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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

District Begusarai, Bihar

Developed by

Gorakhpur Environmental Action Group (GEAG)

Climate Risks and Sectoral Vulnerabilities – District Begusarai, Bihar

Authors
Dr Bijay Singh
Dr Shiraz Wajih

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Introduction

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

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 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 effects 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.

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,

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 the area under rainfed agriculture	2021-22	The National Data and Analytics Platform	Sensitivity (positive)
Area _Cov_ PMFVY	Area covered under 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)
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 improved drinking water sources	2020-21	The National Data and Analytics Platform	Adaptation (Negative)
Change_GW	Changes in groundwater table during last five years (mbGL)	2021-22	The National Data and Analytics Platform	Sensitivity (Positive)
State_GW	State of groundwater utilisation(in %)	2021-22	The National Data and Analytics Platform	Sensitivity (Positive)
HHs _improv_ Sani	Proportion of HH that have an 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

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:

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

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

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

Assigning weights to indicators through Principal Component Analysis

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	Livstockpopulationper1000population	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 000ha	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 o fRural 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 outrate 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 goundwater utilisation (in%)	2.4	2.4	0.1
24	% Area Under Wetlands in	2.4	2.8	4.8
25	% of available groundwater 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: Begusarai , Bihar

Begusarai is a district located in the central part of Bihar. Geographically, it lies between 25°15' and 25°45' north latitude and 85°45' and 86°36' east longitude, bordered by the Ganges River in the south. Covering an area of approximately 1,918 square kilometres, Begusarai is known for its fertile plains, which contribute significantly to the agricultural activities in the region. The district's terrain is predominantly flat, with a few small rivers and streams traversing through it.

As per the 2011 census, Begusarai has a population of around 2.97 million people. The population density of the district is relatively high due to its fertile land and agricultural opportunities. The district is characterized by a mix of rural and urban settlements, with the majority of the rural population engaged in agriculture, while towns like Begusarai, Barauni, and Balia serve as centres of commerce and administration.

Climate profile

The district experiences a subtropical climate with distinct seasons. Summers, extending from March to June, are characterized by hot and humid conditions, when temperatures often rise above 40°C. During this period, the district receives minimal rainfall. The monsoon season, which remains active from July to September, brings relief from the scorching heat as most of the rainfall occurs during this period. The average annual rainfall of 1026 mm, often ranging between 1,000 to 1,200 mm, is vital for agriculture, which is the backbone of the local economy. The winter season, lasting from November to February, is relatively mild and dry, with temperatures dropping to around 10-15°C. Foggy conditions are common during winter months, particularly in early mornings and late evenings.

Trend and seasonal variability in rainfall

The rainfall pattern in Begusarai over the last 30 years exhibits considerable variability. From the period between 1993 to 2023, the annual rainfall ranged from 780.18 mm in 2018 to 1493.71 mm in 2021, indicating significant fluctuations in precipitation levels. Analysing the trend, there is no clear linear increase or decrease in annual rainfall over the period. However, certain years stand out with notably varied rainfall. For instance, there was a relatively dry spell around the late 1990s and early 2000s, with below-average rainfall recorded in the years 1994, 1999, and 2002. Conversely, the mid-2000s witnessed above-average rainfall, particularly in years 2006, 2007, and 2008. **(Chart 1)**

A more recent trend shows a mix of wet and dry years. Notably, years 2020 and 2021 experienced exceptionally high rainfall, while 2018 had notably low rainfall. The years 2010 and 2012 also saw below-average precipitation. The reasons for such fluctuation may include regional climate dynamics, monsoon variability, and larger-scale climate phenomena like El Niño and La Niña. These factors can influence the strength and duration of the monsoon season, which significantly impacts rainfall in the region. Thus, understanding these patterns is crucial for water resource management, agriculture, and disaster preparedness in Begusarai. Strategies to mitigate impacts of both excessive rainfall, such as flooding, and insufficient rainfall, or drought, can be developed by analysing these trends and variations over time.

