Disaster Resilience Management through Climate Risk Informed Programming with Systemic Change

A Flagship CSR initiative of IndusInd Bank

In Partnership with

UNICEF, Mission Samriddhi, Gorakhpur Environmental Action Group and
Indian Institute of Technology (Gandhinagar)

Climate Risks and Sectoral Vulnerabilities

Bahraich, Uttar Pradesh

Developed by

Climate Risks and Sectoral Vulnerabilities – District Bahraich, Uttar Pradesh

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Introduction

World Meteorological Organization's (WMO) 'State of the Global Climate' report, released in 2023, highlights severe concerns for the human race. It explicitly states that climate-induced risks, both global and local, are emerging as the greatest threat to humanity. The year 2023 has been recorded as the hottest in Earth's documented history, with the global average temperature rising by 1.45°C above pre-industrial levels, within a margin of uncertainty of ±0.12°C. Extremely worrying, this rise is very close to the threshold limit of 1.5 °C agreed upon by different nations during the Paris Agreement in 2015.

The year 2023 has been recorded as the hottest in Earth's documented history

The WMO has expressed serious concern over this rise in the global average temperatures, warning that this will significantly affect the occurrence of extreme weather events, such as heatwaves, torrential rains, and tropical cyclones. Such events will undoubtedly have a direct impact on many development sectors including agriculture, health, education, and WASH all around the world. The effect of such extreme weather events have been well documented in numerous reports and research articles, manifesting in human casualties, injuries, homelessness, or distress displacement. Direct economic losses due to climate risks have surged by almost 151% in the last 20 years (UNISDR 2018).

As in other parts of the world, climate induced risks, including extreme rainfall and floods, heat waves are increasing in India too (Guhathakurta et al., 2011). The warming trend over the Indian Ocean has enhanced moisture supply, leading to extreme rainfall due to cyclones in coastal areas in recent decades (Ray et al., 2019). In the country, floods due to extreme rainfall alone cause losses of about $3 billion per year, which is 10% of the global economic loss (Roxy et al., 2017). There has also been a significant increase in the probability of hydro-climatic hazards all over India (Vittal et al., 2020). Therefore, a comprehensive understanding of climate risks and their impact becomes a prerequisite to trigger collective public action at the local level.

This study report is part of the UNICEF-supported programme entitled **"Climate Risk Informed Programming Project - Nature Solves-Nature Resolves," funded by IndusInd .** The aim is to reach community groups like Mahila Sabhas and farmers through Risk-Informed Gram Panchayat Development Plans (RiGPDP), and mainstream developmental resources in DRR-CCA in selected Gram Panchayats as a pilot project. In the process, the climate risk profile of three selected districts, namely Virudhunagar, Tamil Nadu, Bahraich, Uttar Pradesh; Begusarai, Bihar; Baran, Rajasthan and Dharashiv, Maharashtra, were developed to guide and shape the mindset of key stakeholders to assess the capacity of related line departments and local technical institutions. The goal is to ensure that government development schemes and programs, at both national and state levels, are effectively aligned to contribute to resilient development.

floods due to extreme rainfall alone cause losses of about $3 billion per year

Methodological framework, Approach and Process

The methodologies followed in this study are as suggested by the IPCC (2014). The IPCC defines two streams of vulnerability assessment—the contextual vulnerability assessment and the outcome vulnerability assessment. The first provides a qualitative overview of vulnerability with the help of survey instruments and case studies, while the index-based outcome vulnerability assessment is done by calculating a score, after quantifying a specific set or combination of indicators.

A score-based approach can be used at any scale such as national, sub-national, district, and sub district level (Gbetibouo and Ringler 2009). And, this study used a score-based approach to analyse the climate hazards risk and sectoral vulnerabilities in selected districts to understand the links between sensitivity of the district and its ability to cope and adapt. Risk causing climate hazards were determined based on Indian Meteorological Department (IMD) norms. The sectoral indicators which directly or indirectly increase vulnerability or resilience to climate risks, were used as sensitivity and adaptive capacity indicators. Data from each district for all identified indicators were collected from authentic sources and categorized into five components: **Climate Hazards Index (CHI)**, **Agriculture and allied sector vulnerability Index (AVI), Health Sector vulnerability Index (HVI), Education sector vulnerability Index (EVI) and Water and sanitation sector vulnerability Index (WSVI).** The facts related to the indicators were analysed, and weightage was assigned to each as per their influence/ contribution to vulnerability using the Principal Component Analysis (PCA) statistical tool to determine indicator specific scores.

To frame out an adaptive strategy and advocacy at local level for climate risk informed programming, data related to climate risks, climate change policies and impacts across different spatial and temporal scales and sectors is essential. NITI Aayog , the 'Think-tank of India' also recognises comprehensive data gathering at the district level as essential for risk planning, developing coping strategies, and adaptation. The recently developed National Data Analytic Portal by the NITI Aayog is a comprehensive platform that provides a single window for this wide range of data at national, state and district levels.

Identification of indicators

Vulnerability to climate induced risks is multidimensional and determined by a complex interplay of multiple factors (Piya et al. 2012). There are two approaches in the selection of indicators: data driven and theory driven (Vincent 2004); and each approach has its own limitations. Therefore, the best approach is to verify the accuracy of the theory-based indicators with data from authentic sources (Maiti et al. 2015). Theoretically, vulnerability encompasses a variety of perceptions and elements, including sensitivity and the lack of capacity to cope and adapt. IPCC defines vulnerability as "the propensity or pre disposition to be adversely affected" and is determined by the sensitivity and adaptive capacity of the system (IPCC 2014). Sensitivity reflects the extent to which a system is sensitive or responsive to external stress or hazard, such as a drought or flood. Adaptive capacity is the ability of a system (technology, infrastructure, ease of access to resources, wealth, etc.) to cope with the consequences of climate stress, which includes several factors. (McCarthy et al. 2001). Vulnerability to climate change is a function of biophysical and socio-economic factors (O'Brien et al. 2004). Thus, the dynamics of vulnerability are captured through physical, demographic, social, and environmental components to denote sensitivity and adaptive capacity of the system. Considering this, a combined approach was used to select the indicators.

