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Science-Based Climate and Crop Models in Policy and Planning

A Baseline Study Report

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Developed by:
Centre of Excellence in Disaster Mitigation and Management Indian Institute of Technology, Roorkee

Supported by:
Climate Adaptation, Resilience and Climate Finance in Rural India (CAFRI II), GIZ India

Published by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices:
Bonn and Eschborn

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Design and Layout:
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Photo credits:
Vertiver, unsplash.com

As of April 2025

New Delhi, India

GIZ is responsible for the content of this publication

On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ)

Table of Contents

List of Figures

List of Tables

1. Key Synthesis

i. Climate Impact and Vulnerability Assessment at Local Levels:
The common framework document for State Action Plan on Climate Change (SAPCC) requires each state to have a climate change vulnerability assessment of the physical and economic impact on the most vulnerable sectors. While we observed detailed climate vulnerability assessment across local, regional or state and sector-specific in the Uttar Pradesh State Action Plan on Climate Change (UP SAPCC) document. There was a lack of detailed local and sector-specific vulnerability assessment, and of related climate change research in the Himachal Pradesh State Action Plan on Climate Change (HP SAPCC) document. They are very broad and general, and overlook specific local issues.

ii. Climate Trends and Future Projections:
The climate data analysis in the SAPCC documents seems to involve a combination of historical and current climate data assessment, and modelling of future climate scenarios. While the UP SAPCC presents exhaustive findings at the state and district levels, we found that district trends and future climate projections are incoherent in HP SAPCC.

iii. Limited Cross-Sectoral Model Integration:
There is scant discussion on cross-sectoral integration of climate and crop models in the SAPCC documents. Given the interconnectivity of climate change impacts across agriculture, water, forestry, urban planning, and energy sectors, a more integrated modelling approach could yield comprehensive adaptation strategies.

iv. Consideration of Gender-disaggregated Data:
Although both documents do not explicitly detail the integration of gender-disaggregated data into vulnerability and risk assessment, they recognize the importance of community involvement in sustainable agriculture and water management practices. It is crucial to understand how climate change impacts men and women differently, especially in the agriculture and water sectors, where gender roles significantly influence lab or distribution, access to resources, decision-making capacities, and vulnerability to climate risks.

v. Bottom-Up Approach and Community Participation:
The SAPCCs do not explicitly mention whether a bottom-up approach has been used for vulnerability assessment. However, the methodology described suggests a blend of top-down and bottom-up approaches. It utilises a structured, indicator-based (top-down) framework to quantify vulnerability at a macro level (state-wide), while also implying the need for localised (bottom-up) insights through the selection of indicators that reflect the specific sensitivities and adaptive capacities of the communities within those districts. The mixed method approach allows for the integration of broad climate projections and trends with local level vulnerabilities and capacities that can inform effective adaptation measures.

vi. Institutional Framework for Monitoring and Evaluation:
Himachal Pradesh and Uttar Pradesh have proposed an effective institutional framework to oversee the implementation and monitoring of SAPCCs. Different climate change departments and cells as focal points have been established for the execution of all the processes related to their SAPCCs. Within each sector, a few nodal departments and relevant stakeholders have been allocated with the implementation of sector-wise adaptation strategies. Both states have proposed certain indicative indicators for assessing the extent of reduction in vulnerability achieved through the proposed adaptation strategies. For instance, in UP SAPCC a few Tier 1 indicators involve -the extent of crop diversification, micro irrigation, the number of houses saved from an increase in the intensity of extreme flooding events, access to knowledge for decision-making by communities and policymakers etc.

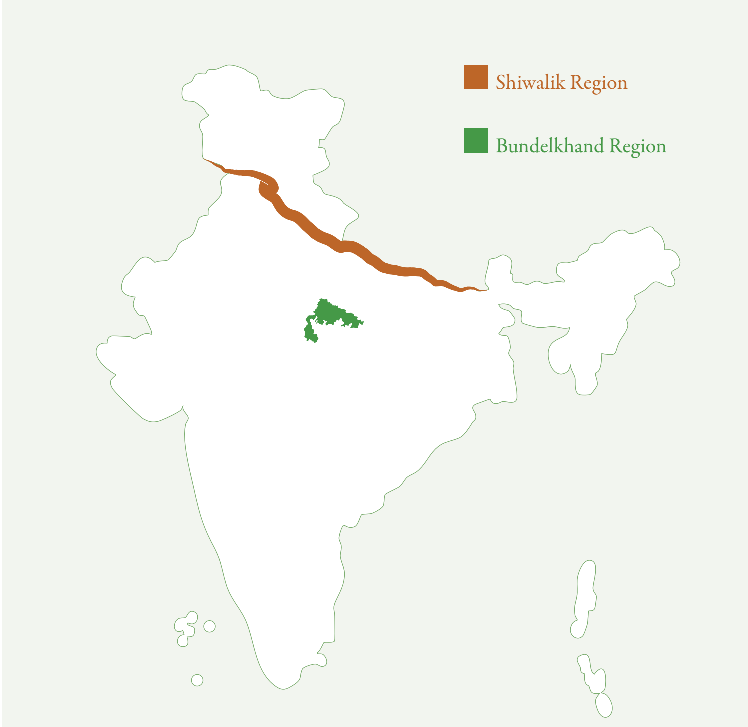
Key Parameters	Indication	Himachal Pradesh	Uttar Pradesh
Methodological Framework	IPCC Framework	IPCC AR5	IPCC AR5
Assessment Approach	Top-Down or Bottoms-Up	No explicit mention but methodology indicated mixed method approach	No explicit mention but methodology indicated mixed method approach
Spatial Scale	Subregions/District/ Sectoral Level	District and Sectoral level studies/findings not clearly interpreted	Systematic district and sectoral level assessment and interpretation
Variables	Bio-physical, Socio-economic	Considered	Considered
Adaptive Capacity	Economic, Environmental, and Human Resources	Considered	Considered
Agriculture Vulnerability	Districts (Highest)	Bilaspur	Mahoba, Banda, Chitrakoot
Agriculture Vulnerability	Major Crops Affected	Wheat, Barley, Maize, Rice	Rice, Sugarcane
SAPCC Linkages	SDGs, NDCs, State Level Plans/ Schemes/Policies	Considered	Considered
Adaptation Finance	Financial Allocations and Gap Assessment	Considered	Considered
Stakeholder Engagement	Consultations with Central/State/Local Level Players	Multi-level stakeholder participation, but local level engagement not clear	Multi-level stakeholder participation, but local level engagement not clear
Gender Risk Data Disaggregation	Integration with Vulnerability Assessment	No explicit mention	Only % of male-female engagement in agriculture profile presented

Figure1: State-wise Comparative Vulnerability Assessment Approach (Author-own compilation)

2. Need of the Study

Synthesise evidences and gaps in climate-risk-informed adaptation strategies at the grassroots level in the Bundelkhand and Shiwalik regions.

As countries and societies brace for the ongoing climate risks on agriculture and water systems, adaptation to climate change has progressed rapidly. There are global and national mandates on adaptation to climate change that call for strengthening adaptation planning and associated risk assessment. Even the recent IPCC Assessment Report 6 (AR6) highlights “the need to advance the understanding of climate change risks at sub-national levels, as well as the opportunities and impediments to adaptation action”. The present study aims to support global and national calls to assess i) if and ii) how effectively climate adaptation policy documents and scientific literature align with climate-risk-based knowledge and suggest climate-risk-informed planning at the local level.



Map disclaimer:
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Scientific literature from Bundelkhand and Shiwalik (Himachal Pradesh), highlights serious concerns regarding climate change, within these regions, with adverse effects on the livelihoods and food security of dependent farmers, as agriculture forms the main livelihood source in these regions.

In the Shiwalik region (of Himachal Pradesh), agriculture is primarily subsistence, with a high dependency rate of 70% of the state’s population engaged in this sector. Despite the reliance, only a limited land area of the state’s total area is cultivable. Productivity is constrained by small and fragmented landholdings, where 70% of plots are less than 1 hectare. The topography exacerbates the problem with excessive soil erosion and reliance on rainfall for irrigation. Similarly **agriculture in Bundelkhand**, despite being the mainstay of the rural economy, is fraught with challenges. The soil quality is poor, with both red and black soils lacking essential nutrients like phosphate and nitrogen, deeming them unsuitable for cultivation. Yields are low and water scarcity is a critical issue in Bundelkhand. With erratic and below-average rainfall, the region has seen an increase in drought frequency, impacting both agriculture and daily life. Traditional crops that required less water have been replaced by those demanding more water, straining the already limited resources in both regions.

Gender disparities are also prevalent in these regions, with women - particularly from lower castes and impoverished backgrounds - having limited access to land and water resources, and are often relegated to the low-income jobs and insecure food conditions.

Current scholarship on climate-risk-informed planning reveals severe limitations for climate risk management that are rooted in a lack of attention to interacting social drivers and their effects on risk, as well as an orientation toward analysis of climate risk at coarse social and spatial levels. These course scales of analysis do not match well with the localized natural impacts of climate change in the two identified regions. Local risk-informed planning will better inform the design of interventions targeting those dimensions and scales that have the greatest proportional contribution to adjusting to risks and will contribute informed safeguards against maladaptation.

Therefore, there is an urgent need for climate-risk-informed adaptation interventions at a local scale to reduce the adverse impacts of ongoing (and expected to increase) climate risks and foster capacities in farmers, especially women farmers.

The primary objective of this study is to synthesize evidence and gaps in climate-risk-informed adaptation strategies at the grassroots level in the Bundelkhand and Shiwalik regions. The analysis identifies gaps and presents a framework to plan and conduct a climate risk assessment (at the local level).

The study is being supported under the Indo-German **Climate Adaptation, Resilience, and Climate Finance in Rural India (CAFRI II)** project, commissioned by the **German Federal Ministry for Economic Cooperation and Development** (**BMZ**) and implemented by **GIZ India.** The CAFRI II project supports the **Ministry of Environment, Forest and Climate Change** (**MoEFCC**) and the **National Bank for Agriculture and Rural Development** (**NABARD**) to strengthen the planning, implementation, financing, and monitoring of gender-responsive, transformative, and climate-risk-informed interventions to enhance climate resilience in rural India.

Output of the study will provide an analytic framework (including recommended steps on models, methods, data and sources for in-depth science-based modelling for identifying adaptation measures in the agriculture and water sector) which shall support climate risk assessments at the local scale.

2.1 Key objectives

The specific research objectives for the study **"Science-Based Climate and Crop Models in Policy and Planning"** are:

To develop an analytical framework for assessing the evidence and climate science informed nature of the State Action Plan for Climate Change (SAPCC)/District Agriculture Contingency Plans (DCP) and literature documents.

To analyze if the SAPCCs/DCPs/Literature provide information on climate projections and its impact on crops in future (near, medium or long-term) scenario and further suggests suitable crops for the selected district.

To assess the availability of gender-disaggregated risk data in the reviewed documents and provide suggestions to incorporate such data into risk assessments.

To review if the climate models in the documents provide information of change in soil, water parameters and crop growth in the long-term scenarios.

To understand modelling and methodology gaps that need to be addressed for enabling climate-risk-informed prioritization of adaptation measures.

To recommend methods for assessing climate risk at agroclimatic zone (Bundelkhand and Shiwalik) to identify block-level adaptation options.

3. Climate-risk-informed Adaptation Planning

Why a climate risk lens? In the 5th Assessment Report (AR5), the IPCC introduced risk-based approaches for the scientific understanding of climate change, and to support adaptation decision-making. Risk is more holistic as it moves beyond impacts, and includes a cost-benefit analysis of different adaptation measures under different scenarios.

In the face of increasing climate challenges, under the purview of climate-risk-informed planning adaptation actions are informed by the magnitude and frequency of climate change impacts, and future climate scenarios, along with accounting for uncertainties inherent to future conditions highlights the importance of adaptive policies that are informed by climate risks and can guide development in the face of future climate uncertainties. The risk-based approach allows for flexibility in dealing with uncertainty and a wide variety of scenarios for not only high-probability events but also low-probability (potentially highly damaging) events.

3.1 Top-down approach

The top-down approach to risk-informed planning uses climate as a starting point for analysis. Due to the difficulty of assigning appropriate probabilities to various consequences of climate change scenarios, the effectiveness of this approach has been investigated in contemporary applications (Desai and Hulme, 2004). Despite its widespread use, this approach tends to ignore the subtle complexities of local socio-economic and resource availability, requiring more granular planning for effective local-level implementation.

3.2 Bottom-up approach

In contrast, the bottom-up approach begins with current vulnerabilities, focusing on the resilience and robustness of planning alternatives. It is tailored to address the complex interplay of social, economic, and resource dynamics within specific locales. This methodology is dynamic, allowing for the evolution of adaptation strategies with continuous integration of new information and technological advancements (Borgomeo et al., 2018). Techniques such as decision-scaling and the adaptation pathways approach exemplify this method, emphasizing a more empirical and localized analysis that aligns with the credible climate information available (Brown et al., 2012).

