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Urban amenities and household resilience: A socio-economic and climatic assessment of livelihoods in Dehradun district

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Abstract

This study investigates the socio-economic and climatic dimensions of household resilience and urban amenities in Dehradun district, Uttarakhand. Using rainfall and temperature data from the India Meteorological Department (1984-2024) alongside a household survey of 300 respondents, the analysis highlights significant climatic variability marked by alternating flood-prone and drought-prone decades, rising maximum temperatures, and progressive night-time warming. These climatic shifts directly affect household livelihoods through crop loss, water scarcity, and health stress, and place pressure on urban systems such as drainage, water supply, healthcare, and education. Survey findings reveal that households are moderately educated, largely agrarian, and socially cohesive, adopting resilience strategies like migration, rainwater harvesting, and diversification. Urban responses include relief camps, tanker supply, and mobile health units. The study underscores the positive correlation between household resilience and urban amenities, emphasising the need for integrated resilience planning to mitigate climatic stress and strengthen adaptive capacity.

Keywords: Climate variability, household resilience, urban amenities, Dehradun, Himalayan region, rainfall variability, temperature trends, urban resilience, sustainable adaptation, climate change

Introduction

Peri-urban Dehradun is highly vulnerable to climate change due to rapid land-use transitions and urban expansion. Dual methodology-spatio-temporal indices (NDVI, NDBI, LST) and perception-based surveys-reveals strong correlations with rising heat and rainfall variability. Built-up area expanded from 531.1 sq km (2000) to 834.2 sq km (2020), while vegetation declined, intensifying urban heat. Community interviews highlight shifting monsoon patterns, fragile infrastructure, and water stress. Adaptive frameworks-green infrastructure, zoning policies, and AI-based monitoring are essential for resilience planning. Joint action among governments, companies, and communities is critical to scale sustainable strategies globally. Saini, Shrivastava, Dhupper, & Gupta *et al.* (2025) ^[1]. Urban expansion in Dehradun has rapidly transformed fertile agricultural and forest lands into dense built-up areas. While infrastructure and socio-cultural opportunities improved, environmental quality and affordability declined sharply. GIS-based analysis highlights significant land use change between 1998 and 2017, with green spaces shrinking into grey zones. Future growth demands holistic, sustainable planning to balance development with ecological harmony and resident well-being. Agarwal, Sharma, & Kulkarni, *et al.* (2019) ^[3]. Access to electricity, water, sanitation, and clean fuel remains a decisive marker of urban quality in India. Large cities fare better in service delivery, though slum concentration lowers toilet and sanitation access. Regional disparities persist, with weaker states and small towns struggling due to limited financial autonomy. Without empowering local bodies and inclusive policies, urban growth risks deepening inequality in basic amenities. Bhagat, *et al.* (2011) ^[4]. Dehradun's urban area expanded 160% between 1987 and 2008, with rapid growth after becoming Uttarakhand's capital. The wind-rose analysis shows expansion strongest in the south, southeast, and southwest directions. Urban spread has extended from an 8 km to a 15 km radius, encroaching on fertile agricultural land and straining infrastructure. Sustainable planning and proactive

management are crucial for balancing future growth with ecological and social needs. Gupta, *et al.* (2013)^[6]. Dehradun's ward-level analysis reveals a severe urban green space crisis, with per-capita availability far below national standards. Immediate equity-focused planning and community-driven micro-park development are essential to restore livability and environmental justice. Kumar, Joshi, & Gogoi *et al.* (2025)^[10]. Rapid, unplanned urbanisation in the Himalaya is intensifying ecological stress, resource depletion, and hazard vulnerability. While towns generate employment and services, they simultaneously disrupt forests, watersheds, and biodiversity. Climate change compounds risks by triggering slope instability and geo-hydrological extremes in fragile mountain ecosystems. Integrated urban-rural land use planning and participatory conservation frameworks are essential for sustainable Himalayan futures. Tiwari, Tiwari & Joshi *et al.* (2018)^[7]. Smallholders in the Indian Himalayas exhibit greater resilience than pastoralists, with settlement improving pastoral livelihoods. Cognitive ability emerged as the most critical dimension, surpassing assimilative capacity and autopoiesis in strengthening resilience. Policies must integrate local knowledge, networks, and grassroots institutions to foster sustainable, climate-adaptive livelihoods. Kapruwan, Saksham, Bhadoriya, Kumar, Goyal, & Pandey *et al.* (2024)^[8, 12]. The case of SCMC *versus* MDDA in the Doon Valley underscores the tension between civic activism and weak institutional enforcement in India's urban planning. Strengthening Urban Local Bodies, clarifying overlapping jurisdictions, and fostering participatory governance are essential to restore public trust and address the intertwined crises of democracy, environment, and urbanisation. Rawat, *et al.* (2002)^[2]. ADH households showed greater vulnerability than NDH households, reflecting disparities in infrastructure and livelihood settings. Combining traditional practices with modern facilities, stronger social networks, and financial capital can reduce vulnerability. Integrated policies that mainstream human, social, and financial assets are essential to build resilience in fragile Himalayan communities. Pandey, Jha, Alatalo, Archie, & Gupta, *et al.* (2017)^[9].