A total of 34 indicators that included climate hazards and four sectors (Agriculture and allied, Health, Education and Water and sanitation) were used in the study to denote the sensitivity and adaptive capacity of the districts (Table 1). The coefficient of variation in annual rainfall, frequency of heavy rainfall events, coefficient of variation in maximum and minimum temperature were calculated from high resolution IMD daily gridded data of the last 30 years (1993-2023). The sectoral indicators, which captured the sensitivity and adaptive capacity of the districts and states, were identified and their data collected from authentic sources. The indicators, the rationale for using them, and their functional relationship with vulnerability are described below in greater detail.

Table : 1

Code	Indicator	Baseline	Source	Relation with climate Vulnerability impact
CV_A rain(%)	Coefficient of variation of Annual Rainfall in %	1993-2023	IMD daily Gridded data	Exposure (Positive)
Fre_Hrain	Frequency of heavy rainfall events	1993-2023	IMD daily Gridded data	Exposure (Positive)
Con_DRY_Mday	Consecutive dry days during monsoon	1993-2023	IMD daily Gridded data	Exposure (Positive)
CV_MaxT	Coefficient of variation of Daily max Temperature %	1993-2023	IMD daily Gridded data	Exposure (Positive)
CV_MINT	Coefficient of variation of Daily min Temperature %	1993-2023	Disaster Management Department, Bihar	Exposure (Positive)
Area_ Flood (%)	% of area prone to flood	2019	Vulnerability Atlas of India , 2019 BMTPC	Exposure (Positive)
Fre_ E Drought	Frequency of Severe to extreme drought event	1991-2020	District web portals	Exposure (Positive)
Agriculture and allied sector				
Mar_Small_ LandH	% of marginal and small landholders	2011	Census of India , 2011	Sensitivity (Positive)
L_HR	No. of livestock per 000 population	2019	The National Data and Analytics Platform	Adaptation (Negative)
Rainfed_Agri	% Of area under Rain fed Agriculture	2021-22	The National Data and Analytics Platform	Sensitivity (positive)
Area _Cov_PMFVY	Area covered for crop insurance under PMFBY in 000 ha	2023	The National Data and Analytics Platform	Adaptation(Negative)
Empy_MNERGA	Average person days per household employed under MNREGA	2023	The National Data and Analytics Platform	Sensitivity (Positive)
Y_Vari_ FoodGrain (%)	% of Yield Variability of food grains	2021-22	The National Data and Analytics Platform	Adaptation (Negative)
Wo_ Part_Labour	Women participation in the workforce (%)	2023	The National Data and Analytics Platform	Adaptation (Negative)
Health Sector				
Health_ Infra	No. of rural healthcare infrastructure facilities per lakh population	2021-22	The National Data and Analytics Platform	Adaptation (Negative)
Mem_Insurance	HH with any member covered under a health and insurance / financial scheme	2020-21	The National Data and Analytics Platform	Sensitivity (Positive)

Code	Indicator	Baseline	Source	Relation with climate Vulnerability impact
Child _Vac	Children age 12-23 months fully vaccinated based on information from vaccination card (%)	2020-21	The National Data and Analytics Platform	Adaptation (Negative)
Child_ Stunt	Children under 5 years who are stunted	2020-21	The National Data and Analytics Platform	Sensitivity (Positive)
Child _ underweight	Children under 5 years who are underweight	2020-21	The National Data and Analytics Platform	Sensitivity (Positive)
IMR	Infant Mortality rate (IMR)	2022-23	The National Data and Analytics Platform	Adaptation (Negative)
Women_Anemic	All women age 15-49 years who are anaemic	2020-21	The National Data and Analytics Platform	Sensitivity (Positive)
Education Sector				
Women_10_ education	Women with 10 or more years of schooling (%)	2021-22	UDISE Plus	Adaptation (Negative)
ScL_Girl_Toilet	% of schools with functional girls toilet	2021-22	UDISE Plus	Sensitivity (Positive)
Sch_Drinking	Percentage of schools with functional drinking water facilities	2021-22	UDISE Plus	Sensitivity (Positive)
S&TR	Average Student teacher Ratio	2021-22	UDISE Plus	Adaptation (Negative)
Drop_out	Average dropout rate in secondary level	2021-22	UDISE Plus	Adaptation (Negative)
Sch_approach	% of Schools approachable by all-weather roads	2021-22	UDISE Plus	Adaptation (Negative)
Sch_electricity	Percentage of schools with electricity connection	2021-22	UDISE Plus	Adaptation (Negative)
Water and Sanitation Sector				
HHs_Impr_ Drinkingwater	% of households with an with improved drinking water sources	2020-21	The National Data and Analytics Platform	Adaptation (Negative)
Change_GW	Changes in ground water table during last five years (mbGL)	2021-22	The National Data and Analytics Platform	Sensitivity (Positive)
State_GW	State of ground water utilisation(in %)	2021-22	The National Data and Analytics Platform	Sensitivity (Positive)
HHs _improv_Sani	Proportion of HH that have improved sanitation facilities	2020-21	The National Data and Analytics Platform	Adaptation (Negative
Area_water_ Bodies	Area under water bodies (%)	2023	India Wris web Portal	Adaptation (Negative)
No_ODF	No of ODF village	2023	The National Data and Analytics Platform	Adaptation (Negative)

Ghaghara River Bahraich

Normalisation of dataset

The identified indicators were from different sources, measured in dissimilar units. Since the Vulnerability Assessment is a rank, all the indicators used in the assessment had to be of common units, for which they needed to be normalized. The normalization process varies depending on the nature of the relationship of an indicator with vulnerability. The following formulae (UNDP 2006) were used to normalize indicators which tend to increase vulnerability with an increase in the values.

