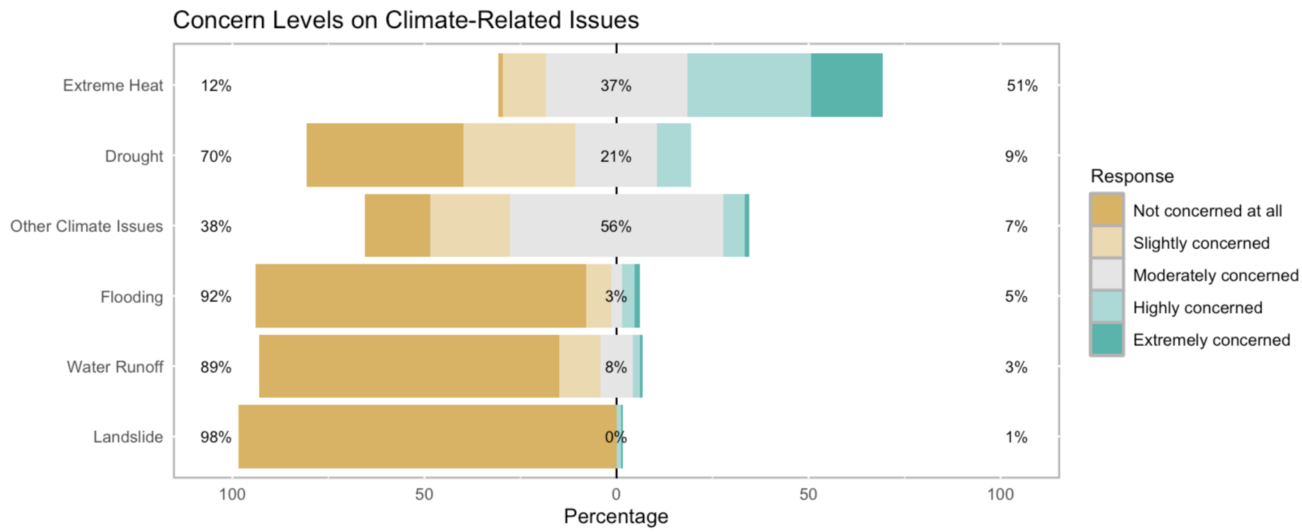


Figure 7: Community concern for different climate-related hazards. Bars represent climate issues, and color fill indicates levels of concern reported by respondents.

climate issues (mean = 2.53) and drought (mean = 2.00), whereas flooding (mean = 1.28), water runoff (mean = 1.36), and landslides (mean = 1.07) were rated lowest.

A Friedman test revealed significant differences in concern across the six issues (χ^2 (5) = 1989.1, $p < 0.001$). Pairwise Wilcoxon signed-rank tests with Bonferroni correction confirmed that extreme heat was significantly more concerning than all other issues ($p < 0.001$). Drought and other climate-related issues were perceived as more concerning than flooding, landslides, and water runoff ($p < 0.001$), while the difference between flooding and water runoff was not significant ($p = 0.12$). These results highlight the heterogeneous perception of climate risks among the community.

Comparisons between buffer zone and non-buffer zone residents using Mann–Whitney U tests showed that buffer zone households were significantly more concerned about extreme heat (W = 30,642, $p_{adj} = 0.015$), drought (W = 45,344.5, $p_{adj} < 0.001$), and other climate-related issues (W = 46,846, $p_{adj} < 0.001$) than non-buffer zone households. In contrast, concern for flooding (W = 34,386, $p_{adj} = 0.744$), water runoff (W = 32,709, $p_{adj} = 0.074$), and landslides (W = 37,064, $p_{adj} = 0.249$) did not differ significantly between zones. Households were also asked to report the impacts of climate-related events. “Other impacts” were most frequently cited (51.6%), followed by crop failure (30.7%) and health-related issues (21.8%). Less commonly reported consequences included income loss (4.1%), property damage (2.6%), water scarcity (2.3%), and migration (1.5%). Zone-specific differences emerged: crop failure was higher among buffer zone households (37.8% vs. 28.1%, p = 0.028), health issues were more prevalent in non-buffer zones (25.8% vs. 11.0%, p < 0.001), and migration was slightly more common in buffer zones (3.7% vs. 0.7%, p = 0.015). Other impacts were broadly similar across zones (p > 0.05).

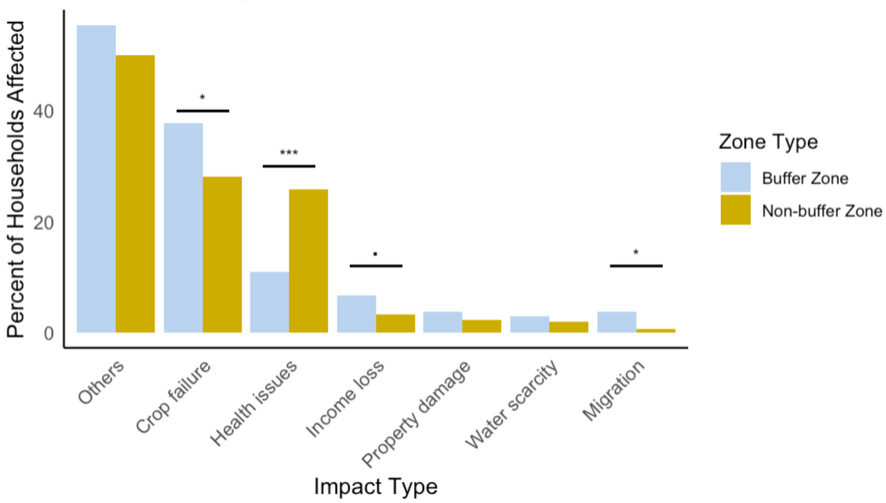


Figure 8: Percentage of households affected by different climate impacts in buffer and non-buffer zones. Asterisks indicate significant differences (p < 0.05, ** p < 0.01, *** p < 0.001, . = marginal, p < 0.1).*

Overall, these results indicate that climate hazards affect households in multiple dimensions, with extreme heat and drought eliciting the highest concern. Certain livelihood and health impacts are more pronounced in specific zones, while other consequences are widely shared, emphasizing the need for context-sensitive adaptation strategies that account for both hazard perception and observed impacts (Figure 8, Table 5).

Table 5: Household-level impacts of climate-related events by zone type. Percentages of affected households are shown for buffer and non-buffer zones, with statistical significance indicated (p < 0.05, Chi-square or Fisher's exact test)

Zone Type	Impact Type	n	total	Percent	p_value
Buffer Zone	Crop failure	62	164	37.8	0.03*
Non-buffer Zone	Crop failure	124	442	28.1	0.03*
Non-buffer Zone	Health issues	114	442	25.8	0.00***
Buffer Zone	Health issues	18	164	11.0	0.00***
Buffer Zone	Income loss	11	164	6.7	0.09·
Non-buffer Zone	Income loss	14	442	3.2	0.09·
Buffer Zone	Migration	6	164	3.7	0.01*

Zone Type	Impact Type	n	total	Percent	p_value
Non-buffer Zone	Migration	3	442	0.7	0.01*
Buffer Zone	Others	91	164	55.5	0.28
Non-buffer Zone	Others	221	442	50.0	0.28
Buffer Zone	Property damage	6	164	3.7	0.51
Non-buffer Zone	Property damage	10	442	2.3	0.51
Buffer Zone	Water scarcity	5	164	3.0	0.67
Non-buffer Zone	Water scarcity	9	442	2.0	0.67

4.1.3.4 Perception of Climate Change Seriousness

Survey results indicate that most respondents recognize climate change as a pressing issue in their community. The majority (62.5%) considered it “Somewhat serious,” while nearly one-third (30.1%) viewed it as “Very serious.” A smaller proportion perceived it as “Not serious” (4.8%), and 2.6% reported “Don’t know.” Statistical analysis using Pearson’s Chi-squared test revealed no significant differences between buffer zone and non-buffer zone households, suggesting that concern about climate change is widespread and consistently acknowledged across both community types.

4.1.4 Awareness and adaptation strategies

4.1.4.1 Awareness of Nature-Based Solutions (NbS)

Respondents were asked about their awareness of local NbS. Overall, 59.2% of respondents reported having heard of the term *NbS*, while 40.8% had not. Nevertheless, even respondents unfamiliar with the terminology recognized specific initiatives.

