Disaster Resilience Management through Climate Risk Informed Programming with Systemic Change

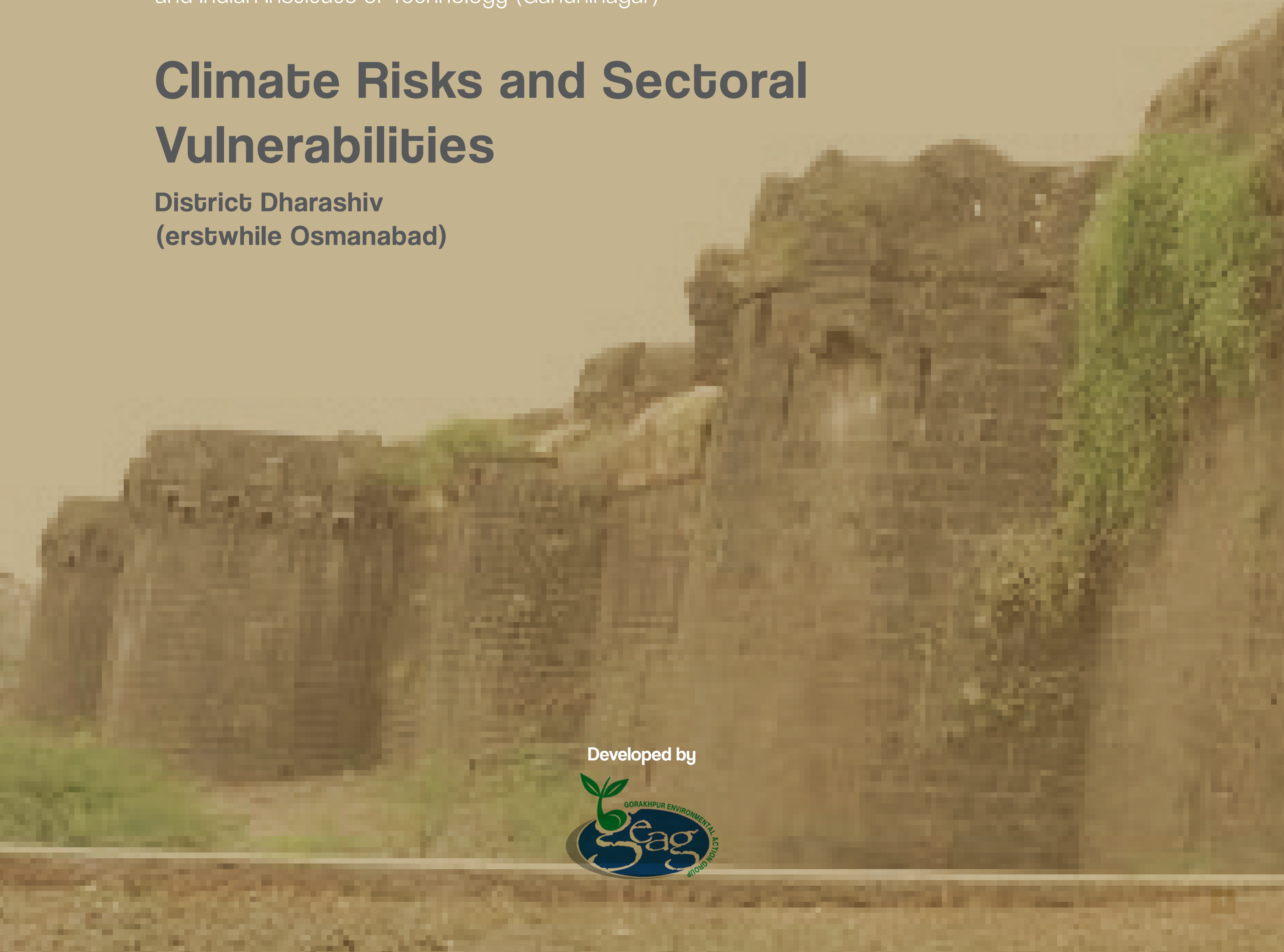
A Flagship CSR initiative of IndusInd Bank

In Partnership with

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

Climate Risks and Sectoral Vulnerabilities

District Dharashiv
(erstwhile Osmanabad)



Developed by

Climate Risks and Sectoral Vulnerabilities – District Dharashiv (erstwhile Osmanabad)

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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 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:

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

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 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

Geographical Profile

District Osmanabad (currently known as Dharashiv), located in the southern part of Maharashtra, India, has a distinct geographical profile, characterized by diverse landscapes and climatic conditions. It is bordered by Maharashtra's districts of Solapur to the north, Beed to the northwest, Latur to the east, and the state of Karnataka to the south. The topography of Dharashiv features a varied landscape that includes plateaus and hills. The district is part of the Deccan Plateau, with elevations ranging from 400 to 600 meters above sea level. The Sahyadri mountain range lies to the west, contributing to the district's unique geography. Major rivers, such as the Bhima, flow through the region, alongside smaller rivers like the Manjra and the Purna, which play a vital role in supporting agricultural activities. As of the latest census of 2011, it has a population of approximately 1.4 million, with a rural majority following predominantly agrarian lifestyles.

Over the last three decades, the analysis of climatic components in the district has raised serious concerns about climatic risks that threaten the livelihoods of its residents, health system and other key sectors related to child development. The region's key concern is drought, which often occurs during periods of below-average rainfall, which is heavily dependent on the southwest monsoon, and whose insufficiency often leads to crop failures and water shortages, leaving farmers vulnerable and threatening food security in the region. On the other hand, the district is also at risk of flooding, particularly during heavy monsoons, which lead to soil erosion, further compromising agricultural land. These extremes weather patterns create an unstable environment for farming, making it challenging for farmers to plan their planting and harvesting cycles.

Increasing average temperatures pose another significant risk. During the summer months (May and June), maximum temperatures often exceed 40°C, leading to heat stress in crops, livestock and humans. Such conditions exert pressure on agricultural yields and increase the demand for water, exacerbating existing water scarcity issues. This scarcity, over the last few decades, compounded by changing rainfall patterns, has made irrigation more formidable, further threatening agricultural viability. Additionally, climatic variability /changes have led to increased outbreaks of pests and diseases, affecting crop health and yields. Fluctuating temperature and its impacts on humidity levels has created favourable conditions for pest attack, placing further stress on farmers. The cumulative impact of these climatic risks leads to economic instability, particularly in a district where agriculture is the primary livelihood.