For the indicators that had a positive functional relationship with their respective vulnerability index, the normalization was done through the following equation:

$$\text{Normalisation} = \frac{\text{Actual Value} - \text{Minimum Value}}{\text{Maximum Value} - \text{Minimum Value}}$$

On the other hand, where negative functional relationship occurs, this equation was used for normalization:

$$\text{Normalisation} = \frac{\text{Maximum Value} - \text{Actual Value}}{\text{Maximum Value} - \text{Minimum Value}}$$

Assigning weights to indicators through Principal Component Analysis (PCA)

PCA was used in this study to assign appropriate weights to the indicators (Monterroso et al. 2014). Through this, each indicator was assigned a weight to find out the leading indicator, which further influenced all other indicators. The PCA was carried out using Statistical Package for Social Sciences (SPSS) as detailed in Table 2.

Table 2

S. No	Indicator	Virdhunagar	Begusarai	Bahraich
1	% of marginal and small landholders	5.3	5.1	5.6
2	Livstock population per 1000 population	5.2	0.2	4.9
3	% of The Area Under Rainfed Agriculture	0.8	0.9	0.0
4	%Area Covered into crop insurance Under PMFBY in 000 ha	3.4	1.9	4.6
5	Average person days per household employed under MGNREGA	5.3	0.2	2.6
6	Yield Variability Of Food Grains %	5.4	4.9	5.3
7	Women Participation In The Workforce (%)	0.3	6.1	3.6
8	No of Rural healthcare infrastructure facilities per lakh population	5.0	1.6	0.0
9	% HH with any usual member covered under a health and insurance / financial scheme	4.8	5.2	5.4
10	Children age 12-23 months fully vaccinated based on information from vaccination card (%)	0.4	0.3	4.4
11	Children under 5 years who are stunted	5.3	5.4	4.8
12	Children under 5 years who are underweight	5.3	5.7	3.6
13	IMR	5.3	0.8	4.7
14	% women age 15-49 years who are anaemic	4.6	5.9	5.6
15	% Women with 10 or more years of schooling	5.3	6.1	3.9
16	% of schools with functional girls toilet	4.9	4.3	5.6
17	% of schools with functional drinking water facilities	0.1	5.4	4.4
18	Average Student teacher Ratio	5.0	4.9	5.2
19	Average Drop out rate in secondary level	5.1	6.1	3.2
20	% of Schools Approachable by All-Weather Roads	1.5	2.6	2.9
21	% of schools with electricity connection	4.9	0.0	0.1
22	% of households with an with improved drinking water sources	5.2	5.5	5.4
23	% State of gound water utilisation(in %)	2.4	2.4	0.1
24	%Area Under Wetlands in	2.4	2.8	4.8
25	% of avaialble ground water used for irrigation Purpose	4.1	4.8	0.3
26	%of HH that has an improved sanitation facilities	0.0	5.7	3.8
27	% of ODF plus village to total villages	2.7	5.2	5.4

District Profile – Bahraich, Uttar Pradesh

Bahraich district is situated in the north-eastern part of Uttar Pradesh, India. Geographically, it lies along the rivers Ghaghra, and shares an international border with Nepal to the north. Although known for its rich cultural heritage and historical significance, the area faces challenge typical of rural Indian districts, such as access to healthcare, education, and infrastructure development.

As per the 2011 Census, Bahraich has a population of approximately 3.5 million people. The district is primarily rural, with agriculture as the main occupation. The district is prone to various climatic risks due to its geographical location and is also vulnerable to extreme weather events such as floods, droughts, and wind storms, which have a devastating effect on agriculture, infrastructure, and livelihoods. Hence, adaptation measures, including improved disaster preparedness and resilient infrastructure, are crucial to mitigate the climatic risks faced by Bahraich district.

Climate profile

The district, experiences a subtropical climate with distinct seasons. Summers are hot with temperatures often soaring above 40°C, while winters are relatively cool with temperatures dropping to around 5-10°C. The monsoon season typically spreads between June and September, bringing in the maximum of the district's annual rainfall. The average annual precipitation in Bahraich is around 1,000-1,200 mm. However, rainfall distribution is uneven, leading to occasional droughts or floods. The region also experiences sporadic cyclones, especially during the monsoon season, which cause significant damage.

Trend and seasonal variability in rainfall

Bahraich district receives approximately 1000.6 mm of rainfall annually. **Chart 1** below illustrates rainfall patterns during the pre-monsoon, monsoon, post-monsoon, and annual periods over the past 30 years. The rainfall dataset from 1993 to 2023 reveals fluctuating annual rainfall patterns in the district. Despite notable variations, there is an overall upward trend in rainfall volumes over the decades in all seasons, with occasional spikes and dips. The mid-2000s to late 2010s saw a notable increase in rainfall, wherein some of the highest rainfalls were recorded during this period. However, there is a considerable variability from year to year, with certain years experiencing significantly higher or lower rainfall compared to the average. Nevertheless, extreme events, such as the exceptionally high rainfall in 2008, 2011, and 2018, highlight the district's vulnerability to climate extremes. These fluctuations hold implications for agriculture, water resource management, and flood risk in the region, necessitating ongoing monitoring and adaptation strategies to mitigate the impact of climate change and ensure sustainable development in the district.

Over the past three decades, analysing pre-monsoon, monsoon, and post-monsoon rainfall patterns in Bahraich district provides insight into the region's climatic dynamics. Pre-monsoon rainfall, occurring from March to May, exhibits considerable variability and constitutes about 8.4% of the total annual rainfall. During the last 30 years, the district experienced an increasing trend in pre-monsoon rainfall. During the monsoon season, from June to September, the district receives the bulk of its annual rainfall (85.1%). Here too an upward trend in monsoon rainfall has been noticed. In the post-monsoon season (October to December), rainfall also varies from year to year, albeit with generally lower amounts compared to the monsoon season. These variations in the seasonal rainfall impose significant impact on water availability, soil moisture retention, and crop growth, emphasizing the importance of understanding and adapting to changing rainfall patterns to enhance agriculture development in the district.

