



Maharashtra State Action Plan on Climate Change: Pathways for 2030





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DoE&CC is the nodal agency in the administrative
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coordination and overseeing the implementation of the
Environment and Climate Change Policies and
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Government of Maharashtra and Council on Energy, Environment and Water (CEEW).

SUGGESTED CITATION:

Department of Environment and Climate Change, Government of Maharashtra and Council on Energy and Environment (CEEW). 2025. *Maharashtra State Action Plan on Climate Change: Pathways for 2030*. Mumbai: Department of Environment and Climate Change, Government of Maharashtra.

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Environment and Climate Change Department
Government of Maharashtra

Technical Support:
Council on Energy, Environment and Water (CEEW)

2025



GOVERNMENT OF MAHARASHTRA

SHRI DEVENDRA FADNAVIS

Chief Minister

It gives me great pleasure to dedicate to the people of the state the “Maharashtra State Action Plan on Climate Change”, revised by the Environment and Climate Change Department, Government of Maharashtra. In the past two decades, there has been a significant increase in extreme weather events such as heatwaves, unseasonal rainfall, flash floods, droughts and cyclones in different parts of the state having adverse economic impact and causing social disruption. The swapping trend observed in certain districts, in terms of drought and heavy rainfall is a challenging phenomenon to map and manage.

Maharashtra is an engine of India’s economic growth. It is the largest sub-national economy in the country aspiring to be a trillion-dollar economy. The state must therefore charter a sustainable path of development to bring about a massive green energy transition.

The State Climate Action Plan would act as a vision document that shapes our agenda for green growth. It would help various departments to identify future climatic anomalies and thereby help safeguard the state’s vital resources. The State Action Plan would enhance the adaptive capacity of the state and help it negotiate better with the impacts of climate change. The revised plan is very detailed; it addresses significant climate challenges, supports affordable clean energy technologies, promotes innovative practices of climate adaptation and mitigation and identifies the sources of climate finance.

The Government of Maharashtra is dedicated in continuing its efforts to help the country realize its goal of attaining Net Zero carbon emissions by 2070 by supporting the Nationally Determined Contributions (NDCs) towards achieving the targets committed under the Paris Agreement.

I am confident that robust implementation and effective monitoring of the Maharashtra State Action Plan on Climate Change will help in building resilience of the state against climate change, especially of its vulnerable communities. I compliment the Environment and Climate Change Department for its leadership in making this plan a living document. I would like to congratulate all the concerned departments for their support in bringing out the revised “Maharashtra State Action Plan on Climate Change 2020-30”. I hope the recommendations of the State Action Plan on Climate Change will help build a climate-resilient and prosperous Maharashtra.

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SHRI EKNATH SAMBHAJI SHINDE

Deputy Chief Minister

Populations across the world are facing various challenges that are induced by climate change in multiple sectors such as agriculture, water, health and tourism. Our State, Maharashtra, due to its geographical location, is prone to the various hazards of climate change and susceptible to the impacts of extreme climatic events. Increased storm intensity, hailstorms, floods, extreme droughts and heat waves, irregular rainfall and recurring cyclones bear considerable significance for Maharashtra as these adversely affect agricultural production, marine fisheries, biodiversity and human health. The state of Maharashtra is fully committed towards the all-round development of the state even while protecting its citizens from natural calamities.

This underscores the importance of the revision of the State Action Plan on Climate Change. The plan spells out both Adaptation and Mitigation strategies for various sectors for the period of 2020-2030.

I would like to congratulate the Department of Environment and Climate Change and all the stakeholders who have worked tirelessly and contributed immensely to shape this vital document. This action plan will create a roadmap for the sustainable development of Maharashtra, act as a guiding document for the various departments of the state government and enable the state achieve the targets set in alignment with the vision of the Government of India for a carbon-emission free India by 2070.

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SHRI AJIT PAWAR

Deputy Chief Minister

The state of Maharashtra is one of the most industrialised states in the country, with the largest size of the economy contributing the highest to the national GDP. This calls for the state to be more responsive and responsible towards climate change. The state, with its diverse geography, strategic location, skilled manpower and financial strength can take stringent actions to adapt and prepare vulnerable communities for the challenges of climate change, while at the same time making all-out efforts towards climate change mitigation.

I am happy to find a robust action plan prepared for the state by the Department of Environment and Climate Change and their support team. The plan sets out targets and outlines elaborate measures for all the crucial departments such as Agriculture, Public Health, Energy, Industries, Forest and Tribal Development amongst others. The plan provides for Climate Budget and resource mobilisation to generate climate finance in the coming years. The Cooling Action Plan will support India's commitment to reduce the emission intensity of its GDP by 45 per cent of the 2005 level by 2030 and achieve about 50 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030.

I would extend my greetings to the participating state government departments once again and look forward to a productive decade by honouring India's commitments towards Nationally Determined Contributions (NDCs).

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GOVERNMENT OF MAHARASHTRA

SMT PANKAJA GOPINATH MUNDE

Minister of Environment & Climate Change,
Animal Husbandry

I am pleased to present the Maharashtra State Action Plan on Climate Change 2.0 a pathway for 2030, a forward-looking and inclusive roadmap, that reflects our collective commitment to climate resilience and sustainable development.

Drafted under the leadership of the Environment and Climate Change Department and supported by the State Climate Action Cell, this Plan is not just a policy document-it is a dynamic, evolving strategy designed to address Maharashtra's climate priorities till and beyond 2030. It aligns with the national goals even while responding to the unique socio-economic and ecological realities of our state.

I commend all line departments for their collaborative efforts in shaping sector-specific, actionable strategies. I also extend my acknowledgement to CEEW for their technical expertise and unwavering support throughout this process.

I extend my gratitude to the efforts by the Ministry of Environment, Forest and Climate Change, Government of India, for their valuable guidance. I urge all departments to Implement the recommendations outlined in this Plan with a sense of urgency and dedication, as a shared responsibility to protect and preserve our planet for future generations, and to ensure the well-being of our people.

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GOVERNMENT OF MAHARASHTRA

SMT SUJATA SAUNIK, IAS Chief Secretary

Maharashtra, a land of diverse geography and rich biodiversity, stands as a vital engine of both economic growth and environmental stewardship. The accelerating impacts of climate change present significant challenges to our people's livelihoods, food security, public health, and critical infrastructure. This impacts our economic activity and threatens our long-term development goals.

The state's exposure to a range of natural hazards—from droughts and floods to heatwaves and cyclones—makes it particularly vulnerable to the increasing risk of recurring and even compound disasters. These complex and interconnected threats require coordinated, science-based, and community-driven adaptation strategies.

In response, Maharashtra is undertaking bold and transformative actions to confront these challenges while advancing inclusive and sustainable growth. Through initiatives such as housing, solarizing agricultural feeder lines, promoting solar-powered irrigation, expanding urban green spaces, provisioning social forestry, and strengthening nature-based solutions, we are actively greening our economy and building resilience across sectors.

With rising temperatures and intensifying heatwaves, it is also imperative that we prioritize sustainable and inclusive cooling strategies—particularly to protect vulnerable populations and ensure the well-being of both rural and urban communities. Maharashtra is striving to deliver excellence in the field through collaborating with several agencies.

The State Action Plan on Climate Change (SAPCC) – Vision 2030 sets forth a strategic and future-ready roadmap for a climate-resilient, low-carbon Maharashtra. This comprehensive plan is the result of collaborative efforts across departments and stakeholders and aligns with India's national commitments under the Paris Agreement and our shared net-zero ambitions.

“पृथिव्याः माता धर्मस्य पुत्राः”

“The Earth is our mother, and we are her children—bound by the duty to protect and nurture her.”

All departments and stakeholders need to implement the SAPCC recommendations with a sense of purpose and accountability. We all need to work together to protect and safeguard Maharashtra's natural heritage and build a resilient, equitable, and sustainable future for future generations.

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SMT JAYASHREE BHOJ, IAS

Secretary,
Department of Environment and Climate Change

The challenge of climate change is at the doorstep of India. Maharashtra is not an exception. The extreme climate events such as rising temperatures, heavy rainfall, flash floods, droughts and cyclones have increased manifold. The Conference of Parties has time and again called for a coordinated climate action carried out in a fair and inclusive manner.

Following the common framework provided by the MoEFCC, and in order to realize international commitments towards the Paris Agreement, the Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs), the Environment and Climate Change Department has now revised the State Action Plan on Climate Change for the period 2020-30.

The State Climate Action plan analyses the past climate trends, makes future projections and conducts risk analysis for climatic events across the districts. It delineates detailed recommendations based on which departments can formulate their adaptation and mitigation strategies. The plan provides for Climate Finance, the Integrated Cooling Action Plan and Decentralized Renewable Energy Livelihoods among others.

The SAPCC has been prepared in technical collaboration with the Council on Energy, Environment and Water (CEEW), New Delhi. They have undertaken scientific analysis of simulated climate models to project how the climatic fluctuations will span out in future. I would like to acknowledge their support and compliment them for their contribution. I also acknowledge the contribution from the various departments of the state government towards preparing the State Climate Action Plan.

The State Climate Action Plan is only a beginning. We intend to follow this with sectoral action strategies towards its effective implementation. The Department has formed the State Climate Action Cell for implementing the plan. We have also set up Climate Action Cells to formulate Climate Action Plans for the Districts and all the major cities in the state. We are fully committed to attaining the objective of an emission free and climate resilient state.

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ACKNOWLEDGMENT

The team tasked with the revision of the Maharashtra State Action Plan on Climate Change 2.0 (2020-2030) at the Department of Environment and Climate Change, Government of Maharashtra, has received great support from various stakeholders, such as scientists, policy researchers, administrators, professionals, and reviewers.

We are thankful to the MoEFCC, GoI for their guidance and financial support during the Plan revision in the state. We express our gratitude to the India Meteorological Department, Indian Institute of Tropical Meteorology and the Ministry of Earth Sciences for providing granular climate data and downscaled climate projections that have been used for the climate profile assessment of this plan.

We deeply acknowledge the significant contribution of the expert team from the Council on Energy, Environment and Water (CEEW), led by Dr Arunabha Ghosh, Chief Executive Officer, and Dr Vaibhav Chaturvedi, Fellow. The dedication and expertise of the CEEW research team across various programs have been instrumental in shaping this plan.

We are grateful for the dedication, knowledge, and expertise of more than 30 nodal officers of 22 line departments and their sub-offices/cells/projects/companies for providing us the relevant information and support. We would also like to thank the State level Steering Committee on Climate Change under the chairmanship of the Chief Secretary, GoM to review the plan and to make the plan a reality. We sincerely acknowledge the guidance, support in mentoring and coordination by Mr Abhay Pimparkar, Director; Mr Abhijit Ghorpade, Director, State Climate Action Cell; Mr Joy Thakur, Scientist-I/Deputy Secretary; Ms Archana Parshurane, Scientist-II/Under Secretary and Mr Sudhakar Bobade, Mission Director – Majhi Vasundhara Abhiyan, DoECC, GoM.

We thankfully acknowledge the technical support and knowledge provided by UNICEF and Jhpiego team in the review process of the plan.

The exceptional support provided by the administrative and ministerial employees of the Department of Environment and Climate Change, Majhi Vasundhara Abhiyan and State Knowledge Management Centre on Climate Change, especially during the multi-tier consultative meetings, is acknowledged.