Chart 1

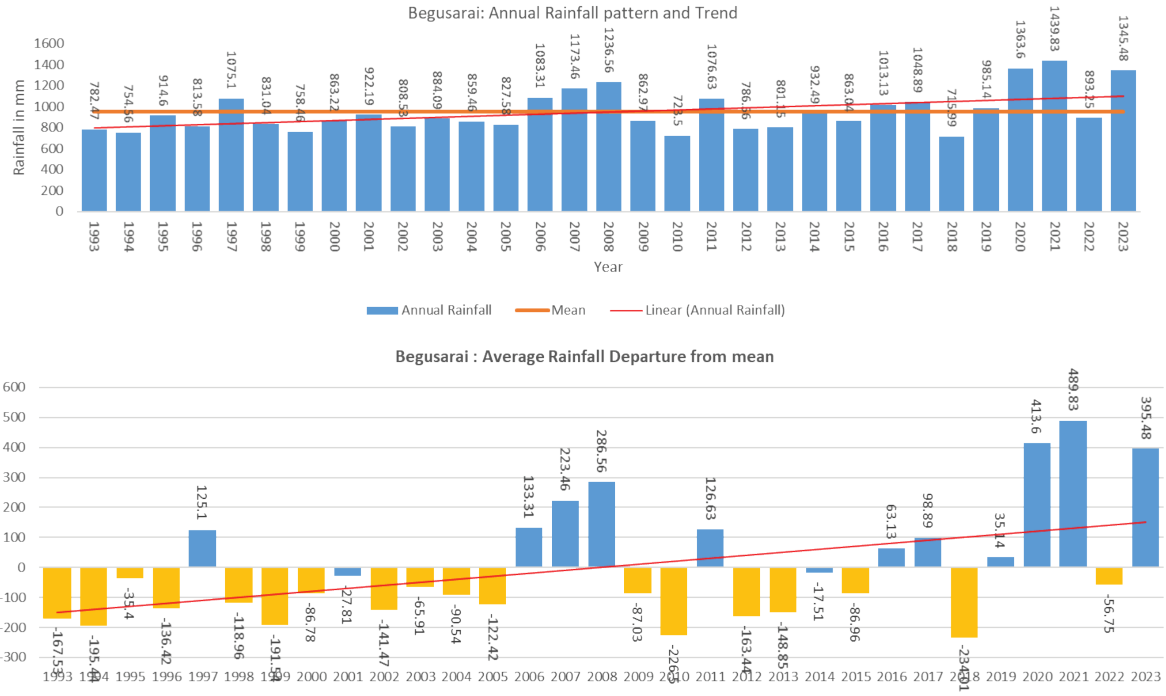
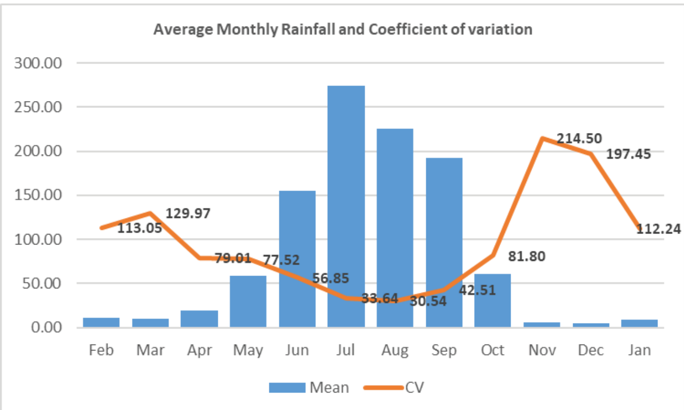


Chart 2 below shows the month-wise mean and coefficient of variation of rainfall of Begusarai district. The highest coefficient of variation is observed in November (214.50%) and December (197.45%), indicating high variability in rainfall during these months. Conversely, the months with the lowest CV are July (33.64%) and August (30.54%), suggesting relatively consistent rainfall patterns during the peak monsoon season.

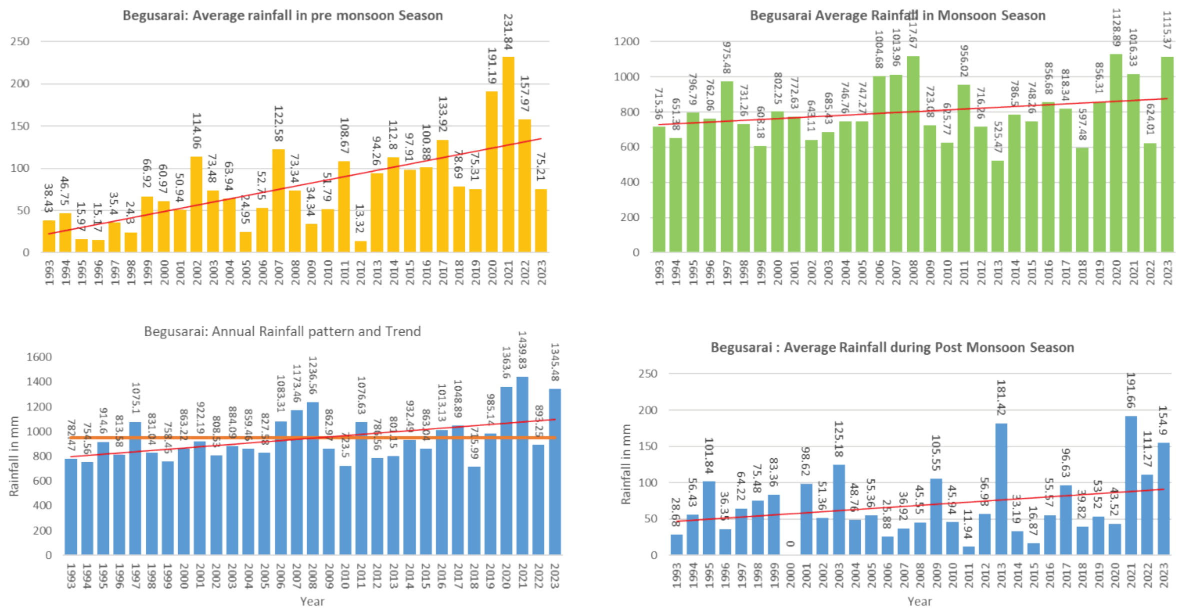
Chart 2



Analysing the contribution of rainfall to the annual total, it is evident that the monsoon months of June, July, August, and September collectively contribute towards the majority of the annual rainfall, accounting for approximately 69.57% of the total. June alone contributes 15.15%, followed by July (26.74%), August (21.99%), and September (18.70%). Pre-monsoon months like May also contribute significantly (5.70%) to the annual rainfall. The post-monsoon months, including October, November, and December, collectively contribute around 1.96% to the annual rainfall. These months typically experience lower rainfall compared to the monsoon season.