For this study, we categorized NbS into 15 types (Table 6). Across all respondents, tree planting initiatives, street trees, spiritual areas, and urban parks had the highest recognition. For instance, in non-buffer zones, 68.3% of respondents reported tree planting initiatives, 54.8% noted spiritual areas, and 54.5% mentioned urban parks. In buffer zones, the most recognized were street trees (61.0%), tree planting initiatives (54.9%), and urban parks (49.4%).

By contrast, awareness of hiking trails, rain gardens, mini zoos, wetlands, and cycling paths was very low in both zones. For example, rain gardens were mentioned by only 2.3% of respondents in non-buffer zones and by none in buffer zones. Statistical tests (Chi-square or Fisher's exact tests) highlighted significant zone-based differences:

- Permeable pavements: More common in non-buffer zones (15.6%) than buffer zones (1.8%) (*Fisher's exact test, $p < 0.001$*).
- Tree planting initiatives: Higher in non-buffer zones (68.3%) than buffer zones (54.9%) (*Chi-square, $p = 0.0025$*).
- Street trees: Higher in buffer zones (61.0%) than non-buffer zones (46.4%) (*Chi-square, $p = 0.0021$*).
- Spiritual areas: More frequent in non-buffer zones (54.8%) than buffer zones (30.5%) (*Chi-square, $p < 0.001$*).
- No significant differences were observed for urban parks, vertical gardens, ecofriendly building designs, wetlands, and playgrounds, cycling paths, mini zoos, or hiking trails ($p > 0.05$, Figure 9).

Table 6: Awareness of Nature-based Solutions among respondents (n=606)

NbS Type	N	Percent
Tree planting initiatives	392	64.8
Urban parks and green spaces	322	53.2
Street Trees	305	50.4
Spiritual area	292	48.3
Play stations and Natural playgrounds	170	28.1
Vertical gardens	148	24.5
Ecofriendly building designs	133	22.0
Permeable pavements	72	11.9
Riverbank greening	52	8.6
Cycling path	40	6.6
Wetland restoration (e.g. storm water management ponds)	28	4.6
others	19	3.1
Mini Zoo or Animal parks	14	2.3
Rain gardens	10	1.7
Hiking trails	2	0.3

4.1.4.2 Community perceptions of NbS benefits

Most respondents expressed a positive view of NbS. About 74.0% agreed and 23.3% strongly agreed that NbS improved the local environment, while only a small share were neutral (2.3%) or disagreed (0.3%).

When asked about the effectiveness of green spaces (parks, trees, etc.) in reducing climate-related risks, the largest share of respondents rated them as slightly effective (43.0%), followed by moderately effective (29.3%) and very effective (27.6%).
Only 0.2% of respondents felt that green spaces were not effective. This suggests that while majorities acknowledge some level of benefit, perceptions lean more toward slight to moderate effectiveness rather than very high effectiveness.

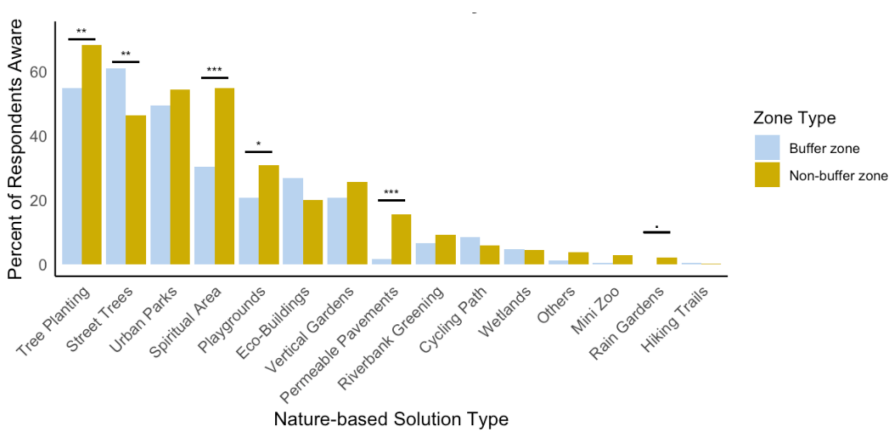


*Figure 9: Awareness of NbS by buffer and non-buffer zones. Bars show % of households; asterisks denote significant differences (*p < 0.05, **p < 0.01,*

Respondents also recognized a broad range of environmental, social, and economic benefits, with several differences observed between buffer and non-buffer zones.

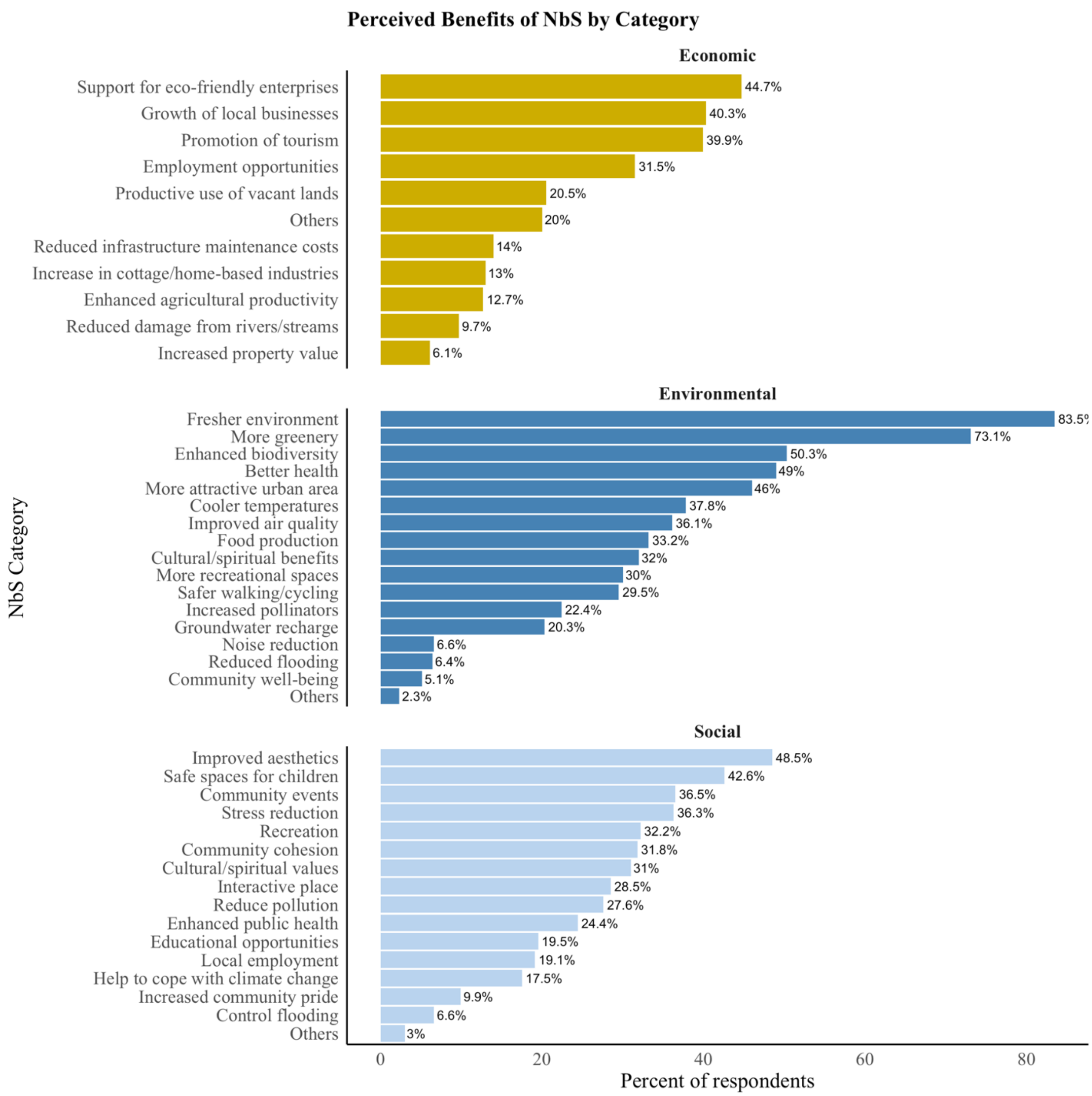


Figure 10: Perceived environmental, social, and economic benefits of nature-based solutions (NbS), showing the percentage of respondents reporting each benefit within its respective category.