We sincerely appreciate the efforts of Maharashtra's State Knowledge Management Centre on Climate Change team members Dr Vishal Rasal, Mr Amit Bhalerao, Mr Avinash Nagargoje, Majhi Vasundhara Abhiyan Climate Fellows, Chief Minister Fellow Mr Aditya Bhairu Yejare, and CEEW team members Mr Gaurav Sahni, Mr Praveen Chandrasekharan, Dr Vishwas Chitale, Mr Nitin Bassi and Dr Vaibhav Chaturvedi, who played a crucial role in coordinating with stakeholders along with contributing to the finalisation of this action plan. We would like to also acknowledge the valuable contributions of CEEW team members who contributed different chapters (mentioned in alphabetical order): Ahana Chatterjee, Ankita Borah, Anju Bhaskaran, Ajinkya Kale, Aparna Sharma, Aryan Bajpai, Bhuvan Ravindran, Dishant Rathee, Ekansha Khanduja, Gaurav Sahni, Gursimer Gulati, Dr Hamid Hussain Varikkodan, Jitendra Bhambure, Dr Joy Rajbanshi, Medhavi Sandhani, Mousumi Kabiraj, Dr Muneer Kutty, Namrata Kulsreshtha, Nitin Bassi, Pallavi Das, Pallavi Dhandhanian, Dr Priti Dubey, Priyanka Singh, Priya Tayde, Priyatam Yasaswi, Ramesh Veluru, Dr Richa Joshi, Ruchira Goyal, Saahil Parekh, Shanal Pradhan, Shravan Prabhu, Shreya Wadhawan, Srishti Mishra, Sonal Kumar, Swati Sharma, Vanya Pandey, and Vishaka Gulati, and the Outreach team for supporting every aspect of this report's publication, design and outreach.

Executive summary

Under the Prime Minister's Council on Climate Change (PMCCC), the National Action Plan on Climate Change (NAPCC) was formulated in 2008, which comprised eight national missions. The missions focus on promoting understanding of climate change, adaptation and mitigation, energy efficiency, and natural resource conservation. Following the launch of NAPCC, in August 2009, it was mandated that all the Indian States & Union Territories (UTs) prepare their respective State Action Plan on Climate Change (SAPCC) following the guidelines of the NAPCC. The states and UTs were required to integrate the local variability in climate, geography, ecosystems, socio-economic dimensions, and other factors to develop the adaptation strategies for the States and UTs to address the climate change impacts for the next 5-7 years. Accordingly, the Government of Maharashtra submitted the Maharashtra State Adaptation Action Plan on Climate Change in 2014, which provided the current status of climatic impacts on agriculture, forest and biodiversity, water resources, urban habitat, and energy.

In May 2019, MoEFCC directed all the states and UTs to update their SAPCCs, in accordance with the directive framework for revision of the State Action Plan on Climate Change. Accordingly, the State Government of Maharashtra initiated the process of updating its state climate action plan for preparation of Maharashtra State Action Plan on Climate Change (MHSAPCC 2.0) for the period 2020 to 2030 following the common guiding principles and framework. Owing to the varied geography, geology, and climatic conditions, the State of Maharashtra depicts vast diversity in its livelihoods

profile, agricultural practices, culture, and economy. Due to climate change it has experienced several hydro-meteorological disasters such as floods, cyclones, and droughts. Maharashtra is highly vulnerable to climatic impacts, which include both slow-onset disasters such as droughts and extremes such as flash floods and calls for strengthening the adaptation mechanisms across different sectors.

Further, in November, 2022 India updated its National Determined Contributions (NDCs) to achieve net zero carbon emissions by 2070. Achieving the targets at the country level needs the states to develop and meet their own net zero carbon emission targets. Considering this, the MHSAPCC 2.0 envisions a climate resilient-low carbon future for Maharashtra with defined actions and recommendations for different sectors for the duration 2020-2030 on both climate change adaptation and mitigation. MHSAPCC 2.0 spans across a total of eight sectors viz., a) Agriculture and allied sectors b) Water Resources c) Forest & Biodiversity d) Tourism e) Energy f) Habitat (urban, rural and tribal) g) Public Health and h) Disaster Management, two cross-cutting areas, Finance and Planning and four additional sectors industries, transport, tribal development, and tourism. The development of MHSAPCC 2.0 has seen over 66 consultation meetings with stakeholders from different departments and agencies for feedback on:

- Sector-wise recommendations,
- Exploring linkages with existing schemes and programs in the state for effective uptake of the recommendations,

- Expected budgetary allocations, and
- MHSAPCC 2.0 follows an approach of quantifying climatic risks for priority sectors and accordingly proposes adaptation and mitigation strategies.

A. Climate change analysis and projections

The analysis of temperature variability in Maharashtra from 1971 to 2020 indicates a rising trend in annual average maximum and mean temperatures. District-level analysis shows most districts witnessing a rise in mean daytime temperatures, while districts in Konkan as well as Pune, Nashik, Jalgaon, Thane, etc. experiencing an increase in both daytime and night time temperatures. The climate change projections suggest that both daytime and night time temperatures will continue to increase linearly across all regions of Maharashtra during the 2030s under both RCP scenarios i.e., RCP 4.5 and 8.5. Under RCP 4.5, the mean daytime temperature is projected to increase by 0.90°C, and under RCP 8.5, it may rise by 1.56°C. The mean night time temperature is expected to increase by 1.04°C in RCP 4.5 and 1.83°C in RCP 8.5. This will lead to the annual average diurnal temperature range to decrease by -0.66°C in RCP 4.5 and -0.78°C in RCP 8.5. Analysis reveals that eastern Maharashtra, particularly Nagpur and Amravati divisions, will experience the highest daytime temperatures under both RCP scenarios. The predicted five warmest districts in the 2030s are projected to be Chandrapur, Gadchiroli, Nandurbar, Yamatval, and Gondia. The frequency of both daytime and night time temperature extremes is also increasing across Maharashtra. A district-level analysis indicates that all districts are witnessing a rise in daytime heat extremes during the summer months (March, April, and May), with 84 per cent of districts showing statistically significant trends. Additionally, more than 40 per cent of districts are experiencing an increase in the number of warmer nights. These projections further suggest a 2 fold increase in daytime extremes and 5 fold increase in night-time extremes under both RCP 4.5 and RCP 8.5 scenarios.

Rainfall analysis indicates a linear increasing trend in both annual and monsoon months (JJAS) rainfall, while a decreasing trend during non-monsoon (OND) season (October to December). The latter is not significant statistically. Projections suggest the highest monsoon rainfall will be in Konkan, with significant increase in central Maharashtra, parts of Pune, and Ahmednagar districts compared to their historical climatological profile. The eastern part of Maharashtra may receive slightly less rainfall. While no significant changes are observed in the frequency of dry and moderate intensity rainy days, heavy rainfall events will increase in regions like Konkan, Pune, and Nashik. The magnitude of increase is the highest in Pune, Thane, Raigad, Sindhudurg, and Mumbai. Overall, Maharashtra is expected to experience higher temperatures and rainfall in the 2030s, with temperature extremes uniformly increasing and rainfall changes

marked by high spatial variability. Detailed findings are presented in Chapter 3.

B. Climate change vulnerabilities and risk

Maharashtra is highly vulnerable to extreme climatic events, such as floods, cyclones, and droughts. This necessitates a focus on enhancing climate resilience of the state. While the state has majorly been prone to droughts and floods, a noticeable surge in cyclonic events along the western coasts has been observed in recent years. The sub-district climate risk assessment of Talukas in Maharashtra reveals that 78 per cent are prone to extreme droughts, with districts of Chhatrapati Sambhaji Nagar, Ahmednagar, Dharashiv, Jalgaon, and Nashik being the most vulnerable districts. Additionally, 21 per cent of Talukas are prone to extreme floods, with districts Mumbai, Mumbai Suburban, Ratnagiri, Pune, Jalgaon, Amravati, Wardha, Chhatrapati Sambhaji Nagar, Thane, and Nashik facing higher risks. However, 71 per cent of Talukas have moderate to high adaptive capacity, which is attributed to the regularly updated district disaster management plans that enable proactive response to disasters. Detailed Taluka level climate risk assessment is available in chapter 4 of the plan.

C. Proposed adaptation strategies and actions (2020-2030)

Agriculture & allied sector: In Maharashtra, more than 80 per cent of agriculture is rainfed, which predominantly relies on South West Indian monsoon rainfall, which occurs from June to September. Climate change impacts in Maharashtra include increasing temperatures, prolonged drought and water scarcity, leading to reduced fodder and drinking water for livestock, and decreased productivity of livestock and poultry. The agriculture risk index ranks Parbhani, Osmanabad, Latur, Hingoli, and Ahmednagar as the most at risk districts in Maharashtra. The proposed key actions for agricultural sector focus on:

- Improving the research capacity on key areas pertaining to climate change adaptation of the agriculture sector,
- Improving the capacity of the stakeholders (farmers, Civil Society Organisations (CSOs), farmer-facing government institutions) to take up climate change adaptation measures,
- Mainstreaming climate-resilient agricultural practices,
- Increasing coverage of crop insurance programme to small and marginal farmers in the most vulnerable districts in the state,
- Providing hand-holding support and building capacities of the tribal communities to improve the Agri-allied based livelihoods opportunities and
- Supporting and strengthening the livelihood activities of the tribes residing near the forest fringe areas.

The recommendations and key actions of allied sectors include:

- Improving the research capacity on key areas pertaining to climate change adaptation of the animal husbandry sector,
- Improving the information dissemination capacity on key areas pertaining to climate change adaptation of the animal husbandry sector and make information and knowledge accessible to the most vulnerable livestock-rearers,
- Mainstreaming climate-resilient and remunerative animal husbandry practices among livestock rearers, and
- Increasing livestock insurance for all small and marginal farmers in the most climate-vulnerable districts. The total overall financial outlay needed for implementing the recommendations for agriculture and allied sector is INR 37099.17 crore.

Water resources: It is assessed that out of the 35 districts in Maharashtra, 11 districts are water stressed, i.e., having less than 1700 cu m of water availability per capita per annum, and 18 districts are water scarce, i.e., less than 1000 cu m of water availability per capita per annum. Further, the state experiences seasonal groundwater scarcity especially in Vidarbha and Marathwada regions. A substantial area in the state (about 42.5 per cent) lies in deficit or highly deficit sub-basins. The districts with high water risk index include: Ahmednagar, Nandurbar, Parbhani, and Solapur. The main actions and recommendations for the water sector include strategies for:

- Water supply augmentation that focus on utilising untapped or unutilised water in different river basins and making reuse of treated water,
- Water demand management through increasing the coverage under micro-irrigation systems and introducing volumetric pricing of water in canal command areas, and
- Climate proofing of water supply and its infrastructure. Some specific actions such as enhancing water harvesting mechanisms by building check dams are proposed especially for Vidarbha region. The proposed budget for implementing the recommendations for the water sector is INR 207760 crore.

Forest and biodiversity: As per the recent statistics of 2021, 16.51 per cent of Maharashtra's geographical area is covered by forests, which has seen an increase from 14.31 per cent in 1991. This excludes trees outside forests (ToF). The mangroves span across 304 sq. km. The main climate change impacts seen on forests and biodiversity include:

- a. Changes in phenology of plants, which affects the productivity of the ecosystems, b. Early/late flowering and fruiting,

- b. Changes in leaf fall pattern, and
- c. Direct impacts on biodiversity habitats.

The prolonged dryness in the weather results in large dry areas of forests and causes a higher number of forest fires directly causing the damage to the forests. The key actions and recommendations for the forest and biodiversity sector include:

- Protecting existing forests and increasing the green cover including tree outside forests (ToF),
- Conservation of biodiversity and forest ecosystems and protection of habitats,
- Protection, restoration and rehabilitation interventions for mangroves, wetlands and corals to ensure their continued survival, and
- Incorporating participatory monitoring, evaluation and learning. The proposed budget for implementation of these actions is INR 13181 crore.