Chart 1

Potential risks

Table 3 below reveals distinct seasonal and annual variations in rainfall patterns. The monsoon season from June to September, stands out as the period with the highest rainfall, with mean rainfall reaching 853.64 mm and a relatively low coefficient of variation (CV) ranging from 47.98% to 74.17%, indicating relatively consistent rainfall during this period. In contrast, the pre-monsoon season, particularly April, exhibits considerable variability, with a high CV of 147.66%, indicating fluctuations in rainfall amounts. The post-monsoon season, from October to December, experiences comparatively lower rainfall, with a mean of 58.86 mm and the highest CV of rainfall between 97.11% to 210%, suggesting high variability. As the monsoon season dominates the annual rainfall, variability is more pronounced in the pre-monsoon and post-monsoon periods, highlighting the need for adaptive strategies to manage these seasonal fluctuations and ensuring water resource sustainability in the region.

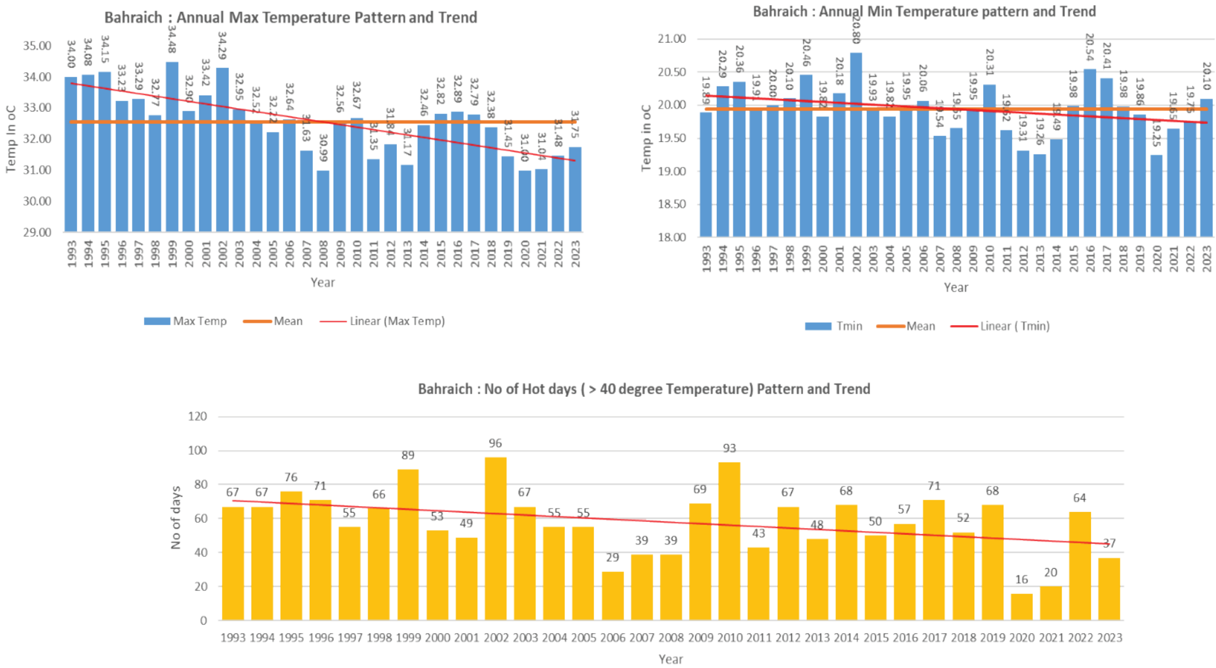
Table 3

	Pre monsoon				Monsoon				Post Monsoon				Annual
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	
Mean	19.64	12.52	9.21	42.48	137.73	310.10	253.55	150.26	39.41	2.06	6.53	17.13	1000.60
Standard Deviation	28.11	22.69	13.59	44.90	102.16	151.51	121.65	74.88	58.11	4.88	13.77	16.63	334.69
CV	143.18	181.28	147.66	105.70	74.17	48.86	47.98	49.84	147.45	237.08	210.79	97.11	33.45

Maximum and Minimum Temperature

The district, characterized by a subtropical climate, exhibits notable temperature variations. Summer months' witness maximum temperatures exceeding 40°C, while winters bring relatively cooler conditions, with minimum temperatures dropping to around 5-10°C. The average annual maximum temperature ranges between 30°C to 35°C, while the average minimum temperature hovers around 10°C to 15°C. Over the past three decades, the district's average temperature has remained stable at approximately 26.25°C. Analysis of maximum temperature data from 1993 to 2023 indicates a slight decreasing trend, particularly from the mid-1990s to the early 2000s, followed by relative stability until the mid-2010s. **(Chart 2)** However, a slight temperature increase is noticeable thereafter. Conversely, the average minimum temperature fluctuates between approximately 19°C to 21°C annually, with no significant trend over the decades. While some years exhibit slightly higher or lower minimum temperatures, overall consistency characterizes the district's minimum temperature patterns, as evidenced by decadal analysis.