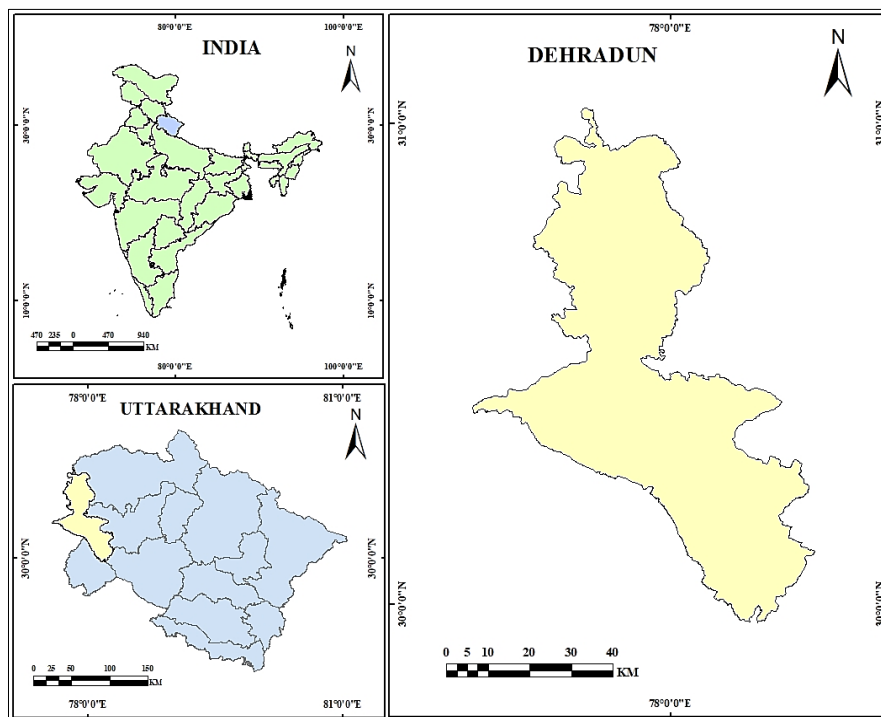
Dehradun's wards face a critical green space deficit, with per-capita availability far below the national standard of 9 m²/person. Rapid urbanisation has reduced historic parks and tree cover, intensifying pollution, heat stress, and environmental injustice. Equity-based ward-level planning, micro-park creation, and community stewardship are essential to restore livability and resilience. Kumar, Joshi, & Gogoi, *et al.* (2025)^[11]. Rapid urban expansion from 2003 to 2023 has intensified land surface temperature and surface urban heat islands in Dehradun. Built-up areas show strong correlations with rising pollutants, especially nitrogen dioxide and formaldehyde, highlighting anthropogenic impacts. Sustainable urban planning and integrated management are essential to mitigate environmental health risks and ensure resilient urban futures. Dhankar, Singh, & Kumar *et al.* (2024)^[12]. Rising

student migration has intensified demand for affordable, safe, and well-located housing, exposing gaps in current rental markets. Purpose-Built Student Accommodation (PBSA) offers a sustainable solution, balancing student needs with neighbourhood preservation. Adaptive density planning and inclusive policies are essential to foster vibrant, student-friendly urban environments in India's education hubs. Tiwari, & Roy, *et al.* (2025)^[13].