Health: Climate change impacts on human health in Maharashtra are evident through floods, droughts, extreme temperatures, heat-related illnesses, waterborne and vector-borne diseases, respiratory illnesses, and agricultural productivity loss leading to food insecurity and malnutrition. Vector-borne diseases like malaria and dengue have surged due to increased rainfall and temperatures, with dengue cases rising from 7,829 in 2017 to 12,720 in 2021, and malaria cases increasing from 10,757 in 2017 to 19,303 in 2021. Findings indicate Vidarbha and Marathwada are most at risk for climate-sensitive diseases. Proposed measures prioritise inclusive planning, communication, and interventions to safeguard communities. Actions include mapping vulnerable populations, enhancing emergency response capabilities, improving adaptive capacity, implementing Climate Resilient and Sustainable Health Services, strengthening disease surveillance and health system preparedness, and capacity building for health workers and communities. The proposed budget for implementation is INR 8249.56 crore.

Habitat: Maharashtra's habitats face rising risks from floods, droughts, cyclones, landslides, and heatwaves. Urbanisation and population growth worsen housing shortages, particularly in slums. Mumbai, Pune, Thane, Nagpur, Kolhapur, Nashik, and Chhatrapati Sambhaji Nagar are among the most affected districts. Water supply and sanitation face challenges due to climate-induced water scarcity and contamination. Extreme flooding poses a threat to waste management infrastructure. Climate change disrupts transportation and tourism, impacting mobility and tourist destinations. Around 70 per cent of tourism-dependent districts are exposed to hydro-met disasters. To address these challenges, strategies have been proposed to create safe, inclusive, sustainable, and resilient communities in Maharashtra by 2030 that focus on:

- Mainstreaming the components of climate change into the planning, design, and construction of the road infrastructure process (Climate Proofing Infrastructure);

- 20 per cent capacity of the storm-water drainage to be increased by 2030;
- 100 per cent segregation of waste at the source to reduce the waste disposal in landfills by 40% by 2030 and transitioning to cleaner energy sources in supply and treatment plants;
- Implementation of risk-informed tourism planning; and,
- Building capacities and training for sensitising climate adaptation at all levels.

Tribal development: Most tribal communities in the state reside in forest areas, primarily in districts like Amravati, Chandrapur, Dhule, Gadchiroli, Jalgaon, Nandurbar, Nanded, Nashik, Pune, Palghar, and Thane. Tribal communities are at the forefront of experiencing the direct effects of climate change due to their strong dependence on and interaction with the natural resources. The impacts of climate change have resulted in a lack of livelihood opportunities such as loss of agricultural productivity, leading to a significant migration of tribal populations from rural to urban areas, either temporarily or permanently. One such region is the Gadchiroli district. Major tribal communities in this district include Gond, Madia, Pardhan, and Kolam. The key actions and recommendations for tribal development sector focus on:

- Providing hand-holding support and building capacities of the tribal communities to improve the Agri-allied based livelihoods opportunities in the region to enhance their income and build their resilience in overcoming future challenges caused due to climate change,
- Supporting and strengthening the livelihood activities of the tribals residing near the forest fringe areas that are dependent on NTFPs,
- Supporting tribal forest communities to overcome climate change challenges and uplift their livelihoods and diversify it, and
- Generating awareness among the tribal population on climate change adaptation strategies and increasing engagement of tribals in the decision-making process to make them aware and resilient to climate change impacts projected in near future.

Disaster management: Various districts in Maharashtra are hotspots for extreme climatic events. The state experiences a swapping trend of drought-prone areas becoming flood-prone and vice versa. To create climate-resilient pathways, the main strategies are:

- Improved flood hazard mitigation through a Real-Time Flood Decision Support System (RTDSS),
- Risk-Informed Disaster Risk Reduction strategies at sub-district levels,

- Increased Disaster Response in the State by 2025,
- Infrastructure development of State and District Emergency Operation Centres (SEOC, DEOCs), and
- Building Institutional capacity of relevant agencies.

Decentralised renewable energy: Around half of Maharashtra's population resides in rural areas, with agriculture contributing only 11.9 per cent to the state's economy. The majority of farmers (79.5 per cent) are small and marginal. To improve livelihoods and quality of life, reliable access to electricity and technological solutions in rural areas is vital. Decentralised renewable energy and energy-efficient appliances can enhance clean energy transition, boost incomes and productivity, offering a significant opportunity for rural-level income generation while transitioning to clean energy. Decentralised Renewable Energy (DRE) livelihood applications use renewable energy sources like solar, wind, micro-hydro, and biomass to support income-generating activities. They offer reliable electricity access, reduce reliance on conventional energy like diesel, and enhance productivity. Successful pilots and business models in agriculture, agro-processing, dairy, poultry, fisheries, and tailoring have been tested in India, Africa, and Southeast Asia, showing potential for replication on a larger scale. Collaboration between organisations like the Maharashtra Energy Development Agency (MEDA), Maharashtra State Rural Livelihoods Mission (SRLM), and Agriculture departments can drive the transition to DRE livelihood solutions. Recommendations include creating infrastructure and enabling ecosystems in the pilot phase and deploying 2500 DRE livelihood solutions in the first two years. In the scale-up phase, promote widespread deployment of DRE technologies across Maharashtra to support sustainable livelihoods.

D. Proposed climate mitigation strategies and actions (2020-2030)

Climate change mitigation actions can take two main approaches: reducing Greenhouse Gas (GHG) emissions and enhancing carbon sequestration in natural systems. Maharashtra has witnessed a significant (80 per cent) rise in emissions over the last fifteen years, reaching 290 MtCO₂e. The energy sector is the largest contributor, accounting for about 82.13 per cent of the state's total emissions, followed by Industrial Processes and Product Use (IPPU - 7.66 per cent), Agriculture Forestry and Other Land Use (AFOLU - 6.16 per cent), and waste (4.05 per cent). IPPUs and energy sectors showed rapid increases, with CAGRs of 7.45 per cent and 4.46 per cent respectively. Maharashtra currently contributes about 10 per cent of India's total emissions. The mitigation strategies are aligned with the seven principles laid down in India's Long-Term Low Carbon Development Strategy submitted by MoEFCC to the UNFCCC under the Paris Agreement. These seven goals aim at the low-carbon development of the country's electricity, transport, urbanisation,

industries, agriculture and forestry, and the financial sector. This plan's mitigation scenario analysis utilises the Global Change Analysis Model (GCAM) to understand Business as Usual (BAU) projections for energy demand and emissions in various sectors. GCAM is a widely used energy sector model, representing interactions between energy systems, water, agriculture, land use, the economy, and climate. The recommendations for climate change mitigation strategies broadly include two main sectors:

- i. Energy, and
- ii. Agriculture, Forestry and Other Land Use (AFOLU).

i. Energy: Sector-wise long-term modelling results and mitigation strategies

Emissions from the energy sector account for the largest share (approximately 82.13 per cent) in the state's total GHG emissions. Within the energy sector, power generation accounts for the largest emissions at 58 per cent of total energy emissions in the year 2018, which is followed by transport (19 per cent), industries (17 per cent), buildings (5 per cent) and agriculture sector (1 per cent). The total CO₂ emissions is 203 MtCO₂ in 2020, which will rise to 256 MtCO₂ in 2030, that is, by 1.26 times. The overall budget outlay for mitigation strategies for the energy sector is expected to be INR 207780.4 lakh.

Power: As of November 2022, Maharashtra's electricity generation capacity is 44.32 GW. The current electricity generation is dominated by coal that accounts for almost 72 per cent of the total generation. The share of renewable energy in generation accounts for only 5.20 per cent. With the current growth rate and dropping costs of solar, the share of coal generation is expected to reduce to 54 per cent in 2030 with the share of renewable energy rising to 18.75 per cent while the overall electricity generation increases by 1.49 times of the demand. Key recommended targets for mitigating power sector emissions include:

- Establishing an installed capacity target 45 GW of renewable energy including solar, wind and other renewables.
- Reducing AT&C losses from 26.55 per cent to 15 per cent by 2030,
- Achieving 100 per cent energy audit compliance for large industries, government buildings, and large residential complexes by 2030.

Industries: In Maharashtra, the leading industries in terms of energy demand are Iron and steel (36 per cent), followed by other industries (26 per cent) and cement (22 per cent). These sectors have high emissions intensity because of their use of fossils. Over the next decade (2020-2030), industry sector energy demand is projected to increase by 1.7 times, resulting in a 1.7 times increase in total emissions from about 43.66 MtCO₂ in 2020 to 72.96 MtCO₂ in 2030.

Key strategies for reduction in industrial emissions include:

- Preferential plot allotment to green industries and promote Best Available Techniques (BAT) in industrial subsectors,
- Establishing a green hydrogen hub with 0.5 GW annual electrolyser capacity by 2030, aiming for a total 0.5 MTPA green hydrogen capacity,
- Setting up plantations and green belts around industrial units,
- Targeting a 30 per cent renewable energy mix in ETPs and STPs by 2030.

Buildings: Emissions from the building sector consist of cooking emissions and are expected to rise by 1.3 times between 2020 and 2030. Emissions rise as population increases and people move away from traditional biomass for cooking to either LPG cylinders or piped natural gas.

Transport: The transport segment includes passenger and freight categories. The passenger segment comprises 2-Wheeler, 4-Wheeler, 3-Wheeler, bus, railways, aviation, and Non-Motorised Transport (cycle and walk). 4-Wheelers' service demand is projected to rise by 1.84 times between 2020 and 2030, becoming the dominant mode due to increased incomes and urbanisation as people prefer private and more convenient modes of transport. As a result, total transport emissions will increase by 1.31 times from 28 MtCO₂ in 2020 to 37 MtCO₂ in 2030, mainly driven by 4-Wheelers and 2-Wheelers. Key strategies for the transport sector include:

- Continue to build a robust public transport network to reduce car and 2W trips in the future,
- Aim for at least 30 per cent EVs in new 2W registrations, 40 per cent in 3W, and 15 per cent in 4W by 2030, based on the modelling and the EV Policy, 2021,
- Develop Mass Rapid Transit System in Tier 1 and Tier 2 cities,
- Implement Extended Producer Responsibility (EPR) on all EV battery sales by 2030.

ii. Agriculture, Forestry and Other Land Use (AFOLU): Sector-wise long-term modelling results and mitigation strategies

Agriculture emissions

The historical observation over the past 15 years in Maharashtra reveals significant trends in various agricultural aspects. The livestock population increased from 2003 to 2007 but declined in subsequent periods, with a projected future increase in goat and sheep population and a limited decline (not more than 2 per cent) in indigenous dairy cattle. Additionally, rice cultivation has been steadily decreasing over the past 15 years, and this trend is expected to persist in the future as some districts

shift towards crop diversification. Fertiliser consumption is expected to increase in correlation with agriculture productivity growth. If the current trends continue, the state of Maharashtra will be emitting 20.6 MtCO₂e into the atmosphere by 2050. While overall emissions from the agriculture sector may decline due to the decreasing livestock population, resulting in reduced emissions from enteric fermentation and manure management, the need to support a rising population will drive an increase in crop production and crop residue burning. Additionally, supporting crop production in the same cropland will require more fertiliser application, leading to increased emissions from fertiliser consumption and crop residue burning.

Forest emissions: Between 2005 and 2021, Maharashtra's forest and tree cover area increased from 18.35 per cent to 20.45 per cent. Pursuing the ambitious goal of a 33 per cent increase as per the forest policy, the area is projected to reach 101.55 × 103 km². In the first scenario, adding 500 km² annually, carbon sequestration may decline due to slower growth in existing mature forests. The second scenario targets 33 per cent cover by 2050, leading to an impressive -38.66 MtCO₂ reduction in emissions and a carbon stock increase from 1.97 BtCO₂ to 2.93 BtCO₂ by 2050, with an annual growth rate of 1.29 × 103 km².

Cropland emissions: Three scenarios were quantified for CO₂ emissions from cropland converted to:

1. Agricultural fallow,
2. Rangeland, and
3. Forestland.

In the first scenario, emissions follow a linear decreasing rate due to declining cropland area, emitting 0.26 MtCO₂ in 2030 and 0.65 MtCO₂ in 2070. In the second scenario, emissions decrease to -4.87 MtCO₂ in 2030 and -4.81 MtCO₂ in 2070. In the last scenario, cropland converted to forestland increases sequestration from 10.63 MtCO₂ in 2030 to 10.67 MtCO₂ in 2070, 121 per cent higher than the second scenario.