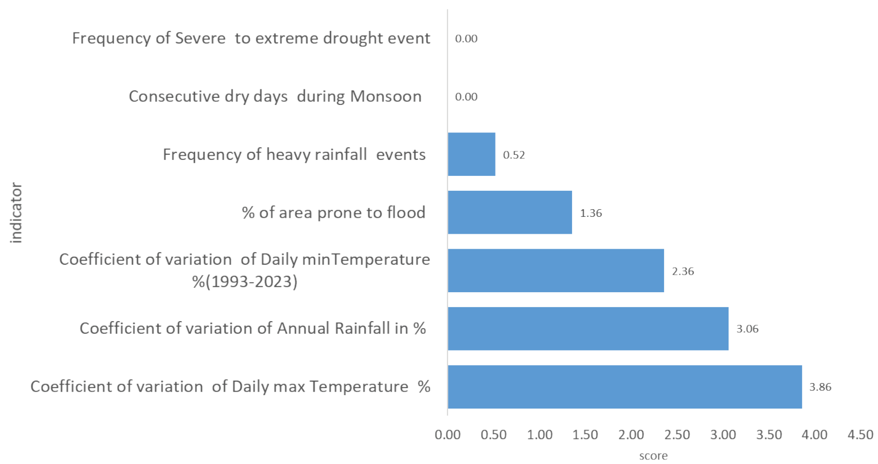
Chart 2



The analysis of hot days above 40 degrees Celsius over the years' highlights fluctuations and a potential trend. In the early years, from 1993 to the early 2000s, the number of hot days varied, with occasional spikes and drops **(Chart 2**). However, from the mid-2000s to the mid-2010s, there seems to be a noticeable increase in the frequency of hot days, reaching a peak in 2010 with 93 such days recorded. Subsequently, there's a slight decrease in the number of hot days, but it remains relatively high compared to earlier years. The years 2016 to 2019 reveal a consistent number of hot days above 40 degrees Celsius. Notably, the data for 2020 and 2021 shows a significant decrease, with only 16 and 20 hot days recorded, respectively. While there's some variability, the overall trend suggests an increase in the frequency of hot days over the years, with intermittent fluctuations.

Climate hazards index and ranking of key drivers

Chart 3



As mentioned in the methodology section, the climate hazard risk index for the districts under study was evaluated using seven indicators, including variations in annual rainfall, maximum and minimum temperatures, frequency of heavy rainfall events, proportion of flood-prone areas, and frequency of drought events. The climatological analysis spanning three decades, coupled with the assessment of physical exposure to flood and drought, revealed notable findings for the district. There was a higher coefficient of variation observed in maximum temperatures (Score 3.86), followed by variations in annual rainfall (Score 3.06) and minimum temperatures (Score 2.36) **(Chart 3).** Consequently, these three indicators emerged as the pivotal factors influencing the district's vulnerability. Their impact extends to shaping rainfall patterns and the nature of flood occurrences in the region. As a result, they scored higher ranks in the risk index, underlining their significant role in determining the district's susceptibility to climate hazards. Hence, understanding these indicators' dynamics is crucial for developing targeted mitigation and adaptation strategies to enhance the district's resilience to climate-related risks.

Sector Vulnerability assessment

Agriculture and allied sector

Agriculture serves as the backbone of the district's economy, with the majority of the population engaged in farming activities. T**able 4** below states the indicators of agriculture and allied sectors used in the study to assess sectoral vulnerability. The data reflects that the district has a higher percentage of marginal and small landholders, indicating a predominance of small-scale farming. Despite this, the number of livestock per 000 human population and crop insurance coverage under PMFBY are relatively similar to the state average. However, Bahraich has a higher proportion of area under rain-fed agriculture, potentially indicating greater reliance on irrigation or vulnerability to water scarcity. Additionally, the district exhibits a higher yield variability of food grains, and a lower women participation in the workforce, suggesting higher sensitivity in agricultural activities.

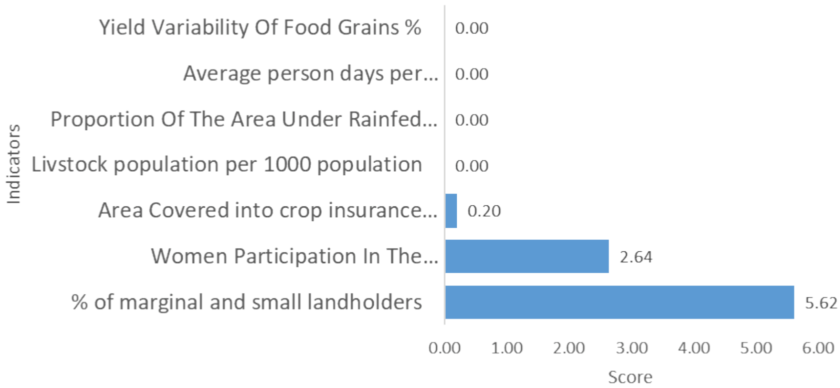
Table 4

Indicators	District	State
% of marginal and small landholders	95%	92%
Livestock to human ratio	835	816
Proportion of Area Under Rain fed Agriculture	47.35%	75%
Area Covered into crop insurance Under PMFBY	22.64%	23.11%
Average person days per household employed under MNREGA	49.7	34
Yield Variability of Food Grains	13%	18.54%
Women Participation in the Workforce	22%	16.75%

The above climate data analysis of rainfall and temperature states that variation in rainfall patterns, temperature fluctuations, and extreme weather events like floods and droughts disrupt farming activities in the district, and impact crop yields and livelihoods. Further, limited access to irrigation and dependence on monsoon rainfall exacerbates these challenges. Farmers struggle to adapt to changing climatic conditions, facing risks of crop failures and subsequent income loss. Hence, efforts to mitigate climate risks through resilient farming practices, improved water management, and infrastructure development are essential to enhance agricultural resilience and ensuring food security in Bahraich district.

Based on the district's scores, the key drivers of vulnerability are the high percentage of marginal and small landholders, and lesser women participation in workforce (Chart 15). These two factors need further assessment and underscore the importance of targeted interventions to enhance resilience and sustainability in the agriculture sector, including diversification of livelihood options, and gender-inclusive agricultural development programs **(Chart 4).**

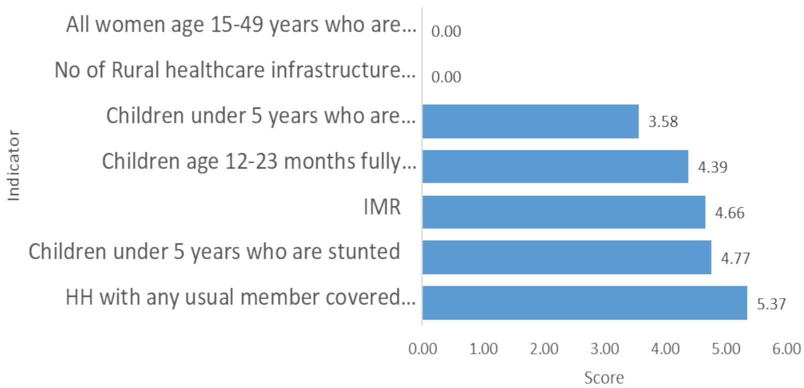
Chart 4



Health Sector

The health sector in the district is in a dire state, facing a range of challenges that require urgent and substantial efforts for improvement. Although healthcare infrastructure facilities have gradually improved, accessibility continues to be a persistent issue, particularly in remote areas. The district faces high infant mortality rates (80 /000 live birth) due to various factors including inadequate prenatal care, limited access to healthcare facilities, and socio-economic disparities. Child nutrition status is a concern, with a significant portion of children stunted (52.1%) and underweight (38%) due to poverty and food insecurity. All the health issues mentioned above are closely linked to climate risks and require further assessment to identify the underlying causes.