The trend of seasonal rainfall pattern given in **Chart 3** below surmises that the amount of rainfall is slightly increasing in all the seasons but the rate of increase in pre monsoon is comparatively more than the monsoon and post monsoon seasons.

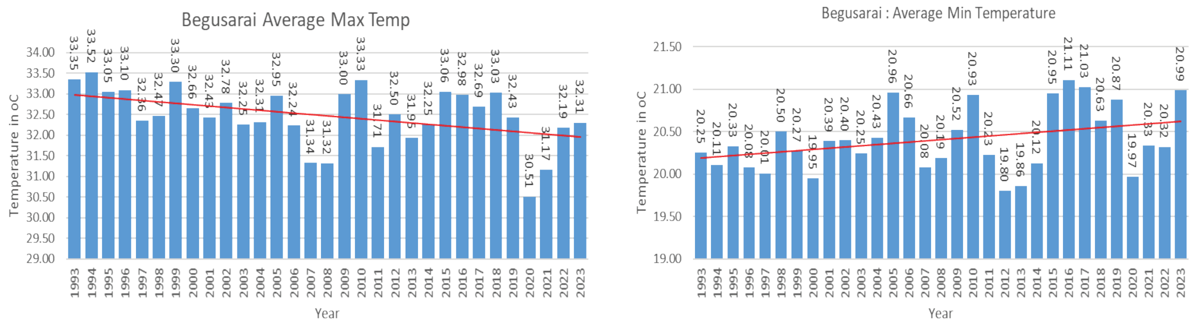
Chart 3



Maximum and minimum Temperature

As mentioned above, the district experiences a subtropical climate with hot summer temperatures often soaring above 40°C, while winters are relatively cool with temperatures dropping to around 5-10°C. Analysing the temperature data of the district over the last three decades reveals several ups and downs **(Chart 4**). Firstly, there is a slight decreasing trend in the

Chart 4

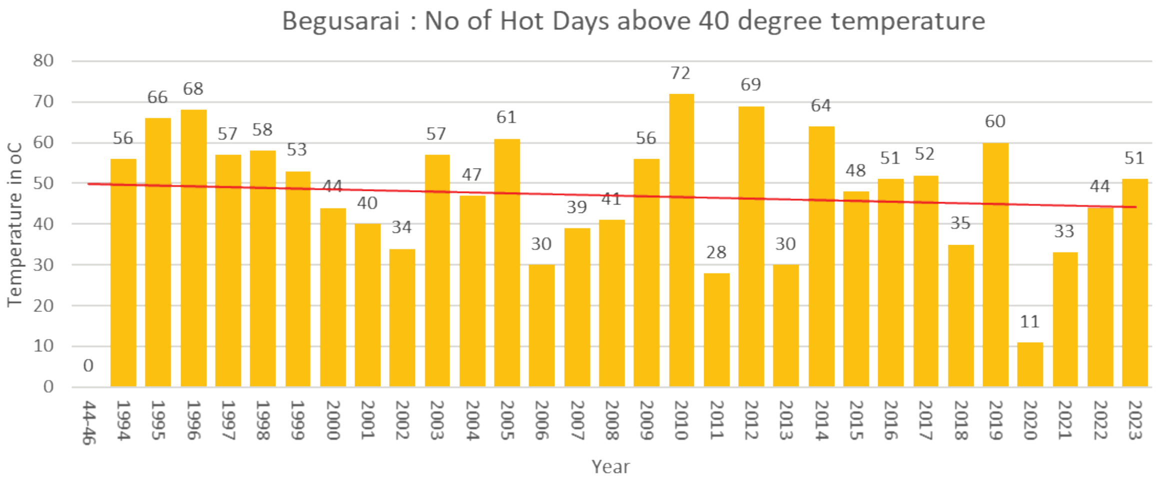


maximum temperatures and an increasing trend in minimum temperature over the years. The average minimum temperature has increased from around 20.25°C to 20.99°C, while the average maximum temperature has fallen from 33.35°C to 32.31°C. However, the rate of increase is relatively small, indicating a minor change in temperature rather than a drastic shift.

Extreme temperature events

Chart 5 of extreme hot temperature days (No. of days above 40°C) over the last three decades reveals several variations. The highest number of extreme hot days occurred in the year 2010, with 72 days recorded, followed closely with 69 days in 2012. Conversely, the lowest number of extreme hot days was observed in the year 2020, with only 11 days recorded, possibly due to anomalous weather conditions or other factors.