Key strategies for AFOLU emission mitigation as per:

- Increase additional tree cover area of 500 km² by 2030 (50 km²/per year) and restore 1,571 km² of dense forests with canopy cover above 40 per cent through afforestation.
- Achieve an increase in forest and tree cover area to 33% by 2050.
- Promote agroforestry and reduce fallow land.
- Reduce livestock emissions by 10 per cent from 2030 Business as Usual (BAU) level.
- Reduce Rice emissions by 10 per cent in 2030 BAU level.

- Reduce Fertiliser emissions by 15 per cent in 2030 BAU level.
- Cut crop residue burning by 80 per cent in 2030 BAU level.

E. Integrated cooling strategy for Maharashtra

CEEW's climatological assessment reveals a nearly two-fold rise in hot and extreme heat days in Maharashtra over the last five decades. This directly affects cooling requirements for comfort and productivity, impacting the state's energy and emissions. Space cooling contributes up to 60 per cent of Mumbai's peak load, while inadequate post-harvest infrastructure leads to a loss of up to 30 per cent of fruits and vegetables in the state. Building upon the India Cooling Action Plan, the following recommendations are suggested to leverage the cooling sector's mitigation and adaptation potential in Maharashtra.

- Mandate replacing old cooling units in government and incentivise private infrastructure upgrades in urban clusters like Mumbai, Pune, and others,
- Adopt evaporative coolers in semi-arid regions for 80-90 per cent energy savings and natural refrigerant use,
- Undertake training of technicians to reduce refrigerant leakage and ensure optimal cooling system efficiency,
- Implement passive cooling measures in cities through building codes, urban greening, and sponge cities to address urbanisation challenges,
- Aim to achieve a 15 per cent reduction in energy consumption from cooling across the state,
- Prioritise energy-efficient cold storages at village level, pack-houses, and reefer vehicles to enhance farmers' income and reduce post-harvest losses in horticulture and fisheries,
- Develop farmers' skills through a roadmap and offer credit guarantee schemes for small farmers to boost subsidy uptake,
- Target a 10 per cent reduction in post-harvest losses at the state level. The total proposed budget for the space cooling strategies is INR 7,708.22 lakh, whereas the overlapping budget with the agriculture budget is INR 36,000 lakh (post-harvest infrastructure and capacity building).

F. Climate Finance

Maharashtra must build resilience and adaptation for climate impacts while mitigating GHG emissions. For this, climate finance is vital, sourced from national, international, and local sectors across private, public, and alternate sources. Government and public finance play a key role in

accelerating climate action due to limited private financing. Climate budget, expenditure on climate action within the government's budgetary structure, can accelerate climate finance, attract private investments, and ensure transparent, accountable, and responsible spending on climate action. In Maharashtra, the climate budget for FY 2023-24 is INR 21420 crore, comprising 11.95 per cent of the total state budget. Adaptation activities receive 88 per cent of the climate budget, while mitigation gets 9 per cent, and the rest funds schemes addressing both. Key sources of climate finance are state government, central government, Development Finance Institutions (DFIs), and externally aided projects (EAPs). The proposed climate budget for 2024-2030 in this plan for Maharashtra is INR 297558.74 crore. This proposed budget corresponds to targets and interventions recommended for each sector in MHSAPCC, and around 80 per cent of this budget focuses on adaptation, while 20 per cent on mitigation. In addition to substantial increases in the climate budget, existing schemes can also be utilised for proposed interventions.

G. Institutional Mechanism

According to the governance structure of the Maharashtra State Action Plan on Climate Change (MH SAPCC), oversight and guidance are provided by the Chief Minister's Council on Climate Change. The State Steering Committee on Climate Change, which the Chief Secretary of Maharashtra heads, is responsible for approval of the SAPCC as an apex body. At the departmental level,

the Principal Secretary of the Environment and Climate Change Department takes the lead in spearheading the overall initiatives. These efforts are further concentrated under the Director of the State Climate Action Cell, which has been set up to implement the State Action Plan on Climate Change, channelise the state's climate change initiatives, address the climate change issues through the relevant line departments, manage relevant projects, identify funding opportunities in collaboration with various government departments, national and international agencies and supervise the operation of the State Knowledge Management Centre on Climate Change (SKMCCC).

The creation of SKMCCC aligns with the National Mission on Strategic Knowledge for Climate Change, positioning it as the primary focal point for research and knowledge management of climate-related matters in the state.

Furthermore, climate and emission modelling for Maharashtra indicates a noticeable increase in temperature and rainfall variability, in addition to rising emissions, as the state progresses along its developmental path. Given these challenges, the effective implementation of both adaptation and mitigation strategies outlined in the plan is essential to ensure Maharashtra's resilience in the face of climate change. By adopting a holistic approach and actively engaging stakeholders from diverse sectors and communities, Maharashtra can proactively address the challenges of climate change and work towards a sustainable and resilient future.

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Acronyms

ADB	Asian Development Bank
AMT	Annual Mean Temperature
NWP	National Water Policy
AEs	Accredited Entities
ASHA	Accredited Social Health Activist
AF	Adaptation Fund
APEDA	Agricultural and Processed Food Products Export Development Authority
ATMA	Agricultural Technology Management Agency
AFOLU	Agriculture, Forestry and Other Land Use
AIILSG	All India Institute of Local Self Government
AR	Assessment Report
BEV	Battery Electric Vehicles
BAT	Best Available Techniques
BCM	Billion Cubic Metres
BDD	Bombay Development Directorate
BMC	Brihanmumbai Municipal Corporation
BEE	Bureau of Energy Efficiency
BAU	Business as Usual
CCCma	Canadian Centre for Climate Modelling and Analysis
CCS	Carbon Capture and Storage
CDRI	Coalition for Disaster Resilient Infrastructure
CRIDA	Central Research Institute for Dryland Agriculture
CWC	Central Water Commission
CCCR	Centre for Climate Change Research
CEE	Centre for Environment Education
CM	Chief Minister

CIDCO	City and Industrial Development Corporation Limited
CCF	Climate Change Fund
CCIP	Climate Change Innovation Programme
CVI	Climate Vulnerability Index
CV	Coefficient of variation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CHCs	Community Health Centre
CBDRR	Community-based Disaster Risk Reduction
COP	Conference of Parties
CORDEX	Coordinated Regional Climate Downscaling Experiment
CMIP	Coupled Model Intercomparison Projects
DRE	Decentralised Renewable Energy
DoF	Department of Fertilisers
DST	Department of Science & Technology
DFIs	Development Finance Institutions
IDECs	Direct–indirect Evaporative Coolers
DES	Directorate of Economics and Statistics
DMER	Directorate of Medical Education and Research
DM	Disaster Management
DCMG	District Crisis Management Group
DDMAs	District Disaster Management Authorities
DDMC	District Disaster Management Cell
DDMP	District Disaster Management Plan
DEOC	District Emergency Operation Centre
DEOCs	District Emergency Operation Centres
DRDA	District Rural Development Agency
DEWS	Drought Early Warning Systems
DPAP	Drought Prone Area Programme
EMC	Electronics Manufacturing Cluster
EbA	Ecosystem-based Adaptation
ECBC	Energy Conservation Building Code
ESRI	Environmental Systems Research Institute
EEs	Execution Entities
EPR	Extended Producer Responsibility
FPOs	Farmers Producers Organisations
FY	Financial Year
FRUs	First Referral Units
FAO	Food and Agriculture Organization
FDST	Forest Dwelling Scheduled Tribes
FRA	Forest Rights Act
FSI	Forest Survey of India
FDRVC	Foundation for Development of Rural Value Chains
GW	Gigawatt
GCAM	Global Change Analysis Model
Gol	Government of India
GoM	Government of Maharashtra

GCF	Green Climate Fund
GIM	Green India Mission
GRIHA	Green Rating for Integrated Habitat Assessment
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GSDP	Gross State Domestic Product
GVA	Gross Value Added
GSDA	Groundwater Surveys and Development Agency
HTED	Higher and Technical Education Department
HFCs	Hydrofluorocarbons
IRS	Incident Response System
ICAP	India Cooling Action Plan
IMD	India Meteorological Department
ICAR	Indian Council of Agricultural Research
IITM	Indian Institute of Tropical Meteorology
INR	Indian National Rupee
ISHRAE	Indian Society for Heating, Refrigeration, and Air-conditioning Engineers
ISRO	Indian Space Research Organisation
ISM	Indian Summer Monsoon
IFR	Individual Forest Right
ICT	Information and Computer Technology
IEC	Information, Education and Communication
IPSL	Institut Pierre-Simon Laplace
IDWH	Integrated Development of Wildlife Habitat
IPCC	Intergovernmental Panel on Climate Change
JJM	Jal Jeevan Mission
JNPT	Jawaharlal Nehru Port Trust
JGCRI	Joint Global Change Research Institute
KCC	Kisan Credit Cards
KGE	Kling-Gupta Model Efficiency
LULC	Land-use and Land-cover
LDCF	Least Developed Countries Fund
LiFE	Lifestyle for Environment
LPA	Long Period Average
LSG	Local Self-Governments
MERC	Maharashtra Electricity Regulatory Commission
MEDA	Maharashtra Energy Development Agency
MHADA	Maharashtra Housing and Area Development Authority
MJP	Maharashtra Jeevan Pradhikaran
MPCB	Maharashtra Pollution Control Board
MahaRERA	Maharashtra Real Estate Regulatory Authority
MH SAPCC	Maharashtra State Action Plan on Climate Change
MSHMPB	Maharashtra State Horticulture and Medicinal Plants Board
MSWC	Maharashtra State Warehousing Corporation
MYCA	Maharashtra Youth for Climate Action
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme

MSL	Mean Sea Level
MtCO ₂	Metric Tons of Carbon Dioxide
MtCO ₂ Eq.	Metric Tons of Carbon Dioxide Equivalent
MoA	Ministry of Agriculture
MoES	Ministry of Earth Sciences
MoEFCC	Ministry of Environment, Forest and Climate Change
MoFPI	Ministry of Food Processing Industries
MNRE	Ministry of New and Renewable Energy
MoSPI	Ministry of Statistics and Program Implementation
MIDH	Mission for Integrated Development of Horticulture
MHEWS	Multi-Hazard Early Warning Systems
MMRDA	Mumbai Metropolitan Region Development Authority
MTHL	Mumbai Trans Harbour Link
MCGM	Municipal Corporation of Greater Mumbai
NAPCC	National Action Plan on Climate Change
NASA	National Aeronautics and Space Administration
NAFED	National Agricultural Cooperative Marketing Federation of India
NABARD	National Bank for Agriculture and Rural Development
NCCD	National Centre for Cold Chain Development
NDAs	National designated authorities
NDCs	National Determined Contributions
NDMA	National Disaster Management Authority
NFHS	National Family Health Survey
NHRSC	National Health Systems Resource Centre
NIPHT	National Institute of Post Harvest Technology
NMEEE	National Mission for Enhanced Energy Efficiency
NMSKCC	National Mission on Strategic Knowledge for Climate Change
NOAA	National Oceanic and Atmospheric Administration
NAINA	Navi Mumbai Airport Influence Notified Area
NTFPs	Non-timber Forest Products
ND-GAIN	Notre Dame Global Adaptation Initiative
OND	October, November, and December
OTFD	Other Traditional Forest Dwellers
PRIs	Panchayati Raj Institutions
PB	Percentage Bias
PMFBY	Pradhan Mantri Fasal Bima Yojana
PIB	Press Information Bureau
PHCs	Primary Health Centres
PPC	Primary Processing Centre
PMCCCC	Prime Minister's Council on Climate Change
PoCRA	Project on Climate Resilient Agriculture
PVTG	Particularly Vulnerable Tribal Groups
PWD	Public Works Department
RKVY	Rashtriya Krishi Vikas Yojana