Chart 4



The ranking of indicator wise scoring reveals that health insurance coverage is relatively low, leaving many residents vulnerable to financial burdens associated with healthcare expenses **(Chart 5).** Additionally, vaccination coverage at 51.8% is also much below the State average of 78.4%. Hence, among the seven indicators, the following five indicators- health insurance coverage, stunting, IMR, vaccination and underweight children due to malnutrition, contribute significantly towards health sector vulnerability.

Hence, addressing these health challenges requires comprehensive approaches that integrate climate resilience into healthcare systems initiatives. These actions are crucial for improving healthcare infrastructure resilience, enhancing emergency response capacity, and strengthening community-based healthcare services. Moreover, efforts to promote sustainable agriculture, ensure food security, and increase access to clean water are vital for mitigating climate-related health risks in Bahraich district. Collaborative strategies involving government agencies, healthcare providers, and local communities are vital for building resilience and improving health outcomes in the face of climate change.

Education Sector

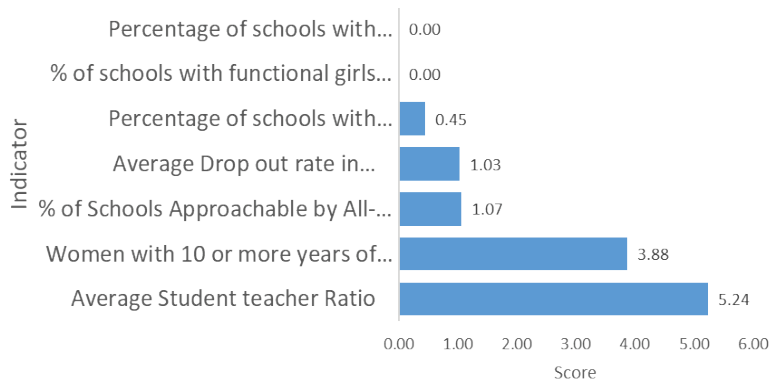
The educational environment for children in Bahraich district exhibits both strengths and vulnerabilities, along with disparities when compared to the state average. T**able 5** below shows that the percentage of women with 10 or more years of schooling is notably lower in the district compared to the state average, indicating limited educational opportunities for girls and women. However, the district performs well in terms of infrastructure, with a high percentage of schools equipped with functional girls' toilets, drinking water facilities, electricity connections, and accessibility via all-weather roads, exceeding state averages in most cases.

Despite this, challenges such as a higher student-teacher ratio and dropout rates at the secondary level compared to the state average persist. These factors indicate strains on educational quality and retention, and may potentially be exacerbated by climate risks. For instance, extreme weather events can disrupt school attendance and upset existing infrastructure, further impacting learning outcomes. Therefore, while infrastructure is relatively satisfactory, addressing the causes of educational disparities and opportunities for improving quality of education, especially in the face of climate risks, remains crucial to ensure equitable access to education and develop resilience in Bahraich district.

Table 5

Indicator	District	State
Women with 10 or more years of schooling (%)	14.4	39.3
% of schools with functional girls' toilet	98.9	96.73
Percentage of schools with functional drinking water facilities	99	99.09
Average Student Teacher Ratio	40.25	29
Average Dropout rate in secondary level	10.64	9.7
% of Schools Approachable by All-Weather Roads	91.0	92.09
Percentage of schools with electricity connection	88.2	81.32

Chart 6



Indicators with higher scores labelled in Chart 6 indicate greater vulnerability. Thus, Average Student Teacher Ratio (5.24), % of Women with 10 or more years of schooling (3.88) % of Schools Approachable by All-Weather Roads (1.07) and Average dropout rate in secondary section of girls and boys emerge as the key drivers of vulnerability in the district. **(Chart 6)**

Limited educational attainment for women indicates a lower ability to withstand climate risks as educated women are generally better prepared to adapt and manage changing environmental conditions. A high student-teacher ratio in the district suggests that the quality of education is being compromised, which hampers students' ability to cope with climate-induced disruptions and increases the likelihood of dropouts. Additionally, the accessibility of schools via all-weather roads impacts students' attendance, particularly during extreme weather events.

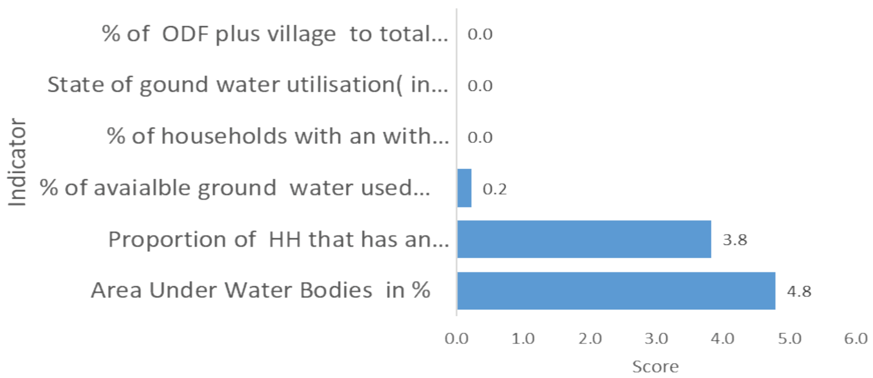
To address these vulnerabilities, inherent causes must be identified and planned actions must focus on enhancing educational opportunities, improving infrastructure resilience, and fostering climate-resilient communities. This may include promoting girls' education through targeted interventions, such as scholarships and awareness campaigns. Investing in teacher training and hiring additional staff can help reduce student-teacher ratios and improve educational quality. Furthermore, infrastructure upgrades, such as road improvements and alternative transportation options, can ensure uninterrupted access to schools, even in adverse weather conditions.