Chart 5



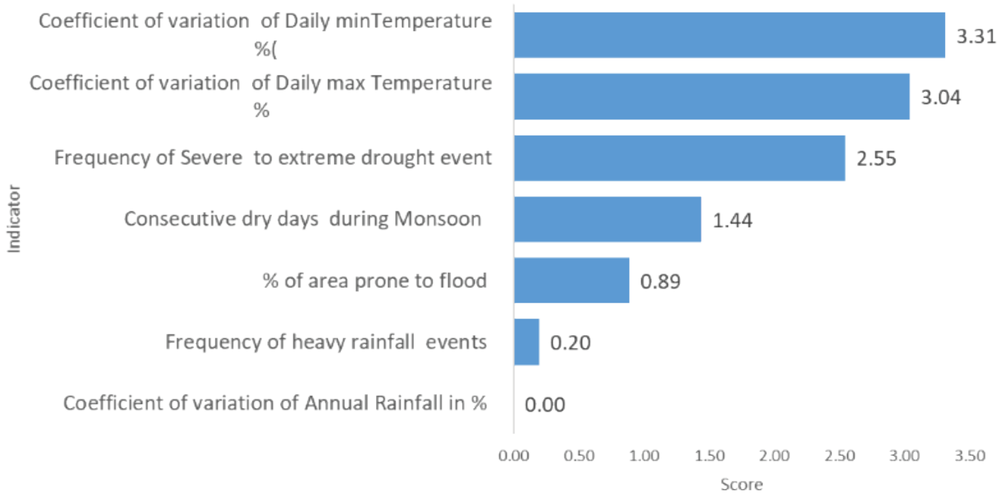
Examining the overall trend, there appears some variability but no clear linear trend in the occurrence of extreme hot days over the three decades. However, there are periods of relatively higher and lower occurrences. For example, from the period between 1993 to 1996, there was a consistent occurrence of extreme hot days, where each year recorded over 50 days. Similarly, from years 2010 to 2014, there was another period of increased occurrences of extreme hot days. The data also highlights some years with unusually low occurrences of extreme hot days, such as 2006, 2011, and 2013, where the number of extreme hot days recorded was notably lower compared to surrounding years.

Thus, understanding the patterns and variations in extreme hot temperature days is crucial for assessing the impact of heatwaves, planning for adaptation measures, and mitigating the effects of extreme heat on human health, agriculture, and infrastructure. Further analysis, including studying the underlying factors driving these variations, will provide deeper insights into the dynamics of extreme hot temperatures in the region over the last three decades.

Climate hazards index and ranking of key drivers

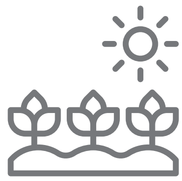
As previously mentioned, in determining the climate hazard risk score for the districts, we considered seven indicators and assigned weightage though the PCA tool to derive the score **(Chart 6)**. These included variations in annual rainfall, maximum and minimum temperatures, frequency of heavy rainfall events, proportion of flood-prone areas, and frequency of drought events. Through a climatological analysis spanning three decades and evaluating physical exposure to floods and droughts, it was noticed that the coefficient of variation in minimum and maximum temperatures showed the highest scores (3.31 and 3.04, respectively), followed by severe to extreme drought events (2.55) and consecutive dry days in the monsoon (1.55). These four indicators emerged as crucial factors influencing the district's vulnerability, shaping rainfall patterns and occurrences of drought. Consequently, they ranked higher in the risk index, emphasizing their pivotal role in determining the district's susceptibility to climate hazards. Understanding the dynamics of these indicators is vital for developing strategies for resilience against climate-related risks.

Chart 6



Sectoral Vulnerability

Agriculture and allied sector



As the majority of the population of the district is engaged in agriculture and allied sectors, it plays a vital role in the economic landscape of the region, serving as a backbone for rural livelihoods and food security. Analysing **Table 3** below, it is evident that the district exhibits both strengths and challenges in comparison to the state averages across various indicators. With a slightly higher percentage of marginal and small landholders than the state average (98% compared to 97%), the district reflects a prevalence of small-scale farming. However, the lower livestock population per 000 human population in the district (290 compared to the state average of 380) suggests a lesser reliance on livestock for livelihoods, potentially impacting the diversity and resilience of agricultural activities.

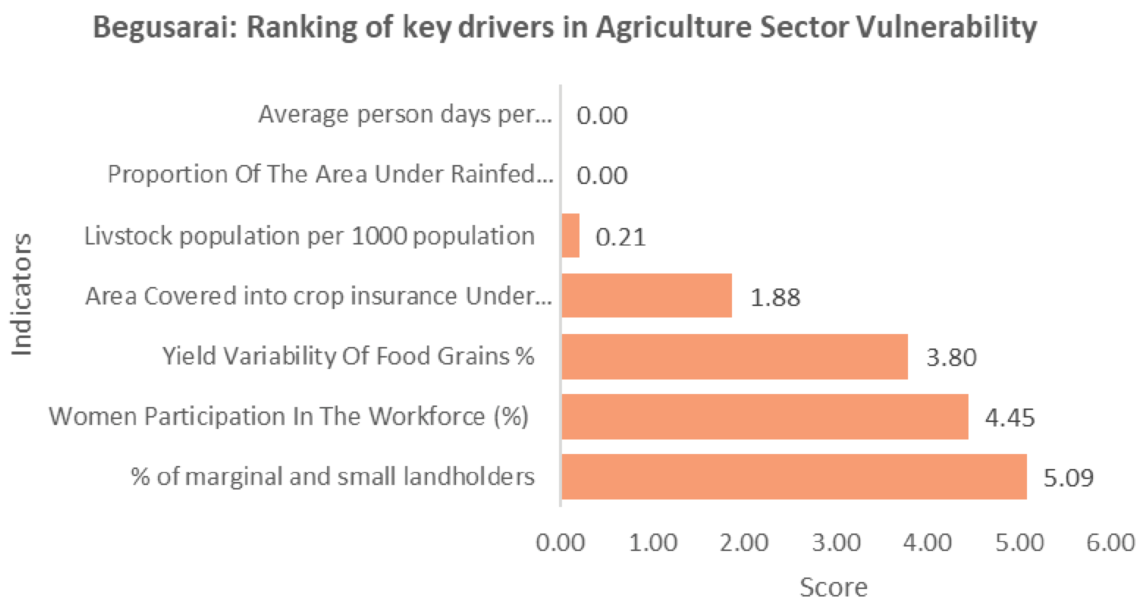
Furthermore, the significantly lower proportion of area under rain-fed agriculture in the district (15.9% compared to the state average of 43.0%) highlights that the region has a good irrigation system. The absence of crop insurance coverage under PMFBY indicates a vulnerability to crop-related risks, further compounded by higher yield variability of food grains in the district (40% compared to the state average of 20%). Despite these challenges, a higher women participation in the workforce in the district (24% compared to the state average of 19.07%) suggests a more inclusive agricultural sector, potentially contributing to enhanced productivity and income generation.