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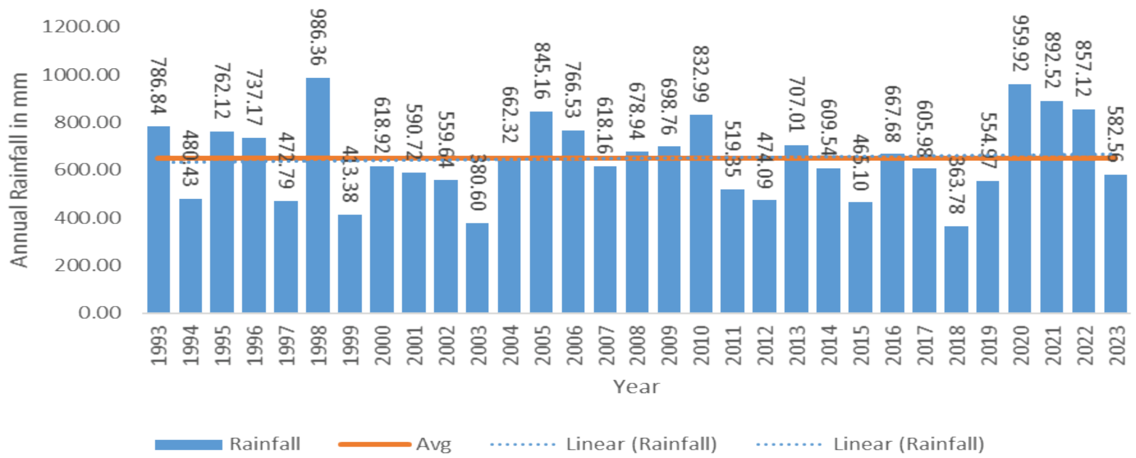
Climate Profile

Over all, the district experiences a tropical wet and dry climate, where average annual rainfall fluctuates mostly between 700 to 900 mm, primarily received from the southwest monsoon from June to September. Summer temperatures increase, reaching a maximums of 40°C, while winter temperatures are milder, averaging between 10°C and 25°C. This temperature variation plays a crucial role in shaping human practices and crop selection in the region. The district's climate influences its agrarian economy, water and sanitation, health and other key development sectors making it essential for the people of the district and local administration to adapt to these seasonal changes to ensure sustainable development.

Rainfall: Trend and Seasonal Variabilities

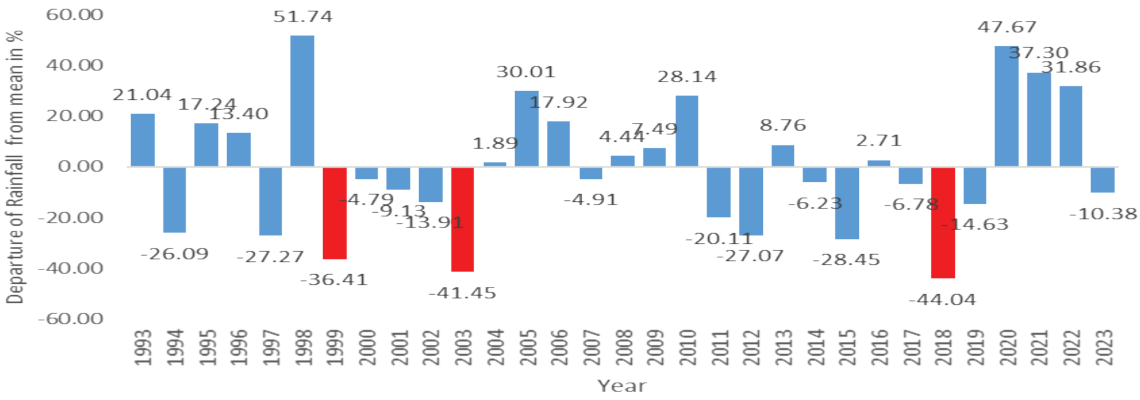
The rainfall analysis of the last three decades indicates that the district receives approximately 650 mm of rainfall annually (Fig. 1). The analysis of average annual rainfall data for Dharashiv district from years 1993 to 2023 reveals almost no trend, although Figure 1 indicates variability in rainfall, with a maximum recorded value of 986.36 mm in the year 1998 and a minimum of 363.78 mm in 2018. The decadal rainfall analysis of variation indicates that from 1993 to 1999, rainfall exhibited considerable variability. Notably, the rainfall peaked in year 1998, followed by a steep decline in subsequent years, reaching its lowest point in the year 1999. This period reflects a pattern of inconsistency, where extreme values are followed by drastic reductions. The years 2000 to 2010 saw a relative recovery, with a general increase in rainfall, peaking again in year 2010 at 832.99 mm. This decade illustrates a rebound in precipitation levels, indicating improvements in monsoonal patterns. However, the subsequent years from 2011 to 2018 show a decline again, closing in at the lowest rainfall in 2018. The last five years present a more stable trend, with years 2020 and 2021 exhibiting above-average rainfall, while year 2023 saw a decline to 582.56 mm.