Water and sanitation Sector

The indicator used in the study to assess the strength and vulnerability in water and sanitation sector of Bahraich district presents a mixed picture, and highlights variations as compared to the state average. The 100% accessibility of households to improved drinking water sources and stage of utilization of groundwater resources indicate a robust infrastructure coverage, and a promising indication of potential resource.

Furthermore, the area under water bodies is significantly lower (0.6%) in the district compared to the state average (1.93%), indicating limited natural water resources. This could heighten vulnerability to water scarcity during periods of low rainfall or drought conditions, impacting both drinking water availability and agricultural irrigation. Moreover, access to improved sanitation facilities of a low proportion of households (44.2%), indicates potential challenges in sanitation infrastructure and hygiene practices, which could increase vulnerability to waterborne diseases, particularly during extreme weather events or flooding.

Chart 7



From the scores obtained through PCA, it is evident that " percentages of Area Under Water Bodies (4.8) and percentage of households with improved sanitation facilities (3.8) are the key drivers of the water and sanitation sector in Bahraich district **(Chart 7)**.

These indicators received the highest scores, indicating their crucial contribution to the overall vulnerability assessment. Thus, targeted actions for resilience building should focus on enhancing water conservation and sanitation infrastructure. For water management, initiatives could include promoting rainwater harvesting techniques to augment water bodies and recharge groundwater supplies. Additionally, implementing water-efficient irrigation practices and crop diversification strategies can optimize groundwater utilization for agricultural purposes, reducing dependency on depleting water sources.

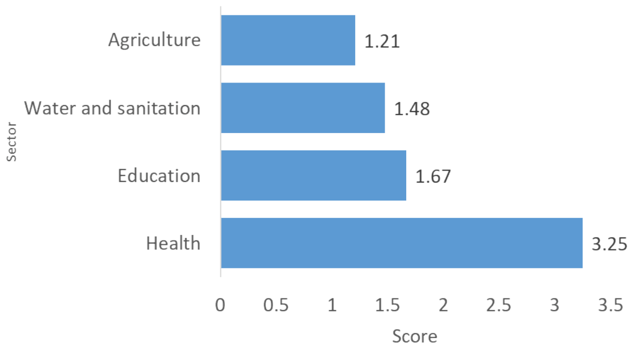
In the sanitation sector, efforts should prioritize improving access to improved sanitation facilities, such as toilets and waste management systems, particularly in rural areas. This could involve community-led sanitation programs, hygiene education campaigns, and the construction of decentralized sanitation facilities to ensure equitable access across the district. Furthermore, incentivizing the adoption of Open Defecation Free (ODF) practices and promoting sustainable sanitation behaviours can enhance public health outcomes and resilience to climate-related health risks. Hence in short, a holistic approach integrating water management and sanitation interventions is essential for building resilience in the water and sanitation sector of Bahraich district. Collaboration between government agencies, local communities, and non-governmental organizations is crucial to implement these actions effectively to achieve sustainable development outcomes.

Composite level of sectoral Vulnerability and ranking of indicators

The above indicator based sectoral vulnerability analysis reveals that the health sector is the most vulnerable in Bahraich district, with a composite score of 3.25, significantly higher than the state average of 1.37. This indicates major challenges and weaknesses in the district's healthcare infrastructure, accessibility, and health outcomes. The high vulnerability in the health sector emphasizes the urgent need for interventions to improve healthcare services, enhance access to medical facilities, and address public health concerns.

The education sector also exhibits vulnerability, although to a lesser extent compared to health. With a composite score of 1.67, the education sector in Bahraich district faces challenges related to infrastructure, quality of education, and access to educational opportunities **(Chart 8).** Hence, efforts to enhance educational facilities, reduce dropout rates, and promote equitable access to education are crucial to address vulnerabilities in this sector **(Chart 8).**

Chart 8



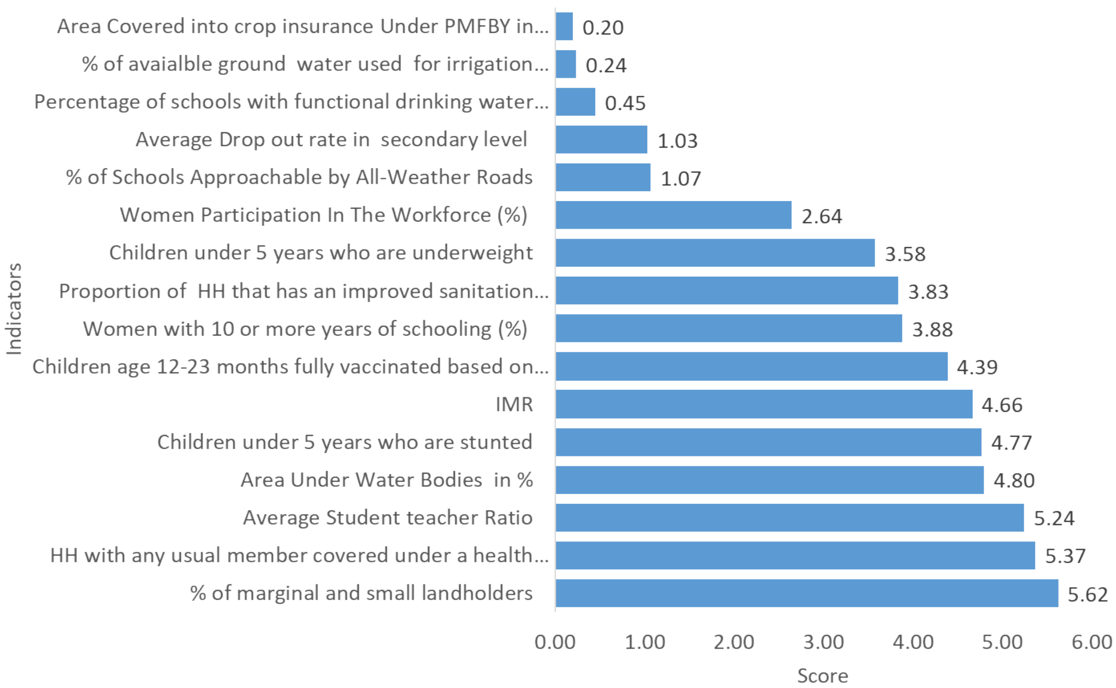
Additionally, the water and sanitation sector, with a composite score of 1.48, requires attention to improve water management practices, enhance sanitation infrastructure, and ensure access to clean drinking water and sanitation facilities. Finally, while the agriculture sector is relatively less vulnerable compared to other sectors, its importance for livelihoods and food security necessitates measures to address climate risks, enhance agricultural resilience, and promote sustainable farming practices.