RTDSS	Real-Time Flood Decision Support System
RCUES	Regional Centre for Urban & Environmental Studies
RPO	Renewable Purchase Obligation
RCP	Representative Concentration Pathway
R&D	Research and Development
RMSE	Root Mean Square Error
SHGs	Self Help Groups
SPCS	Semi-Public Charging Stations
SSPs	Shared Socioeconomic Pathways
SRA	Slum Rehabilitation Authority
SHM	Soil Health Management
SPAEF	Spatial Efficiency Metrics
SCCF	Special Climate Change Fund
SAPCC	State Action Plan on Climate Change
SDMA	State Disaster Management Authority
SEOCs	State Emergency Operation Centres
SEOC	State Emergency Operations Centre
SKMCCC	State Knowledge Management Centre on Climate Change
SLC	State Level Committee
SLCCCI	State Level Coordination Committee on Crop Insurance
SMART	State of Maharashtra's Agribusiness Rural Transformation Project
SRLM	State Rural Livelihoods Mission
SMAM	Sub Mission on Agricultural Mechanisation
SMPPQ	Sub Mission on Plant Protection and Plant Quarantine
SDGs	Sustainable Development Goals
SGSY	Swarna-Jayanthi Grameen Swarozgar Yojana
TRTI	Tribal Research and Training Institute
UT	Union Territory
UNICEF	United Nations Children's Fund
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Risk Reduction
UNDRR	United Nations Office for Disaster Risk Reduction
USD	United States Dollar
USGS	United States Geological Survey
ULBs	Urban Local Bodies
VPD	Vapour Pressure Deficit
WIM	Warsaw International Mechanism
WRI	Water Risk Index
WSSO	Water Supply and Sanitation Organisation
WB	World Bank
WMO	World Meteorological Organisation
ZBNF	Zero Budget Natural Farming

Chapter – 1

Introduction

India is witnessing a rise in the severity and frequency of climate-related extreme events such as heatwaves, cyclones, floods, and droughts, a phenomenon seen as a direct consequence of climate change. As the effects of climate change intensify and have a greater impact on people and the environment, it is crucial to develop action plans and recommendations that will lead to increased resilience at the district and regional levels. An action plan is crucial for a better understanding of the impacts of climate change, management of extreme events, and design and implementation of relevant policies to protect people and the environment from the detrimental effects of climate change.

Several countries, including India, have committed to keeping global average temperatures well below 2°C above pre-industrial levels under the Paris Agreement in 2015. This is intended to increase the ability to mitigate the adverse effects of climate change and reduce greenhouse gas (GHG) emissions while promoting climate-resilient development. In 2016, India adopted its Nationally Determined Contributions (NDC) and submitted them to the United Nations Framework Convention on Climate Change (UNFCCC), along with other nations that have ratified the agreement. For this purpose, nations have declared their goals and targets under their NDCs. India has also committed to achieving the Sustainable Development Goals (SDGs) by 2030, especially Goal 13 (Climate Action), which calls for the creation and implementation of technology that is sensitive to climate change, cognizant of biodiversity, and resilient. This makes it abundantly clear how vital it is to engage in cross-sectoral planning that considers the various synergies, trade-offs, and interlocking

priorities that exist among the numerous economic sectors, such as agriculture, water, forestry, health, tourism, urban development, industries, transport and energy.

Initiatives taken by different states towards achieving the goals mentioned in the NDCs must correlate with the scope of the respective State Action Plans on Climate Change (SAPCCs) to achieve a synergistic output.

As an update to the first NDC, the Government of India committed to realising net zero emissions by 2070 at the Conference of Parties (COP) 26 in Glasgow, which calls for a significant shift in energy use, land use and management, and other developmental activities. While enhancing their capacity for climate change adaptation, states must identify the essential initiatives required to achieve these goals and allocate funding options.

The National Action Plan on Climate Change (NAPCC), which was formulated by the Government of India in 2008, is geared towards the formulation of SAPCCs for all states. The NAPCC recognised that each state should have its own action plan to deal with climate change extremes and their impacts. The SAPCCs are intended to create a framework considering all the potential adverse effects of climate change and provide recommendations, suggestions, and guidelines for improved ways to protect communities and the environment, including strategies pertaining to adaptation and mitigation.

The Constitution of India, which allocates duties and defines the boundaries of authority among the different levels of the federal government, justifies the SAPCC as well. The directive principles explicitly state the

responsibility of states to provide a healthy environment to the citizens. Moreover, Article 21 guarantees the fundamental right to life within which an individual is entitled to their right to the environment.

To define the scope of state-level climate policy in India, the Union List and State List serve as a crucial basis. Agriculture, water, fisheries, and mining are a few of the sectors directly tied to natural resources under the purview of different states. Additionally, the State List includes businesses like industries and transportation, which are crucial considerations due to their energy- and emissions-intensive nature. On the other side, the union is concerned about several issues related to climate policy, including trade representation, accords and conventions, atomic power, and mineral and oil resources.

The Ministry of Environment, Forest and Climate Change (MoEFCC) has created and distributed a common framework for the revision of all SAPCCs in 2019, which underlines the following guidelines:

1. The SAPCC should be a policy document of the states/UTs describing the primary initiatives and strategies that represent the states' commitments and planned measures to address the vulnerabilities and consequences of climate change across all socio-economic sectors.
2. The SAPCC should envision inclusive, sustainable, and climate-resilient low-carbon development pathways with a focus on climate change adaptation and mitigation in the key sectors of the states/UTs, and should be able to protect the most vulnerable communities and societies from the negative effects of climate change.
3. SAPCCs should take into account recent scientific assessments and projections on global warming, vulnerability, and impacts. States/UTs may consult Ministry of Earth Sciences- Indian Institute of Tropical Meteorology, Pune with respect to downscaled data on medium-term and long-term impacts of climate change in the States/region viz. climate models and high resolution downscaled projections, while assessing the vulnerability and preparing sectoral adaptation plans.
4. SAPCCs should synergise with the goals of NDCs under the Paris Agreement, though the targets under NDCs are national targets. It should also contribute towards achieving other development goals including Sustainable Development Goals (SDGs). SAPCC should also complement prevalent national development and policy initiatives inter alia National Forest Policy, Biodiversity Goals, National E-Mobility Programme, Swachh Bharat Mission to reap greater developmental co-benefits.
5. The SAPCC should highlight the links with national missions related to climate change. It should bring out climate actions of the state government from

their own sources, over and above the Government of India schemes.

6. The SAPCC should also be built on the evolving socio-economic development context and priorities of the state. SAPCCs should integrate and mainstream climate change concerns in the different sectors and policies. The programmes of the states should be aligned and consistent with the existing schemes and programs within the states/UTs.
7. States/UTs can strengthen existing climate action measures as well as launch new initiatives in their priority sectors.
8. The time period of the implementation of SAPCCs should be clearly brought out starting with the implementation cycle of NDCs i.e. 2021-2030 and beyond.
9. Financial resources required for the implementation of the action plan should primarily be leveraged from the existing budget of the state governments and convergence with the relevant schemes and programmes. The SAPCC should bring out the likely funding from State's own resources over and above from the ongoing schemes and programmes of Govt. of India.
10. The SAPCCs should set out the institutional mechanism for implementation including stakeholder engagement ensuring inclusiveness along with the mechanism for capacity building and monitoring and evaluation with clear indicators for reporting.

1.1 Maharashtra State Action Plan on Climate Change (MHSAPCC)

Maharashtra is highly vulnerable to the impacts of climate change due to its geography, socio-economic diversity, long coastline, several agro-climatic zones, and economy that is reliant on agriculture, manufacturing and other industries. Recurrent droughts, extreme rainfall, floods, heatwaves, hailstorms, lightning, and sea-level rise are potential climatic hazards to the state.

Climate change adaptation and mitigation must be a key component of the state's overall development plan. In light of this, the MoEFCC authorised the Maharashtra State Adaptation Action Plan on Climate Change (MHSAPCC 1.0) in 2014, which was created by the Department of Environment, Government of Maharashtra. The eight major sectors: agriculture, water, health, forest and biodiversity, rural and urban development, disaster management, tribal development, and energy, were considered in MHSAPCC 1.0.

In 2021, The Government of Maharashtra and the Brihanmumbai Municipal Corporation (BMC) launched

Mumbai Climate Action Plan. The plan addresses the detrimental impacts of climate change, such as sea-level rise and exponential increase of extreme climatic events, including plans to achieve the net-zero target by 2050.

Due to the emergence of new climate models that can project climatological variables with a fair amount of greater precision, quantification of different consequences of climate change has become more accessible, which will help create sector-specific solutions. Considering this, the existing SAPCC, which was published in 2014, needs to be revised with an updated methodology, datasets and quantification of impacts of climate change on different sectors.

1.2 Maharashtra State Action Plan for Climate Change 2.0 (MHSAPCC 2.0)

The MoEFCC has directed all states to update their SAPCC in accordance with the directive framework made available in May 2019. Therefore, the Maharashtra government has mandated the amendment of the existing SAPCC. In addition to the existing eight sectors, the state has opted to include two cross-cutting areas (finance and planning) and four additional sectors (industries, transport, tribal development, and tourism) while revising the SAPCC in order to align with the goals of the NDCs and SDGs.

The Government of Maharashtra and CEEW signed an agreement to revise the existing SAPCC (MHSAPCC 1.0) in 2022. The revised SAPCC (MHSAPCC 2.0) proposes a framework that addresses the urgent need to incorporate climate change action within the state's development plan, therefore fostering long-term resilience and enabling adaptation to potential climate change-related risks and threats.

1.3 Process of developing the MHSAPCC 2.0

1.3.1 Studying and building on previous SAPCCs

The revision of the MHSAPCC followed the common framework developed by the MoEFCC and was conducted in a systematic and inclusive manner.

The first step in the revision of the SAPCC was to analyse the existing data and information from in the existing SAPCC of Maharashtra and the other documents pertaining to climate change to carry out a critical analysis of policies, schemes, and other programmes and strategies for climate change mitigation and adaptation. By reviewing the existing SAPCC we were able to gain a better understanding of the strategy and framework used, as well as to identifying key gaps and issues in the current policies.

Figure 1.1 Process and approach for the development of the MHSAPCC 2.0



Source: Authors' compilation

1.3.2 Consulting all state line departments

Identifying and mapping the key stakeholders was the most significant phase in the process of redesigning the SAPCC, bearing in mind that stakeholder engagements should be continually prioritised throughout the SAPCC development process. The important stakeholders from each sector were identified based on the significance of their participation in the process of upgrading the SAPCC. Prior to the consultation meetings, various stakeholder departments from multiple sectors – including agriculture, water, health, forests and biodiversity, and industries – were categorised as 'hot', 'warm', or 'cold' based on the significance of their contribution to the SAPCC. Thus, through the classification process, 19 departments were classified as 'hot', 7 as 'warm', and 16 as 'cold'.

1.3.3 Leveraging technical tools to conduct analysis and modelling

To understand future climatic projections, we obtained high-resolution downscaled projections data from the Coordinated Regional Climate Downscaling Experiment (CORDEX) South Asia programme, led by the Centre for Climate Change Research (CCCCR) at the Indian Institute of Tropical Meteorology (IITM), Pune. These projections are based on the CMIP5 climate models, part of the fifth generation of CMIP in the Coupled Model Intercomparison Projects (CMIP).

The CORDEX regional models use data from atmosphere–ocean coupled general circulation model runs conducted under CMIP5 for Representative Concentration Pathway (RCP) scenarios. This assessment focuses on two standardised forcing scenarios known as RCP 4.5 (mid-range emissions) and RCP 8.5 (high-end emissions).