3.3 Climate-risk-informed adaptation planning at the local level in Bundelkhand and Shiwalik region

For regions like Bundelkhand and Shiwalik, local risk-informed planning is not just critical but indispensable for adaptation and the implementation of measures tailored to the regions' specific needs. These areas exhibit unique vulnerabilities and resource management challenges that cannot be effectively addressed by generic top-down strategies. Scientific literature further highlights additional problems linked to the nature of climate change and adaptation when approached from a top-down outlook. For climate-risk-informed planning at the local level, these problems need to be understood and addressed. The current analysis will review the state/district/block-level

Top-down Outlook

- Time scales and time horizons
- Limited understanding and uncertainties of climate projection and scenarios
- (Often) low agreements among different climate models
- Baseline periods, and changing baseline in time
- Cross-sectoral and multi-level nature of adaptation

policy and scientific literature documents to synthesize evidence and gaps around these problems. In addition to the problems stated above further challenges, there are further challenges in implementing local-level climate-risk-informed action. These challenges are crucial for understanding and addressing climate change from a bottom-up perspective, as they relate to the specific difficulties faced when planning and executing adaptation strategies at the local scale. For instance, Spatial Scales (What is meant by local?)', which underscores the importance of defining 'local' in a geographical context. This challenge involves delineating the boundaries within which climate-risk-informed actions are planned and executed, ensuring that local specificities are adequately captured.

3.4 Synthesis of evidence and gaps

For synthesizing the evidence and gaps in the current integration and implementation of climate-risk-informed adaptation in policy and scientific literature, the report evaluates how climate and crop models are integrated into policy frameworks. The documents reviewed using the assessment framework include the State Action Plan on Climate Change (SAPCC), the district contingency plan, and scientific literature (based on crop and climate models from 2000-2023 from Web of Science) for Bundelkhand region (of Uttar Pradesh) and Shiwalik region (in Himachal Pradesh). Figure 1 represents the **Climate-Risk Informed Adaptation Action Assessment Framework (CRIAAAF)** to assess whether/and how climate risk information is integrated into the agriculture-water sector. The CRIAAAF raises three key questions important for locally-informed climate risk management. These questions drive the inquiry into how climate system variables, such as rainfall, temperature, and drought, influence agricultural outputs and how models like General Circulation Models (GCM) and Regional Climate Models (RCM) can inform adaptation strategies. The central importance of understanding the agriculture (related water component) systems is at the core of modelling climate-crop system interactions, requiring the connection of crop models that can simulate crop growth and development under varying climatic scenarios.

However, several challenges (Figure 1 (last row)) in implementing local-level climate risk management emerge, stemming from issues such as scale—which includes spatial, temporal, and governance, model uncertainties (both for climate and crop models), changing baseline periods, data availability, and heterogeneity among the actors like gender and technological disparities among actors. Management issues relating to the use of inputs, resource policies, and services also play a pivotal role in deriving the results of crop modelling however often not available at the granular scale required. Finally, one of the most critical challenges is to integrate the joint assessment of suggested adaptation measures which requires a reconciliation of different interests and priorities among a diverse group of stakeholders, including policymakers, financial institutions, extension services, and farmers. More importantly, the last mile of joint assessment must consider the socioeconomic and gender-related dynamics that influence the vulnerability and capacity of communities to adapt to climate change. **The framework suggests a dual approach incorporating both top-down and bottom-up strategies** to identify suitable adaptation strategies, where top-down focus on future climate scenarios and bottom-up prioritizes adaptive capacity and vulnerability at a local level. By bridging the gap between large-scale climate modelling and local-level applicability, **this framework aims to inform policies that are both scientifically robust and socio-economically equitable.**

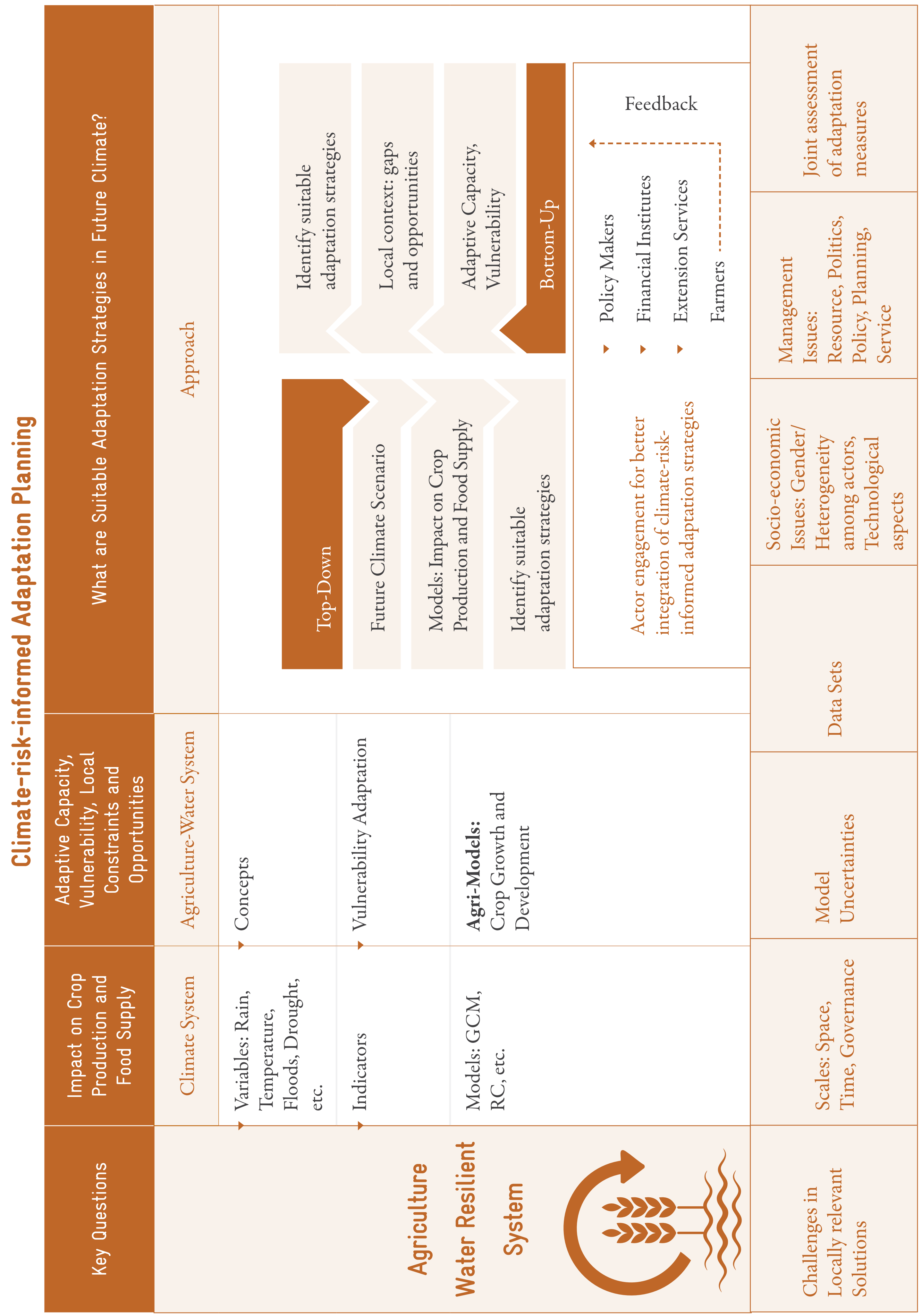


Figure 2: Climate-Risk Informed Adaptation Action Assessment Framework (CRIAAAF). CRIAAAF's 3-step framework showcases the key questions, the complex agriculture-water system, and the challenges in implementing locally relevant climate-risk-inform ed solutions.

4. Key terms

Terms	Definitions	References
Risk	Risk is the **potential/likelihood** for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. Risks can also arise for example from **uncertainty in the implementation**, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions.	Adger et al., 2018; AR6, IPCC WG II, 2022
Climate Risk	In the context of climate change, **risks can arise from potential impacts of climate change as well as human responses to climate change.** In the context of **climate change impacts**, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making. In the context of **climate change responses**, risks result from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals (SDGs).	AR6, IPCC WG II, 2022; Reisinger et al., 2020
Adaptation *(in human systems)*	The **process of adjustment** to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities.	AR6, IPCC WG II, 2022
Adaptation Action	Adaptation actions are defined as a **plans, strategies, or activities** for addressing the impacts of climate change, including climate variability and extremes. Actions could also include a mix of policies and measures that have the overarching objective of reducing vulnerability to climate change impacts. They include a wide range of actions that can be categorised as **structural, institutional, ecological or behavioural.**	Lesnikowski et al., 2011; Biagini et al., 2014; AR 5, Chapter 15, IPCC WG II, 2014
Climate-Risk-Informed Action	Adaptation actions are informed by the magnitude and frequency of climate change impacts, future climate scenarios, along with accounting for uncertainties inherent to future conditions.	Murieta et al., 2021; Mendosa et al., 2018; Matthhews and Mendoza, 2015
Local-level Action	Local-level action focus on tackling climate change from the ground-up, led by communities with more place-based and community approaches at local-level as the scale of action. Local-level action is also defined as a process that is sensitive to local opportunities, priorities, and ideas with more culturally and ecologically appropriate, and more empowering for individuals that are impacted by them. Calls for co-creating solutions through the generation of genuine partnerships, resulting in more inclusive, needs-driven, local-level responses. Ultimately, local-level action aims to enable local governments and communities to be the catalysts of change to adapt to climate risks.	UNESCAP [Localization of SDGs]; Coger et al., 2022; Rahman et al., 2023

5. Evaluation of State Action Plan on Climate Change

5.1 Introduction

In the year 2008, climate change was recognised as a global problem by the Government of India and moving forward, the Prime Minister's Council on Climate Change was formulated to devise a National Action Plan on Climate Change (NAPCC) that elucidated eight national missions to aid the climate change mitigation and adaptation strategies in the country. Recognising the key role of the state/local level in achieving the objectives of NAPCC, a process for decentralisation of action plans was initiated in the year 2009 and each state was requested to prepare a State Action Plan on Climate Change (SAPCC) based on a common framework while factoring in the socio-economic and geographic variations across these regions. In light of evolving policy frameworks and commitments at both global (Paris Agreement) and national levels (Sustainable Development Goals [SDGs], Nationally Determined Contributions [NDCs]), the Ministry of Environment, Forestry and Climate Change (MOEFCC) in the year 2018 released the 'Common Framework for Revision of State Action Plan on Climate Change'. It underscored the Government of India's perspective on evolution in the science of climate change and a better understanding of the socio-economic impacts of the evolving crisis.

This section reviews the SAPCCs within Himachal Pradesh (Shiwalik regions) and Uttar Pradesh (Bundelkhand region) in the agriculture and water sectors. The state-wise information was assessed based on the availability of data on current and future climate projections and their sources, vulnerability assessment methodology, and different adaptation strategies proposed and prioritised based on the climate risks and impacts identified within the respective sector. Scope of this analysis is to bring out the evidence and gaps/challenges in integrating vulnerability and risk assessments at the grassroots level, which remains a critical baseline for planning climate-risk informed adaptation strategies.

An in-depth examination of the state action plans facilitated an understanding of the prevailing vulnerabilities across the states and the key observations from evaluation of SAPCCs- Himachal Pradesh and Uttar Pradesh have been presented in the following sections.

5.2 Himachal Pradesh State Action Plan for Climate Change (HP SAPCC)

5.2.1 Climate change projections under HP SAPCC

Historical Data: Based on the Indian Meteorological Data (IMD) Gridded Data for 63 years i.e.1951-2013, historical climatic data in the SAPCC shows an increase in annual maximum and minimum temperature, however, both trends have been recorded as statistically insignificant. The maximum mean annual temperature i.e. 25 degrees Celsius has been recorded in the Bilaspur and Solan districts of Himachal Pradesh. Whereas, the analysis of annual rainfall and the number of rainy days reveals a negative trend with a statistical significance indicating that both have declined since 1951.

Temperature	Precipitation	Climate Extreme Events
Increasing trend in maximum temperature (low confidence) and minimum temperature (low confidence)	Decreasing trend in average annual rainfall (high confidence) and number of days (high confidence)	Decreasing trend extreme events like 1 day maximum precipitation, warm nights and warm spell duration of indicator (low confidence)

Table 1: Summary of Observed Climate Variability and Trends at the State level (Reference: HP SAPCC 2021-2030)

Future climate projections: The future projections on precipitation, temperature, or extreme events are based on recent studies conducted by the State Department of Environment, Science and Technology along with GIZ (See Table 2). It has utilised the CORDEX multi-model simulated for the Mid-Century Scenario using Representative Concentration Pathways i.e. RCP 8.5 and RCP 4.5 scenarios for 2021-50. However, local, and sector-specific future climate projections with specific periods are not available. These projections remain critical for sectors such as agriculture and water, where the impact of climate change could significantly affect crop yields, water availability, and soil health, among other factors.

Projected Temperature change		Projected Precipitation change		Climate Extreme Events
RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	Heat waves and stress, Heavy rainfall, floods, urban storms and drought going to increase.
T max: 1.4°C T min: 1.4°C	T max: 1.6°C T min: 1.8°C	Increase by 5.9%	Increase by 8.5%	

Table 2: Summary Of Future Climate Projection (Reference: HP SAPCC 2021-2030

5.2.2 Vulnerability assessment under HP SAPCC

The combined vulnerability index of district-level based on 34 indicators (linked with hazard, exposure, sensitivity, and adaptive capacity) for the baseline 2011-12 and 2017 was computed using the Principal Component Analysis method1 after normalisation. Based on findings, except for the Mandi district where vulnerability has increased in comparison to 2011-12, most of the districts have shown only a marginal change while Hamirpur has shown a considerable improvement.