Fig 1. Average Annual Rainfall of Dharashiv District



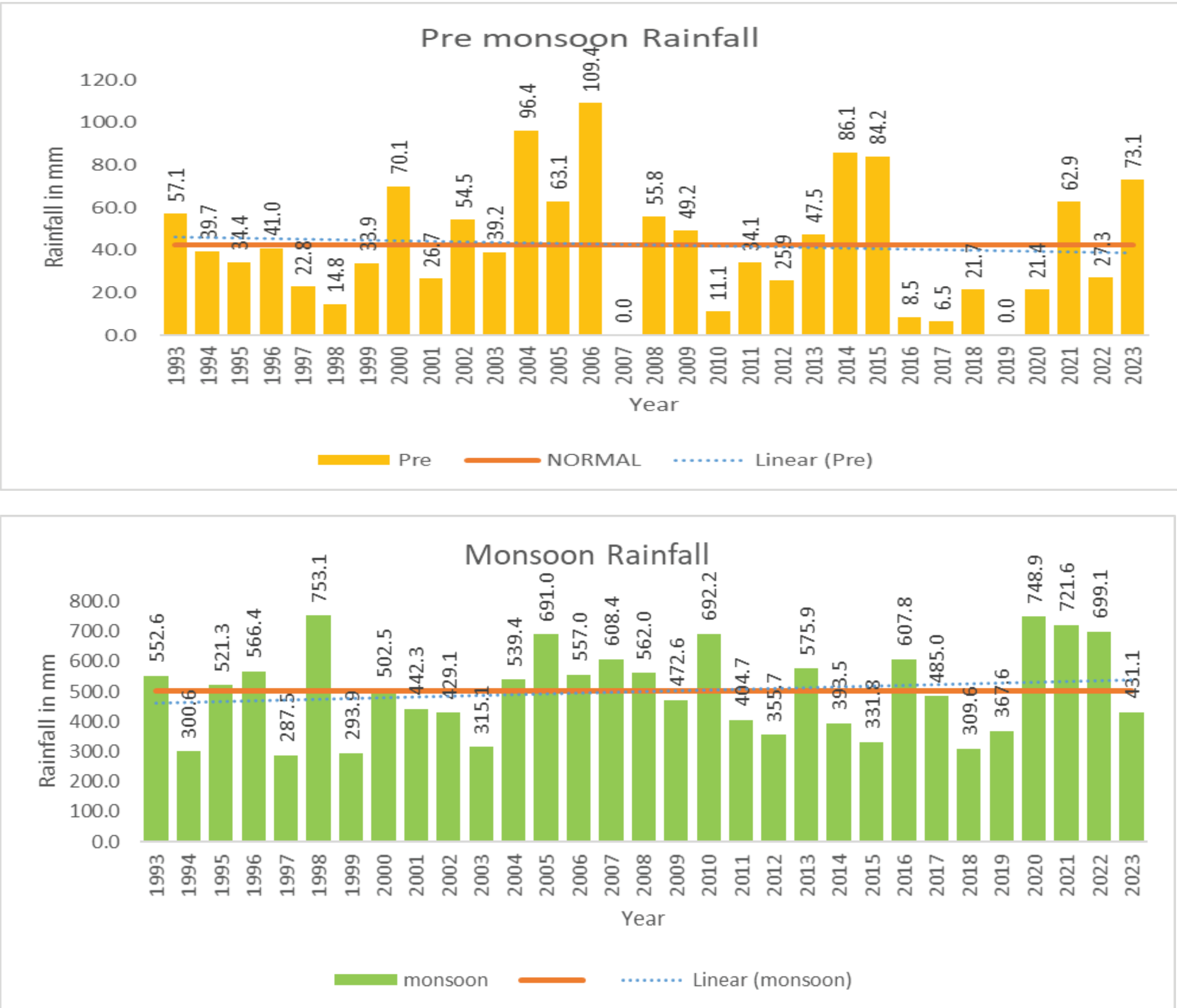
Thus, the average rainfall over the last 30 years in Dharashiv is marked by irregularities, reflecting the region's vulnerability to climate variability (Fig. 2). The variability may pose challenges for agricultural planning and water resource management, necessitating adaptive strategies to mitigate the impact of extreme weather patterns on local livelihoods.

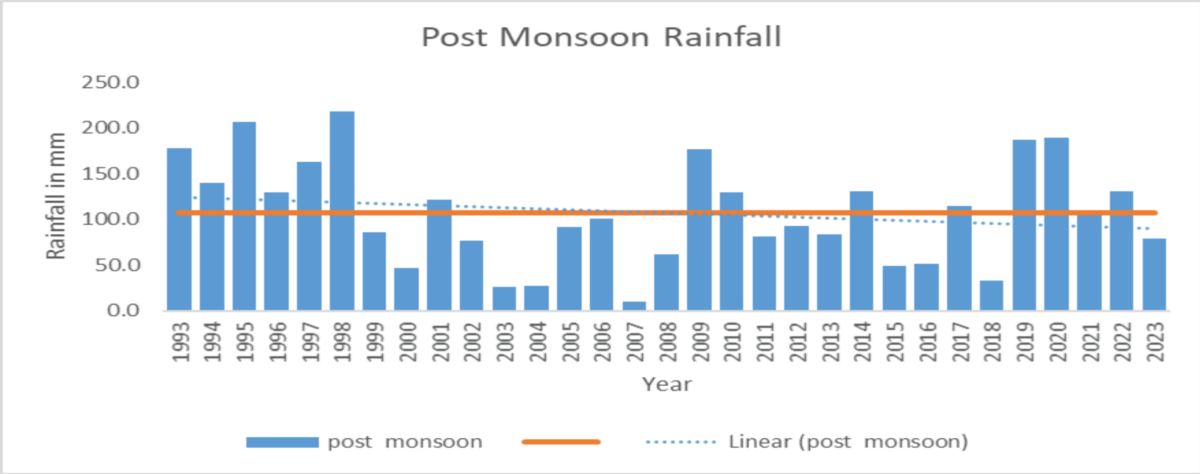
Fig 2 Average annual departure of Rainfall from its long time average (Normal)



Over the past three decades, analysing the pre-monsoon, monsoon, and post-monsoon rainfall patterns in Dharashiv district has provided valuable insights into the region's climatic dynamics (Fig. 3). Pre-monsoon rainfall, which occurs from March to May, accounts for approximately 6.5% of the total annual rainfall. Over the last 30 years, there has been a slight decreasing trend in pre-monsoon rainfall, averaging around 42.5 mm. During the monsoon season, from June to September, the district receives the majority of its annual rainfall, approximately 77.01%, and a modest upward trend in monsoon rainfall has been observed. In the post-monsoon season (October to February), rainfall has slightly declined from its long-term average of 106 mm, which represents about 16.45% of the total annual rainfall (650.0 mm).

Fig 3 Seasonal Rainfall Variation in Dharashiv





These seasonal variations in rainfall have made significant impact on the district's water availability, soil moisture retention, and crop growth, highlighting the importance of understanding, and adapting to changing rainfall patterns.

Temperature Scenario: Maximum and Minimum

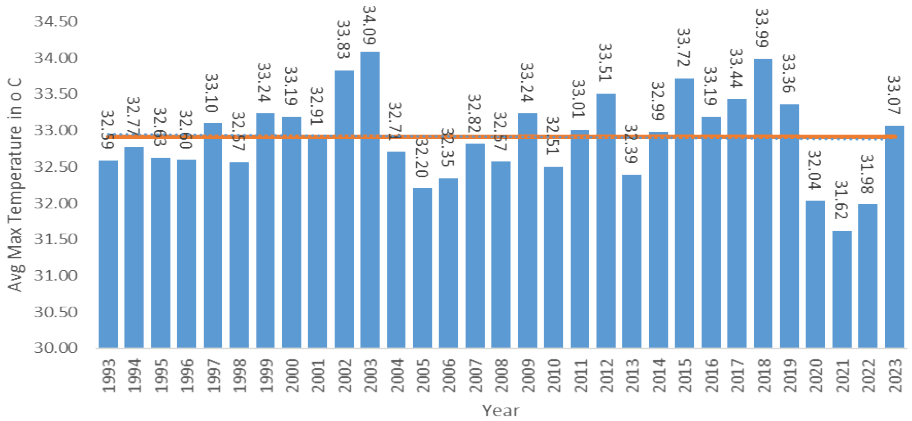
The district experiences a warm climate throughout the year, with relatively high temperatures during the summer months. The average maximum temperature during the summer season (March to June) often exceeds 35°C, with occasional heatwaves. The period from about the middle of February to the beginning of the south-west monsoon season is one of continuous rise in the temperature. May is generally the hottest month with the mean daily maximum temperature at about 40°C and the mean daily minimum at about 25°C. The heat during summers is intense and the maximum temperature sometimes goes up to about 45°C. The hot and dry conditions during this period exert challenges for agriculture and water sectors, and increases the risk of heat-related illnesses among the population. During the winter months (December to February), temperatures in Dharashiv district remain milder, with the average minimum temperatures ranging between 20°C to 25°C.