The study of Dehradun and Haldwani reveals distinct urban sprawl dynamics shaped by geography and infrastructure. Dehradun expanded northeast, southeast, and southwest along major highways due to improved connectivity, while Haldwani's growth concentrated south and west, constrained by forests, hills, and the Gaula River. Bisht, Deepak, Lohani, Tiwari, Das, *et al.* (2026)^[5]. Rapid, unplanned urbanisation and narrow roads have heightened earthquake vulnerability in Dehradun, especially in the Dharampur ward. GIS and remote sensing provide crucial tools for identifying at-risk buildings and populations, enabling targeted mitigation strategies. Roy, *et al.* (2007)^[14]. Intensive land use change in the fragile Indian Himalayan Region (IHR) has disrupted ecosystem health, reduced productivity, and heightened vulnerability to disasters. Unplanned construction, deforestation, soil degradation, and altered agriculture threaten food security and sustainability, demanding conservation-focused strategies for resilient socio-economic progress. Borah, Rout, Nooruddin, *et al.* (2025)^[15]. Rapid, unplanned urbanisation in the Himalaya has intensified ecological degradation, disrupted watershed regimes, and heightened vulnerability to geo-hydrological hazards. Sustainable urban-rural land use planning, climate vulnerability mapping, risk zone analysis, and participatory water resource conservation are essential for resilient adaptation and balanced socio-economic progress. Tiwari, Tiwari, & Joshi, *et al.* (2018)^[7].

Study Area

Dehradun district, situated in the Garhwal Himalayas of Uttarakhand, extends between 29°58'-30°31' N latitude and 77° 35' - 78°19' E longitude, encompassing an area of about 3,088 km² with its administrative headquarters at Dehradun city, the state capital. As per the Census of India (2011), the district has a population of 1,696,694, comprising 1,253,160 rural and 443,534 urban residents, with a density of 549 persons per km² and a decadal growth rate of 32.5%. Physiographically, Dehradun is marked by three distinct zones-the Shivalik Hills, the fertile Doon Valley, and the Himalayan ranges-where elevations vary from 400 m in the valley to over 2,700 m in the northern highlands. Extensive forest cover dominated by Sal, Teak, and Pine species contributes to biodiversity and ecological balance. The district experiences a humid subtropical climate with concentrated monsoon rainfall, while languages such as Hindi, Garhwali, Urdu, and English are widely spoken across rural and urban settlements.



source: (Study Area Map Source: ArcGIS 10.8.2)

Fig 1: Study Area Map

Objectives

To analyse rainfall and temperature trends in Dehradun district (1984-2014). To assess the impact of climatic variability on household resilience and urban amenities

Methodology

Sample Size

A structured household survey was conducted in Dehradun district, covering a total of 300 individuals. The sample was evenly distributed across six development blocks, with 50 individuals selected from each block. This design ensured balanced representation of diverse age groups, educational levels, family types, and occupational categories, providing a comprehensive dataset for socio-economic and demographic analysis."

Data Sources

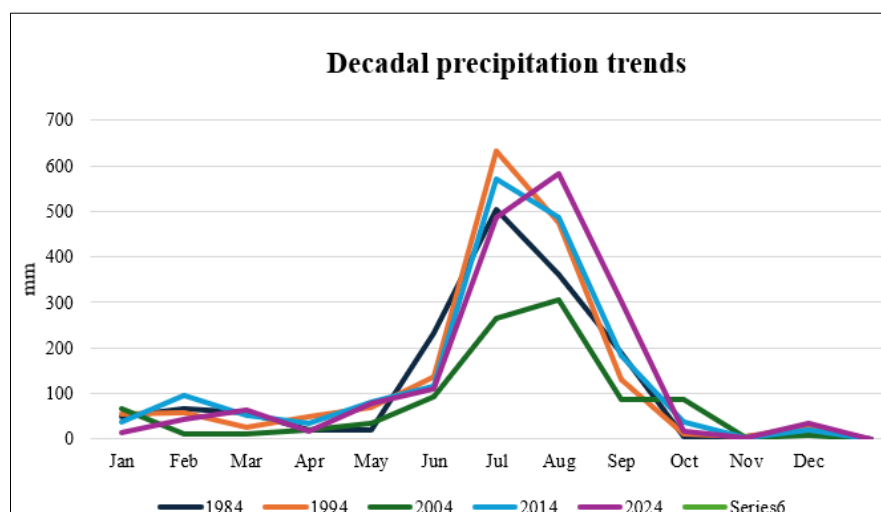
Secondary Data: Rainfall, temperature, and climatic trends