Whereas, the sectoral vulnerability assessment for mid-century and end-century have been documented based on secondary sources like the Indo-German development cooperation project Climate Change Adaptation in Rural Areas of India (CCA-RAI) and National Initiative on Climate Resilient Agriculture i.e. NICRA project. The findings reveal that the overall water resources vulnerability of the district is projected to exacerbate further towards the mid and end centuries for both emission scenarios. The agriculture vulnerability of the Bilaspur district is highly vulnerable as indicated under NICRA. Furthermore, based on the proposed information in the SAPCC, the review also attempted to qualify the vulnerability assessment methodology against a few key parameters as highlighted in above Figure 2.

5.2.3 Risk and Impact Evaluation: Agriculture and Water Sectors

Agriculture Sector

The state has witnessed a decline in the share of agriculture from 26.86% in 1990-91 to 9.68% in 2016-17. The evaluation reveals sectors' historic sensitivities as well as future climatic variations, with rainfall patterns and temperature shifts.

These are presented based on the studies conducted by the State Centre on Climate Change (for instance, Impact of Rainfall on Agriculture in HP for four major crops viz. wheat, barley, rice and maize) and other secondary sources (like the INCAA 2010 report and journal papers).

The climate data from RCP 8.5 and 4.5 indicate an increase in extreme events like heavy rainfall, drought, heat waves and floods in the state which could have severe implications on the agriculture sector along with agriculture-dependent communities and farmers especially with monoculture of wheat/maize, least diversification, low-value addition.

Impacts

It highlights escalating precipitation vulnerabilities in agriculture such as -

- Altered crop seasons
- Impact on crop yields and productivity
- Soil health degradation (like enhanced erosion risks, diminished fertility and modifications in soil moisture content)
- Increased pest activity due to warmer conditions.

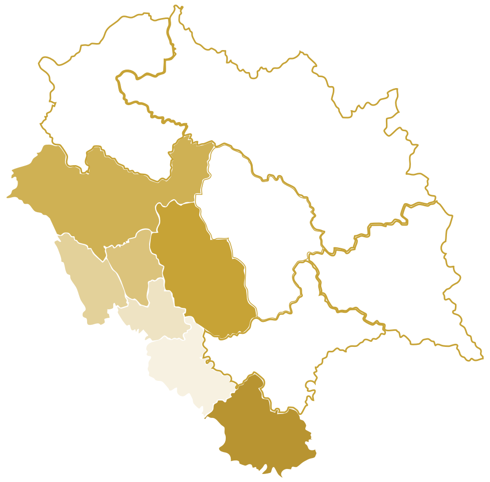
Other challenges related to cultivation on small and terraced plots, and agricultural landscapes, and the absence of advanced irrigation and moisture management infrastructures are further exacerbated due to the climate risk.

Water Sector

For the impact on the water sector, SAPCC proposes key observations based on the GIZ study on climate change impact assessment on the water sector carried out by biophysical models. Except for districts Una, and Hamirpur, the rest of the districts showed high and very high vulnerability indices under both emission scenarios (See Table 3, where L: Low, M: Moderate, H: High, VH: Very High, EH: Extremely High)

Impacts

The analysis also predicted an increase in evapotranspiration in Sirmaur districts and a high magnitude of floods in districts like Kangra and Hamirpur. An expected escalation in water availability variability towards the mid and end of the century poses substantial risks to both the volume and quality of water accessible for agricultural purposes. The other challenges associated with water resources include water accessibility and availability for irrigation and potable supply, compounded by heightened evaporation rates.



District	Baseline Rank	RCP 4.5		RCP 8.5	
		Mid Term	End Term	Mid Term	End Term
Bilaspur	12 (VH)	EH	VH	VH	VH
Hamirpur	2 (L)	L	L	L	L
Kangra	5 (H)	H	H	H	H
Mandi	11 (VH)	VH	VH	VH	H
Sirmaur	6 (H)	H	H	H	H
Solan	9 (VH)	VH	VH	H	H
Una	3 (L)	M	L	L	L

Table 3: Current and Projected Variability in Water sector (Reference: HP SAPCC 2021-2030)

5.2.4 Adaptation Strategies under HP SAPCC

Stakeholder Consultations: The adaptation strategies proposed are based on the findings derived from climate change impacts and vulnerability assessments at the state level. Post adaptation strategies formulation, stakeholder consultations with relevant departments were held to prioritise strategies (See Figure 3a and 3b) for each sector. For this, a multi-criteria -analysis-based scorecard was used for which NDC-SDGs linkage was assigned the highest weightage (50%) followed by Implementation potential (30%) and funding linkage was assigned 20% weightage.

Financial Allocations Vs Vulnerabilities: Considering the sector vulnerability due to climate change and declining occupational profile, out of a total of Rs. 10,917 Crores Budget proposed from 2021-30, the agriculture and water sectors have been allocated Rs. 4895 Crores each from the central and state schemes. The budgetary allocations for adaptation activities across each sector have been based on direct linkages with NDC-SDGs, implementation potential and funding.

Impacts

- Decrease in Agricultural production due to Increasingly small land holdings and climate variables
- Impact on Crop Yields
- Crop failures
- Sensitivity (Food shortages, income) of Agriculture dependent communities w.r.t climate variability
- Soil Health Degradation

Adaptation Strategies

- AG/N/1: Sustainable Land Use Management.
- AG/N/2: Promotion and development of Resilient High Value Crops to promote viable solutions for farmers
- AG/N/3: Analysis of impact of climate change oncrop yield change, demand and supply
- AG/N/4: People centric watershed development and soil conservation
- AG/N/5: Revision and implementation of Contingency Plans
- AG/N/6: Use of communication technology for disseminating weather related information
- AG/N/7: Foster and promote the efficient use of water in agriculture
- AG/N/8: Promate development of eco/bio villages to improve livelihood resillence in high altitude regions
- AG/N/9: Promoting Crop diversification
- AG/N/10: Promote balanced use of fertilizersand pesticides and improvement of market linkages for agro-horticulture products

Funding Sources

Adaptation Fund, NAFCC, Program/Project Linked Funding

Budget Allocation

Total Budget: ₹10,917 Crores
Proposed Budget (2021-30): ₹4,895 Crores
Sources: Central and State Schemes
Funding Gaps: ₹2,473 Crores

Prioritization

- AG/N/1: Sustainable Land Use Management
- AG/N/2: Promotion and development of Resilient High Value Crops to promote viable solutions for farmers
- AG/N/5: Revision and implementation of Contingency Plans
- AG/N/7: Foster and promote the efficient use of water in agriculture
- AG/N/8: Promote development of eco/bio villages to improve livelihood resilience in high altitude regions

Multi-Criteria-Analysis-Based Score Card based on linkages with NDC-SDG, Implementation Potential and Fundings

Linkages

- **SDGs :** Goal 2, Goal 6, and Goal 12.
- **INDC:** To better adapt to climate change by enhancing investment in development programmes in sectors vulnerable to climate change, particularly agriculture.

M & E

- Reduced key risks and adverse impacts of climate change
- Irrigation intensity, cropping intensity
- Agricultural insurance policy, including new crops

State level Schemes:

- G/N/1: Himachal Pradesh Crop Diversification Promotion Project Phase II
- AG/N/4: National Mission on Sustainable Agriculture (NMSA), Integrated farming system.
- AG/N/5: Calamity Relief Fund
- AG/N/6: ATMA, National e-governance Programme
- AG/N/7: Saur Sichai Yojana, Jal se Krishi ko bal, Flow Irrigation Scheme, Per drop more crop-Supplementary management activities under PMKSY
- AG/N/8: Eco Village Scheme
- AG/N/9: Mukhya Mantri Nutan Poly house Pariyojana
- AG/N/10: NMSA, Soil Health Card, Paramparagat Krishi Vikas Yojana (PKVY)

- Crop diversification
- % of individuals who have diversified income sources
- No. of FPOs strengthened.
- Enhanced food and water security
- No. of cold store chains created

Broad Indicators for Evaluating Climate Change Activities

M & E

Implementation Mechanism

- Department of Agriculture,
- Department of Soil Conservation,
- Horticulture Universities,
- Research Institutions

Figure 3a: Climate Impacts and Proposed Adaptation Strategies in the Agriculture Sector from HP SAPCC Evaluation

Photo Credit/Vertiver

Impacts

Reduced Water su pplies for irrigation and potable purposes

Water Quality

Heightened Evaporation Rates

Floods due to increase in water discharge

Adaptation Strategies

- WR/N/1: Reduced demand of water in state by controlling, leaks, water saving programs, cascading and reusing water.
- WR/N/2: Promotion of Integrated water resource management. Expansion and maintenance of STPS in the State to promote recycling of water leading to reduced groundwater extraction.
- WR/N/3: Promotion of spring shed management.
- WR/N/4: Development of Contingency plans for water sector/ improved defense during hazards.
- WR/N/5: Participatory Irrigation management through Water User Association with emphasis on crop water budgeting .

Funding Sources

Adaptation Fund, NAFCC, Program/Project Linked Funding

Budget Allocation

Total Budget: ₹10,917 Crores
Proposed Budget (2021-30): ₹4,895 Crores
Sources: Central and State Schemes
Funding Gaps: ₹1800 Crores

Prioritization

- WR/N/1: Reduced demand of water in state by controlling, leaks, water saving programs, cascading and reusing water.
- WR/N/2: Promotion of Integrated water resource management
- WR/N/3: Promotion of spring shed management
- WR/N/5: Participatory Irrigation management through Water User Association with emphasis on crop water budgeting

Multi-Criteria-Analysis-Based Score Card based on linkages with NDC-SDG, Implementation Potential and Fundings

Linkages

- **SDGs :** Target 6.1, Target 6.3, Target 6.4, Target 6.5
- **INDC:** Adaptation strategies for water sector focus on enhancing efficient use of water, ensuring access and tackling adverse impact of climate change.

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- Enhanced food and water security
- Rise in ground water level
- State water policy addressing climate risk to specific to state

State level Schemes:

- WR/N/3: PMKSY
- WR/N/5: Himachal Pradesh Forest Ecosystems Climate Proofing Project (KfW supported)

Broad Indicators for Evaluating Climate Change Activities

M & E

Implementation Mechanism

- Department of Jal Shakti
- Department of Agriculture

Figure 3b: Climate Impacts and Proposed Adaptation Strategies in the Water Sector from HP SAPCC Evaluation

Photo Credit/Dmytro Glazunov on unsplash.com

5.3 Uttar Pradesh (UP) State Action Plan for Climate Change (UP SAPCC)

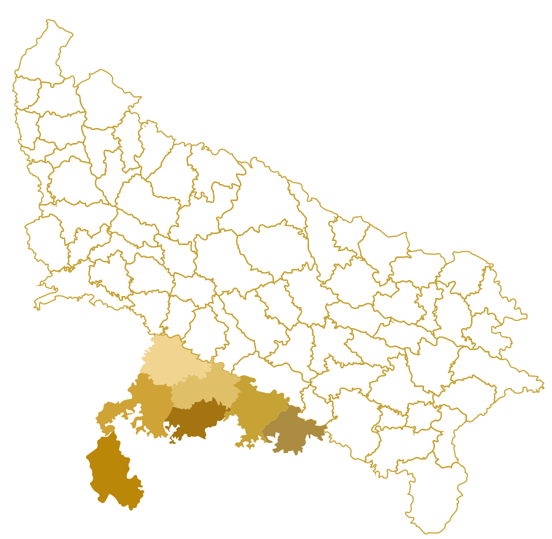
5.3.1 Climate change projections under UP SAPCC

Observed Climatic Trends: The UP SAPCC document presents a comprehensive state as well as district-level analysis of observed temperature and precipitation trends and variability between 1980-2019. For the data sets, daily gridded rainfall and temperature available at a spatial resolution of 0.25°x0.25° and 1.0°x1.0° latitude and longitude respectively have been extracted from the IMD database for the grids of each of the 75 districts in Uttar Pradesh from 1980 to 2019.

As presented, the state-level analysis between 1980 and 2019 for temperature indicates a rising trend in annual average maximum and minimum temperature whereas annual rainfall has shown a decreasing trend. The state-level trend is consistent with the district-level analysis which also shows a consistently increasing trend across districts for both average maximum and minimum temperature. For annual rainfall as well as monsoon rainfall, there is a uniform decrease in all districts (except a few) between 1980 and 2019. During this period the highest average maximum temperature as well as annual rainfall (See Table 5) was recorded in Lalitpur among the seven districts in the Bundelkhand region.

Temperature	Maximum Average Temperature	Minimum Annual Average Temperature
Change% between 1981-2019	Decreasing trend in average annual rainfall (high confidence) and number of days (high confidence)	Decreasing trend extreme events like 1 day maximum precipitation, warm nights and warm spell duration of indicator (low confidence)
Rainfall	Annual Average Rainfall	Monsoon Rainfall
Change% between 1981-2019	Decreased by 6.7 mm per year	Decreased by 5.8 mm per year

Table 4: State-Level Observed Climate Variability (Reference: UP SAPCC 2021-30)



District	Max. Avg. temp (oC)	Min. Avg. temp (oC)	Annual Rainfall (in mm)
Banda	32.4	19.07	822
Chitrakoot	32.36 (Lowest)	19.10 (Highest)	875
Hamirpur	32.52	18.94	751 (Lowest)
Jalaun	32.47	18.92	783
Jhansi	32.7	18.68	783
Lalitpur	32.74 (Highest)	18.52 (Lowest)	940 (Highest)
Mahoba	32.51	18.94	885

Table 5: Table 5: District-Level Observed Climate, Variability (Reference: UP SAPCC 2021-30)

Climate Projections: The climate projections analyzed for both state and district levels (current as well as future) have been derived for temperature and precipitation (both annual as well as seasonal) for two standardised forcing scenarios RCP 4.5 (mid-range emissions) and RCP 8.5 (high-end emissions) scenarios for Near-term (2011-2040), Mid-term (2041-2070) and End-Century (2071-2100) to Baseline (1981-2010). The climate projections have been derived from an ensemble average of 10 of the RCM outputs from Coordinated Regional Climate Downscaling Experiment (CORDEX3) South Asia datasets which is suitable for the Indian region. At the state level, the annual average maximum and minimum temperature in Uttar Pradesh is projected to rise towards the near-term, mid-term and end century under both emission scenarios. Whereas the average rainfall is projected to decrease towards the near term and increase by the end term for both RCP4.5 and 8.5 scenarios. As for mid-term, annual average rainfall is projected to decrease under RCP4.5 but it is likely to increase under RCP8.5. (See Table 6).