Table 3

Indicator	District	State
% of marginal and small landholders	98%	97%
Livestock to human ratio	290	380
Proportion of Area Under Rain fed Agriculture	15.9%	43.0%
Area Covered into crop insurance Under PMFBY	0%	43.37%
Average person days per household employed under MNREGA	42.3%	43%
Yield Variability of Food Grains	40%	20%
Women Participation in the Workforce	24%	19.07%

Identifying the key drivers of agriculture vulnerability of the district based on the scores, it is deduced that the % of marginal and small landholders emerges as the top-ranking factor in both the district and state, highlighting the prevalence of small-scale farming and the potential challenges in accessing resources **(Chart 7)**. Following closely, women participation in the workforce (%) ranks second in the district despite a slightly lower score compared to the state, underscoring a significant contribution of women to the agricultural workforce. Yield variability of food grains with a score of 3.80 ranks third in the district with a relatively high score compared to the state, indicating greater fluctuations in food grain production and potential challenges in crop management.

Chart 7



In the district, the coverage of PMFBY (score1.88) ranks fourth in the district, emphasizing the vulnerability of farmers to crop-related risks and the need for improved risk management mechanisms. These rankings collectively provide insights into the vulnerability of the agricultural sector, guiding policymakers in developing targeted interventions to enhance resilience and sustainability.

Health sector

The health sector in Begusarai, as reflected in Table 10 below, exhibits both strengths and areas for improvement compared to the state average. Firstly, the number of rural healthcare infrastructure facilities per lakh population in the district is slightly higher (14.29) than the state average (13.19), indicating relatively better access to healthcare facilities in rural areas. However, despite this, the district faces challenges in certain health indicators. For instance, the percentage of children aged 12-23 months who are fully vaccinated is lower in Begusarai (65.8%) as compared to the state average (82.7%), suggesting potential gaps in vaccination coverage and immunization programs.

Similarly, the district has higher percentages of children under 5 years who are stunted (37.8%) and underweight (35.6%) compared to the state average (42.9% and 41%, respectively), indicating issues related to child nutrition and overall health. Additionally, the Infant Mortality Rate (IMR) in Begusarai is much (56 per 000 live births) higher than the state average (32), highlighting challenges in maternal and child healthcare. However, the percentage of women aged 15-49 years who are anaemic is slightly lower here (62.9%) as compared to the state average (63.5%). These health challenges can be exacerbated by climate risks, such as extreme weather events which affect food security, waterborne diseases due to flooding, and heat-related illnesses.

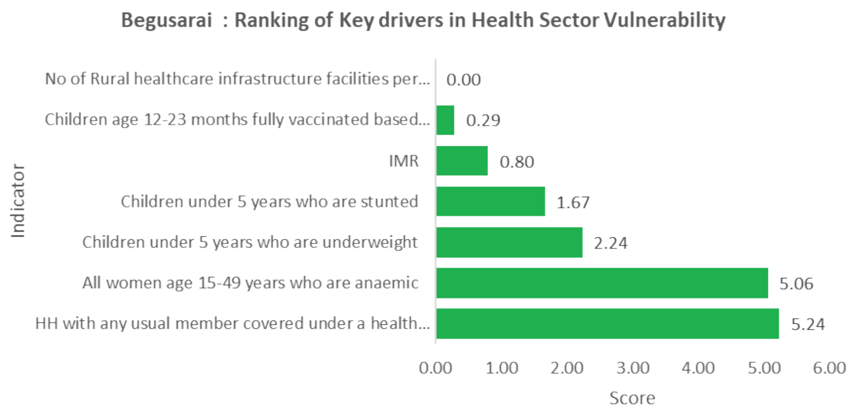
In short, the data indicated in the health sector gives an impression that there are notable areas requiring attention, particularly in child health and mortality rates. Efforts to improve vaccination coverage, child nutrition, and maternal and child healthcare services are crucial for enhancing health outcomes in the district.

Table 4

Indicator	District	State
No of Rural healthcare infrastructure facilities per lakh population		
HH with any usual member covered under a health and insurance / financial scheme	14.29	13.19
Children age 12-23 months fully vaccinated based on information from vaccination card	65.8	82.7
Children under 5 years who are stunted	37.8	42.9
Children under 5 years who are underweight	35.6	41
IMR	56	32
All women age 15-49 years who are anaemic	62.9	63.5

Analysing the scores obtained by each indicator provides insights into their respective contributions towards health sector vulnerability in Begusarai. The key indicators contributing significantly are HH with any member covered under a health and insurance/financial scheme, and all women aged between15-49 years who are anaemic, both scoring relatively high in the district and the state (Chart 8). This highlights potential challenges in accessing healthcare services and addressing issues related to women's health.