Table 1.1 Number of consultations organised with the concerned line departments

S. no.	Name of the department	No. of consultations
1	Water Resources Department	5
2	Disaster Management	5
3	Department of Agriculture, Animal Husbandry, Dairy (PoCRA – World Bank)	8
4	Department of Energy, MEDA, MSEDCL, MSPGCL, MSETC, and MSEB	8
5	Department of Public Health	3
6	Department of Urban Development	4
7	Water Supply and Sanitation Department	2
8	Transport Department	4
9	Department of Soil and Water Conservation	3
10	Public Works Department	3
11	Department of Tribal Development	3
12	Department of Fisheries	2
13	Department of Rural Development	1
14	Maharashtra State Agriculture Marketing Board, Department of Agriculture	1
15	Department of Planning (SDG Cell)	2
16	Forest Department	3
17	Department of Finance	2
18	Department of Relief and Rehabilitation	2
19	Tourism Department	2
20	Department of Industries	3

Source: Authors' compilation

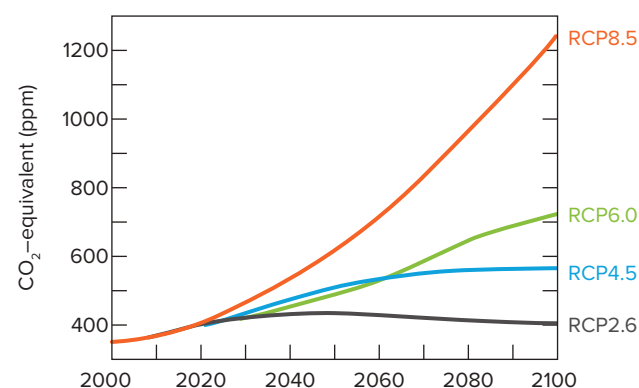
Each scenario represents a time series of emissions and concentrations of GHGs, aerosols, chemically active gases, and land-use changes throughout the 21st century, with resulting radiative forcing values in the year 2100. RCP 4.5 stabilises at 4.5 W/m² radiative forcing in 2100, while RCP 8.5 represents a high-concentration pathway resulting in 8.5 W/m² radiative forcing in 2100.

For scenario analysis in the mitigation section, we have used the Global Change Analysis Model (GCAM). The GCAM is an energy sector-focused model used extensively for energy and climate policy analysis. It represents the behaviour of and interactions between energy systems, water, agriculture and land use, the economy, and the climate. The GCAM is housed at the Joint Global Change Research Institute (JGCRI), USA and models 32 regions of the world, with India as a separate region.

The next step involved in the revision of the SAPCC was to review the existing sectoral strategies. This was accomplished by conducting a detailed review of existing policies and programmes in different sectors of the state and consultations with the stakeholders and experts from various line departments and non-government

organisations. The primary focus of these consultations was to understand the new sectoral initiatives and programmes as well as the gaps and challenges faced by each department in implementing various sectoral policies and programmes pertaining to climate change adaptation and mitigation.

Figure 1.2 IPCC representative concentration pathways



Source: IPCC, 2019

1.4 Unique features of the MHSAPCC 2.0

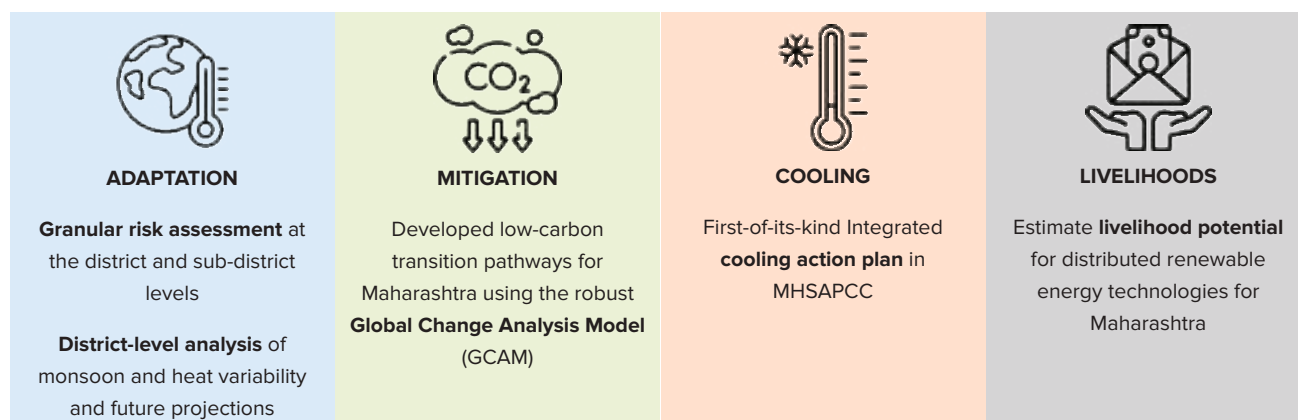
The adaptation components in the MHSAPCC have been based on granular vulnerability and risk assessments at a district and sub-district level, which are defined by the exposure, sensitivity, and adaptive capacity at a sub-district level. We have conducted the sector-level vulnerability and risk analysis for most sectors.

Compared to its predecessor MHSAPCC 2.0 also provides strategies on climate change mitigation. The mitigation components in the MHSAPCC are achieved through

Global Change Analysis Model (GCAM) to develop low-carbon transition pathways for Maharashtra. Apart from laying down the adaptation and mitigation strategies, the MHSAPCC 2.0 has also incorporated all the findings from the previous SAPCC (MHSAPCC 1.0) and the policies and programmes of the Maharashtra government.

India became the first country to develop a cooling plan that is also known as the India Cooling Action Plan (ICAP) and now Maharashtra is set to be the first state to develop its own integrated cooling strategy as part of the state's climate change action plan. In the face of rising heat, compounded by the forces of urbanisation and industrialisation.

Figure 1.3 Unique features of the MHSAPCC 2.0



Source: Authors' compilation

State profile of Maharashtra

The state of Maharashtra spans the western and central parts of India. It is the second-most populous state in the country, with 11.237 crore people (Ministry of Home Affairs 2011). The state shares its borders with six states, including Gujarat, Madhya Pradesh, Chhattisgarh, Telangana, Karnataka, and Goa.

2.1 Geography

The third-largest state in India, Maharashtra, covers a total magnitude of 3.08 lakh sq km by area. It is located between longitude 72° 36' 00" to 80° 54' 00" and latitude 15° 44' 00" to 22° 06' 00", with the fourth-longest coastline among all states in the country, stretching for 720 km along the Arabian Sea.

The Sahyadri and Satpura mountain ranges naturally fortify the state and are divided into three sections based on their topography:

1. The Deccan Plateau,
2. The Sahyadri range, and
3. The Konkan coastal strip.

From Daman in the north to Goa in the south, a 720 km long coastline is part of India's resource-rich western plateau and hill regions. The Western Ghats, which rise to an average height of 1,200 m, act as an important climatic border for the region and are one of the state's three primary watersheds and the source of several important rivers, including the Godavari and Krishna.

2.2 Geomorphology

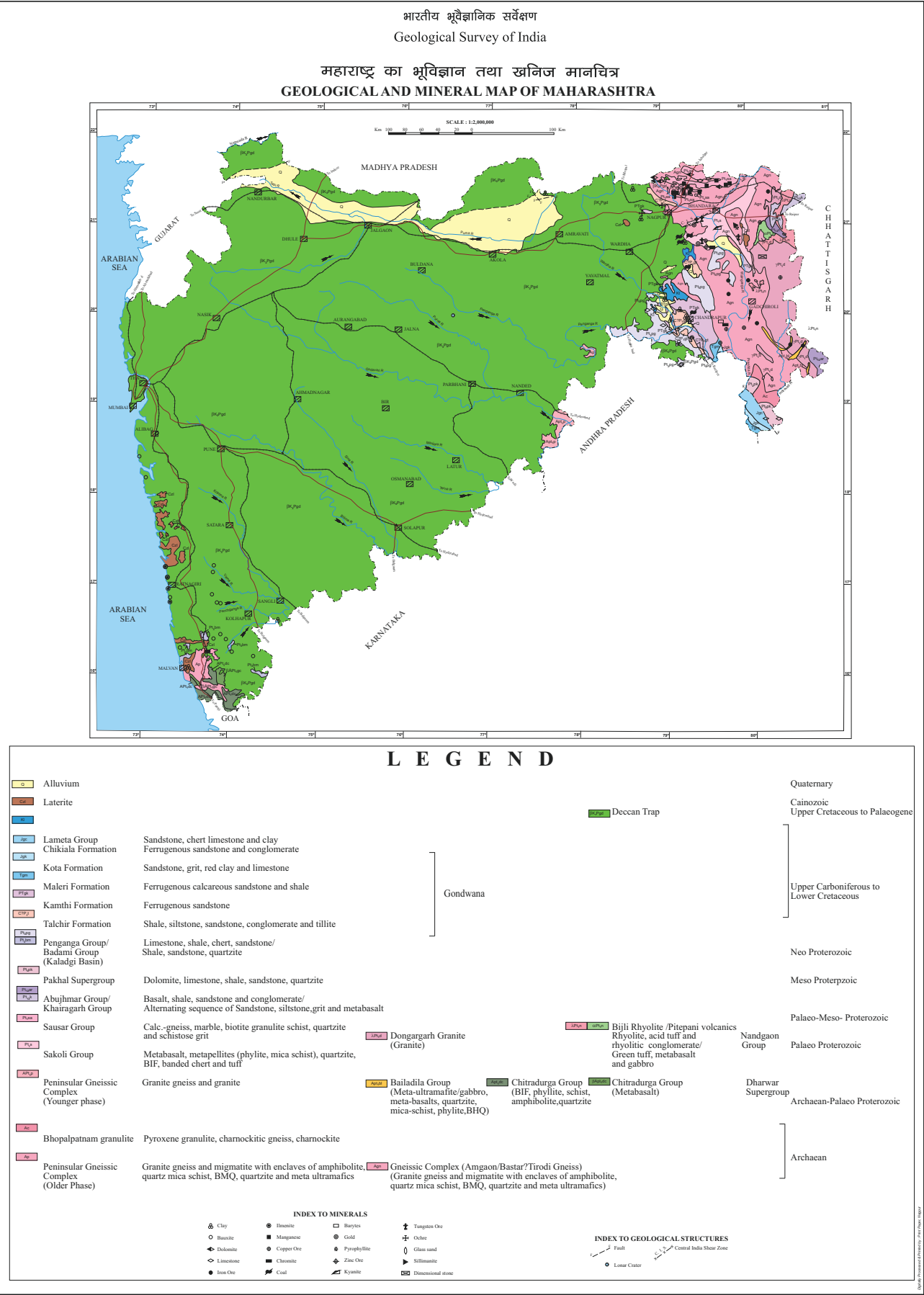
With a presence in the Arabian Sea through its port city of Mumbai, Maharashtra is physically homogeneous according to its underlying geology. The state has the following types of soils: black, alluvial, laterite, yellow-brown to reddish, and grey. The state's predominant physical characteristic is its plateau nature, which includes Maharashtra's western coastal plains, upturned western rims ascending to create the Sahyadri range, and its slopes gradually sloping towards the east and southeast. The plateau is divided into alternating, broad river valleys and intervening higher-level interfluvies – including the Ahmednagar, Buldhana, and Yavatmal plateaus.

Maharashtra's Western Ghats, also called the Sahyadri mountain ranges, have an average height of 1,200 m above mean sea level (MSL). At a height of 1,646 m, Kalsubai is its highest peak. The Sahyadri range is characterised by crowning plateaus on its crest.

The Konkan strip is located between the Arabian Sea and the Sahyadri range. The small coastal plain of the Konkan region is 50 km wide; its width increases in the north and decreases in the south. Konkan is deeply divided and fractured, with a low plateau of laterite alternated with small valleys with steep sides. The significant Konkani creeks are Terekhol, Vijaydurg, Rajapuri, Raigad, Dabhol, Daramthar, Thane, and Vasai.