Variability	Baseline	Near Team		Mid Term		End Term	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 4.5
Maximum Temperature (deg C)	29.4 - 32.9	30.5 - 34 (↑1.04)	30.6 - 34.2 (↑1.24)	31.3 - 34.7 (↑1.75)	32.1 - 35.6 (↑2.60)	31.5 - 35 (↑2.06)	34-37.3 (↑4.37)
Maximum Temperature (deg C)	16.9-19.9	17.9 - 20.9 (↑0.98)	18.1 - 21.1 (↑1.20)	18.9 - 21.9 (↑1.90)	20 - 23 (↑2.98)	19.4 - 22.4 (↑2.40)	21.9 - 25.3 (↑5.01)
Annual Rainfall (in mm)	597.2 - 1515.3	565.5 - 1455.1	557 - 1580.5	568.6 - 1585.6	605.9 - 1569.2	631.8 - 1598.9	691.9- 1706.5

Table 6: State-Level Future Climate Projections (Reference: UP SAPCC 2021-30)

District	Annual Average Maximum Temperature (oC)						
	Baseline (1980-2019)	Near Term		Mid Term		End Century	
Scenerios		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Banda	32.6	33.7	34	34.5	35.3	34.8	37
Chitrakoot	32.6	33.7	34	34.5	32.6	34.7	37
Hamirpur	32.7	33.7	34.1	34.5	32.6	34.8	37.1
Jalaun	32.7	33.8	34.1	34.5	32.7	34.8	37.2
Jhansi	32.6	33.6	34	34.4	32.7	34.7	36.9
Lalitpur	32.4	33.4	33.7	34.2	32.6	34.5	36.9
Mahoba	32.7	33.8	34.1	34.5	32.4	34.8	37.1

District	Annual Average Minimum Temperature (oC)						
	Baseline (1980-2019)	Near Term		Mid Term		End Century	
Scenerios		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Banda	19.5	20.5	20.8	21.5	22.6	22	24.8
Chitrakoot	19.6	20.6	20.9	21.6	22.8	22.1	25
Hamirpur	19.2	20.3	20.5	21.2	22.4	21.7	24.5
Jalaun	19.2	20.2	20.5	21.2	22.3	21.7	24.4
Jhansi	19.1	20.1	20.4	21.1	22.2	21.6	24.3
Lalitpur	19.3	20.3	20.5	21.2	22.3	21.7	24.3
Mahoba	19.2	20.2	20.5	21.2	22.3	21.7	24.5

District	Annual Rainfall (in mm)						
	Baseline (1980-2019)	Near Term		Mid Term		End Century	
Scenerios		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Banda	889.4	851.6	817.4	834.1	884.7	913.6	961
Chitrakoot	941.1	880.9	865.4	871.6	922.8	948.1	989.1
Hamirpur	813.2	800.1	768.1	785	834.5	872.2	932.3
Jalaun	756.2	737.2	712.2	731.1	773.6	814.9	875.9
Jhansi	818.8	777.2	775.4	799.4	817.8	868.3	925.4
Lalitpur	985.7	960.8	927.8	978.9	1020.8	1016.7	1026.8
Mahoba	909.7	855.5	848.4	866	900	934.2	1001

Table 7: District-Level Future Climate Projections (Reference: UP SAPCC 2021-30)

At the district level, the climate projection analysis reveals that all the Bundelkhand region districts are expected to record higher maximum and minimum temperatures in the near-term, mid-term and end-term for both RCP 4.5 and RCP 8.5 scenario than the annual average temperature recorded during baseline (See Table 7). When compared to the baseline, the projection reveals (See Table 7) a decrease in annual average rainfall towards near term and mid-term under RCP 4.5 and RCP 8.5 scenarios for all districts, except Hamirpur, Jalaun and Lalitpur which shows an increase in rainfall towards mid-term under RCP 8.5 scenarios. Whereas towards the end century for both emission scenarios, there is a predicted increase in the average rainfall for all districts.

5.3.2 Vulnerability assessment under UP SAPCC

After the assessment of current climatic trends and future projections, the evaluation extends to current sectoral climate vulnerabilities across all districts guided by the methodological framework of the IPCC AR5. The multi-step exercise identified, ranked and prioritised the most vulnerable districts for each of the specified sectors under the current climate. An integrated vulnerability assessment system has been employed that uses a tier 1 method that quantifies indicators and uses secondary sources of information at the district-level. Both the sectoral vulnerability across each district as well as the composite vulnerability of the districts for these SAPCC missions have been assessed. To assess agricultural and water vulnerability at the district level, a total of fourteen and five indicators respectively, along with the rationale for their selection, sensitivity or adaptive capacity, their functional relationship with vulnerability (i.e. positive or negative) and the sources used to quantify them were considered. The UP SAPCC presents detailed insights on the sectoral (i.e. agriculture and water) vulnerability along with major drivers of the districts based on different Vulnerability Classes- Very High, High, Moderate, Low and Very Low (Percentage Contribution ≥0.035) (See figure 4 a and 4 b).

In the agriculture sector, out of the seven districts, Banda and Chitrakoot were identified as very-high vulnerable districts; Hamirpur and Mahoba were ranked as highly vulnerable and districts with moderate vulnerability were identified as Lalitpur, Jhansi and Jalaun. In the water sector, a total of five indicators were considered to assess district vulnerability on a similar approach. Hamirpur, Jalaun and Lalitpur were ranked as having very low vulnerability; Jhansi and Mahoba ranked as low vulnerable; Banda and Chitrakoot ranked as Moderate vulnerable districts.

5.3.3 Risk and Impact Evaluation in UP SAPCC: Agriculture and Water Sectors

Uttar Pradesh being an agro-climatically diverse state, is known for various food grains, cash crops and horticultural crops. Climatic variability like rainfall and temperature pose a significant impact on major crop yields (like rice and sugarcane). The Bundelkhand region has been identified as drought-prone, and eastern UP has been shown to experience frequent floods and waterlogging risks. The UP SAPCC delineates a rigorous, evidence-based approach to understanding the impacts of climate change on agriculture based on a comprehensive evaluation of secondary sources cited within the document.

Agriculture Sectors

Increased Frequency of Extreme Weather Events: The region has witnessed a marked uptick in the frequency and severity of extreme weather conditions, such as intense rainfall and prolonged dry spells. These events have directly impaired agricultural activities by damaging crops, altering agronomic timelines, and diminishing soil fertility through erosion.

Temperature Escalation and Heat Stress: Rising temperatures across Uttar Pradesh have inflicted heat stress on crops, particularly detrimental during pivotal growth stages, thereby reducing yields.

Variable Rainfall Patterns: An observable trend towards erratic monsoon patterns, characterised by delayed onset and premature cessation, adversely affects rain-fed agriculture. This irregularity in rainfall distribution jeopardizes water availability for irrigation, potentially leading to drought or flood scenarios.

Droughts: As documented, the Bundelkhand region faced an average of nine severe drought episodes, with the 1983-1985 drought in the Jalaun district emerging as particularly calamitous. The persistent drought conditions, intensified by climatic shifts and anthropogenic factors, are identified as key drivers of poverty and environmental degradation in the Bundelkhand region.

Decline in Productivity: Climate change is projected to precipitate a decrease in productivity by up to 25% in irrigated zones and 50% in rain-fed areas, with Bundelkhand notably impacted due to monsoon variability and water scarcity. This trend has significantly undermined crop yields in recent years.

Water Sector

With an increase in temperature and change in flow dynamics, the quality of water bodies (biological and chemical integrity) has been reduced thereby impacting clean water availability for irrigation and other uses. Moreover, climate change, alongside demographic expansion and industrial growth, has resulted in escalated water demand in the agricultural and domestic spheres, intensifying the strain on water resources. The variability in rainfall patterns, coupled with over-extraction for agricultural purposes, has led to a pronounced decline in groundwater levels in Bundelkhand. This decline is further compounded by decreased recharge rates.

5.3.4 Adaptation Strategies under UP SAPCC

Stakeholder Consultations: The UP SAPCC 2021-2030 has prioritised adaptation strategies with an implementation period of 2021–2030 based on identified climate risks and vulnerability (See Figure 4a and 4b) in consultations with departmental stakeholders and experts. A **total of five strategies for each agriculture and water sector have been evolved** to deal with the climate change impacts.

For the five strategies in the agriculture sector, a **total of 19 actions/sub-actions have been proposed while a total of 26 actions/sub-actions are proposed in the water sector.** These strategies are further categorized into **two classes, based on their type of climate actions** i.e., **adaptation-centric, mitigation-centric or both**; and based on the **nature of actions i.e., implementation, policy, research, and capacity building**. In addition, considering the importance of adaptation to extreme weather events and building climate-resilient agriculture **in Uttar Pradesh, 83 per cent of the total 19 actions are adaptation-centric and considering water as a local issue, 84 per cent of the actions proposed are adaptation-centric.**

Finance Allocation Vs Vulnerabilities: The adaptation actions have been prioritized based on their linkages with U-NDCs and SDGs, availability of funds and ease of implementation. **The total budget required to implement UP SAPCC 2.0 has been estimated to be ₹ 1,12,204.79 crores.** To implement the proposed adaptation activities, the **maximum fund allocations have been prioritised to the water sector i.e. ₹ 64,170.13 crores, followed by the Sustainable Agriculture Mission i.e. ₹ 29,798 crores.** In addition, analysis has been undertaken to assess the gap in the availability of finance for the implementation of these strategies. Further, probable sources of funds have been identified for each of the actions to estimate the share of financial requirements to be met by various sources.

Climate Risks and Impacts

1. Socio-economic losses

- Poverty
- Food security
- Livelihood disruptions
- Increased mortality rates, Enforced migrations.

2. Declined Productivity and crop yields

3. Temperature Escalation and Heat Stress

Sugarcane, rice

4. Droughts

Crops

5. Rainfall variability

Sugarcane
rice

Vulnerable Districts

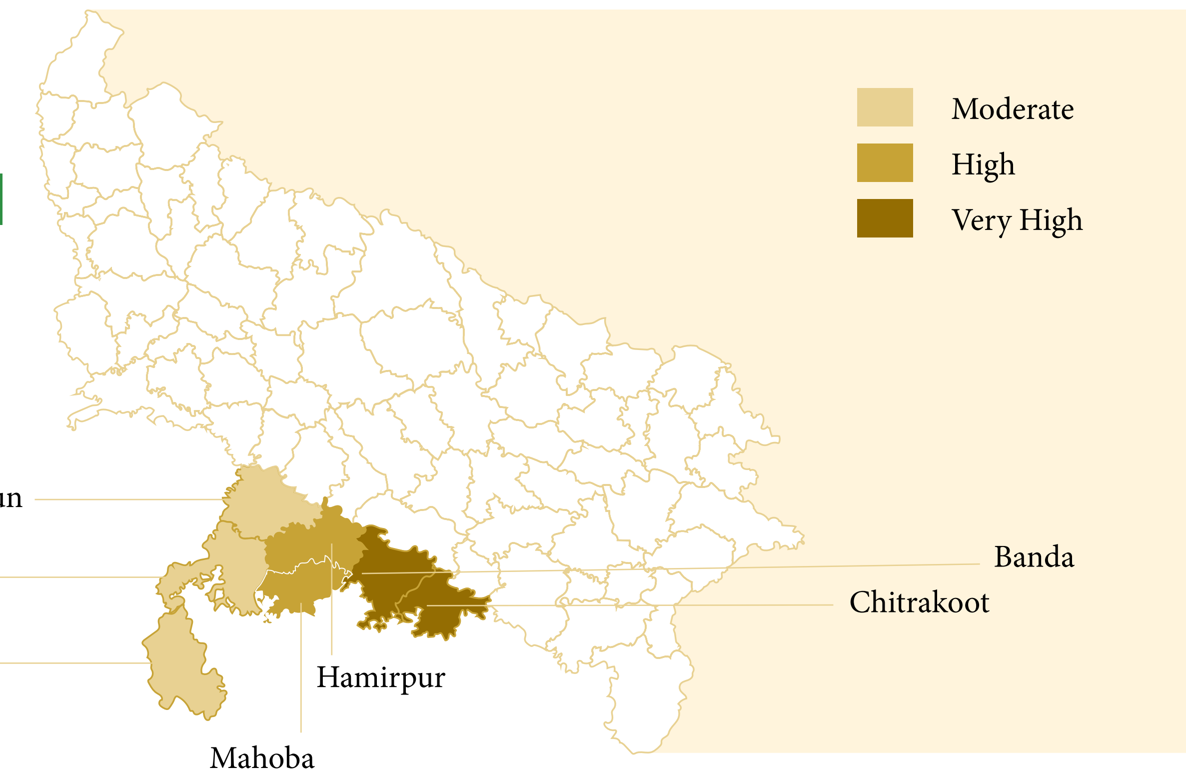


Figure 4 (a): Climate Impacts and Proposed Adaptation 4 Strategies in the Agriculture Sector from UP SAPCC Evaluation