Therefore, prioritizing interventions in the health sector, followed by education, water and sanitation, and agriculture, can effectively address vulnerabilities and enhance resilience in Bahraich district, ultimately improving the well-being and livelihoods of its residents.

Area of concern

The ranking of all the indicators score data reveals the drivers of vulnerability in the district. Out of 27 sectoral indicators, 16 have significant impacts on the district's vulnerability. First, the high percentage of marginal and small landholders (5.62) highlights the susceptibility of agricultural livelihoods to external shocks and stresses, such as climate variability and market fluctuations. Secondly, the limited coverage of health insurance or financial schemes (5.37) indicates potential barriers to accessing healthcare services, exacerbating health-related vulnerabilities among the population **(Chart 9).**

Chart 9



Additionally, the relatively high student-teacher ratio (5.24) suggests potential challenges in delivering quality education, which could impact human capital development and socio-economic resilience. The area under water bodies (4.80) indicates potential risks associated with water-related hazards, including floods and waterborne diseases, affecting both livelihoods and health outcomes. Moreover, the prevalence of stunted children under 5 years old (4.77) reflects underlying issues related to nutrition and food security, highlighting the need for interventions to improve child health and well-being. Similarly, the infant mortality rate (IMR) score of 4.66 underscores challenges in maternal and child health, requiring targeted healthcare interventions and infrastructure improvements.

Furthermore, low vaccination rates among children aged 12-23 months (4.39) pose risks of disease outbreaks, necessitating efforts to enhance immunization coverage and healthcare access. Finally, the proportion of women with 10 or more years of schooling (3.88) and the availability of improved sanitation facilities (3.83) indicate areas for investment in human capital and basic infrastructure, contributing to overall resilience and well-being.

To address these vulnerabilities, actions such as implementing agrarian reforms to support small-scale farmers, expanding health insurance coverage, reducing the student-teacher ratio through recruitment and capacity-building, improving water management and disaster preparedness, enhancing nutrition programs, and promoting gender equality in education and workforce participation are recommended. These interventions can help mitigate risks, boost adaptive capacity, and strengthen resilience in the district.

References

1. UNISDR (2018) Report on economic losses, poverty and disasters 1998 2017, Technical report- Centre for Research on the Epidemiology of Disasters CRED & United Nations Office for Disaster Risk Reduction UNISDR. 31 p , https://www.unisdr.org/2016/iddr/ IDDR2018_Economic%20Losses.pdf

2. Guhathakurta P,Sreejith OP, MenonPA(2011)Impact of climate change on extreme rainfall events and flood risk in India. J Earth Syst Sci 120(3):359–373

3. Ray K, Pandey P, Pandey C, Dimri AP, Kishore K (2019) On the recent floods in India. Curr Sci 117(2):204–218

4. Roxy MK, GhoshS, Amey P,Athulya R, Mujumdar M, Murtugudde R, Terray P, Rajeevan M(2017)A three fold rise in wide spread extreme rain events over central India. Nat Commun Published online on 3rd October 2017 8:708. https://doi.org/10.1038/s41467-017-00744-9

5. Vittal H, Karmakar S, Ghosh S, Murtugudde R (2020) A comprehensive India-wide social vulnerability analysis: highlighting its influence on hydro-climatic risk. Environ Res Lett 15(1):014005

6. Gbetibouo GA, Ringler C (2009) Mapping south African farming sector vulnerability to climate change and variability. A subnational assessment. IFPRI discussion paper 00885. International Food Policy Research Institute (IFPRI), Washington

7. Piya L, Maharjan KL, Joshi NP (2012) Vulnerability of rural households to climate change and extremes: analysis of Chepang households in the mid-hills of Nepal. Selected paper prepared for presentation at the International Association of Agricultural Economics (IAAE) Triennial Conference, Foz do Iguacu, Brazil Published online 7th Dec 2018 https://doi.org/10.1002/wcc.565

8. Vincent K (2004) Creating an index of social vulnerability to climate change for Africa. Technical Report 56. Tyndall Center for Climate Change Research, University of East Anglia, Norwich

9. Maiti S, Jha SK, Garai S, Nag A, Chakravarty R, Kadian KS, Chandel BS, Datta KK, Upadhyay RC (2015) Assessment of social vulnerability to climate change in the eastern coast of India. Clim Chang 131:287–306

10. IPCC (2014) Summary for policymakers in: Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change ed C B Field et al. (Cambridge) (Cambridge University Press) (Cambridge, United Kingdom and New York, NY, USA) pp 1–32

11. McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (2001) Climate change 2001: impacts, adaptation, and vulnerability, Eds edn. Cambridge University Press, Cambridge

12. O'Brien K,LeichenkoR,KelkarU,VenemaH,AandahlG,TompkinsH, Javed A, Bhadwal S, Barg S, Nygaard L, West J (2004) Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob Environ Chang 14:303 – 313