Maximum Temperature

The analysis of maximum temperature data for Dharashiv district over the past 30 years reveals significant trends and variations (Fig. 4). The mean maximum temperature during this period averages around 32.91°C, with individual yearly maxima showing fluctuations around this baseline. In examining the annual maximum temperatures, notable peaks were observed, particularly in the year 2018, when the temperature reached 33.99°C. The years 2002 and 2003 recorded higher maximum temperatures, with values of 33.83°C and 34.09°C, respectively. These points indicate periods of increased heat, which may correlate with the hottest years.

A trend analysis suggests a general increase in maximum temperatures, particularly from the early 2000s onward. However, there have been variations; for instance, temperatures dipped significantly in years 2020 and 2021, with the lowest maximum recorded at 31.62°C in 2021. This fluctuation highlights the influence of variable climatic conditions on temperature patterns.

Fig 4 : Dharashiv: Average Annual Maximum Temperature Variation



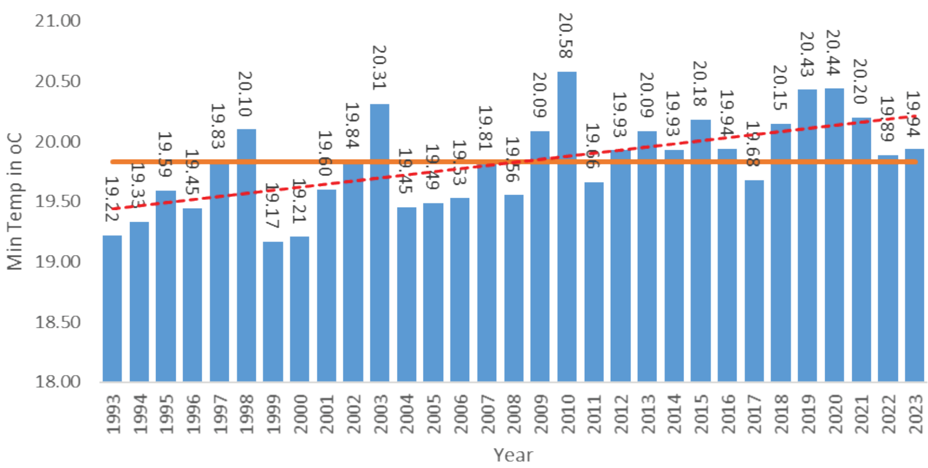
Therefore, while the mean maximum temperature remains relatively stable, the variations indicate a possible warming trend and illustrate the district's vulnerability to temperature extremes. Understanding these temperature dynamics is essential for agricultural planning, water resource management, and preparing for potential heat-related impacts on health and livelihoods in the region.

Minimum Temperature

Analysing the data of minimum temperatures over the past three decades reveals a notable trend towards increasing temperatures (Fig. 5). While fluctuations occur from year to year, there is an apparent pattern of rising minimum temperatures from the early 1990s to the early 2020s. This trend suggests a potential long-term shift in temperature patterns within the region. However, certain years, such as 2019 and 2020, stand out with particularly high minimum temperatures compared to surrounding years, indicating occasional deviations from the overall trend.

A similar analysis of minimum temperature data for Dharashiv district over the past 30 years indicates that the average minimum temperature during this period is approximately 19.83°C. Throughout the years, minimum temperatures generally range between 19.17°C and 20.58°C. The highest minimum temperature recorded was 20.58°C in the year 2010, indicating occasional warmer nights, while the lowest was 19.17°C in year 1999. Increasing minimum temperatures may have various implications, including impacts on agricultural practices, and human health. For instance, warmer nights may disrupt certain plant life cycles and lead to changes in crop cultivation techniques. Moreover, higher minimum temperatures can affect individuals' comfort level and contribute to heat-related health issues, particularly during night-time.

Fig 5. Dharashiv: Average Annual Minimum Temperature Variations



There appears to be a slight upward trend in minimum temperatures, especially from the early 2000s onwards. The years 2018 to 2021 show consistently higher minimums, with values mostly hovering around or above 20°C. This suggests a gradual warming, which could have implications for the local ecosystems and agriculture.

Overall, the minimum temperatures increase over the years highlights potential climatic shifts. Understanding these temperature dynamics is crucial for planning in agriculture and addressing challenges related to heat stress in crops and livestock, as well as its implications for local communities.

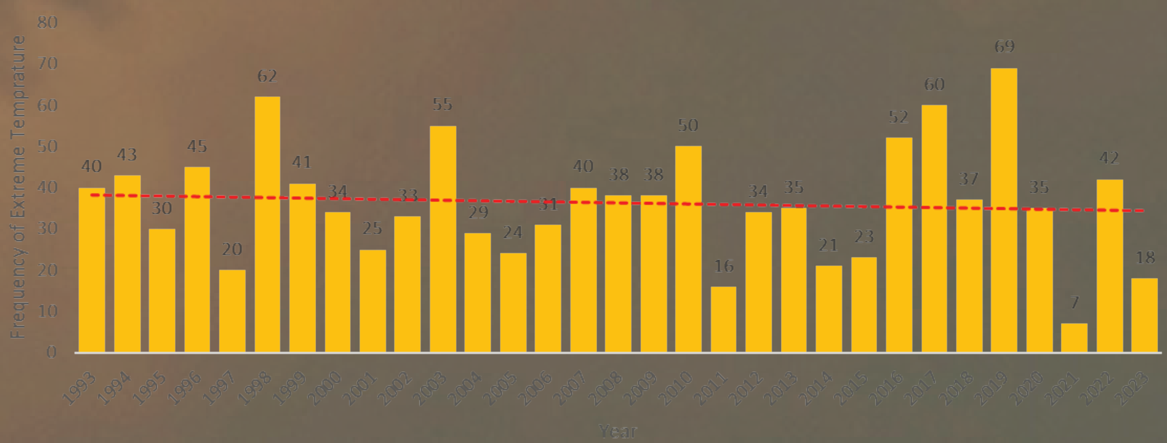
Extreme temperature

Extreme temperature pattern (No. of days above 40-degree temperature) in Dharashiv district over the last 30 years during the summer months reveals interesting insights. Fig. 6 below indicates the number of days with hot temperatures (above 40 degrees centigrade) for each year. There are noticeable variations from year to year, with some years experiencing significantly more hot days than others. For instance, 2019 had the highest total number of hot days, while certain years like 1997, 2011 and 2021 had relatively few hot days.