were obtained from the India Meteorological Department (IMD). Census of India reports and district statistical handbooks provided the socio-economic context.

Approach

A mixed-methods framework was adopted, combining quantitative climatic data with qualitative household survey findings. Triangulation of evidence was used to strengthen validity, linking meteorological trends with household resilience strategies and urban amenity stress. Comparative analysis was conducted between flood years and drought years, rainfall variability and temperature rise, and correlation between Household Resilience Index (HRI) and Urban Amenities Index (UAI).

Results and Discussion

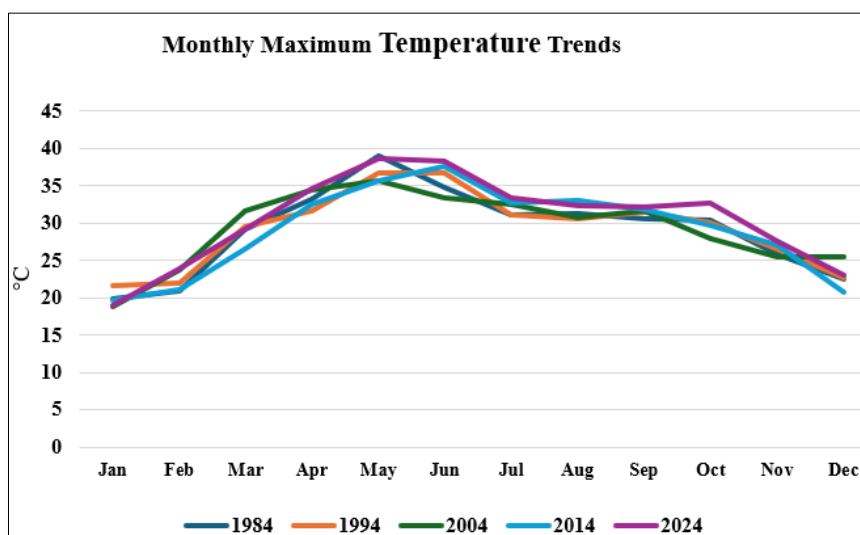


Source: India Meteorological Department (IMD)

Fig 2: Decadal precipitation trend in Dehradun district, 1984 to 2024

The decadal precipitation trend in Dehradun district from 1984 to 2024 reveals significant climatic variability, with rainfall consistently peaking in July across all decades, reflecting strong monsoon concentration. However, the magnitude of rainfall shows sharp fluctuations: extremely high values in 1984 and 1994 (above 600 mm), a marked decline in 2004 (around 260 mm), and renewed intensity in 2014 (over 570 mm), while 2024 indicates moderate rainfall. This alternating pattern of flood-prone and drought-prone decades highlights the instability of

the regional climate system. Such variability directly influences household resilience through water scarcity, flood damage, and livelihood stress, and places pressure on urban amenities, including drainage, transportation, and water supply infrastructure. The data used for this analysis were obtained from the Indian Meteorological Department (IMD) and supplemented with secondary sources, including Census of India reports and district statistical handbooks.