Adaptation Strategies

1. Generate high-resolution weather forecasts. Ensure access to weather forecasts and agro- met services by all farmers (**2 Actions**)
2. Undertake wide spread training of FPO farmers on climate smart practices, techniques and tools to help them understand and address the impacts of climate change (**3 Actions**)
3. Mainstram climate smart adaptation practices and technologies through implementation of pilots covering all agro-climatic zones in UP (**3 Actions**)
4. Improve water use efficiency in agriculture with a focus on rice and sugar cane (**5 Actions**)
5. Enable enhanced access to risk sharing measures for farmers in a changing climate regime (**6 Actions**)

Linkages

SDG 2 | SDG 8 | SDG 13 | NDC 06

Relevant Schemes/Policie/Programs

- UP Atmanirbhar Krishak Samanvit Vikas Yojana
- Promotion of Farmer Producer Organization and Business Activities scheme.
- National Mission on Sustainable Agriculture
- Rashtriya Krishi Vikas Yojana
- National Crop Insurance Program
- Uttar Pradesh Diversified Agricultural Support Project
- Cane Development Schemes
- National Mission on Agriculture Extension and Technology

Budgetary sources:

Private Climate Finance
National Funds and National Financial Institutions

International Funds:

Total Budget: ₹ 1,12,204.79 Cr.
Proposed Budget: (2021-30): ₹ 29,798.00 Cr
Funding Gaps: ₹ 6817.72 Cr

M & E

- Agriculture Department
- Horticulture and Food Processing, Dept. of Fisheries, Dept. of Animal Husbandry and Dairying, Directorate of Sugarcane Development, District Agro-Meteorological Units, KVKs, NABARD
- Relevant technical institutes, Universities, NGOs

Indicative indicators for Tier 1* and Tier 2*

Implementation Mechanism

Figure 4 (a): Climate Impacts and Proposed Adaptation 4 Strategies in the Agriculture Sector from UP SAPCC Evaluation

Climate Risks and Impacts

1. Rainfall Variability

Surface and groundwater

2. Temperature Variability

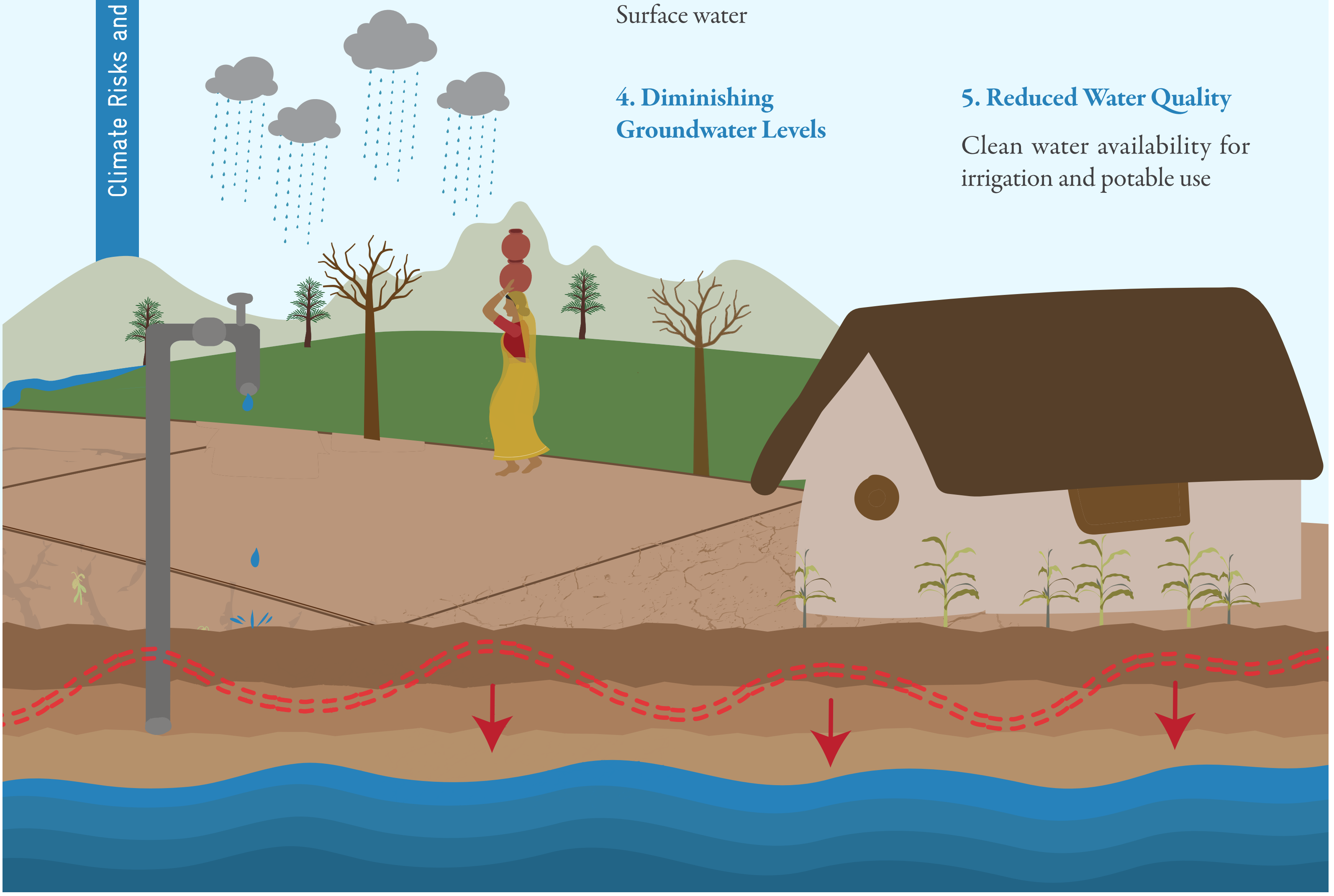
Surface water

3. Escalated Water Demand and Stress

4. Diminishing Groundwater Levels

5. Reduced Water Quality

Clean water availability for irrigation and potable use



Vulnerable Districts

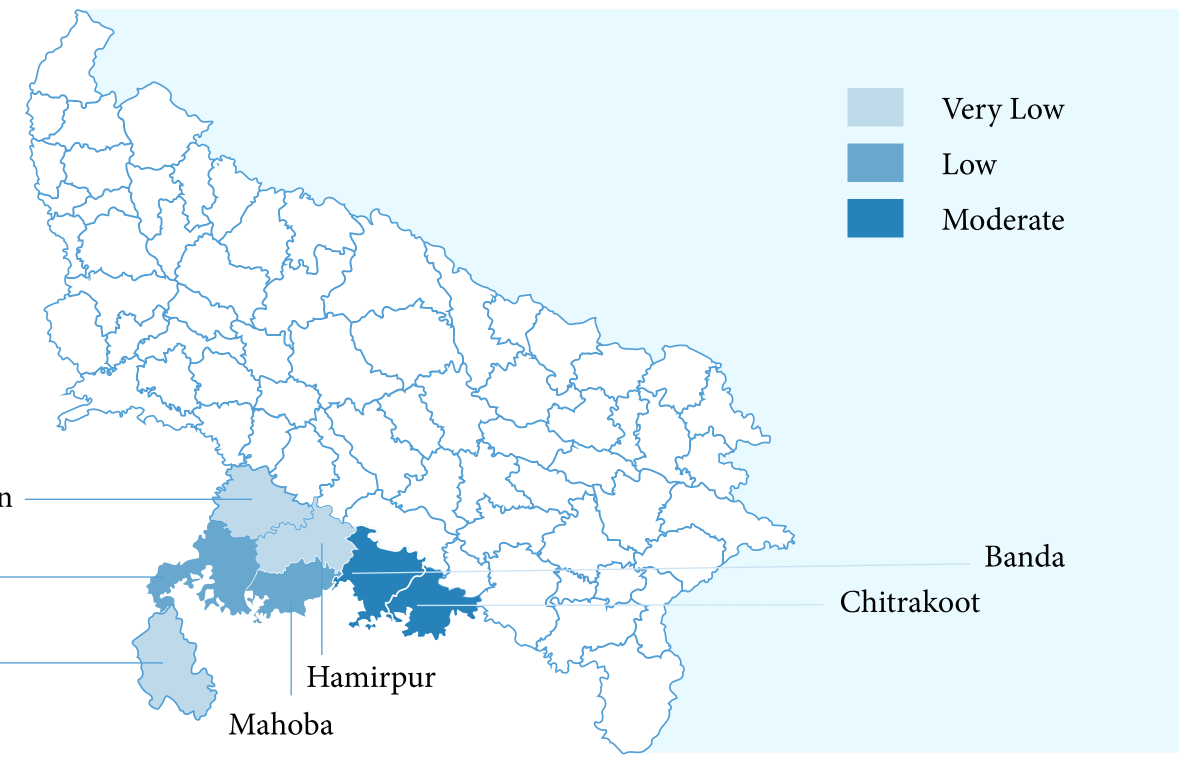


Figure 4 (a): Climate Impacts and Proposed Adaptation 4 Strategies in the Water Sector from UP SAPCC Evaluation

Adaptation Strategies

1. Enhanced monitoring and research to establish water budgets and manage water at micro-watersheds (**5 Actions**)
2. Strengthening water sector infrastructure to adapt to climate change (**3 Actions**)
3. Enhanced water use efficiency across sectors to reduce surface water and groundwater dependency (**9 Actions**)
4. Enhanced efforts towards groundwater recharge (**6 Actions**)
5. Readying for frequent and 0 unprecedented floods at even non-traditional flooding regions and months (**2 Actions**)

Linkages

SDG 2 | SDG 8 | SDG 13 | NDC 06

Relevant Schemes/Policie/Programs

- Namami Gange: Bundelkhand Project, Jal Jeewan Mission, RWSSP
- State Groundwater Board: Rainwater Harvesting, Catch the Rain, National Hydrology Project etc.
- Minor Irrigation: Scheme for the Construction of Check Dams for Rain Water use and Ground Water Recharging, Scheme for Blast well, Tube wells etc.
- Irrigation and Water Resources Department: Construction and maintenance of dams, barrages, canals and tube wells, Participatory irrigation management, Flood protection works and Embankment construction etc.

Budgetary sources:

Private Climate Finance
National Funds and National Financial Institutions

International Funds:

Total Budget: ₹ 1,12,204.79 Cr.
Proposed Budget: (2021-30): ₹ 64,170.13 Cr
Funding Gaps: ₹ 16,868.93 Cr

M & E

- Dept of Namami Gange and Rural Water Supply
- Irrigation and Water Resources Department, Groundwater Department, Minor Irrigation, SWARA, UP Jal Nigam, Gram Panchayats, ULBs
- Relevant technical institutes, Universities, NGOs

Indicative indicators for Tier 1* and Tier 2**

Implementation Mechanism

Photo Credit/Vertiver

Figure 4 (b): Summary of Climate Impacts and Proposed Adaptation Strategies in the Water Sector from UP SAPCC Evaluation

6. Evaluation of District Agriculture Contingency Plans (DCP)

6.1 Introduction

The Ministry of Agriculture and the Department of Agriculture and Cooperation (DAC) requested the Indian Council of Agricultural Research (ICAR) to take up the responsibility of preparing contingency plans at the district level. The ICAR under the National Agricultural Research Project (NARP) delineated existing zones in the country into 126 agro-climatic zones. These zones comprised relatively homogeneous districts or part of districts useful for regional-level planning to deal with weather-related aberrations. The plan aimed at mitigating the repercussions of climate variability and change while following a localized and risk-informed decision-making approach.

The District Level Contingency Plans delineate strategies for weather-related contingencies impacting agricultural practices across each district of various states. These plans are technical documents containing integrated information on agriculture and allied sectors (i.e., horticulture, livestock, poultry, fisheries). It outlines various strategies to mitigate adverse effects on agriculture due to climatic variability and aims to be utilised by district authorities. A standard template (See Figure 5) was developed in consultation with all stakeholders to cover prevailing agroecological situations in the district, possible in-season contingencies and suggested adaptive strategies.

For review, we analyzed each district contingency plan (extracted from https://www.icar-crida.res.in) for its agriculture profile, normal cropping system, and weather aberrations, and suggested changes in crops/cropping systems along with agronomic measures to exhibit resilience to different aberrations (See Annexure 1). In conclusion, through participatory planning, and the implementation of targeted contingency measures, it stands as a valuable resource for stakeholders at all levels—from local communities to government agencies—in establishing a resilient climate-smart agricultural system.

6.2 Key Observations: Evidence/Gaps for Localized and Risk-informed Approach in the District Contingency Plans

Evidences

District-Level Customization: The contingency plans are tailored to the specific needs and challenges of each district, acknowledging the diversity within the state in terms of climate, soil types, topography, and cropping patterns. The prevailing climate-related challenges in each district are unique ranging from drought conditions, floods and cyclones, alongside other climatic perturbations such as hail storms, heat waves, cold waves, and frost events that affect the Kharif and Rabi cropping cycles. These targeted interventions allow to address the unique agricultural vulnerabilities of each district, making the contingency measures more precise and effective.

Near-term/Immediate contingency strategies: The documentation expounds on near-time proposed strategies on alternative crops and varieties tailored to each major farming situation in case of droughts (early-season, mid-season and terminal) and other aberrations. These include crop diversification, use of climate-resilient crop varieties, and improved water and soil management practices etc. However, the contingency plans does not account for strategies under long-term climate scenarios.