The analysis of extreme temperature events in Dharashiv district over the past 30 years reveals significant fluctuations in frequency. The data indicates that the occurrence of extreme temperature events varied greatly, with the highest frequency recorded in year 2019 at 69 events. This peak suggests a period of heightened temperature extremes, potentially linked to broader climate change trends.

The overall frequency of extreme temperature events has shown declining trend, with notable spikes in years 1998 (62 events), 2003 (55 events), and 2016 (52 events). Conversely, year 2021 saw the lowest frequency of just 7 events. This was the period of nationwide lockdown (due to corona virus) which made a significant impact on temperature patterns all over the country.

Fig 6 : Dharashiv: Extreme Temperature Events



Over the decades, a trend towards increased extreme temperature events is evident, particularly in the late 2010s. This increase raises concerns regarding the impact on agriculture, water resources, and local ecosystems. The variability in extreme events underscores the need for climate adaptation strategies to mitigate the effects of temperature extremes on agriculture and community resilience. Understanding these trends is crucial for local planning and disastewr preparedness efforts in the region.

Sectoral Vulnerability

Agriculture and Allied sectors

The above climate analysis clearly indicates that Dharashiv district is experiencing significant agricultural vulnerabilities due to climate change. The landholding structure in the district shows that 68% of farmers are marginal and small landholders, which is lower than the state average of 81%. This suggests that while both regions have a high dependence on small-scale farming, Maharashtra's larger proportion of smallholders makes it particularly susceptible to climate-induced stresses, as these farmers often lack access to resources, technology, and infrastructure. Additionally, both Dharashiv and Maharashtra have a large proportion of agricultural land (79% and 81%, respectively) under rainfed cultivation, making them highly dependent on the increasingly unpredictable rainfall patterns, influenced by climate change. This reliance on monsoon raises the risk of crop failures due to erratic weather conditions, such as droughts or floods.

There are wide differences in the crop insurance coverage under the Pradhan Mantri Fasal Bima in the district with respect to the state average. In Dharashiv, only 1.43% of the agricultural area is covered by insurance, compared to 34% in Maharashtra as a whole. This steep disparity highlights that Dharashiv's farmers are much less protected against climate-related risks, leaving them more vulnerable to the financial impacts of crop loss or damage. The data related to the employment indicates that Dharashiv's average of 45.6 person-days per household is lower than Maharashtra's average of 53 person-days. This suggests that Dharashiv may have fewer opportunities for rural employment and livelihood diversification, which are crucial for building resilience to climate shocks.

Although the yield variability in Dharashiv is slightly lower (9%) compared to the state average of 11%, this still indicates a degree of instability in agricultural productivity that is exacerbated by changing climatic conditions. Furthermore, women in Dharashiv participate more actively in agriculture, with 39% involvement in the workforce compared to 31.06% in the state. While this may increase women's exposure to climate-related challenges, it also positions them as key agents in adaptation and resilience strategies. In nutshell, the district's lower crop insurance coverage, limited rural employment opportunities, and greater reliance on small-scale farming make it more vulnerable to climate impacts compared to the state as a whole.

Health Sector

The health sector vulnerability of Dharashiv district, with respect to Maharashtra state average, reveals several key areas of concern, especially in the context of climate change. One of the more positive aspects for Dharashiv is its relatively higher number of rural healthcare facilities per lakh population (15.92), compared to the state's average of 12.05. This suggests that the district has a somewhat better access to healthcare services, which is vital in addressing climate-induced health crises, such as heat-related illnesses, waterborne diseases, and respiratory conditions linked to pollution. When it comes to child health, Dharashiv performs relatively well in terms of vaccination coverage, with 85.3% of children aged 12-23 months fully vaccinated, compared to Maharashtra's 81.6%. This suggests that Dharashiv has a stronger immunization program, which is critical in protecting children from climate-sensitive diseases like diarrheal diseases or respiratory infections, which can be aggravated by changing weather patterns. However, despite this advantage, the other figures of Dharashiv with respect to the state average highlight that there is still a significant gap in healthcare infrastructure, especially in rural areas, which would need to be addressed to improve resilience against climate-related health risks.

However, Dharashiv lags behind in terms of health insurance coverage. Only 14.8% of households in the district are covered by health insurance or a financial scheme, compared to 20.1% in the state. This indicates a greater vulnerability in Dharashiv, where a larger proportion of the population is without financial protection against health emergencies. As climate change leads to more frequent and intense climate-related health events, such as extreme weather or outbreaks of diseases, the absence of health insurance leaves many households in Dharashiv exposed to the high costs of healthcare.

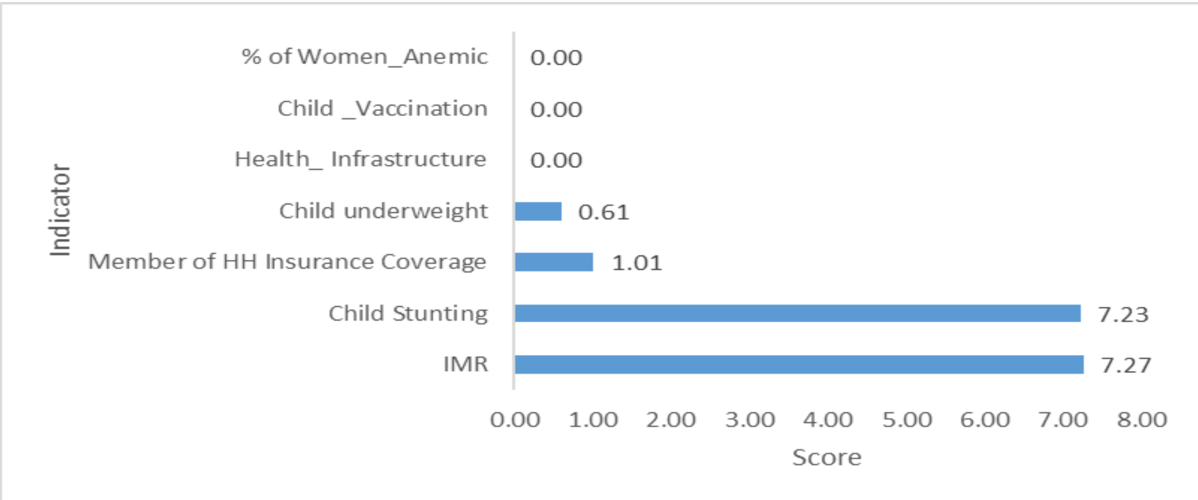
The district still faces challenges with child malnutrition, as 37.2% of children under five are stunted, slightly worse than the state average of 34.9%. The high rates of stunting and underweight children in both Dharashiv (32.5%) and Maharashtra (33.3%) reflect the vulnerability of children to the nutritional impacts of climate change, including food insecurity and extreme weather events that disrupt food production. The infant mortality rate (IMR) in Dharashiv is notably higher (43) compared to Maharashtra's average of 16, indicating a significant health vulnerability in the district. A high IMR suggests that there are issues with maternal health, nutrition, and healthcare access, which are compounded by climate change. For instance, extreme heat, floods, or droughts can put additional strain on the healthcare system, making it more difficult to provide adequate care during critical moments such as childbirth.