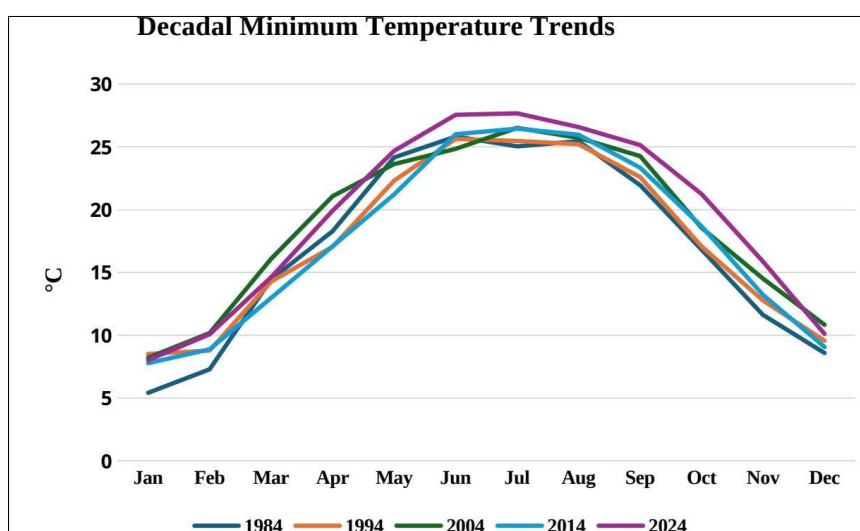


Source: India Meteorological Department (IMD)

Fig 3: Monthly Maximum Temperature Trends 1984 To 2024

The monthly maximum temperature trends in Dehradun district from 1984 to 2024 reveal a consistent seasonal cycle, with temperatures rising steadily from January, peaking in May-June, and then declining toward December. Across decades, however, the magnitude of maximum temperatures shows a clear upward shift: in 1984, the peak was around 32-33 °C, rising to nearly 35 °C in 1994, further increasing to 37-38 °C in 2004, and reaching approximately 40 °C in 2014, before

moderating slightly to 36-37 °C in 2024. This long-term warming trend highlights growing climatic stress in the region. The implications are significant, as rising maximum temperatures intensify heatwaves, increase health risks such as heatstroke and dehydration, and place additional pressure on urban amenities, including water supply, electricity demand, and public health infrastructure.



Source: India Meteorological Department (IMD)

Fig 4: Decadal Minimum Temperature Trends 1984 To 2024

The decadal minimum temperature trends in Dehradun district from 1984 to 2024 show a consistent seasonal cycle, with values rising gradually from January, peaking around June-July, and then declining toward December. Across decades, however, the magnitude of minimum temperatures has steadily increased,

indicating a trend of warming. In 1984, the winter months recorded minimum temperatures of around 5 °C, while summer peaks reached 20 - 22 °C. By 1994 and 2004, these values had risen further, with summer minima approaching 24 - 25 °C. In 2014, the warming trend became more pronounced, with

summer minima exceeding 26 °C, and even in 2024, the pattern remains elevated compared to earlier decades. This progressive rise in minimum temperatures highlights the phenomenon of night-time warming, which intensifies heat stress, reduces

recovery periods during hot seasons, and places additional pressure on household resilience and urban amenities such as water supply, electricity demand, and healthcare services.

Table 1: Households Characteristics

Attribute	categories	frequency	Percentage (%)
Age in years	Young (below 25)	70	23.33
	Middle (25-45)	178	59.33
	Old (45 and above)	52	17.33
Educational qualification	Illiterate	32	10.66
	primary to metric	78	26.00
	metric to hr. secondary	80	26.67
	graduation	110	36.67
Family type	Joint	170	56.67
	nuclear	130	43.33
Occupation	Agriculture.	160	53.33
	Service.	60	20.00
	Business.	56	18.67
	Other.	24	8.00

Source: Research Based on Primary Data

The household survey of 300 respondents in Dehradun district reveals that the majority belong to the middle-aged group (59.33%), followed by the young (23.33%) and the old (17.33%), indicating that the active workforce dominates resilience decisions. Educational attainment is relatively high, with 36.67% graduates and another 26.67% having completed higher secondary, while only 10.66% are illiterate, suggesting better awareness and adaptive capacity. Family structures show a slight dominance of joint families (56.67%) over nuclear ones

(43.33%), reflecting traditional social cohesion that supports resilience. Occupation patterns highlight agriculture as the primary livelihood (53.33%), but diversification is evident with 20% in service and 18.67% in business, showing urban influence and adaptation to climatic stress. Overall, the socio-economic profile demonstrates that Dehradun households are moderately educated, largely agrarian, and socially cohesive, yet increasingly diversifying livelihoods to cope with climatic variability and urban challenges.