Chart 8



Furthermore, children under 5 years of age who are underweight as well as children under 5 years who are stunted also contribute significantly to vulnerability. These indicators reflect challenges in child nutrition and overall health outcomes. Moreover, the relatively low score for IMR in Begusarai compared to the state suggests progress in reducing infant mortality rates, albeit still posing a vulnerability. Conversely, indicators such as children aged 12-23 months and fully vaccinated (based on information from the vaccination card and number of rural healthcare infrastructure facilities per lakh population) contribute less to vulnerability, with lower scores indicating potential areas for improvement although with a lesser immediate impact on the overall vulnerability. This inferences can be crucial for policymakers to develop targeted interventions aimed at addressing specific health challenges and enhancing healthcare resilience in Begusarai.

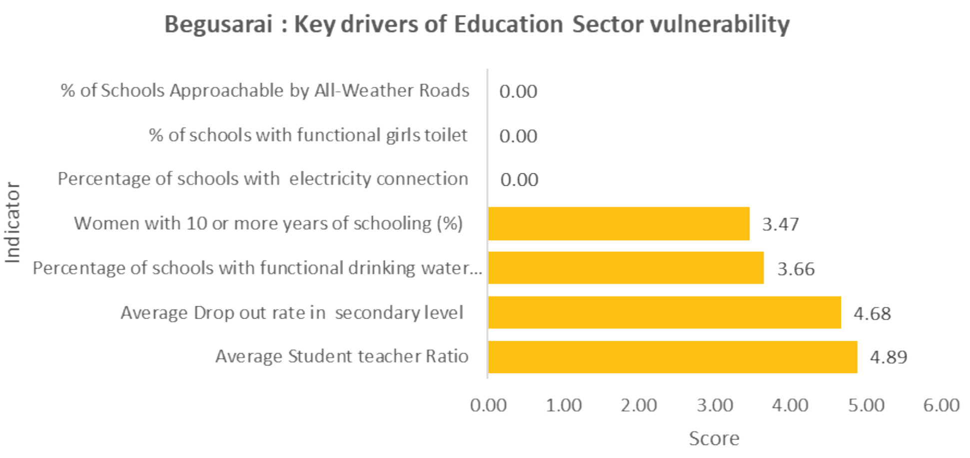
Education Sector

The education sector in Begusarai, showcases several strengths compared to the state average, with a few areas needing attention. Firstly, the percentage of women with 10 or more years of schooling in Begusarai (34.1%) surpasses the state average (28.8%), indicating relatively higher educational attainment among women in the district. Additionally, both the availability of functional girls' toilets (98.5%) and drinking water facilities (98.7%) in schools are higher than the state average, reflecting a commitment to providing basic amenities for students. Moreover, while the average student-teacher ratio in Begusarai (51.75) is slightly higher than the state (48), it remains within manageable limits, ensuring adequate attention to students in classrooms.

However, the average dropout rate in the secondary level (18.65%) is lower than the state average (20.46%), suggesting relatively better retention rates in Begusarai schools. Furthermore, the percentage of schools approachable by all-weather roads (89.9%) exceeds the state average (86.17%), ensuring better accessibility to educational institutions, which is crucial for promoting enrolment and attendance. Despite these strengths, the percentage of schools with electricity connection (81.11%) in Begusarai lags behind the state average (87.54%), indicating a need for improved infrastructure to support effective teaching and learning.

In Begusarai, the Average Student-Teacher Ratio ranks highest among the key drivers contributing to vulnerability, with a relatively high score **(Chart 9).** This suggests potential challenges in maintaining an optimal student-teacher ratio, impacting the quality of education, and imparting individual attention to students. Additionally, the Average Dropout Rate in the secondary level emerges as another significant driver, with a higher score (4.68) in the district compared to the state, indicating potential issues in student retention and completion of secondary education.

Chart 9



Furthermore, the Percentage of Schools with Functional Drinking Water Facilities and Women with 10 or more years of schooling also contribute significantly to vulnerability, with relatively high scores in the district. These indicators reflect challenges related to basic infrastructure and educational attainment among women, which can affect overall educational outcomes. On the other hand, indicators such as Percentage of Schools with Electricity Connection, % of Schools with Functional Girls' Toilets, and % of Schools Approachable by All-Weather Roads contribute less to vulnerability, with lower scores indicating potential areas for improvement but lesser immediate impact on overall vulnerability. Thus, there is need for ground level assessment to understand the causal facts for poor performance. These are crucial to develop targeted interventions aimed at addressing specific challenges and enhancing educational resilience in the district.