Finally, anaemia in women is another significant concern as the percentage of women aged 15-49 years who are anaemic is slightly lower in Dharashiv (49.1%) than in Maharashtra (52%), but still reflects a major public health issue. Anaemia, particularly in women, can worsen the effects of climate change, as it weakens the body's ability to cope with heat stress, infection, and malnutrition, all of which are expected to increase due to changing climatic conditions.

The indicator wise ranking of health sector reveals several areas where the district is particularly vulnerable (Fig. 7). The Infant Mortality Rate (IMR) is the most critical vulnerability, with Dharashiv scoring 7.27. This indicates a significantly higher infant mortality rate in the district, highlighting a major public health issue. The high IMR makes Dharashiv especially vulnerable, as climate-related health risks such as extreme heat, flooding, and waterborne diseases can worsen infant health outcomes and contribute to higher mortality rates. Therefore, the district's healthcare system is under considerable strain in addressing the needs of new-borns and infants, making it a priority for intervention.

Similarly, child stunting in Dharashiv is a major vulnerability, (score of 7.23), and is ranked second among the indicators used for the vulnerability assessment. This suggests a severe issue with chronic malnutrition among children, which can be exacerbated by climate-induced disruptions in food security. Climate change is expected to increase the frequency of extreme weather events, droughts, and floods, further impacting agricultural productivity and food availability, thereby worsening the rates of child stunting and malnutrition in the district. Stunted growth not only affects children's immediate health but also their long-term cognitive and physical development, compounding the district's vulnerability.

Fig 7 : Dharashiv : Ranking of key Drivers of Health Sector Vulnerability



Thus, while Dharashiv has certain strengths, such as better healthcare infrastructure and vaccination coverage, the district faces considerable health vulnerabilities. These include a higher IMR, high rates of child malnutrition, and low health insurance coverage. These factors make Dharashiv particularly vulnerable to the health impacts of climate change, emphasizing the need for greater investment in healthcare access, nutrition, and climate adaptation strategies

Education Sector

The education sector vulnerability is assessed on the basis of female literacy, Facilities in schools, Dropout rate, Student teacher ratio and Accessibility of school during stress period. One of the most significant challenges is the lower percentage of women's literacy (41.5%) compared to Maharashtra's average of 61.1%. This educational gap puts women in Dharashiv at a higher risk when facing climate change induced impacts. Educated women are better equipped to adapt and mitigate the consequences of climate disruptions, as they tend to have more access to information, resources, and decision-making powers. The relatively low level of educational attainment among women in Dharashiv suggests that the district may have a more limited capacity to respond to climate-induced stresses, such as droughts, floods, and agricultural disruption, which disproportionately affect women and children.

In terms of school infrastructure, Dharashiv has performed well, with 97.91% of schools having functional girls' toilets, slightly higher than Maharashtra's 96.87%. This indicates a strong commitment in providing gender-sensitive facilities, which are crucial for maintaining girls' attendance and well-being, especially in rural areas. Additionally, 100% of schools in Dharashiv have functional drinking water facilities, surpassing the state's 99.47%, ensuring that students have access to clean water even during periods of water scarcity caused by droughts or changing rainfall patterns. This infrastructure is vital in protecting children's health and ensuring continuity in their education during climate-related shocks.

However, there are areas where Dharashiv lags behind. The average dropout rate in secondary education is higher in Dharashiv (14.88%) compared to Maharashtra's state average of 10.72%. This higher dropout rate indicates that more students are leaving school, which could worsen by climate change impacts. For instance, extreme weather events, like floods or droughts, may force children to abandon their education to support their families, contributing to long-term socio-economic vulnerabilities. This challenge highlights the need for targeted interventions to reduce dropout rates, especially in the context of increasing climate risks.

On a more positive note, Dharashiv fares better than the state in school accessibility. With 99.06% of schools in Dharashiv being approachable by all-weather roads, compared to 97.34% in the state, the district benefits from relatively better infrastructure that ensures students can reach their schools even during extreme weather events such as heavy rains or floods. This is crucial for maintaining uninterrupted education in rural areas, where access to schooling can be severely impacted by climate-related events. Additionally, electricity access in Dharashiv is relatively higher, with 90.51% of schools having electricity connections, compared to the state's 85.55%. Access to electricity is essential for supporting digital education tools, especially as climate change may drive the need for alternative learning methods in the event of disruptions to traditional schooling. With reliable electricity, schools in Dharashiv are better equipped to continue teaching during power outages caused by extreme weather conditions, such as storms or heatwaves.

Overall, while Dharashiv exhibits strength in infrastructure, such as functional toilets, drinking water facilities, school accessibility, and electricity access, it faces significant vulnerabilities in terms of women's education and higher dropout rates. The district's relatively low levels of educational attainment for women, coupled with a higher dropout rate in secondary education, create barriers to building long-term resilience to climate change. Addressing these gaps by improving educational opportunities, particularly for women and marginalized groups, and reducing dropout rates will be essential for reducing the district's vulnerability to climate-related impacts on education.

The ranking analysis of key education sector indicators in Dharashiv district reveals several areas of vulnerability, with higher scores indicating greater challenges. The most pressing vulnerability is the dropout rate, which has a score of 7.14, the highest among the indicators. Next to the dropout, the level of women's education, with Dharashiv scoring 3.90 for women with 10 or more years of schooling, much lower than the state's score. This gap in female education increases the district's vulnerability to climate change, as educated women are better able to contribute to climate adaptation and resilience-building efforts. In rural areas, where climate impacts are often more severe, a lack of educational opportunities for women can limit their ability to mitigate and respond to climate-related challenges.

Water and Sanitation sector

The water and sanitation sector in Dharashiv district reveals both strengths and vulnerabilities in the context of climate change. Water access and sanitation are key sectors affected by climate-related challenges such as droughts, floods, and changing rainfall patterns, and these indicators highlight how the district is positioned to cope with such impacts. In terms of drinking water access, Dharashiv has better access to improved drinking water (96.4%) though slightly lower than the state average (99.3%). While the district has relatively high coverage, the gap highlights a potential vulnerability as the district may face greater challenges in ensuring sustainable water access in the future. Climate change, which is expected to increase the frequency and severity of droughts and erratic rainfall, could affect Dharashiv's water supply, making it crucial to strengthen water management and infrastructure to cope with future anticipated uncertainties.