Among environmental benefits, the most commonly selected changes included fresher environment (83.5%), more greenery (73.1%), enhanced biodiversity (50.3%), and better health (49.0%). Statistical comparisons indicate that some benefits were significantly more reported in buffer zones, such as better health (p = 1.14e-05), cooler temperatures (p = 1.17e-04), improved air quality (p = 1.72e-06), enhanced biodiversity (p = 1.11e-03), groundwater recharge (p = 4.63e-06), increased pollinators (p = 1.72e-13), and safer walking/cycling environment (p = 6.45e-08). Other benefits, including more attractive urban areas, cultural/spiritual benefits, and noise reduction, did not differ significantly between zones.

For social benefits, improved aesthetics (48.5%) and safe spaces for children and elderly (42.6%) were top-rated. Benefits such as recreation (32.2%), community cohesion (31.8%), educational opportunities (19.5%), and control of flooding/landslide (6.6%) were significantly higher in buffer zones based on chi-square or Fisher tests. Some benefits, including interactive places, cultural/spiritual values, and other minor items, were not significantly associated with buffer status.

Support for eco-friendly enterprises (44.7%), local business growth (40.3%), tourism (39.9%), and employment opportunities (31.5%) were the most recognized economic benefits. Many of these economic benefits, including reduced damage from rivers/streams, productive use of previously unused/vacant lands, increased cottage/home-based industries, enhanced agricultural productivity, reduced infrastructure maintenance costs, employment opportunities (all p < 0.001), increased property value (p = 3.68e-02), and support for eco-friendly enterprises (p = 3.18e-03), were significantly higher in buffer zones, while others, such as promotion of tourism and growth of local businesses, showed no significant difference (Table 7, Figure 10).

Overall, environmental benefits were most widely recognized, followed by economic and social benefits. The higher recognition of several benefits in buffer zones highlights the local importance of NbS interventions.

Table 7: Summary of respondent-reported benefits of Nature-based Solutions (NbS) by category

Category	N	p_value	Test Type	Higher in	Item
Environmental	39	0.473	Chi-sq	Buffer zone	Reduced flooding
	443	0.481	Chi-sq	Buffer zone	More greenery
	506	0.564	Chi-sq	Buffer zone	Fresher environment
	297	0.000	Chi-sq	Buffer zone	Better health

	229	0.000	Chi-sq	Buffer zone	Cooler temperatures (urban heat reduc tion)
	219	0.000	Chi-sq	Buffer zone	Improved air quality
	305	0.001	Chi-sq	Buffer zone	Enhanced biodiversity
	123	0.000	Chi-sq	Buffer zone	Groundwater recharge
	182	0.000	Chi-sq	Buffer zone	More recreational spaces
	136	0.000	Chi-sq	Buffer zone	Increased pollinators (bees, butterflies, birds)
	179	0.000	Chi-sq	Buffer zone	Safer walking/cycling environment
	31	0.035	Chi-sq	Buffer zone	Noise reduction
	279	0.372	Chi-sq	Buffer zone	Community well-being or mental peace
	194	0.165	Chi-sq	Non-buffer zone	More attractive urban area
	201	0.175	Chi-sq	Non-buffer zone	Cultural/spiritual benefits
	40	1.000	Chi-sq	Buffer zone	Food production
	14	0.768	Fisher	Non-buffer zone	Others
	193	0.412	Chi-sq	Buffer zone	Community cohesion
	173	0.002	Chi-sq	Non-buffer zone	Interactive place
	195	0.000	Chi-sq	Buffer zone	Recreation
	167	0.648	Chi-sq	Buffer zone	Reduce pollution
	106	0.104	Chi-sq	Buffer zone	Help to cope with climate change
	40	0.000	Chi-sq	Buffer zone	Control flooding/landslide
	148	0.351	Chi-sq	Buffer zone	Enhanced public health
Social	118	0.000	Chi-sq	Buffer zone	Educational opportunities (e.g., school visits, awareness programs)
	188	0.062	Chi-sq	Non-buffer zone	Cultural/spiritual values
	294	0.016	Chi-sq	Non-buffer zone	Improved aesthetics/beauty of the area
	258	0.051	Chi-sq	Buffer zone	Safe spaces for children and elderly
	60	0.000	Chi-sq	Buffer zone	Increased community pride/ownership
	220	0.586	Chi-sq	Buffer zone	Stress reduction and mental well-being
	116	0.240	Chi-sq	Buffer zone	Local employment opportunities
	221	0.103	Chi-sq	Buffer zone	Community events or gathering spaces
	18	0.055	Fisher	Non-buffer zone	others
	242	0.444	Chi-sq	Non-buffer zone	Promotion of tourism
	244	0.905	Chi-sq	Non-buffer zone	Growth of local businesses
Economic	59	0.000	Chi-sq	Buffer zone	Reduced damage from rivers/streams
	124	0.000	Chi-sq	Buffer zone	Productive use of previously unused/v acant lands

79	0.000	Chi-sq	Buffer zone	Increase in cottage/home-based industries
77	0.000	Chi-sq	Buffer zone	Enhanced agricultural productivity
85	0.000	Chi-sq	Buffer zone	Reduced infrastructure maintenance co sts (e.g., drainage, roads)
37	0.037	Chi-sq	Buffer zone	Increased property value
191	0.000	Chi-sq	Buffer zone	Employment opportunities (e.g., park m aintenance, guides)
271	0.003	Chi-sq	Buffer zone	Support for eco-friendly enterprises
121	0.150	Chi-sq	Non-buffer zone	others

4.1.4.3 Community Perceptions, Needs, and Engagement in Nature-Based Solutions in Bharatpur

A majority of the respondents (74%, n = 448) felt that existing NbS in Bharatpur are not sufficient, while only 26% (n = 157) considered them adequate. Among respondents who answered "No," the most requested additional NbS types were Urban parks (13.7%, n = 281) and Street Trees (13.6%, n = 280), followed by Playgrounds (12.4%, n = 256), Tree planting initiatives (12.2%, n = 251), and Cycling paths (12.0%, n = 247). Other notable preferences included Eco-buildings (10.2%, n = 209), Riverbank greening (5.2%, n = 108), and Permeable pavements (4.3%, n = 89). Less frequently requested NbS types were Spiritual areas (3.2%), Green roofs (2.9%), Rain gardens (2.8%), Wetlands (2.7%), Vertical gardens (1.9%), Mini Zoos (1.7%), Others (0.9%), and Hiking trails (0.3%) (Figure 11).

Overall, the results highlight a strong demand for urban greening, recreational spaces, and infrastructure that enhances environmental quality and community well-being in

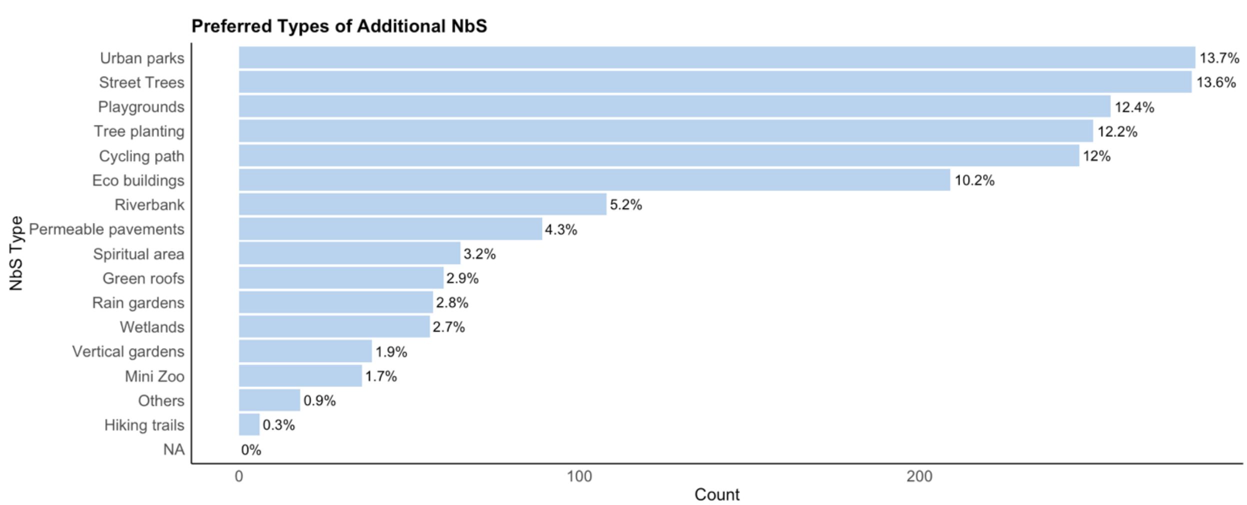


Figure 11: Preferred additional nature-based solutions (NbS) among respondents in Bharatpur.