Along with creating physical obstacles that make mobility difficult, the Satpura hills on the state's northern border and the Bhamragad-Chioli-Gaikhuri ranges on its eastern border act as the state's natural boundaries. Maharashtra's geology is uniquely positioned globally due to two

Figure 2.1 Geological and mineral map of Maharashtra



Source: Geological Survey of India, 2018

remarkable features: The Lonar meteorite crater and the Deccan volcanism. These geological phenomena shaped its surface through lava from basalt eruptions through fractures. They are primarily found in Vidarbha, Khandesh, Marathwada, and parts of Western Maharashtra, covering around 81 per cent of the state's total area. Basalts from the Deccan region show consistent chemical and mineralogical characteristics, including secondary minerals such as quartz, apophyllite, heulandite stilbite, and many more. Much of the state's geology is composed of basalt granite and schist, both of which were created by volcanic lava.

2.3 History

The history of Maharashtra is shaped by its geography and climate; the history of human civilisation in the state can be traced back to 2200–2300 BCE. Maharashtra was among the most important regions of the Indian subcontinent. An archaeological site in the Ahmednagar district, Daimabad, is located on the left bank of the Pravara River, a tributary of the Godavari River. The site suggests late Harappan culture extended into the Deccan Plateau in India. The Satavahanas, Vakatakas, Rashtrakutas, Yadavas, and many more dynasties governed this area. Maharashtra's culture underwent distinctive shaping under the Deccan sultanates. The mighty Maratha empire carved out Maharashtra's identity.

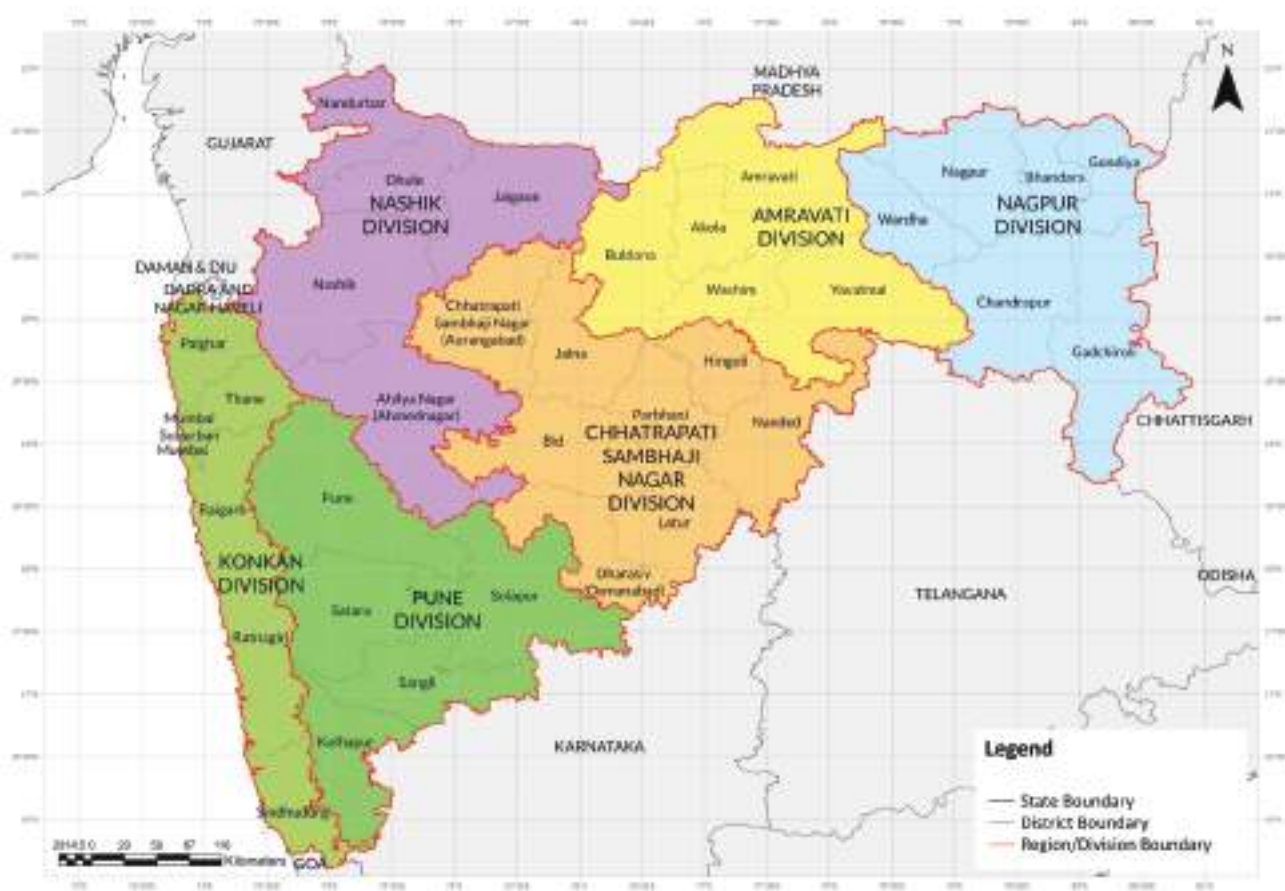
The region has produced several important leaders in medieval and modern times, and they have all contributed to changing the course of events both during and after independence. After India gained independence, several industrialists and technocrats stepped up to help the country and its economy by launching the Bombay Plan and other national programmes to promote growth and employment.

The state houses various world heritage sites such as Ajanta, Ellora, and Elephanta caves from the Vedic era; 19th-century Victorian Neo-Gothic public buildings; 20th-century Art-Deco buildings, Chhatrapati Shivaji Maharaj Terminus, and several others. Tourists from around the globe visit these world heritage sites – architectural marvels like the Gateway of India, Viharas and Chaityas, animal sanctuaries, bird sanctuaries, beaches, forts, and Ramsar sites, etc. There are three Ramsar sites viz. Lonar crater in the Buldhana district, Nandur Madhameshwar in the Nashik district, and Thane Creek inlet in the shoreline of the Arabian Sea that isolates the city of Mumbai (Bombay).

2.4 Current state of Maharashtra

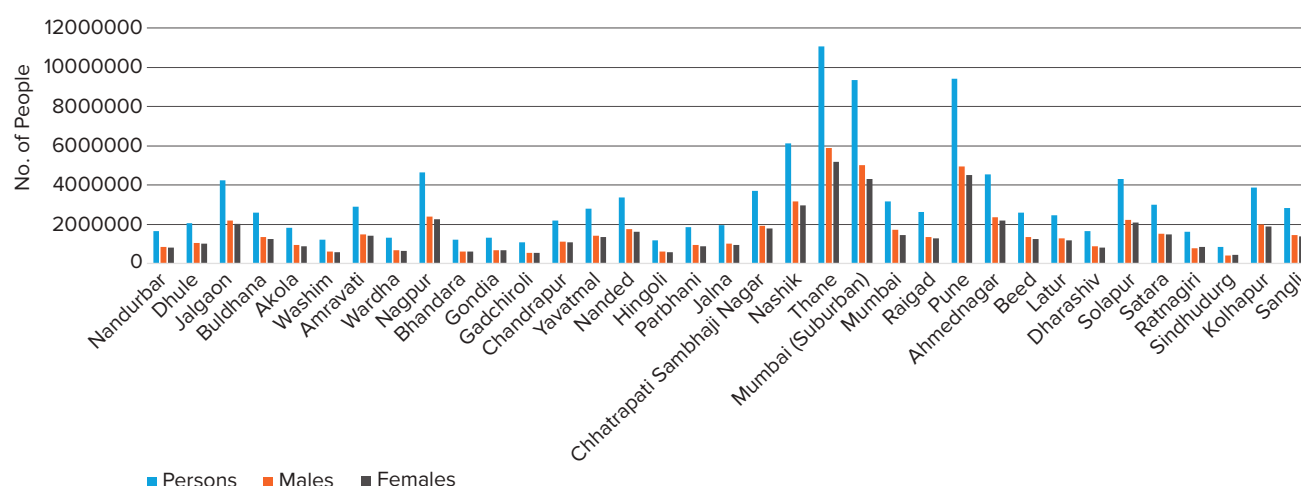
Mumbai serves as the state capital and a significant economic and entertainment centre for the nation. One of

Figure 2.2 Map of Maharashtra



Source: Government of Maharashtra 2018

Figure 2.3 District-wise population of Maharashtra (males and females)



Source: Ministry of Home Affairs 2011, Government of India

India's well-urbanised states, Maharashtra is extensively connected by roads, rivers, airways, and trains. According to the 2011 census, the state has 43 cities; and as per Smart City Mission 2015, the state has 8 smart cities.

2.5 Demographic profile

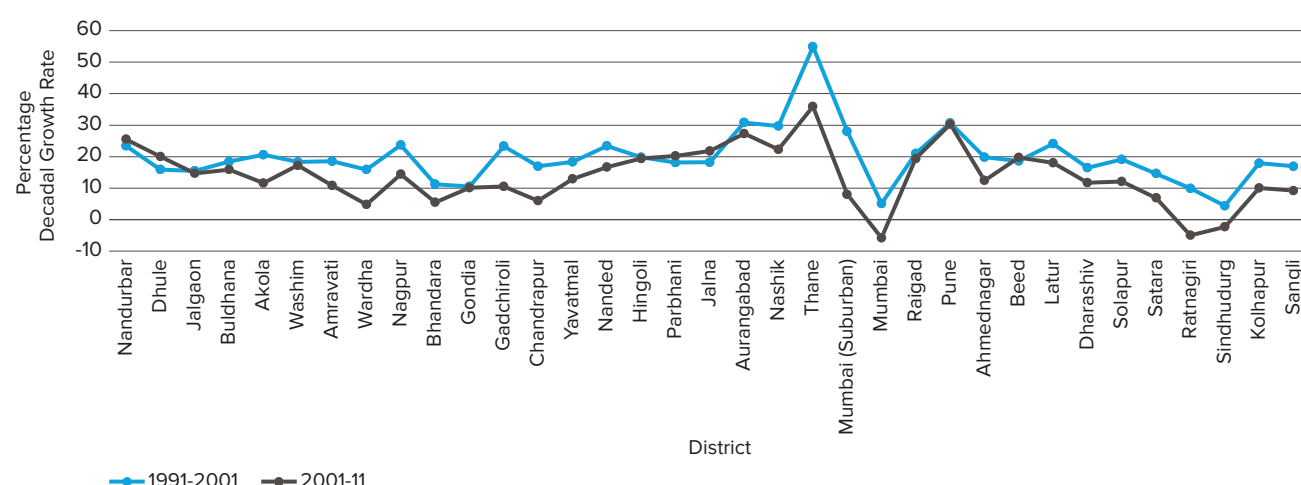
For administrative reasons, Maharashtra has been split into six divisions: Amravati, Aurangabad, Konkan, Nagpur, Nashik, and Pune. The state has a higher proportion of urban population than the national average. At the national level, the shares of rural and urban population are 68.9 per cent and 31.1 per cent, respectively, while the state has 54.8 per cent of rural population or around 6,15,56,000 persons, and 45.2 per cent of the urban population or roughly 5,08,18,000 persons. The state's population growth rate from 2001–11 was 16 per cent, which is about 1.7 per cent less than the national average. Around 82.3 per cent of the

state's population is literate, compared to 73 per cent of India's population (Economic Survey of Maharashtra 2021–22, Directorate of Economics and Statistics, Planning Department, Government of Maharashtra)

According to the 2011 census, the state has a total population of around 11.24 crore or 9.3 per cent of the total population of the nation. Males make up 5.82 crore, females 5.41 crore, and transgender people 40.8 lakh. In contrast to India, where the ratio is 943 females for every 1,000 males, Maharashtra has 929 females for every 1,000 males (Ministry of Home Affairs 2011).