The district's groundwater utilization is notably higher than the state's, with 62% of available groundwater being used in Dharashiv, compared to 53.83% in Maharashtra. This higher reliance on groundwater makes Dharashiv particularly vulnerable to climate change impacts. Depleting aquifers due to over-extraction, coupled with reduced rainfall and increased evaporation rates caused by rising temperatures, could lead to severe water scarcity in the district. As agriculture heavily depends on groundwater for irrigation, this poses a serious threat to both drinking water availability and agricultural productivity in times ahead.

In context of proportions of wetlands area, 3.57% of Dharashiv's geographical area is under wetlands which is nearly at par with the state average of 3.3%. Wetlands play a critical role in maintaining water balance, filtering pollutants, and managing floodwaters. However, with climate change contributing to more extreme weather events, wetlands are increasingly at risk of degradation, which could further reduce natural water storage capacity and worsen flood risks in both the district and the state.

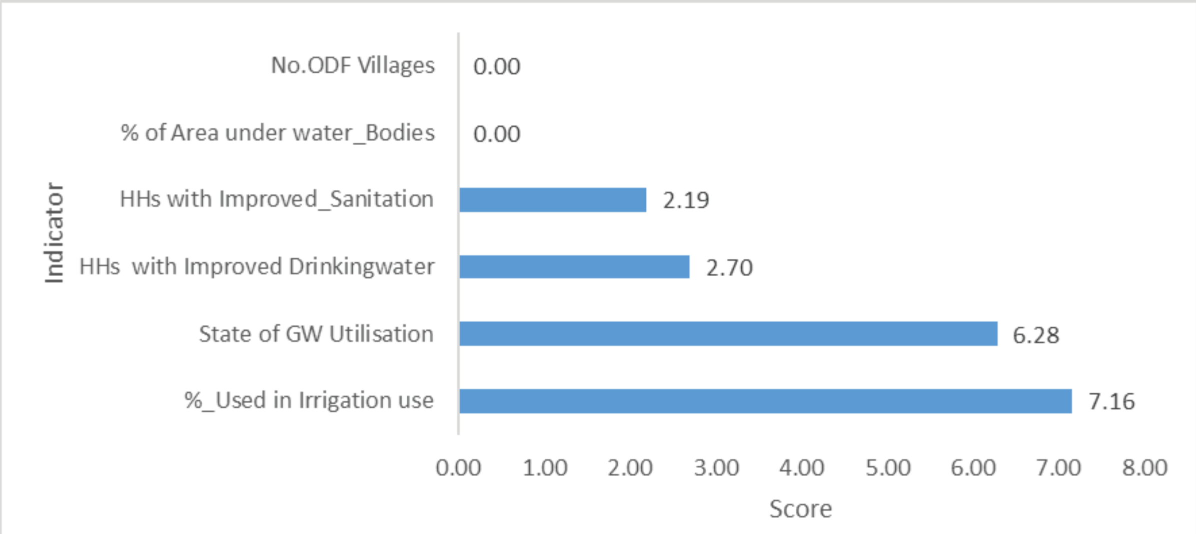
In the area of sanitation, Dharashiv lags slightly behind the state, with 71.2% of households having access to improved sanitation facilities, compared to Maharashtra's 75.1%. Improved sanitation is essential for preventing waterborne diseases, especially in rural areas where floods and water contamination due to climate events can exacerbate health risks. Although the district has made significant progress, there is still work to be done in ensuring universal access to improved sanitation.

Dharashiv's sanitation efforts is seen in its high percentage of ODF Plus villages, at 98.6%, compared to the state's 91.6%. This status signifies that the district has not only eliminated open defecation but also improved the sustainability and hygiene of sanitation infrastructure. This achievement is vital in reducing the risks of waterborne diseases, which could become more prevalent as climate change increases the frequency of extreme weather events, such as heavy rains or flooding.

The indicator wise ranking analysis of the key water and sanitation sector of the district reveals that the most significant vulnerabilities in Dharashiv is its irrigation water use, with a score of 7.16, much higher than the state's score (Fig. 8). This indicates that a substantial portion of available water resources in Dharashiv is used for irrigation, placing considerable strain on local water supplies. The district's dependence on water for agriculture makes it particularly susceptible to the impacts of climate change, such as changing rainfall patterns and droughts, which can exacerbate water scarcity. Overuse of water resources for irrigation has the potential to deplete both surface and groundwater sources, reducing water availability for households and further threatening agricultural productivity.

Similarly, the second most important indicator of water and sanitation sector vulnerability is the state of groundwater utilization in Dharashiv district which is notably higher, with a score of 6.28. This signifies that the district is heavily reliant on groundwater for both drinking and irrigation purposes. Over-extraction of groundwater has long-term consequences, such as the depletion of aquifers, making the region increasingly vulnerable to water shortages, especially as climate change is likely to reduce recharge rates and increase evaporation.

Fig 8 Dharashiv : Ranking of key Drivers of Water and Sanitation sector Vulnerability



In terms of improved drinking water access, the indicator ranked third and scores 2.70, indicating that while a majority of households have access to clean water, the district still faces challenges in ensuring universal and sustainable access. This situation can worsen due to the pressures of climate change, which can disrupt water supply systems through erratic rainfall or prolonged dry spells.

The indicator ' HHs accessibility to improved sanitation facilities' ranked 4th and scores 2.19, reflecting a gap in accessibility of sanitation infrastructure compared to Maharashtra, which scores better on this front. The lack of widespread access to improved sanitation facilities leaves communities in Dharashiv vulnerable to waterborne diseases, especially during extreme weather events such as floods, which are expected to increase due to climate change. Climate-related disasters can overwhelm existing sanitation systems, leading to contamination of water sources and public health risks.

Overall, the water and sanitation sector of the Dharashiv district faces considerable challenges, particularly in groundwater use, irrigation practices, and sanitation access. The district's high reliance on groundwater and irrigation for agriculture, combined with insufficient sanitation infrastructure, makes it highly vulnerable to climate change impacts. The district needs to prioritize sustainable water management, strengthen infrastructure resilience, and continue improving sanitation facilities to adapt to the growing pressures of climate change.

Composite level of sectoral Vulnerability and ranking of indicators

The composite vulnerability analysis of key sectors—water and sanitation, health, education, and agriculture—in the context of climate change risks, reveals varying degrees of exposure and resilience across Dharashiv district.

Water and Sanitation emerges as the most vulnerable sector with a composite vulnerability score of 3.06, indicating significant concerns. The district's over-reliance on groundwater for irrigation and drinking water, coupled with challenges in sanitation access, particularly in rural areas, makes it highly susceptible to climate change. Rising temperatures and erratic rainfall can exacerbate water scarcity, and insufficient sanitation infrastructure increases the risk of waterborne diseases, particularly during floods or droughts. This sector requires urgent attention to improve water management, infrastructure resilience, and sanitation facilities to mitigate the impacts of climate variability.