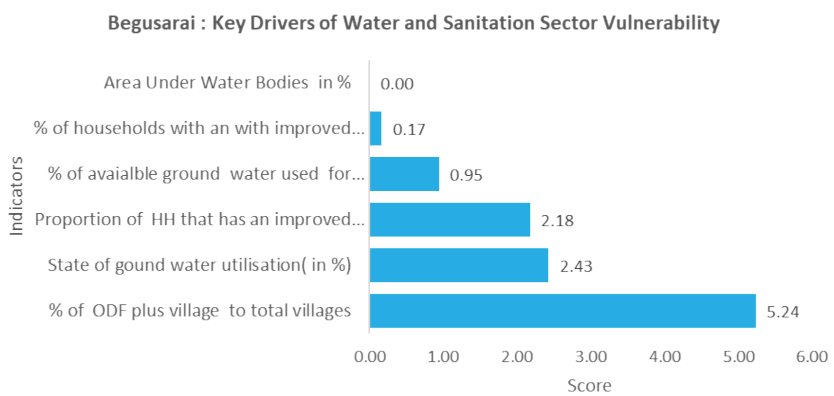
Water and sanitation sector

The water and sanitation sector in Begusarai demonstrates several positive aspects compared to the state average, with some areas showing improvement potential. Firstly, the percentage of households with improved drinking water sources in the district (99.1%) is slightly lower than the state average (99.2%), indicating widespread access to safe drinking water. But on the other side it also reflects the increasing demand for water that may escalate strain on water sources due to climate-related factors like erratic rainfall patterns and prolonged droughts. The state of groundwater utilization in Begusarai is also very high (63.38%) surpassing, the state average (44.76%), suggesting urgent management and control utilization of groundwater resources. Despite this, the area under water bodies in the district (1.66%) is lower than the state average (2.53%), indicating potential challenges in water conservation and natural water resource management. This may exacerbate water scarcity issues during periods of water stress, potentially affecting water availability for domestic and agricultural use.

Moreover, the proportion of available groundwater used for irrigation purposes in Begusarai (44.59%) is significantly higher than the state average (16.68%), indicating a reliance on groundwater for agricultural activities and potential concerns regarding sustainable water use. In terms of sanitation, the proportion of households with improved sanitation facilities in Begusarai (62.2%) exceeds the state average (49.4%), indicating progress in sanitation infrastructure. Additionally, the percentage of Open Defecation Free (ODF) plus villages to total villages in the district (76.7%) is comparable to the state average (77.6%), reflecting efforts towards achieving improved sanitation and hygiene practices. Therefore, while Begusarai demonstrates progress in water and sanitation infrastructure, addressing climate risks through sustainable water resource management, adaptation measures, and resilient infrastructure development is crucial for ensuring continued access to safe water and sanitation services in the face of changing climatic conditions.

Percentage of ODF villages and the State of Groundwater Utilization ranks highest among the drivers, with a relatively higher score in the district compared to the state, indicating potential challenges in sanitation drive and groundwater management and sustainable use (**Chart 10**). This suggests a need for improved water resource management practices to mitigate climate risks associated with groundwater depletion and contamination.

Chart 10



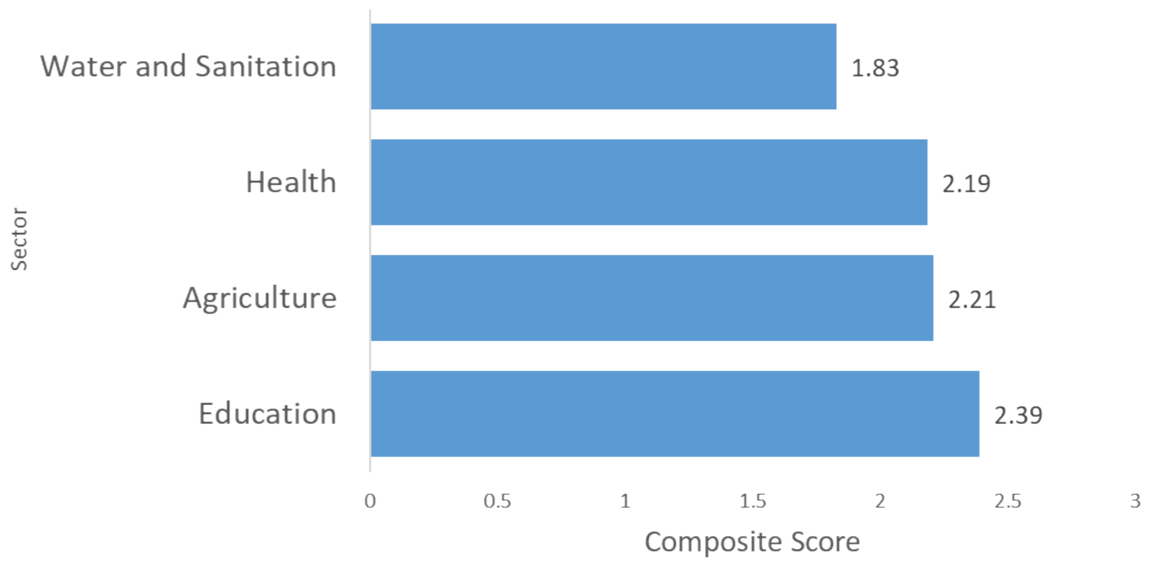
Additionally, the Proportion of Households with Improved Sanitation Facilities emerges as another significant driver, with a lower score in the district compared to the state, highlighting gaps in sanitation infrastructure and services. Efforts to enhance access to improved sanitation facilities are crucial for reducing health risks and improving overall sanitation standards. Furthermore, the Percentage of Available Groundwater Used for Irrigation Purpose contributes significantly to vulnerability, with a lower score in the district compared to the state, indicating potential challenges in water allocation and irrigation practices. Hence, it is important to address these drivers through effective policies and interventions aimed at sustainable water management and sanitation infrastructure development, which are essential for reducing vulnerability and enhancing resilience in the water and sanitation sector in the district.