Bharatpur. When asked about the challenges or problems associated with Nature-based Solutions (NbS), respondents identified a range of issues. The most frequently mentioned concern was "Others" (18.1%), followed by poor maintenance or neglect (13.6%) and solid waste/littering (11.2%). Overcrowding (10.8%) and an increase in social crime or unsafe areas (8.8%) were also notable concerns. Noise pollution (8.4%), conflicts over land use or access (8.3%), and vandalism or damage to green infrastructure (7.6%) were cited by several respondents. A smaller proportion of participants highlighted NbS areas becoming dating or hangout spots (7.5%) and misuse of public spaces (5.5%). These results indicate that while NbS are generally valued, effective management and maintenance remain key challenges to their successful implementation and public acceptance (Figure 12).

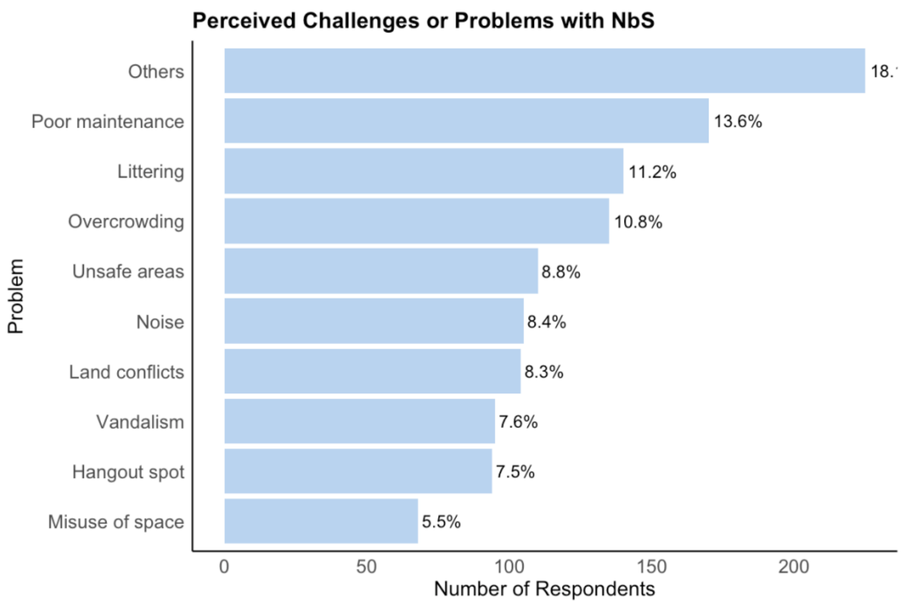


Figure 12: Perceived challenges associated with NbS.

Community engagement in environmental initiatives was notably high. A large majority (84%) reported participation in activities such as tree planting or clean-up drives, while 16% had not participated. Regarding the importance of community involvement in NbS planning, 53% considered it *very important* and 47% *somewhat important*, with only 1% viewing it as not important. Similarly, when asked about willingness to join community NbS projects, 42% indicated *yes*, 54% responded *maybe*, and only 3% said *no*, highlighting substantial potential for mobilizing local participation. Respondents also identified the types of support needed to engage in NbS activities. Awareness programs (37%) and training (36%) were most frequently requested, followed by technical guidance (14%) and funding (12%). This underscores the importance of building knowledge and capacity alongside financial and technical resources.

Preferences for NbS management further reflected a strong inclination toward participatory approaches. Community management was the most common choice (44%), followed by ward-level management (38%). Less common were entry-fee-based models (9%), fund-generated management (8%), and other approaches (2%). These responses highlight local demand for inclusive, community-led governance of NbS initiatives.

The survey findings reveal a consistent pattern in how respondents perceive and prioritize Nature-based Solutions (NbS). Across all categories of responses, urban greening and green spaces clearly stand out as the dominant priority, while other themes are viewed as important but secondary. In the suggestions, respondents most frequently emphasized the need for more green spaces and urban greening (249 mentions). Waste and pollution management (142), awareness and community participation (62), and forest, land, and ecosystem protection (61) were also highlighted, though less strongly. Housing and urban planning (46), energy and technology (40), and governance and implementation (37) appeared less often, while tourism and infrastructure-related issues received only minimal attention. For the Best-suited NbS, green spaces and urban greening were again overwhelmingly prioritized (372 mentions). Water and flood management (64) and forest, land, and ecosystem protection (58) followed at a distance, with sustainable housing and infrastructure (48), awareness and participation (39), and waste and pollution management (39) also identified as relevant. Tourism (5) and governance (3) were rarely viewed as suitable solutions.

The additional comments reinforced this overall trend. Urban greening and green spaces once more dominated (339 mentions), followed by awareness and community participation (134), waste and pollution management (62), and sustainable housing and infrastructure (55). Mentions of forest and ecosystem protection (11), tourism and local economy integration (3), and water and flood management (3) were far less common. Taken together, these results demonstrate that respondents consistently see visible greenery and urban greening as the cornerstone of effective NbS. Waste and pollution management, awareness and participation, and sustainable housing and infrastructure are also recognized as significant but secondary concerns. In contrast, themes such as tourism, governance, and water/flood management receive comparatively little immediate attention, even though they may hold long-term importance for building resilient and sustainable cities (Figure 13).

4.2 Stakeholder interactions

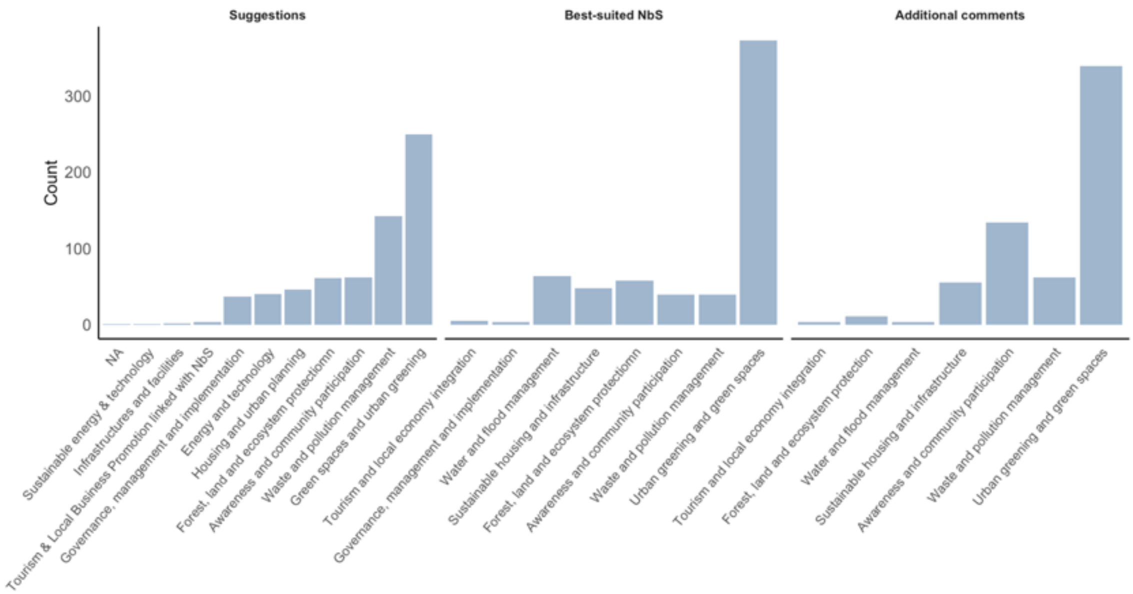


Figure 13: Frequency of themes derived from open-ended survey responses, grouped by source.