Integrative Approaches to Planning/Implementation: The DLCPs advocate for a participatory process engaging stakeholders ranging from policymakers to local farmers at all planning and implementation stages. It involves utilizing advanced weather forecasts, government coordination, and state and district-level monitoring at various levels. By involving local farmers, agricultural experts, and research institutions in the planning process, the plans are informed by a deep understanding of each district's unique environmental conditions, crop patterns, and challenges. This ensures that contingency measures are relevant and practically applicable, enhancing their effectiveness.

Proactive and Adaptive Management: The contingency plans being developed and refined continuously based on the latest weather forecasts, crop progress reports, and emerging challenges. This adaptive management ensures that the plans remain relevant and effective in the face of changing weather conditions and agricultural practices.

Implementation Mechanism: At the national level, the Ministry of Agriculture monitors weather conditions and coordinates preparedness for droughts and other contingencies through the crop weather watch group. At the state level, the Commissioner Department of Agriculture oversees the weather situation at the block level and prepares reports on the progress of sowing and the status of farm inputs. The Relief Commissioners are responsible for coordinating the implementation of contingency plans during natural hazards like droughts and floods. The coordination between various levels of government and departments ensures that there is a comprehensive understanding of the situation on the ground, allowing informed decisions and timely and effective responses during weather aberrations.

Gaps

Capacity Building and Awareness: While the plans are exhaustive, the success largely depends on the awareness and preparedness at the farm level. There is a need for continuous capacity building and awareness programs to ensure that farmers are well-informed about the contingency plans and the actions they need to take in response to weather alerts.

Funding and Resources:

The implementation of contingency plans requires significant resources, including funding for mobilizing inputs, conducting awareness programs, and infrastructure development for effective water management. The document does not explicitly address the financial aspects, which could be a potential gap in ensuring that adequate resources are available when needed.

Factsheet: District Contingency Plans Climate Risk Integration In Himachal Pradesh and Uttar Pradesh

Key Questions Addressed?

- Impact on crop production and food supply: No reference
- Adaptive Capacity: No reference
- Local Level Constraints: Yes
- Adaptation Strategies: Yes (Immediate/Near-Term agronomic measures)

Agriculture Water Resilient System

Climate System

Weather Abberations: Droughts, floods, heat wave, cold wave and pest outbreaks
Time scale: Near/Immediate term situations
Climate Models: No information

Agri-Water System

Vulnerability: District-wise major contingencies (weather aberrations) indicated
Adaptation: Suggested measures for change in cropping system and agronomic measures based on local level bio-physical andcrop conditions
Agri/Crop Growth and Development Model : No information

Assessment Approach:No reference

Stakeholders Engagement on Climate-risk-informed Strategies

- Ministries/ Key Departments, Financial Institutes, Research Universities/ Institutions
- Local communities/ farmers– No information

Evaluation of Climate-risk-informed Adaptation Planning in District Contingency Plans for Himachal Pradesh and Uttar Pradesh

A GLIMPSE ON STANDARD TEMPLATE OF DCPs

Agro-climatic zones	ICAR-NARP-126 zones Delineation Parameters: topography, rainfalls, soils, cropping patter, agricultural practices adopted by local farming community	
Climate Risks	Droughts, floods/cyclones, heat wave/cold wave, frost, pest outbreaks, Seawater intrusion /coastal salinity	
Standard Template of Contingency Plans	**Profile 1: District agriculture profile** • Agro-climatic/ecological zone • Rainfall—seasonal, total, rainy days • Land use • Soils • Gross and net sown area • Irrigation—gross area, net area • Major field and horticultural crops • Livestock—large and small ruminants • Poultry • Fisheries • Production and productivity of major crops • Sowing window • Major contingencies in the district • Location map and soil map of district	**Profile 2: Strategies for weather related contingencies** • Drought-rainfed situation Early season drought Delay in onset by 2, 4, 6, and 8 weeks Normal onset of monsoon followed by early, midseason and terminal drought • Drought-irrigated situation Delayed release of water due to low rainfall Limited release of water due to low rainfall No release of water in canals Lack of inflows into tanks Insufficient groundwater recharge • Unusual rains (untimely/unseasonal) for both rainfed and irrigated situation • Floods • Hailstorm • Heat wave/cold wave
Inputs for developing Contingency Plan	Agro-climatic/ecological zone, Rainfed/irrigation level, Sowing/Planting Window, Crops/Production Systems, Rainfall pattern, Types and Frequency of Weather Aberration	

KEY HIGHLIGHTS

- District level customization planning tailored to the specific needs and, weather anomalies.
- Multi-stakeholder consultations involving ICAR-NRM, ICAR-CRIDA,ICAR-RCER, ICAR-NEH, NBSSandLUP, DWM, CSWCRandTI, PDFSR, CAZRI, KVKS, SAUs.
- Presents near-time proposed strategies on alternative crops and varieties to each major farming situation in case of droughts (early-season, mid-season and terminal) and other aberrations.
- DCPs does not account for strategies under long-term climate scenarios.

KEY WEATHER ABERRATIONS IDENTIFIED

Himachal Pradesh:

- Bilaspur/Kangra: Drought, Heat Wave, Cold Wave, Frost (Occasional: Hailstorm)
- Hamirpur: Drought, Cold Wave, Frost (Occasional: Hailstorm)
- Mandi: Drought, Hail-storm, Cold Wave, Frost (Occasional: Heat wave)
- Solan: Drought, Hailstorm (Occasional: Flood, Heat wave, frost)
- Sirmaur: Heat and Cold wave, Frost (Occasional: Drought)
- Una: Drought, Cold Wave, Frost (Occasional: Flood, Cyclone, Hailstorm, Heatwave)

Uttar Pradesh

- Banda/Chitrakoot/Hamirpur/Lalitput/Jalaun/Jhansi: Drought, Heatwave
- Mahoba: None (Occasional: Drought, Heat Wave, Cold wave, Frost)

BARRIERS

- Inefficient capacities and unawareness at farm level for weather aberrations
- No indication on funding and resource allocation linkages with plans
- No information on crops under long term climate scenarios

Figure 5: Factsheet for Climate Risk Integration in DCPs of Himachal Pradesh and Uttar Pradesh

7. Evaluation of scientific literature on climate risk and agri-water sector in Shiwalik and Bundelkhand region

7.1 Introduction

For understanding how climate risk concerns have been addressed in scientific-literature, peer-reviewed journal articles were analyzed. We downloaded the literature published between 2000-2024 from SCOPUS and Web of Science literature search platform for both the regions. Search keywords included 'climate', 'climate risk', 'agriculture', 'water', and 'farmer'. The published literature present the multifaceted nature of climate change impacts in the Bundelkhand and Shiwalik region, showcasing the importance of both macro-level climatic variable assessments (including analysis of mean climatic condition based on temperature and precipitation variables) and local-level studies (using participatory and perception related studies) to understand and address the climatic risks.

For Bundelkhand finally a total of 30 articles were selected after deleting the non-relevant articles5, and duplicate articles. Table 9 presents the findings of key studies in the Bundelkhand region, a full list of literature is attached as annexure. Table 9 illustrate the diverse range of studies focusing encompassing temperature and rainfall variability, droughts, agriculture growth (Lemon Grass), Non-Timber Forest Produces (NTFPs), and the impacts of these changes on agriculture, livelihoods, and water resources.

Agro-climatic variables	Summary
Temperature (Rai et al, 2021)	• Significant increasing trend in both annual maximum (0.5 to 2.0°C per 100 years) and annual minimum (0.5 to 1.1°C per 100 years) temperatures across 6 locations in Bundelkhand. • An increase in minimum temperature more significantly than the maximum temperature over a period of 37 years. • Jhansi and Banda districts show a warming trend also in the monsoon season. • Banda district exhibited a significant increase in TM during the monsoon season, with a rise of 2.9°C over the century.
Rainfall (Jana et al., 2017; Pandey et al., 2021; Ahmed et al., 2019)	• Decline in Monsoon • Annual, seasonal, and monthly rainfall and temperature trends, with an overall decreasing trend in annual rainfall for the region. • Another study analyzing annual and seasonal scales from 1981 to 2018, this research highlighted negative rainfall trends and their implications on drought conditions. • Sagar, Panna, and Damoh shown the lowest annual rainfall, indicating specific areas of concern for water scarcity.
Drought	• SPEI and SPI indictors used to assess drought severity and frequency. • August and September are the most sensitive months towards climate variability, showing a negative trend in precipitation, which could increase the risk of drought events.
(Jana et al., 2017; Dwivedi, et al., 2024)	• Significant drought periods in the region impact on the water resources and agricultural productivity in the region. The study found a declining trend in precipitation over the years, contributing to the exacerbation of drought conditions and challenging water resource management efforts.

Agro-climatic variables	Summary
Crop yield and climate (Sah et al., 2024)	• Impacts of climate variables studied on **pulses, groundnuts,** and NTFPs. • Pulses: With every 0.1degree C increase in maximum temperature during crop period would lead to yield reduction by 38.5 kg/ha, 40.7 kg/ha and 26.9 kg/ha in chickpea, lentil and pigeon pea, respectively. • Groundnuts: High-intensity rainfall events (64 mm/day ≤ rainfall intensity < 128 mm/day) and delays in the onset of monsoonal rainfall showed a negative correlation with groundnut yields, indicating that excessive or untimely rain is detrimental to crop production. Most impact recorded for Jhansi district. • The frequent and prolonged periods of drought in Bundelkhand severely affect the water availability for irrigation, leading to decreased pulse production. Pulses like pigeon peas (tur), mung beans, and urad beans are particularly vulnerable as they require consistent water supply during certain growth stages.

Table 8: Summary of Key Trends Of Climatic Variables from Literature for Bundelkhand Region

The findings reported from the observed climate data also match with the findings from perception of framers in the region (Study by Jatav et al., 2024). The findings of the study also reveal that farmers observe an increase in seasonal temperature and decrease in rainfall. Such local level studies based on perception are critical as they reflect on the understanding of farmers, because when farmers correctly understand the nature and extent of climate change, they are more likely to adopt appropriate strategies that can mitigate the adverse effects on their agriculture and livelihood.

As no clear boundary of the **Shiwalik region** was found (also reported ambiguity in the spelling of the term (Kumar et al., 2020)) we searched for peer-reviewed articles for state of Himachal Pradesh, India. Along with the search keywords 'climate', 'climate risk', 'agriculture', 'water', 'farmer', 'Himachal Pradesh' was added. A total of 80 articles were selected for the final review. The detailed list of the papers attached in the Annexures. Based on the classification detailed by Yadav et al., 2005; 2014, Shiwalik region follow the ecological zone of Sub Montane and Low Hill Sub-tropical in the Himachal Pradesh State. Therefore, information on district Kangra, Una, Hamirpur, Bilaspur, Solan, Chamba, Sirmour were synthesized. Major Crops include Wheat, Maize, Paddy, Pulses, Oilseeds, Barley, Sugarcane, Potato, and dominant fruits include Citrus fruits, Mango, Litchi.

Agro-climatic variables	Summary
Temperature (Arundhati et al., 2021; Panwar et al., 2019; Vaidya et al., 2018; Rana et al., 2017)	• Minimum temperatures in Kullu (0.82°C), Shimla (1.09°C), and Kinnaur (0.03°C) from 1985 to 2020, indicating increased temperatures may be affecting apple cultivation by altering chilling requirements necessary for optimal fruit development. • Temperature fluctuations across different altitudinal zones in the North-Western Himalayas, with annual minimum temperatures decreasing by -0.09°C at lower altitudes (350-400 m) and maximum temperatures increasing by 0.05°C at mid-altitudes (1400-1500 m) and decreasing by -0.08°C at higher altitudes (2000-2100 m). These variations affect local climatic conditions and agricultural productivity. • A general warming trend in Kullu District, with an increase of 0.02°C in mean minimum temperature during both rabi and kharif seasons from 1971 to 2016, potentially influencing crop phenological stages and productivity. • Increase in mean temperatures in Shimla (0.050°C), Palampur (0.019°C), and Kullu (0.046°C) over the past 3 to 4 decades, impacting chill unit accumulation and consequently, the productivity of temperate fruits like plums, pears, peaches, and apricots.
Rainfall (Mehta et al., 2022; Panwar et al., 2019)	• The spatiotemporal variability of rainfall in Himachal Pradesh from 1971 to 2020, noting a decreasing trend in annual rainfall with a significant decrease of approximately 2.28 mm/year. This change indicates a shift that could impact water availability and agricultural practices in the region. • The irregular and seasonal rainfall patterns across different altitudes in the North-Western Himalayas, noting the highest variability at lower altitudes and the lowest at higher altitudes. This highlighted increased frequency of extreme rainfall events at lower to mid-altitudes post-2005, suggesting shifts in climate dynamics that could exacerbate water management challenges. • Another study reported a decreasing trend in rainfall in the apple-growing regions of Kullu, Shimla, and Kinnaur, with decreases of 5.3 mm, 3.3 mm, and 0.9 mm respectively. This reduction in rainfall contributes to increased drought risk and impacts the suitability of these areas for traditional apple farming.
Drought (Arundhati et al., 2021; Panwar, et al., 2019; Rana et al., 2017)	• **Kullu, Shimla, and Kinnaur Districts:** A decrease in precipitation alongside increasing temperatures, which increases drought risk and impacts the suitability of these regions for traditional apple farming. The reduction in precipitation of 5.3 mm, 3.3 mm, and 0.9 mm respectively in these districts signals potential water scarcity issues, affecting both agricultural practices and the natural chilling periods required for apple cultivation. • **North-Western Himalayas:** Seasonal rainfall variability, particularly in the post-monsoon season, indicates a heightened risk of drought, especially at lower altitudes. The study discusses how irregular and seasonal rainfall patterns, with longer dry seasons, pose challenges for agricultural productivity and water resource management. • Increased frequency of extreme rainfall events observed at lower to mid-altitudes after 2005 suggests shifts in climate dynamics that could exacerbate drought conditions intermittently. • The decreasing winter rainfall noted in the study, with reductions of 9.86 mm, 11.1 mm, and 8.6 mm per year in Shimla, Kullu, and Palampur respectively, affects the accumulation of chill units. This reduction in winter rainfall, coupled with observed temperature increases, contributes to reduced snowfall and delayed snow onset, which in turn can lead to drought-like conditions by affecting the moisture availability crucial for winter crop success and temperate fruit productivity
Crop yield and climate (Mehta et al., 2022; Singh et al., 2022; Arundhati et al., 2021)	• Erratic rainfall patterns shorten cropping calendars and impact agricultural productivity, indicating potential challenges for crop yield stability. • The impact of climate, agricultural, and socio-economic factors on crop diversification in Himachal Pradesh, India: - Rainfall and minimum temperature negatively affect crop diversification, while factors like population density and farm size positively influence it. Additionally, irrigation intensity and food crop productivity have a negative impact on crop diversification, indicating a tendency towards crop specialization. • Despite temperature increase, areas in Shimla, Kullu, and Kinnaur remain suitable for apple farming, with growers shifting to low chilling varieties to maintain production. • Another study highlights that irregular and markedly seasonal rainfall patterns pose potential challenges for crop yield stability, particularly with longer dry seasons impacting farming systems in the North-Western Himalayas.