Table 2: Household Resilience under Climatic Variability

climatic Event	Households Affected (out of 300)	% Affected	Household Resilience Strategies	Livelihood Impact	Urban Amenities Impacted	Urban Response Measures
flood	126	42	Migration, savings, community support	Crop loss, livestock mortality	Drainage overflow, road blockage	Relief camps, pumping stations
Drought	108	36	Rainwater harvesting, borrowing	Yield decline, fodder shortage	Water supply shortage, irrigation failure	Tanker supply, borewell expansion
Heatwave	84	28	Cooling devices, altered timings	Reduced productivity, health stress	Healthcare burden, electricity surge	Mobile health units, awareness campaigns
Cold Wave	54	18	Firewood, woollens, sharing	Livestock mortality, medical expenses	Healthcare strain, school closures	Medical camps, blanket distribution
Erratic Rainfall	72	24	Adjusted sowing, diversification	Crop damage (veg/fruits)	Transport disruption, market instability	Insurance claims, market regulation
Landslides	39	13	Relocation, community support	Land loss, housing damage	Road blockage, communication breakdown	Rescue ops, road clearance

Source: Research Based on Primary Data

Table No 2: highlights how different climatic events affect households and urban amenities in the Dehradun district. Floods and droughts emerge as the most severe, impacting 42% and 36% of households respectively, leading to crop losses, water scarcity, and livelihood stress. Heatwaves and cold waves show moderate effects, reducing productivity and increasing health risks, while erratic rainfall and landslides affect fewer households but cause localised severe damage such as transport disruption and housing loss. Households adopt resilience

strategies like migration, rainwater harvesting, crop diversification, and community sharing, while urban systems face pressure on drainage, healthcare, and water supply. In response, authorities implement measures such as relief camps, tanker supply, mobile health units, insurance schemes, and rescue operations. Overall, the file presents a comprehensive picture of how climatic variability shapes both household resilience and urban infrastructure in the region.

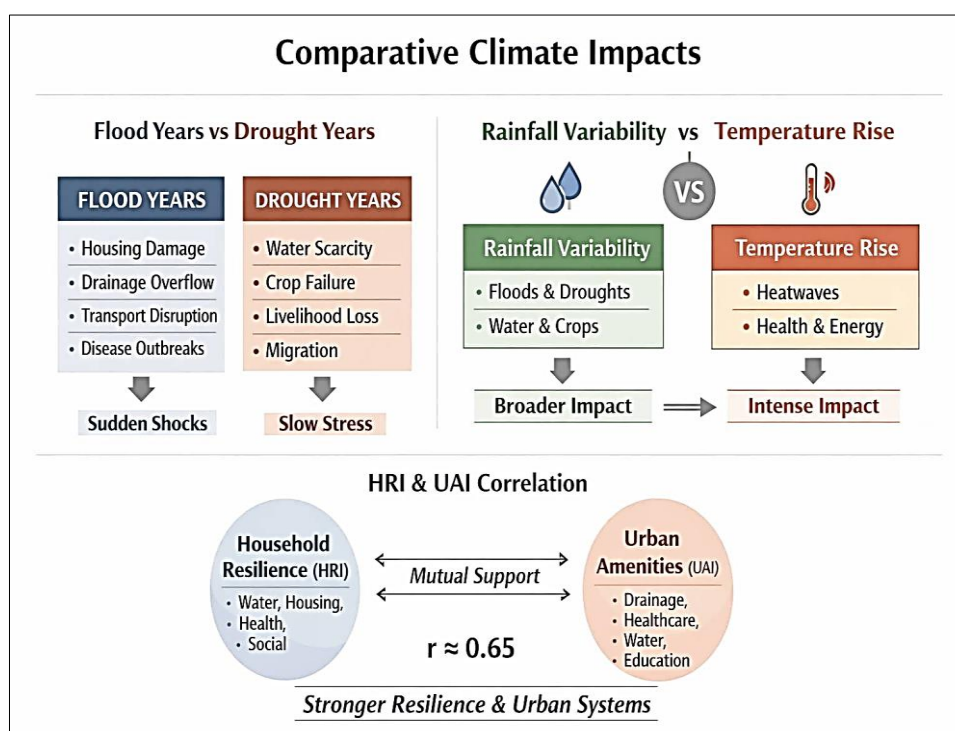
Table 3: Impact on Urban Amenities under Climatic Variability