4.2.1 Key Informant Interview (KII)

The Key Informant Interviews reveal how communities perceive climate change, its impacts, and the strategies being adopted to cope with these challenges.

4.2.1.1 Perceptions of Climate Change and Its Impacts

Respondents consistently reported noticeable changes in climatic conditions, including:

- Irregular rainfall patterns and rising temperatures.
- Increased frequency of floods, droughts, and landslides.
- Significant impacts on agriculture, water resources, forests, and community livelihoods.
- Specific concerns included declining crop productivity, growing pest infestations, forest degradation, drying water sources, increasing human–wildlife conflict, and more frequent forest fires.

4.2.1.2 Mitigation and Adaptation Measures

Key informants highlighted a diverse set of strategies, many of which are already being implemented at the community level:

- Community forest management as the cornerstone for regulating ecosystems and providing alternative resources.
- Tree plantation and roadside greenery, often initiated by ward leaders to reduce dust, improve aesthetics, and provide shade.
- Controlled harvesting practices to prevent overexploitation of forest resources.
- Agroforestry, integrating fodder trees and fruit species to improve soil fertility and diversify incomes.
- Alternative energy and improved cooking stoves to reduce reliance on firewood.
- Parks and community ponds for recreation, groundwater recharge, and cultural activities.
- Rooftop farming, increasingly adopted in urbanizing areas for food security.
- NbS such as reforestation, riverbank plantation, wetland and watershed conservation, and grassland management.
- These strategies were widely seen as essential for restoring ecosystems, enhancing water regulation, conserving soil, and improving livelihoods.

4.2.1.3 Role of Local Leaders and Institutions

Ward chairpersons and community leaders were recognized as pivotal actors in climate action. Their roles include:

- Mobilizing communities to raise awareness and promote collective adaptation/mitigation actions.
- Integrating climate change priorities into ward-level planning and budgeting.
- Regulating natural resource use through forest management, plantation, fire control, and harvesting rules.
- Facilitating linkages with government agencies, NGOs, and donors for technical and financial support.
- Promoting alternative livelihoods such as eco-tourism, sustainable agriculture, and renewable energy.
- Encouraging recreational spaces and parks for community well-being, including facilities specifically designed for adults.
- Conflict resolution and enforcement of local rules on encroachment, overgrazing, and illegal logging.
- Overall, leaders were described as crucial for providing leadership, coordination, and accountability, while fostering collective responsibility for coping with climate impacts.

4.2.1.4 Challenges Identified

Despite active efforts, several barriers limit effectiveness:

- Limited financial resources and technical expertise.
- High dependency on natural resources.
- Weak coordination among government agencies.
- Limited public awareness and participation.
- Constraints on land availability in some wards, making it difficult to establish parks and green infrastructure.

4.2.1.5 Future Directions and Policy Alignment

Respondents emphasized the need to:

- Strengthen institutional capacity and inter-agency coordination.
- Expand technical and financial support for local adaptation.
- Integrate land-use planning with climate adaptation strategies.
- Develop sustainable green infrastructure in wards with limited public land.
- These priorities align closely with Nepal's National Adaptation Plan (NAP) and Local Adaptation Plans of Action (LAPA), both of which emphasize ecosystem-based adaptation, community-led solutions, and integration of resilience into governance structures. Linking ward-level initiatives to these frameworks can help secure policy backing, attract funding, and ensure long-term sustainability.

4.2.2 Stakeholders meeting

A stakeholder meeting was held at CMT Hotel, Bharatpur with 20 participants representing diverse fields such as municipal authorities, conservation officers, ward chairpersons, philanthropists, environmental activists, agriculturists, and medical professionals. The discussion focused on the challenges and opportunities for making BMC greener, more climate-resilient, and environmentally sustainable.

Municipal authorities highlighted ongoing efforts to make Bharatpur greener and more climate-resilient, including roadside and community plantations, promotion of flowering and fruit-bearing trees, the sacred fig-Park concept (The Sacred Fig-Park concept involves creating and managing green spaces centered around sacred fig trees (Ficus religiosa) that hold cultural, religious, and ecological significance), and initiatives to enhance groundwater recharge. Programs supporting organic fertilizers, environmentally friendly building designs, and urban research for sustainability were also noted. Stakeholders emphasized the need to strengthen these efforts through better planning, inter-agency coordination, and community engagement.

4.2.2.1 Urban Greening and Water Management

Stakeholders highlighted the importance of roadside and community plantations, fruit-bearing trees in suburban areas, and initiatives such as the sacred fig-Park concept. Groundwater recharge was a recurring concern, with many criticizing deep boring systems as costly and ecologically harmful. Instead, shallow boring, preservation of natural flows, and revival of traditional water channels were emphasized. Conservation of wetlands, streams, and culturally significant chautaras was also viewed as vital.

4.2.2.2 Waste and Pollution Management

Concerns were raised about rising waste collection fees, which risk encouraging burning and river dumping. Suggested alternatives included free or subsidized collection, school-based education, mandatory household recycling using three-bin systems, and better community participation. Broader pollution issues, including cross-border air pollution, were also mentioned.

4.2.2.3 Governance and Participation

Several participants expressed frustration that local suggestions are often overlooked by concerned agencies. Stronger governance, sectoral collaboration, and community participation were repeatedly emphasized. Proposals included adopting Payment for Ecosystem Services (PES), integrating Indigenous knowledge into planning, and ensuring housing plans mandate green spaces.

4.2.2.4 Agriculture and Resource Management

Participants urged a shift toward organic farming, promotion of algal fertilizers, and use of locally adapted species such as *Melia azedarach* trees for urban cooling and biodiversity. Overreliance on chemical fertilizers and subsidies was criticized. Controlled harvesting, eco-friendly building designs, and rooftop farming were highlighted as innovative practices with potential for scale-up.

4.2.2.5 Broader Sustainability Concerns

Stakeholders linked local challenges to global crises of biodiversity loss, climate change, and pollution, stressing that local actions should align with frameworks such as the

Kunming–Montreal Protocol. Issues such as invasive alien plant species, riverbed encroachment, and human–wildlife conflict were also flagged as pressing threats.

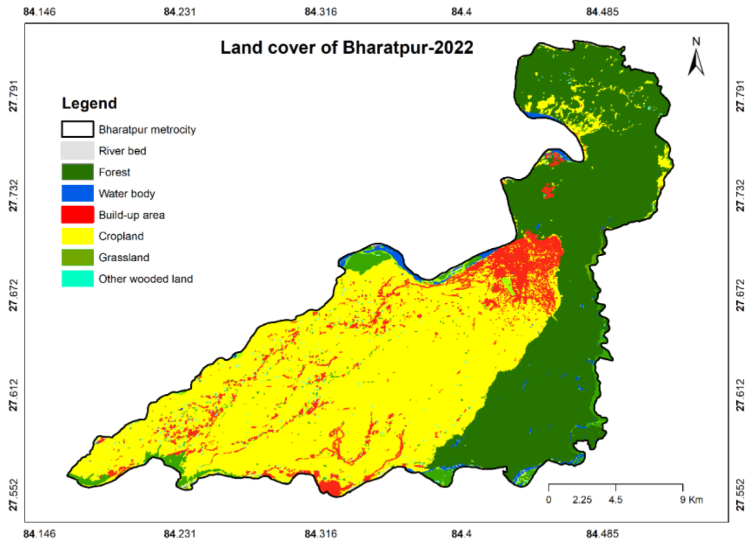


Figure 14: Land-cover types of Bharatpur Metropolitan City in 2022, derived from Landsat imagery

Overall, stakeholders emphasized that Bharatpur Metropolitan City requires a balance between development and environmental conservation. Locally adapted, community-driven solutions, backed by stronger governance, financial and technical support, and long-term master planning, are essential for sustainable urban growth and resilience.

4.2.3 School Program

Awareness programs were conducted in multiple schools across Bharatpur, including Orbit Unique English School, Shree Narayani Vidya Mandir Ma. Vi., Gunjanagar Ma. Vi., Kabilash Ma. Vi., and Nayakiran Ma. Vi., reaching over 300 students.