Table 9: Summary of Key Trends of Climatic Variables from Literature for Shiwalik Region

7.2 Key Observations: Evidence/Gaps for Localized and Risk-informed studies in the two regions

While there's progress in understanding climate impacts, significant gaps remain in localized data interpretation, risk assessment, and decision-making frameworks to guide farmers and decision-makers in regions facing climate vulnerabilities. Studies have provided a significant amount of data regarding the increasing trends in both annual maximum and minimum temperatures across various locations in the Bundelkhand and Shiwalik regions, indicating a warming trend that affects agriculture and water resources. **There's evidence of a decline in monsoon rainfall, with negative trends over the years, impacting drought conditions and water scarcity** in specific areas such as Banda. Further, the influence of climate variables on crop productivity has been quantified for certain crops like pulses and groundnuts, showing that temperature increases and irregular rainfall patterns negatively affect yields. The gaps for localized and climate-risk-informed studies still remain. Following are the critical gaps:

There is a lack of engagement with climate change accounting for long-lived assets in agriculture, pointing to a broader gap in integrating climate scenarios into financial and asset planning.

Data collection and technological tools for modelling climate impacts are underdeveloped, limiting the ability of farmers and accountants to make informed decisions about long-lived agricultural assets.

The decision framework for climate-risk integrated asset measurement is in its nascent stages and requires further testing and development to be practical and effective in diverse agricultural industries and regions.

8. Recommendations: How to plan for a science-based climate risk analysis at local-scale?

Planning for a science-based climate risk analysis at a local scale involves a combination of sophisticated modelling, on-the-ground knowledge, and an understanding of both the potential impacts of climate change and the vulnerabilities of local systems. Following are the key recommendations that can help to overcome the gaps identified in the SAPCCs, DCPs, and Scientific literature – that address the science of climate change, the incorporation of multi-climate models, the acknowledgment of uncertainties in the long-term scenarios, and the need to focus on locally relevant as agro-climatological indices, along with participatory stakeholder approaches for evaluating and prioritizing locally-relevant adaptation strategies:

- **Understanding local climate systems:** Develop a comprehensive understanding of local climate systems, leveraging historical climate data and observed trends in temperature, precipitation, and extreme weather events. Utilize localized agro-climatic variables and indices, such as the onset of rainfall, dry spells, and percentile-based temperature thresholds, to better predict the start and end of growing seasons and identify risk periods for crops. Prioritize the use of agroclimatological indices that are directly relevant to agricultural productivity, such as the number of days with significant rainfall or extreme temperatures, and the duration of dry periods. Building a correlation model with these indices with crop yield data to understand the impacts of different climate variables on agricultural output can also further aid in crop-specific interaction of different climate variables.
- **Multi-model climate projections and long-term scenarios**: Usage of regional climate models to generate projections, understanding that each model has its own set of assumptions and potential biases. Use ensemble model outputs to capture a range of possible futures, which can provide a more robust picture of potential climate scenarios than any single model. Incorporating long-term climate scenarios into planning efforts, considering changes over decades rather than just a few years. This involves planning for different time horizons (e.g., 2020s, 2050s, 2080s) to understand how risks may evolve and what that means for agricultural practices and water management.
- **Uncertainty and communication of uncertainty:** Uncertainty in climate risk assessments arises from various sources, including limitations in climate models, variability in future emissions scenarios, and incomplete knowledge about the impacts of climate change on specific systems. Uncertainty complicates the task of making precise predictions which can affect the robustness of the adaptation strategies proposed in SAPCCs. Effective communication of uncertainty involves transparency about its scope and origins, using visual tools like probabilistic maps and uncertainty bands, and engaging stakeholders through discussions and interactive tools. Adaptation strategies must be robust and flexible, incorporating no-regret measures and adaptive management, with regular monitoring and updates to reflect new data and evolving conditions. **This approach ensures action plans remain resilient and responsive to the uncertainties inherent in climate risk assessments.**
- **Consideration of Gender risk data:** Conducting gender-sensitive data collection on access to resources, lab or distribution, decision-making processes, and vulnerability to climate risks. Focussing on sectoral gender-specific vulnerabilities assessment in agriculture and water sectors and tailoring adaptation measures to address these differentiated needs. Further development of gender-sensitive indicators for monitoring and evaluating could further enhance the effectiveness of these measures. And finally integrating gender considerations into climate adaptation policies and plans by using gender-disaggregated data to inform decision-making and ensuring women's participation.
- **Participatory Approach and Local Knowledge:** This involves engaging local communities and stakeholders for improving access to information, feedback mechanisms for model development and refinement and strengthening institutional capacities at the local level. This participatory and community-focused approach is essential for the successful implementation of bottom-up adaptation measures. This localized and participatory allows for the identification of specific vulnerabilities and risks ensuring that adaptation measures are relevant and tailored to the needs of local communities for building a climate resilience system.
- **Cross-Sectoral Integration:** Integration of extensive climate and crop models across sectors is critical since climate change impacts on agriculture and water are deeply interconnected with other sectors like forestry, urban planning, and energy. This involves fostering cross-sectoral collaboration to develop integrated management strategies. Such a holistic approach integrating models across sectors could lead to more robust adaptation strategies.

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9.1 Annexure1: Summary of District-Wise Weather Aberrations and Proposed Contingency Strategies

1a: Himachal Pradesh (Reference: District Contingency Plans)

Condition		Normal Cropping System		Change in Crop/ Cropping System	Agronomic Measures	Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures
		Banda, Chitrakoot, Hamirpur, Jalaun, Jhansi	Lalitpur			Mahoba		
Early Season Drought- Delayed Onset	2 weeks	Rice- Wheat Sesame- Pea Sesame- Gram Black Gram- Pea/Gram Jowar- Wheat Bajra- Wheat Pigeon Pea Green Gram- Lentil	Maize- Pea Maize- Gram Black Gram- Pea/ Gram Jowar- Wheat Bajra- Wheat Pigeon Pea Green Gram- Lentil	Rice- Short duration Maize- Hybrid, HQPM- 1 Pearl Millets- Raj-171 and Hybrid, Sorghum- Csv- 13,15 and Hybrid	Mulching, Line Sowing , Light Irrigation, Weed Management and thinning,	Sorghum (Varsha,CSV 13,15 SPV 1616 Bundella, CSH 16 and 13)+ Pigeon pea (Ajad , Pusa 9, PDA 11, Narendra Arhar 2)+ Urd/ moong Sesame- T-78, Pragti, Sekhar	No Change	Intercropping of Sorghum (Varsha, CSV 13, SPB 1388, Bundella, CSH 16 and 13)+ Pigeon pea (Ajad , Pusa 9, PDA 11, Narendra Arhar 2) with ratio of 2:1 on raised bed Line sowing of sesame
	4 week	Sesame- Pea Sesame- Gram Black Gram- Pea/Gram Jowar- Wheat Bajra- Wheat Pigeon Pea Green Gram- Lentil		Replace rice with Green gram, Black Gram and Sorghum, Green Gram- PM-8, PDM-11, Samrat, Jyoti, Jagriti, Janpriya, Black Gram- T-9 PU- 19,PU- 40,PU-35 Sekhar- 1,2and3		Sorghum (CSB 13 CSH 9 14, 16, 18)+ Pigeon pea (Ajad , Pusa 9, PDA 11, Narendra Arhar 2) Sesame (Type 4, Type12,Type13, Sekhar, Pragati and Tarun) Sorghum+ pigeon pea+ Black gram/ Green gram		
	6 weeks			Replace rice with Green gram and pearl millet Green Gram- PM-8, PDM-11, Samrat, Jyoti, Jagriti, Janpriya Pearl Millets- Raj-171 and Hybrid.	Wider spacing 25 enhanced nutrients			
	8 weeks			Plan for Toria	none		Fodder Sorghum (hybrid 5, Pigeon pea(PDA 11, Narendra MFSH3A) Arhar 1) / Urd (Pant U 35, Narendra Urd 1, Ajad urd 2, Sekhar 1, Sekhar 2 and Sekhar 3)	10% higher seed rate for fodder sorghum

Condition		Normal Cropping System: Banda, Chitrakoot, Hamirpur, Jalaun, Jhansi	Normal Cropping System: Lalitpur	Change in Crop/ Cropping System	Agronomic Measures	Normal Cropping System: Mahoba	Change in Crop/ Cropping System	Agronomic Measures
Early Season Drought	Normal Onset	Rice-Wheat Sesame- Pea Sesame-Gram Pigeon Pea Black Gram-Pea/Gram Jowar-Wheat Bajra-Wheat Green Gram- Lentil	Rice-wheat Maize- Pea Maize-Gram Pigeon Pea Black Gram- Pea/ Gram Jowar- Wheat Bajra- Wheat Green Gram-Lentil	Pigeon Pea- NDR-1, NDR-2,MA-6, MA- 13 Drought tolerant rice varieties- NDR-97, Susk Samrat Sesame-T-78, Pragti, Sekhar Green Gram- PM-8, PDM-11, Samrat, Jyoti, Jagriti, Janpriya, Black Gram-T-9 PU-19,PU-40,PU-35 Sekhar-1,2and3	Ridge-furrow sowing, Use of additional Urea, Zink Sulphate, Mulching,	Sorghum (Varsha, CSV 13, SPB 1388, Bundella, CSH 16 and 13)+ Pigeon pea (Ajad , Pusa 9, PDA 11, Narendra Arhar 2) Sorghum+ pigeon pea+ Black gram/ Green gram	No change	Weeding, Resowing of the crops under less than 30% plant population situation with sufficient soil moisture
Mid Season Drought (Long Dry Spell)	Vegetative				Life saving Irrigation, straw Mulch, Thinning, Inter cropping			Interculture, Foliar spray with 1% KCI
	Flowering			Life saving Irrigation, straw Mulch, Thinning, Inter cropping	Spraying of 2% urea as foliar application KCI Spray			Mulching with local available materials
Early withdrawal of monsoon	Thermal drought	Sesame- Pea Sesame-Gram Jowar-Wheat Bajra-Wheat Green Gram- Lentil	Maize- Pea Mazie-Gram Sesame Jowar- Wheat Bajra- Wheat Green Gram-Lentil Pigeon Pea Black Gram- Pea/ Gram	Toria	Life saving Irrigation, straw Mulch, Thinning, Inter cropping			Harvest at maturity
Drought-Irrigated Situation	Delayed release of water in canals due to low rainfall	Rice- Wheat Millets-Mustard Pigeon Pea Sesame-Lentil Black gram/ Green gram Soybean-Gram	Rice- Wheat Millets- Mustard Pigeon Pea Maize- Lentil Black gram/ Green gram Soybean-Gram	Rice- Short duration Varities- NDR-97, UPS- 212, Susk Smrat, Sahbhagi Rest no change	Direct sowing, Drum Seeder, Micro irrigation/ Thinning, Weed control	Rice, Wheat	Prefer varieties suchas Raj 337, PBW 502, K0307, Halna	Drum seeding under puddle field Alternate wet and dry irrigation. Provide irrigattion at critical stage, ensure K application, chemical control of pest
	Limited release of water in canals due to low rainfall							
	Non release of water in canals under delayed onset of monsoon in catchment			Rice may be replaced buy Pulses Green Gram- Samrat, Janpriya, Jagriti Black Gram- T-9, PU- 40, PU-35 Azad-3 Rest no change	Direct seeding in small beds, Use of Micro- irrigation/ Sub surface irrigation Sowing of Pigeon pea at 90 cm+ two rows of inter crops on ridges Use of Micro-irrigation/ Sub surface irrigation	Sorghum (CSB 13 CSH 9 14, 16, 18)+ Pigeon pea (Ajad , Pusa 9, PDA 11, Narendra Arhar 2). Sesame (Type 4, Type12,Type13, Sekhar, Pragati and Tarun) Sorghum+ pigeon pea+ Black gram/ Green gram	No Change	Intercropping of Sorghum (Varsha, CSV 13, SPB 1388, Bundella, CSH 16 and 13)+ Pigeon pea (Ajad , Pusa 9, PDA 11, Narendra Arhar 2) with ratio of 2:1 on raised bed Line sowing of sesame
	Insufficient water recharge due to low rainfall					Pigeon pea, Sorghum, wheat, Chick pea, rice, black gram, green gram		

Condition	Normal Cropping System		Change in Crop/ Cropping System	Agronomic Measures	Normal Cropping System	Change in Crop/Cropping System	Agronomic Measures
	Banda, Chitrakoot, Hamirpur, Jalaun, Jhansi	Lalitpur			Mahoba		
Cold wave					Wheat, Mustard, Chickpea Lentil		Spray 2% urea and 2% MOP. Apply light irrigation
Heat Wave					Horticulture		Micronutrients spray, mulching with 100 micron plastic or locally available materials.