Composite level of sectoral Vulnerability and ranking of indicators

The composite scores of the sectors reveals varying levels of vulnerability in the district, guiding the prioritization of sectors for targeted interventions. While all sectors exhibit vulnerabilities, the Education sector emerges with the highest composite score, indicating significant challenges that require immediate attention. Investing in education can have long-term positive impacts on human capital development, economic growth, and social well-being.

Second is the Agriculture sector, which also demonstrates a notable vulnerability score (2.21). Interventions in this sector are crucial for ensuring food security, enhancing agricultural productivity, and improving livelihoods of rural communities **(Chart 11).** Additionally, the Health sector exhibits considerable vulnerability, highlighting the need for interventions to strengthen healthcare infrastructure, improve access to healthcare services, and address public health challenges. Finally, the Water and Sanitation sector, although displaying relatively lower vulnerability compared to other sectors, still requires targeted interventions to enhance water resource management, improve sanitation facilities, and address water-related challenges.

Chart 11

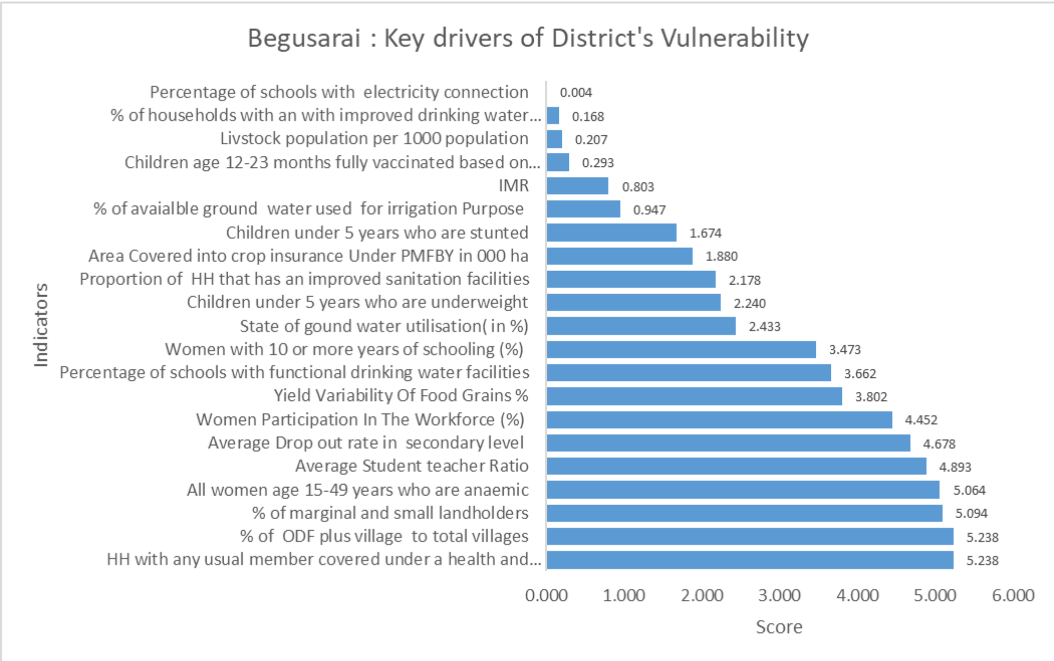


Prioritizing sectors for targeted interventions based on their composite scores allows for a strategic allocation of resources and efforts to address critical vulnerabilities and promote sustainable development in the district. By focusing on Education, Agriculture, Health, and Water and Sanitation sectors, policymakers can work towards building a resilient and thriving community with improved overall well-being and quality of life.

Key Areas of concern

Based on the individual score of indicators, the vulnerability of the district is discerned and key areas of concern identified **(Chart 12).** A prominent area of concern is healthcare access and coverage, as indicated by the high score for "HH with any member covered under a health and insurance/financial scheme." This suggests potential challenges in accessing healthcare services and insurance coverage for community members, which could significantly impact health outcomes and exacerbate vulnerabilities, (**Chart 12)** particularly among marginalized populations.

Chart 12



Furthermore, the high score for "All women age 15-49 years who are anaemic" underscores a significant health concern among women of reproductive age. This points to potential issues with nutrition and healthcare access, highlighting the need for targeted interventions to improve women's health outcomes and address underlying socio-economic determinants of health.

Education quality also emerges as a key area of concern, with high scores for Average Student Teacher Ratio and Average Dropout rate in secondary level. These scores suggest potential challenges in providing quality education and retaining students in schools, which could hinder human capital development and socio-economic progress in the district.

Moreover, the scores for Percentage of schools with functional drinking water facilities and Proportion of HH that has improved sanitation facilities indicate potential gaps in water and sanitation infrastructure, affecting hygiene and health outcomes. Addressing these gaps is crucial for promoting public health and reducing vulnerabilities related to waterborne diseases and sanitation-related illnesses.

Additionally, the scores for child health and nutrition indicators, such as Children under 5 years who are underweight and Children under 5 years who are stunted, highlight potential challenges in ensuring optimal child growth and development. Improving access to nutritious food, healthcare services, and sanitation facilities is essential for addressing these concerns and promoting healthy child development.

Hence, addressing these key areas of concern requires a multi-sectoral approach, involving targeted interventions in healthcare, education, water and sanitation, and nutrition, amongst others. By prioritizing these areas and implementing evidence-based interventions, policymakers and key state holders can mitigate vulnerabilities and improve overall well-being 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