Table 8: Land-cover types of Bharatpur Metropolitan City (2022)

Land cover category	Area (Km^2)	Percentage (%)
Water body	1.58	0.32
Forest	200.06	40.85
River bed	3.99	0.81
Buildup area	18.39	3.76
Cropland	252.26	51.51
Grassland	6.81	1.39
Other wooded land	6.65	1.36

The program aimed to increase students' understanding of climate change, its impacts, mitigation strategies, and the role of NbS. Students participated in interactive group discussions to identify and analyze NbS present in their communities. Each group presented their observations and proposed actions, encouraging critical thinking and practical engagement with local environmental issues.

The program successfully enhanced students' awareness of climate change and NbS. This program was important because students were clear and aware about the climate change and NbS after we have performed our trainings there. The program was for 4 hours in one school or college. It promoted community-oriented thinking and fostered interest in environmental stewardship among young participants.

Building on these educational efforts, a spatial data analysis was undertaken to contextualize the city's environmental landscape. The assessment of landcover patterns in Bharatpur Metropolitan City provided a clear and evidence-based illustration of how land-use dynamics influence climate vulnerability, shape ecosystem service provision, and inform opportunities for the strategic implementation of NbS interventions.

4.3 Spatial Data analysis

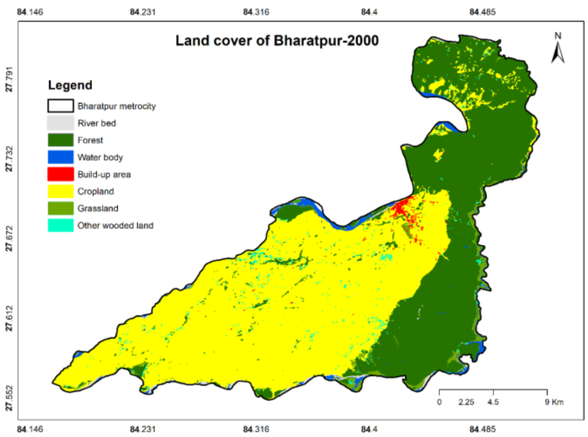
4.3.1 Landcover status of Bharatpur Metropolitan City

The classification of the 2022 Landsat image identified seven land-cover types: water bodies, forest, riverbed, built-up area, cropland, grassland, and other wooded land. Built-up areas were interspersed within the croplands. Cropland covered the largest area (51.5%), followed by forest (40.9%). Built-up areas were scattered within croplands and other land-cover types (Table 8; Figure 14).

4.3.2 Land cover dynamics (2000-2022)

Between 2000 and 2022, cropland, water bodies, and riverbeds decreased by 10.2%, 61.7%, and 39.2%, respectively. In contrast, built-up areas expanded substantially (494.2%), while forest (9.5%), grassland (16.8%), and other wooded land (1.7%) also increased. The most pronounced built-up expansion occurred between 2010 and 2022, while reductions in water bodies and riverbeds were greatest in the same period (Table 9; Figure 15).

(a)



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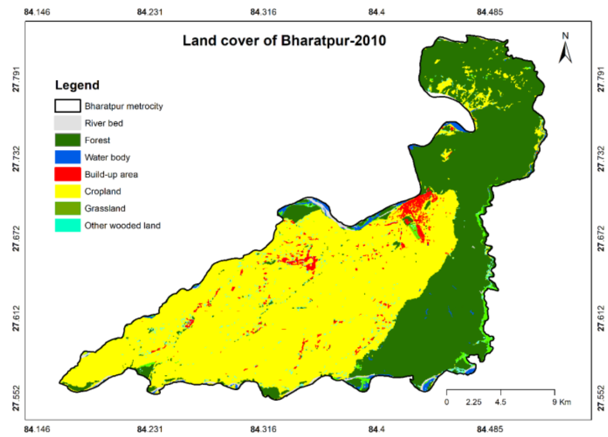

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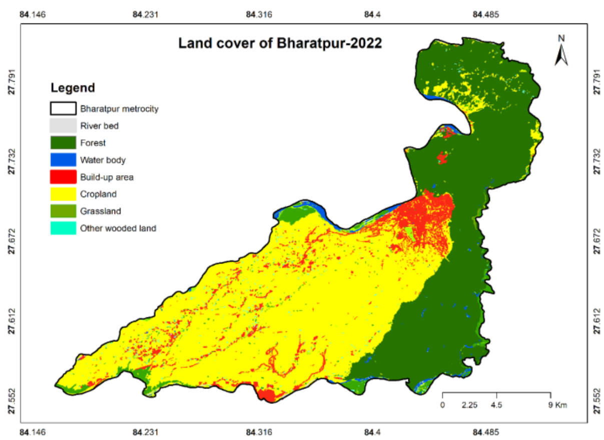

Figure 15: Land-cover change in Bharatpur Metropolitan City from 2000 to 2022. (A) 2000,

Table 9: Land-cover changes in Bharatpur Metropolitan City (2000–2022)

Land cover category	Land cover			Land cover dynamics					
	2000	2010	2022	2000-2010	%	2010-2022	%	2000-2022	%
Water body	4.12	2.82	1.58	-1.30	-31.51	-1.24	-44.10	-2.54	-61.71
Forest	182.68	191.98	200.06	9.30	5.09	8.09	4.21	17.39	9.52
Rive bed	6.56	5.78	3.99	-0.78	-11.88	-1.79	-31.00	-2.57	-39.20
Built-up area	3.10	3.79	18.40	0.70	22.50	14.60	385.07	15.30	494.22
Cropland	280.93	271.35	252.26	-9.58	-3.41	-19.09	-7.04	-28.67	-10.20

Grassland	5.83	3.43	6.81	-2.40	-41.18	3.38	98.58	0.98	16.82
Other wooded land	6.54	10.60	6.65	4.06	62.11	-3.95	-37.25	0.11	1.73

4.3.3 Spatial distribution of NbS interventions across BMC

The spatial configuration of NbS activities in Bharatpur Metropolitan City (Figure 16) reflects a multi-scalar and integrated approach, where interventions such as recharge ponds, riverbank management, roadside plantations, playgrounds, and recreational parks are embedded across both urban cores and peri-urban areas. This distribution demonstrates an intentional effort to align ecological restoration with community well-being, complementing broader land-cover changes observed between 2000 and 2022. Ground-truthing and spatial analysis further indicate that while these nature-based interventions are generally effective—improving vegetation cover and reducing soil erosion—their distribution is uneven, with concentrations near urban parks and community-managed forests. Some initiatives remain small-scale or under-maintained, which may limit their overall ecological impact. Together, these findings provide a comprehensive view of the current status and functional effectiveness of NbS in the city, highlighting both strategic planning and on-the-ground realities.

5. Discussion and Implications

This study shows that communities readily recognize visible and culturally rooted forms of Nature-based Solutions (NbS), even when they are unfamiliar with the terminology. Interventions such as tree planting, roadside greenery, and spiritual areas are widely acknowledged because they are tangible, accessible, and aligned with local traditions. This underscores the importance of designing NbS that build on cultural values and everyday experiences. In contrast, less visible and more technically complex solutions such as rain gardens, wetlands, and permeable pavements—remain poorly understood. This gap highlights the need for targeted awareness campaigns, participatory planning, and demonstration projects that clearly communicate the multiple benefits, including water management, biodiversity enhancement, and climate adaptation. Differences between urban zones further emphasize that NbS planning must be context-specific, as strategies effective in one area may not resonate in another depending on land use, exposure to interventions, and community practices. Localized approaches are therefore essential for ensuring relevance and uptake.

Strong concern among communities about extreme heat and drought provides an opportunity to frame NbS explicitly as climate resilience tools. Linking interventions to urgent local priorities such as heat reduction, water retention, and health can generate wider support from both citizens and policymakers. Integrating NbS into urban planning requires a dual strategy: reinforcing visible and culturally meaningful measures while also raising awareness of less familiar but equally critical interventions. Doing so can help create more resilient, inclusive, and sustainable urban landscapes.