1b: Uttar Pradesh (Source: District Contingency Plans)

Condition		Normal Cropping System	Change in Crop/Cropping System	Agronomic Measures	Normal Cropping System	Change in Crop/Cropping System	Agronomic Measures
		Bilaspur			Hamirpur		
Early Season Drought-Delayed Onset	2 weeks	Maize Rice Wheat	Maize + Soybean (Harit Soya/ Shiwalik)/ Blackgram (UG 218, Him Mash-1)/Sesame (LTK-4) Rice (direct seeded) Wheat+Mustard/Gobi		Maize wheat	Blackgram/ Finger Millet/Cowpea 2.Intercropping/mixed cropping of Maize + Cowpea/Blackgram / Soybean /Sesame Blackgram: UG-218, Him Mash-1 Finger Millet: Baizu Cowpea: C-475 Sesame: LTK-4 Soybean: Shival Wheat late sown: Wheat: Raj 3777, VL 892 and HS 295, HS 490, HPW 42	Increase seed rate by 25% Proper drainage
	4 week		Maize + Cowpea / mash / soybean / sesame Maize Blackgram (Him mash-1,UG-218) Barley (HBL276/Dolma), Oats (PLP1/Kent) , Wheat HS295/Raj3777/HPW42) (late sown	Good Drainage Sow blackgram on raised seed beds with good drainage Increase the seed rate and fertilizer by 25%	Maize wheat	1.Blackgram Intercropping/mixed cropping of Maize (fodder) + Cowpea/ Blackgram/ Blackgram: UG218, Him Mash-1 Soybean: Shiwalik Soybean/ Sesame Cowpea: C-475 Sesame: LTK-4	Increase seed rate by 25% Proper drainage
	6 weeks		Kharif Onion (N-53, Agri Found Dark Red) / Early Cauliflower/ Bajra(Chari) Maize +Bajra (fodder purpose) / Cow pea Oats (PLP1) / Barley (Dolma) wv	Increase seed rate by 20% and reduce the spacing upto 30 cm	Maize Transplanted /Direct seeded Rice Wheat	Mixed cropping of 1.Maize + Cowpea (fodder pur-pose) 2.Sorghum + Cowpea (fodder purpose) 3.Kharif onion 4.Early cauliflower Early peas Maize: African Tall and desi Cow pea C475, Onion N53 Cauliflower: Pusa Deepali Pea: Arkel /Matar Ageta Barley:HBL276, Dolma Onion: N-53, Agrifound Barley/Oats/On-ion Oat: PLP1, Kent Onion:Dark Red	Use 40 kg seed for Maize, 15 kg for Cowpea and 45 kg for Sorghum per hectare.
	8 weeks		Green fodder (Chari/Bajra) Radish (Early) Japanese White/ French bean (Contender) / Cauliflower (Megha/ Shweta)/ Peas (Mater Ageta/ Azad Pea 1) Potato/ Onion		Maize wheat	Toria/ Oat/ Early peas/ Early Cauliflower/Radish Toria: Bhawani Raj3777, HPW42 Oats: Kent -1, Palampur-1 Peas: Matar Ageta, Azad Pea-1, Arkal Radish: Japanese white/Chinese pink Cauliflower: Early Kunwari Onion, Potato	

Condition		Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures	Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures
		Bilaspur			Hamirpur		
Early Season Drought	Normal Onset	Maize Rice (Seeded) Rice (Transplanted) Wheat Barley	Crop management measures	Mulching in crop, Topdressing of N in rain-fed crop coinciding with rain splashes Rain water harvesting of surrounding fields, weed free	Maize Rice (Seeded) Rice (Transplanted) Wheat Barley	Crop management	Topdressing of N, Drainage provision in intercropping
Mid-Season Drought (Long Dry Spell)	Vegetative	Maize Rice (Seeded) Rice (Transplanted) Wheat		Foliar spray of urea after showers - Mulching with the weeds and in-situ conservation through diverting water from adjoining areas	Maize Rice (Seeded) Rice (Trans-planted) Wheat		Foliar spray of urea 1-2% after showers ,mulching with the weeds and in-situ conservation through diverting water from adjoining areas, Mulching
	Reproductive	Maize Rice (Seeded) Rice (Transplanted) Wheat Chick pea			Maize Rice (Seeded) Rice (Trans-planted) Wheat Chick pea		Foliar spray of urea 1-2% after showers ,mulching with the weeds and in-situ conservation through diverting water from adjoining areas, Mulching
Early withdrawal of monsoon	Thermal drought	Maize Rice Wheat Black gram	Crop management measures	Rabi crop planning: Shift to crops like Radish, Peas, Toria for early sown wheat varieties like VL616/ VL829/HPW251	Maize Rice Wheat Black gram		Sowing of Radish/Peas/ Toria as catch where drought is expected quite often crop followed by Wheat OR in areas then go for early wheat varieties VL616/VL829/ HPW251
Drought-Irrigated Situation	Delayed release of water in canals due to low rainfall	Maize Rice Wheat	Maize + soybean Maize + Blackgram Direct seeded rice, (HPR 1156/HPR1028 Sukhara dhan/ VL421 Wheat (HS490, VL982 Raj.3777), Wheat + Gobhi sarson (Neelam) Wheat + Mustard	Mulching, Ridge and furrow planting Irrigation at critical stage, micro irrigation system/alternate furrow SRI Planting, 2% Foliar N	Maize Rice Wheat Black gram	Maize + soybean Maize + Blackgram Direct seeded rice, (HPR 1156/ HPR1028 Sukhara dhan/ VL421 Wheat (HS490, VL982 Raj.3777), Wheat + Mustard	Mulching, Ridge and furrow planting SRI Planting, 2% Foliar N Irrigation at critical stage, micro irrigation system/ alternate furrow
	Limited release of water in canals due to low rainfall		Not applicable			Not applicable	
	Non release of water in canals under delayed onset of monsoon in catchment		Not applicable			Not applicable	
	Insufficient water recharge due to low rainfall		Not applicable			Not applicable	

Condition		Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures	Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures
		Bilaspur			Hamirpur		
Cold wave and Frost		Wheat Mustard		Light frequent irrigation may be practiced wherever irrigation facilities are available	Wheat, Mustard		Light frequent irrigation may be practiced wherever irrigation facilities are available
Heat Wave		Maize Rice Wheat	Light frequent irrigation may be practiced wherever irrigation facilities are available	Irrigation if available may be applied to combat the effect of high temperature			

1b: Uttar Pradesh (Source: District Contingency Plans) Contd...

Condition		Normal Cropping System	Change in Crop/Cropping System	Agronomic Measures	Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures
		Kangra			Mandi		
Early Season Drought- Delayed Onset	2 weeks	Maize Transplanted /Direct seeded Rice Wheat	Rice: Transplanted- RP 2421/ HPR 1156/ HPR 1068 Direct sown: HPR 1156/ VL Dhan 221 Bajaura Makka/ Vivek 21/ Baby corn(VL78/Early Girija and Early composite , Maize short duration, Maize + Cowpea/Blackgram /Soybean/Sesame	Increase seed rate by 25% and fertilizer dose 125% for late sown with rains, Sowing on ridges , Stale seed bed preparation to avoid weeds Follow SRI technique for rice planting	Rice (Transplanted / Direct seeded) (Rice-wheat system) Maize-wheat system Finger millet (Finger millet-wheat system)	Maize, Baby corn Maize+soyabean Cowpea,Blackgram, Soybean Rice (Direct seeded: VL-221/HPR-1156)	Increase the seed rate Proper drainage Increase the seed rate (25%) Addition of organic manures
	4 weeks	Maize Transplanted /Direct seeded Rice Wheat Vegetables	Direct seeded rice varieties, Black gram Maize fodder, maize+ legume fodder, Sesame, Finger Millet				
	6 weeks	Maize Transplanted /Direct seeded Rice Wheat Onion	Change of crop as fodder or Bajra: Chari(fodder taking vegetables Kharif Onion(N53) purpose) Early Cauliflower: Early Kunwari, Pusa Deepali, Raddish: Japneese white, Improved Japani Chinese pink, Pusa Chetaki French bean: Contender VLBoni, Pusa Parvati Arak Komal Maize fodder, Maize+ legume fodder Blackgram/Kulthi /Sesame Maize fodder var.African Black Gram :UG 218, Pant Finger millet: Baizu,Til (for U 19,Him black Gram 1 Tall Zone 1): LTK 4		Rice-wheat system Maize, finger-millet, Blackgram, cowpea	Early pea (Arkel, Matar Ageta, Palam Radish (Pusa Chetki, Pusa Himani) Triloki) French bean (Laxmi, Arka Komal) Kharif onion (AFDR, N-53) Cauliflower (Pusa Dipali, Improved Japani) Broccoli (Palam Vichitra, Palam Samridhi) Cabbage (Golden Acre/ Pusa Mukta) Tomato (Palam Pink, Palam Pride,Solan Sindhur)	
	8 weeks	Rice (Direct seeded) Maize Wheat Vegetables	rabi season vegetables: Oats, fodder(PLP1), Toria (Bhawani) Raddish (Japneese white, Chinese pink, Early menu white Cauliflower(Early Kunwari, Pusa Deepali, Improved Japani)/Peas (Mater Ageta/Azad Pea 1) Potato((Kufri Jayoti)/Onion (small areas with irrigation Palam Lohit,Patana red) Oats fodder(PLP1)	NONE			Delayed sowing of early wheat and barley, Sowing of fodder crops

Condition		Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures	Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures
		Kangra			Mandi		
Early Season Drought	Normal Onset	Maize Rice (Seeded) Rice (Transplanted) Wheat Barley	Crop management	Topdressing of N, Drainage provision in intercropping, Rain water harvesting of surrounding fields	Rice (Transplanted / Direct seeded) (Rice-wheat system) Maize-wheat system Finger millet (Finger millet-wheat system)	Crop management	Topdressing of N, Drainage provision in intercropping, Rain water harvesting of surrounding fields
Mid Season Drought (Long Dry Spell)	Vegetative	Maize Rice (Seeded) Rice (Transplanted) Wheat	Crop management	Foliar spray of urea 1-2% after showers ,mulching with the weeds and in-situ conservation through diverting water from adjoining areas, Mulching	Rice-wheat system Maize, finger-millet, Blackgram, cowpea		Foliar spray of urea 1-2% after showers ,mulching with the weeds and in-situ conservation through diverting water from adjoining areas, Mulching
	Reproductive	Maize Rice (Seeded) Rice (Transplanted) Wheat Chick pea	Crop management	none			
Early withdrawal of monsoon	Thermal drought	Maize Rice Wheat Black gram	Crop management	Sowing of Radish/ Peas/Toria followed by Wheat OR early wheat varieties VL616/VL829/ HPW251			In-situ moisture conservation and sowing of toria/ French bean if possible otherwise done after the rainfall spells Rabi crops sowing should be are received
Drought-Irrigated Situation	Delayed release of water in canals due to low rainfall	Rice Wheat Vegetables	Direct seeded rice, (HPR 1156/HPR1028 Sukhara dhan/ VL421 Wheat (HS490, VL982 Raj.3777), Wheat + Gobhi sarson (Neelam)	Ridge and furrow planting Irrigation at critical stage, microirrigation system/ alternate furrow SRI Planting, Popularization of split application of nitrogen	Rice-wheat system Maize, finger-millet, Blackgram, cowpea, okra	Direct seeded rice, Maize + soybean, maize + cowpea, maize + black gram; Baby Corn: VL 78/ Early Composite	Mulching, Ridge and furrow planting SRI Planting, 2% Foliar N Irrigation at critical stage, microirrigation system/ alternate furrow
	Limited release of water in canals due to low rainfall		Not applicable				
	Non release of water in canals under delayed onset of monsoon in catchment		Not applicable				
	Insufficient water recharge due to low rainfall		Not applicable				

Condition		Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures	Normal Cropping System	Change in Crop/ Cropping System	Agronomic Measures
		Kangra			Mandi		
Cold wave and Frost		Wheat, Mustard		Apply irrigation using sprinklers if available, smoking during frosty night. Light frequent irrigation may be practiced wherever irrigation facilities are available			
Heat Wave		Maize Paddy Wheat		Mulching to buffer effect of high temperature, Light and repeated irrigation at the appearance of hair line cracks in soil surface, Correct iron deficiency with 0.5% iron sulphate spray. Frequent and light irrigation			
Hailstorm		Horticulture crops		Anti hail netting at fruit bearing stage			

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