The health sector follows closely with a vulnerability score of 2.3. The district's high rates of infant mortality, child malnutrition, and anaemia among women highlight health system weaknesses. Climate change can further strain healthcare systems by increasing the frequency of vector-borne diseases, heat stress, and waterborne infections, particularly in the absence of robust healthcare infrastructure and insurance coverage.

The education sector, with a lower composite vulnerability score of 1.59, faces moderate risks. While the district has made progress in improving school infrastructure, challenges like high dropout rates, gender gaps in education, and insufficient access to basic amenities leave it vulnerable. Climate-related disruptions, such as floods or droughts, can affect attendance and further exacerbate educational inequalities.

Lastly, the agriculture sector has the lowest composite vulnerability score of 1.11, reflecting relatively lower exposure compared to other sectors. However, the heavy dependence on irrigation and the variability of crop yields in response to climate change still pose risks to food security and rural livelihoods.

Areas of concern for further investigation and actions

The ranking analysis of all the 26 key vulnerability indicators related to different sectors of in Dharashiv district reveals several critical areas of concern related to climate change risks across various sectors, including health, agriculture, water, and education. The vulnerability scores highlight the district's exposure to climate impacts, and understanding these areas is essential for devising effective climate adaptation strategies. Following are the key concern areas of the district which needs attention:

1. The most pressing concern is the Infant Mortality Rate (IMR), which has the highest vulnerability score of 7.27. A high IMR reflects poor health outcomes, which are often linked to inadequate healthcare and sanitation. Climate change, with its potential to exacerbate waterborne diseases, heat stress, and vector-borne illnesses, could significantly worsen infant health outcomes, particularly in a region with limited healthcare infrastructure.
2. Child stunting follows closely with a vulnerability score of 7.23. Stunting is largely a result of poor nutrition and insufficient healthcare, and climate change-induced food insecurity could make this issue worse. Droughts, erratic rainfall, and shifting agricultural patterns could lead to reduced food availability, worsening malnutrition, and child development outcomes in the district.
3. Groundwater use for irrigation also scores high at 7.16, indicating that Dharashiv's agriculture sector is heavily dependent on groundwater. Over-extraction of water for irrigation, combined with declining rainfall due to climate change, creates a significant risk of water scarcity, which can threaten both agricultural productivity and access to drinking water.
4. The dropout rate from primary to secondary education, scoring 7.14, highlights a critical vulnerability in the education sector. This relatively high dropout rate points to the challenges children face in continuing education,

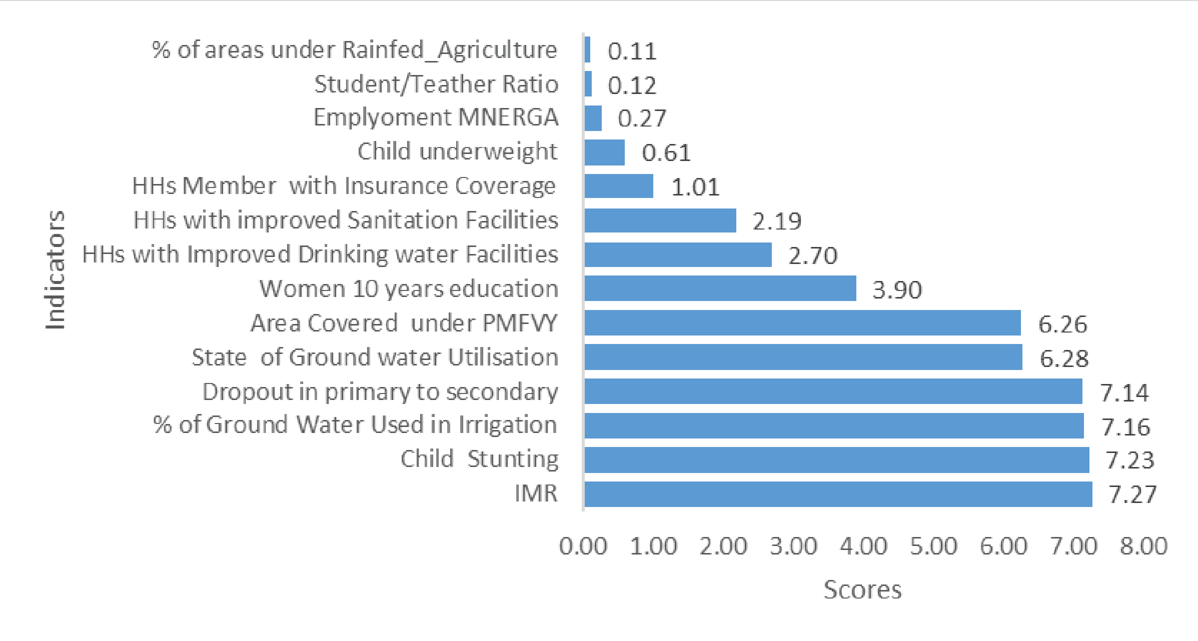
particularly in rural areas where climate-related disruptions such as floods, droughts, and extreme temperatures could further exacerbate this issue. Families may prioritize immediate survival over education, undermining long-term resilience.

5. Groundwater utilization, with a score of 6.28, indicates the district's over-reliance on groundwater as a primary water source. Given the potential for reduced recharge during dry spells and the impacts of changing rainfall patterns, this puts the district at greater risk of water shortages. In addition, PMFBY (Pradhan Mantri Fasal Bima Yojana), with a score of 6.26, shows that while some farmers are covered by crop insurance, the level of coverage is insufficient to fully shield them from the risks posed by erratic weather patterns and crop failures due to climate change.

6. Women's education, with a score of 3.90, also stands out as an area of concern. The relatively low percentage of women with 10 or more years of schooling points to a significant gender gap in education, which could limit women's ability to engage in climate adaptation and decision-making processes. Educated women are more likely to participate in climate resilience strategies and contribute to the community's overall adaptive capacity.

7. The scores for households with improved drinking water facilities (2.70) and improved sanitation facilities (2.19) suggest moderate vulnerability in these areas. Although most households have access to these services, challenges remain in maintaining consistent access, especially during extreme weather events like floods, which can contaminate water sources and overwhelm sanitation infrastructure.

Fig 11 Dharashiv : Ranking of key Drivers of District Vulnerability



In conclusion, the highest areas of vulnerability in Dharashiv are in water and sanitation sectors, and health (IMR and child stunting). To address these vulnerabilities, it is essential to invest in improving healthcare, expanding water management strategies, enhancing educational resilience, and strengthening social safety nets like insurance and MGNREGA. These interventions can help the district build resilience to face and withstand the growing impacts of climate change.