At the broader scale, the city's focus on large riverine systems, including the Narayani and Rapti Rivers, reflects efforts to safeguard ecological corridors that regulate flooding, sustain biodiversity, and maintain long-term ecosystem connectivity (e.g. Adhikari et al., 2024). Simultaneously, wetlands including lakes, groundwater recharge ponds, and traditional village ponds—strengthen hydrological resilience by storing excess water during monsoon events, replenishing aquifers, and mitigating recurrent water scarcity (Gebreslassie et al., 2025). At the intermediate scale, investments in community forests and roadside plantations contribute to urban heat mitigation, carbon sequestration, and improved air quality, while fostering habitat continuity within the urban fabric (Kabisch et al., 2017). At the most localized and community-managed level, the protection and revitalization of recreational parks, playgrounds, and open spaces embed NbS into daily urban life, delivering social, cultural, and ecological co-benefits for residents (Nesshöver et al., 2017).

Importantly, these interventions align with global NbS frameworks, such as the International Union for Conservation of Nature (IUCN)'s Global Standard, which emphasizes context-specific, multi-benefit, and participatory approaches (Cohen-Shacham et al., 2016). Bharatpur's strategy also resonates with international examples, including Singapore's Park Connector Network, which integrates linear greenways to reduce flooding and enhance mobility (Tan, 2006), and Rotterdam's multifunctional water plazas, which combine urban flood management with recreational uses (van Veelen, 2016). In this way, Bharatpur represents an emerging model of ecological urbanism in South Asia, where nature is treated not as an isolated element of conservation but as active infrastructure embedded within planning, governance, and community well-being. Collectively, this multi-scale approach demonstrates how NbS can advance climate resilience, reduce vulnerabilities to flooding, heat stress, and ecosystem degradation, and simultaneously enhance long-term community security and sustainable urban development (Intergovernmental Panel on Climate Change (IPCC), 2022).

6. Conclusions

This study assessed the potential of community-based NbS to strengthen climate resilience in Bharatpur Metropolitan City. Below are the conclusions organized by research objective.

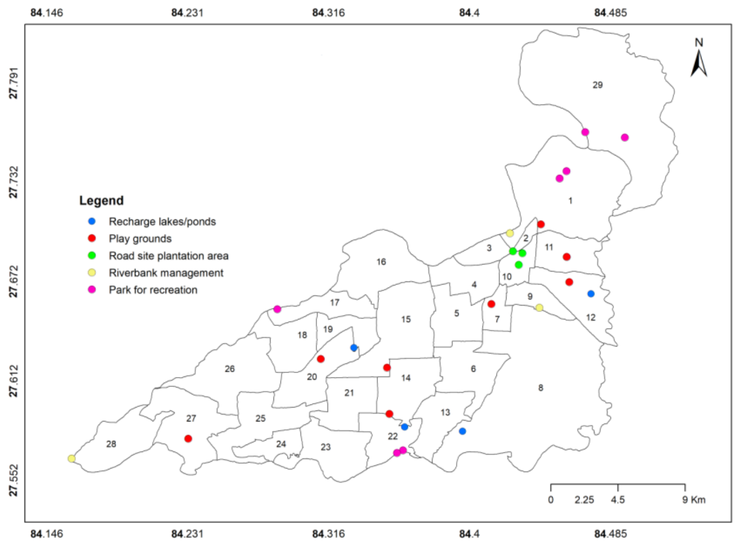

Figure 16: Spatial distribution of NbS interventions across Bharatpur Metropolitan City, Chitwan, Nepal, including recharge ponds, playgrounds, roadside plantations, riverbank

Objective 1: Effectiveness of existing NbS

Findings confirm that NbS are perceived to effectively contribute to ecological stability, social well-being, and economic opportunities. While green parks, tree planting, and community forests are widely recognized and effective in reducing heat and supporting biodiversity, technical NbS such as wetlands and permeable pavements remain underutilized and poorly understood.

Objective 2: Strategies for successful implementation and engagement

Community perceptions, FGDs, and KIIs reinforce that success hinges on culturally grounded, visible interventions combined with strong participatory governance. Strategies such as community and ward-level management, integration of Indigenous practices, awareness programs, and municipal support for eco-friendly infrastructure are essential for enhancing adoption and sustainability.

Objective 3: Framework for scaling NbS

Based on the analysis of existing NbS in Bharatpur, a tailored framework for expanding these solutions should involve four interlinked steps:

Raising awareness and building technical capacity – Community engagement programs and training initiatives can strengthen local knowledge and participation, addressing the gaps identified in public awareness and uneven NbS adoption.

Piloting diverse NbS interventions – Implementing small-scale, context-specific NbS (e.g., riverbank restoration, urban plantations, and recharge ponds) allows for testing effectiveness and adaptability, informed by spatial distribution and ecological outcomes observed in this study.

Embedding NbS into municipal and ward-level planning – Integrating NbS into formal urban planning processes ensures continuity, local ownership, and systematic maintenance, helping overcome current limitations in scale and maintenance.

Aligning with national adaptation frameworks – Linking local initiatives with policies such as NAP and LAPA secures technical, financial, and policy support, enabling replication and scaling across other rapidly urbanizing Nepali cities.

While existing NbS in Bharatpur already deliver tangible ecological and social benefits, this stepwise framework ensures their scalability, sustainability, and long-term impact, providing a model that is both locally grounded and adaptable to broader urban contexts in Nepal.

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Appendices

Annex I: Questionnaires for household survey

1-page informed consent with ethical considerations (a short briefing about the project).
Prior Informed Consent: Is the respondent willing to take part in the interview?
Yes/No _________
If yes, then proceed with the interview
If the response is no, then move to another household for interview

A. Basic Household Information
Date of Interview (B.S.)/AD: ____________
Name of the Enumerator: ____________
Interview ID: ____________
Address: Bharatpur Metropolitan City, Chitwan; Ward No.: _________
Tole:_________ Settlement Name: ____________
GPS Location: _________________
Photograph of respondent (to be inserted in KoBo)
Name of the Respondent: _________________
Age: _________________
Gender: ☐ Male ☐ Female ☐ other
Contact Number: _________________
Which ethnic group/caste do you belong to?
Brahmin/Chhetri/Thakuri/Dasnami
Adivasi Janajati
Dalit
Others
Education:
☐ Illiterate,
☐ Basic (1-8),
☐ Secondary (9-10),
☐ Higher Secondary (11-12),
☐ University
Occupation:
☐ Agriculture,
☐ Business,
☐ Government Job,
☐ Private Job,
☐ Remittance,
☐ Daily wages,

☐ Others (please specify): _______________
Household members: Male: ________, Female: ________, Total: ________
Health status in family:
☐ Healthy
☐ Frequent illness
☐ Chronic disease
☐ Disabled
Land holding status: ☐ Registered ☐ Unregistered
Monthly Household Income: ☐ < NRs. 10,000 ☐ 10,000–30,000 ☐ 30,001–60,000 ☐ > 60,000
Animal husbandry (select all that apply):
☐ Cattle ☐ Buffalo ☐ Goat☐ Poultry ☐ Others: _________
Are you located in a buffer zone area? ☐ Yes ☐ No
Related park or green spaces nearby (list all):
____
____
Distance to nearest park/green area: __________ (in meters/km)
Major ethnic groups in your community:
____
____

B. Climate Risks and Impact Perception

Have you experienced climate-related issues (Tick all that apply):
☐ Flooding ☐ Extreme heat ☐ Water runoff ☐ Landslides ☐ Drought ☐ Others _____________________
How frequently do you experience these issues in your area?

Climate-related issue	Never	Rarely (once every few years)	Sometimes (Once a year)	Frequently (Several times a year)
Flooding				
Extreme heat				
Water runoff				
Lanslides				
Drought				
Others				

How concerned are you about these issues in your area?
Please rate your level of concern for each of the following on a scale of 1 to 5, where 1 means "Not concerned at all" and 5 means "Extremely concerned."