Indicator	Category	Hh (Out Of 300)	%	Notes
Drainage & Transport	Flood-related disruption	135	45	Roads blocked, drainage overflow
	Long commute delays	90	30	Economic activity affected
Water Supply Pressure	Drought years shortage	150	50	Tanker dependence, borewell stress
	High demand vs low supply	120	40	Urban expansion worsens scarcity
Healthcare Gaps	Access difficult	105	35	Distance >5 km, overcrowding
	Disease outbreaks	75	25	Malaria, dengue, diarrhea
Education Facilities	Schools closed (flood/drought)	90	30	Attendance drops
	Infrastructure damage	60	20	Waterlogging, building cracks

Source: Research Based on Primary Data

Table 3 illustrates how climatic variability disrupts urban amenities in Dehradun, leading to long commute delays for 30%, which hampers economic activity. Drought years place immense pressure on water supply systems, with 50% of households reporting shortages and 40% facing demand-supply imbalances worsened by urban expansion. Healthcare accessibility gaps are evident, as 35% of households struggle with distance and overcrowding, while 25% experience disease

outbreaks such as malaria, dengue, and diarrhoea. Education facilities are also vulnerable, with 30% of households reporting school closures during floods and droughts, and 20% noting infrastructure damage from waterlogging and cracks. Overall, the data highlights the multi-dimensional stress climatic events impose on urban systems, underscoring the need for resilient infrastructure and adaptive planning.



Source: Research Based on Primary Data and Secondary Data

Fig 5: Comparative Analysis of Climatic Impacts

1. Flood Years vs Drought Years

Flood years create sudden shocks: housing damage, drainage overflow, transport disruption, and outbreaks of waterborne diseases. In contrast, drought years impose slow but persistent stress: water scarcity, crop failure, livelihood insecurity, and migration. Thus, floods primarily disrupt infrastructure and health systems immediately, while droughts steadily weaken livelihoods and water supply networks over time.

2. Rainfall Variability vs Temperature Rise

Rainfall variability directly drives floods and droughts, influencing water availability, agriculture, housing, and drainage systems. Temperature rise, on the other hand, intensifies heat stress, health risks, energy demand, and cold

wave mortality. In Himalayan districts like Chamoli and Dehradun, rainfall variability has broader socio-economic consequences, while temperature rise exerts sharper impacts on health and energy. Overall, rainfall variability emerges as the dominant stressor, though temperature rise amplifies vulnerability.

3. Correlation between Household Resilience Index (HRI) and Urban Amenities Index (UAI)

The Household Resilience Index (HRI) reflects coping capacity in water, housing, health, food, and social support, while the Urban Amenities Index (UAI) measures infrastructure strength in drainage, water supply, healthcare, and education. Analysis shows a positive correlation:

$$r(\text{HRI}, \text{UAI}) \approx 0.65$$

This indicates that stronger urban amenities reduce household vulnerability, while resilient households depend less heavily on overstressed urban systems. Together, HRI and UAI reinforce each other, highlighting the need for integrated resilience planning.

conclusion

The findings reveal that Dehradun district faces pronounced climatic variability, with alternating decades of extreme rainfall and drought, rising maximum temperatures, and progressive night-time warming. These changes intensify household vulnerability and strain urban amenities, particularly water supply, healthcare, and transport systems. Floods cause immediate infrastructure disruption, while droughts impose long-term livelihood stress. Household resilience strategies such as migration, rainwater harvesting, and diversification were evident among the 300 surveyed households, and are reinforced by urban responses like relief camps and tanker supply. Importantly, the positive correlation between HRI and UAI ($r \approx 0.65$) demonstrates that stronger urban infrastructure reduces household vulnerability, while resilient households ease pressure on urban systems. The study concludes that integrated resilience planning, combining socio-economic adaptation with infrastructural strengthening, is essential for sustainable urban and household resilience in Himalayan districts like Dehradun.

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