Climate-related issue	Not concerned at all (1)	Slightly concerned (2)	Moderately concerned (3)	Highly concerned (4)	Extremely concerned (5)

Flooding					
Extreme heat					
Water runoff					
Lanslides					
Drought					
Others					

Have these climate events impacted your livelihood or property?
☐ Yes ☐ No — If yes, how? ___________________
How have these changes affected your household?
☐ Income loss ☐ Health issues ☐ Migration ☐ Property damage
☐ Water scarcity ☐ Crop failure ☐ Others: ______________
Do you think climate change is a serious issue in your community?
☐ Very serious ☐ Somewhat serious ☐ Not serious ☐ Don't know

C. Awareness and Perception of Nature-based Solutions (NbS)
Have you heard of "Nature-based Solutions" before? ☐ Yes ☐ No
Which local NbS have you seen/are aware of?
☐ Urban parks and green spaces
☐ Rain gardens
☐ Green roofs
☐ Permeable pavements
☐ Tree planting initiatives
☐ Street Trees
☐ Vertical gardens
☐ Wetland restoration (e.g. storm water management ponds)
☐ Riverbank greening
☐ Spiritual area
☐ Play stations and Natural playgrounds
☐ Mini Zoo or Animal parks
☐ Hiking trails
☐ Cycling path
☐ Ecofriendly building designs
☐ Others

Name the known Nbs project/s in your area
____
Distance of your house from this NBs project site___________(m/Km)
Do you agree on "NbS improves local environment"?
☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

How effective do you think the green spaces (parks, trees, etc.) are in reducing climate-related risks?

☐ Not effective ☐ Slightly effective ☐ Moderately effective ☐ Very effective

What environmental or health changes do you associate with NbS? (tick all that apply)

☐ Reduced flooding
☐ More greenery
☐ Fresher environment
☐ Better health
☐ Cooler temperatures (urban heat reduction)
☐ Improved air quality
☐ Enhanced biodiversity
☐ Groundwater recharge
☐ More recreational spaces
☐ Increased pollinators (bees, butterflies, birds)
☐ Safer walking/cycling environment
☐ Noise reduction
☐ Community well-being or mental peace
☐ More attractive urban area
☐ Cultural/spiritual benefits
☐ Food production (e.g., community gardening)
☐ Others: __________

What are the added social benefits from Nbs? (Tick all that apply)

☐ Community cohesion
☐ Interactive place
☐ Recreation
☐ Reduce pollution
☐ Help to cope with climate change
☐ Control flooding/landslide
☐ Enhanced public health
☐ Educational opportunities (e.g., school visits, awareness programs)
☐ Cultural/spiritual values
☐ Improved aesthetics/beauty of the area
☐ Safe spaces for children and elderly
☐ Increased community pride/ownership
☐ Stress reduction and mental well-being
☐ Local employment opportunities
☐ Community events or gathering spaces
☐ Others: __________

What are the economic benefits of Nature-based Solutions (NbS)? (Tick all that apply)

☐ Promotion of tourism

☐ Growth of local businesses

☐ Reduced damage from rivers/streams

☐ Productive use of previously unused/vacant lands

☐ Increase in cottage/home-based industries

☐ Enhanced agricultural productivity

☐ Reduced infrastructure maintenance costs (e.g., drainage, roads)

☐ Increased property value

☐ Employment opportunities (e.g., park maintenance, guides)

☐ Support for eco-friendly enterprises

☐ Others: ___________

Are existing NbS in Bharatpur sufficient? ☐ Yes ☐ No

If no, what types of NBs would you like more of? (Tick all that apply)

☐ Urban parks and green spaces

☐ Rain gardens

☐ Green roofs

☐ Permeable pavements

☐ Tree planting initiatives

☐ Street Trees

☐ Vertical gardens

☐ Wetland restoration (e.g. stormwater management ponds)

☐ Riverbank greening

☐ Spiritual area

☐ Play stations and Natural playgrounds

☐ Mini Zoo or Animal parks

☐ Hiking trails

☐ Cycling path

☐ Ecofriendly building designs

☐ Others

What are the challenges or problems do you associate with Nbs?

☐ Solid waste/littering

☐ Noise pollution

☐ Becoming a dating or hangout spot

☐ Increase in social crime or unsafe areas

☐ Overcrowding

☐ Vandalism or damage to green infrastructure

☐ Misuse of public spaces

☐ Poor maintenance or neglect

☐ Conflicts over land use or access

☐ Others: __________

D. Community Involvement and Practices

Are you involved in any community-based environmental activities (e.g., tree planting, clean-up drives)?

☐ Yes ☐ No — If yes, please specify: ________________

Is community participation important in climate or NbS planning?

☐ Not important ☐ Somewhat important ☐ Very important

Would you be willing to participate in a community NbS project?

☐ Yes ☐ No ☐ Maybe

What kind of support would help you engage in NbS activities?

☐ Training ☐ Funding ☐ Awareness programs ☐ Technical guidance

How should NbS be managed/maintained?

☐ Community management ☐ Ward management ☐ Fund-generated management

☐ Entry-fee based management ☐ Others __________________

E. Suggestions and feedback

What types of NbS do you think are most suitable for your neighborhood?

(Open-ended) ____

Any additional comments or ideas to improve urban climate resilience in Bharatpur?

Annex II: KII Questionnaire

A. Background and Role of the Informant

Can you briefly describe your role and responsibilities related to urban planning, environment, or community development in Bharatpur?

How familiar are you with the concept of Nature-based Solutions (NbS)?

B. Effectiveness and Implementation of Existing NbS

What types of NbS have been implemented in Bharatpur? (e.g., parks, rain gardens, riverbank greening)

In your view, how effective have these NbS interventions been in addressing urban climate risks such as flooding, heat, or water runoff?

What are some measurable ecological, social, or economic benefits you've observed from these interventions?

Are there any monitoring or evaluation systems in place to track the performance of NbS projects?

C. Community Engagement and Participation

How have communities been involved in planning, implementing, or maintaining NbS?

What factors encourage or hinder community participation in NbS initiatives?

Are there any successful examples of community-led or co-managed green infrastructure projects in Bharatpur?

D. Institutional Support and Policy Environment

What role do local government bodies, NGOs, or the private sector play in NbS implementation?

Are there existing policies in Bharatpur that promote NbS or urban greenery?

☐ Yes ☐ No ☐ Not sure

If yes, could you please mention or describe them?

____

What are the biggest challenges to implementing NbS in the city? (Choose all that apply)

- ☐ Land availability
- ☐ Funding
- ☐ Technical capacity
- ☐ Community participation
- ☐ Policy gaps
- ☐ Others: ____________________

How can local government better support community-based NbS?

(Open-ended)

What are the main institutional, financial, or technical challenges in scaling up NbS in Bharatpur?

E. Sustainability and Scalability

How sustainable are the current NbS practices? Are there long-term maintenance plans in place?

In your opinion, which NbS models or practices have the most potential for scaling in other urban areas in Nepal?
What resources or support (technical, policy, financial) would be needed to expand NbS in Bharatpur?

F. Reflections and Suggestions
Are there any lessons learned or best practices from Bharatpur's experience that could inform future NbS projects?
What recommendations would you offer to strengthen the effectiveness and scalability of NbS in urban settings like Bharatpur?

Annex III: Questionnaires for FGD

Do you think there have been any noticeable changes in local weather patterns in recent years?
How has climate change affected your community's livelihood such as farming, livestock, and water sources?
Has your community adopted any nature-based solutions like afforestation or biodiversity conservation to cope with climate change?
Which areas of Bharatpur are most vulnerable to climate impacts?
Can you name any nature-based practices in your area (e.g., community forests, wetlands, parks, agroforestry)?
Who do you think is responsible for implementing such solutions (government, community, NGOs)?
Have you or your community ever been involved in the planning or implementation of any environmental or nature-based projects?
In your opinion, how effective are the existing NbS (e.g., urban greenery, wetland restoration) in addressing climate risks?
Has there been any support from the government or organizations in tackling climate change impacts? If yes, what kind of support was it?)
Are there examples where NbS have clearly improved conditions (e.g., reduced flooding, improved air quality?
What role does youth, women, or marginalized groups play or should play in scaling NbS?
How responsive do you think local authorities are to community needs and feedback on environmental issues?
What policies or programs do you think need improvement or introduction to better support NbS in Bharatpur?

Annex IV: Photographs

Focus group discussion

Dr. Susma Giri presenting during school interaction program in one of the schools of the Bharatpur Municipality

Stakeholder meeting in Bharatpur Metropolitan city

Presenting in the stakeholder meeting at CMT hotel