Of the state's overall population, tribal residents make up 9.4 per cent of the population. As per Census 2011, the population of scheduled tribes in the state is 1.05 crore persons and the state has the highest proportion of slum population in the country at 18.1 per cent. In 2001, the slum population was 1.12 crore, and in 2011, it was 1.18 crore.

Figure 2.4 Decadal growth rate of Maharashtra in per cent (1991–2001, 2001–11)



Source: Ministry of Home Affairs 2011, Government of India

Table 2.1 Population trends of Maharashtra

Population (in cr)	Type	1961	1971	1981	1991	2001	2011
Rural	Persons	2.84	3.47	4.08	4.84	5.58	6.15
	Male	1.42	1.75	2.05	2.45	2.85	3.15
	Female	1.42	1.72	2.03	2.39	2.73	3.00
Urban	Persons	1.12	1.57	2.20	3.05	4.11	5.08
	Male	0.62	0.86	1.19	1.63	2.19	2.67
	Female	0.50	0.71	1.01	1.42	1.92	2.41
Scheduled Caste	Persons	0.22	0.30	0.45	0.88	0.99	1.33
	Male	0.11	0.16	0.23	0.45	0.51	0.68
	Female	0.11	0.15	0.22	0.43	0.48	0.65
Scheduled Tribe	Persons	0.22	0.30	0.58	0.73	0.86	1.05
	Male	0.12	0.15	0.29	0.37	0.44	0.53
	Female	0.12	0.15	0.28	0.36	0.42	0.52
Population (age group 0–6 years)	Persons	0.84	1.04	1.09	1.35	1.37	1.33
	Male	0.11	0.15	0.22	0.43	0.48	0.65
	Female	0.42	0.51	0.53	0.66	0.65	0.63
Adolescent population (age group 10–19 years)	-	0.76	1.05	1.40	1.62	2.09	2.14
Decadal growth rate (%)	-	23.6	27.50	24.50	25.70	22.70	16.00
Sex ratio	-	936	930	937	934	922	929
Literacy rate	-	35.1	45.80	55.80	64.90	76.90	82.30
Population density	-	129	164	204	257	315	364
Total	Persons	3.96	5.04	6.28	7.89	9.69	11.24
	Male	2.04	2.61	3.24	4.08	5.04	5.82
	Female	1.91	2.43	3.04	3.81	4.65	5.41

Source: Economic Survey of Maharashtra 2021–22, Directorate of Economics and Statistics, Planning Department, Government of Maharashtra

According to demographic forecasts published by the National Commission on Population, Government of India, the projected population of the state as of 1 March 2022 was 12.54 crore. The district-wise population (male and female) trends are shown in Figure 2.3, and the decadal growth rate of population district-wise in per cent for 1991–2001 and 2001–11 for Maharashtra is shown in Figure 2.4.

As India's second-most populated state – following Uttar Pradesh – Maharashtra has a population density of 365 people/sq km. The state's population increased by 16 per cent from 2001–11. At an all-India level, it ranks fifth in terms of urban population and sixth in terms of literacy. The average household size was 4.6 persons in Maharashtra, compared to 4.9 persons for all of India.

2.6 Economic profile

As of 2023–24, Maharashtra's economy is the biggest in India. Its projected Gross State Domestic Product (GSDP) at current prices is INR 38,79,792 crore, showing a growth of 10 per cent compared to 2022–23. In 2023–24, a total of INR 5,47,450 crore is anticipated in expenditures (apart from debt payments). Over the updated forecast for 2022–23, this represents a rise of 3.6 per cent. This expense is expected to be covered by net borrowings of INR 76,649 crore and revenues (apart from borrowings) of INR 4,51,949 crore. Other than borrowings, total receipts for 2023–24 are anticipated to rise 4.3 per cent above the updated forecast for 2022–23.

The national GDP (Gross Domestic Product) is anticipated to expand at a rate of 7 per cent between 2022 and 2023. Services sector growth in 2021–22 increased by 10.6 per cent from a low base in 2020–21. The manufacturing industry expanded by 4 per cent. The agricultural industry

Table 2.2 Per capita state income and nominal GSDP in Cr (base year 2011–12)

Particulars	2011–12	2012–13	2013–14	2014–15	2015–16	2016–17	2017–18	2018–19+++	2019–20++	2020–21+	2021–22\$
Nominal GSDP	12,80,369	14,59,629	16,49,647	17,79,138	19,66,225	21,98,185	23,52,782	25,67,897	27,34,552	27,11,685	31,97,782
Per capita state income	99,597	1,12,092	1,25,261	1,32,836	1,46,815	1,63,726	1,72,663	1,86,074	1,96,100	1,96,100	2,25,073

Source: *Economic Survey of Maharashtra 2021–22*, Directorate of Economics and Statistics, Planning Department, Government of Maharashtra

Notes: +++ Third revised estimates ++ Second revised estimates + First revised estimates \$ Advance estimates

expanded by 9.8 per cent in 2020–21 and 8.8 per cent in 2022–23, respectively. Agriculture, manufacturing, and services are predicted to make up 16 per cent, 25 per cent, and 59 per cent in 2021–22, respectively (at current prices) (PRS Legislative Research, 2022–23).

According to the Maharashtra State Budget of 2023–24, Maharashtra's projected per capita GSDP would be INR 2,48,632 in 2021–22 (at current prices), a 6 per cent yearly rise from 2018–19. Service-sector growth in 2021–22 increased by 10.6 per cent from a low base in 2020–21. Sector growth in manufacturing was 4 per cent. The agricultural industry rose by 9.8 per cent in 2020–21 and 8.8 per cent in 2022–23, respectively. Agriculture, manufacturing, and services are expected to make up 16 per cent, 25 per cent, and 59 per cent of the GDP in 2021–22, respectively (at current prices).

The downward trend in the growth rate in FY 2020–21 faced by the state was due to the global pandemic

Covid-19, due to which economic growth, employment, and development have shrunk. However, the government has provided large-scale support, which resulted in an increase in growth in all the sectors in the coming fiscal years, which can be seen in 2021–22.

2.7 Profile of Maharashtra for the Sustainable Development Goals (SDGs)

Maharashtra ranks ninth with a score of 70 out of 100 marks in the *SDG India Index 2020–21 Report*. Maharashtra is the second highest in SDG 3 (Good Health and Wellbeing). It reflects the efforts taken by the state to improve health infrastructure in the state. The state is in the 'achiever' category in SDG 7 (Affordable and Clean Energy), 'performer' in five SDGs, 'front runner' in nine SDGs, and 'aspirant' in one SDG.

Climate: Historical trends and projections

This chapter focuses on understanding state and district-level climate variabilities, historical trends, and projections for Maharashtra. It presents the analysis of temperature and rainfall variability trends over the last decade (2011–20) to understand the present scenario as well as the 50 years between 1971 and 2020. It also makes projections of future climatic trends under two standardised forcing scenarios called Representative Concentration Pathways (RCPs), namely, RCP 4.5 (mid-range emissions) and RCP 8.5 (high-end emissions) scenarios for the future period, referred to as the 2030s (2021–50). This analysis helps in generating empirical evidence of past, current, and future climate trends, and identifies regions that need to be prioritised for implementation of climate change mitigation and adaptation actions, which have been outlined in the subsequent chapters of the report.

3.1 Context

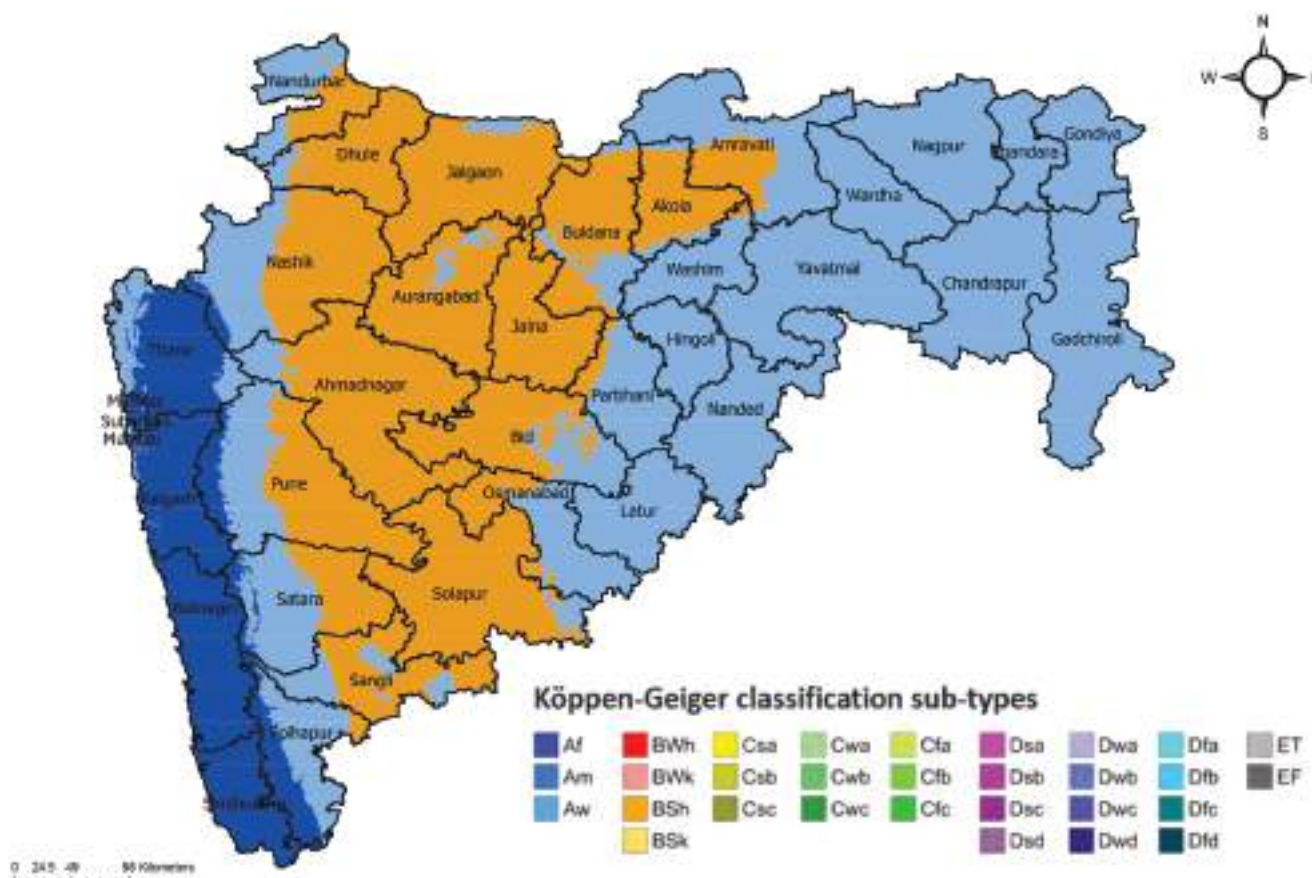
Across the world, the impacts of climatic fluctuations and extreme occurrences have become evident. According to the most recent assessment by the Intergovernmental Panel on Climate Change (IPCC 2021), the previous four decades have been consistently and increasingly warmer than any decade since 1850. The impacts of global warming have already been observed on natural and human systems, as many land and ocean ecosystems as well as the ecosystem services they provide have altered drastically due to increasing warming (IPCC, Special Report: Global Warming of 1.5°C 2022). According to a CEEW analysis, nearly 85 per cent of the districts in Maharashtra

are vulnerable to hydro-met disasters i.e. floods, droughts and cyclones (Mohanty and Wadhawan 2021). Given the vulnerabilities, the effects of the severe climate-related disasters that India is currently experiencing and is projected to experience might be catastrophic. While both the Indian government and the Maharashtra state government have developed strategies to enhance community and ecosystem resilience, it is crucial to have a factual and evidence-based comprehension of historical climate patterns and future climate projections at the district level to support these initiatives.

3.2 Climate profile of Maharashtra

The state of Maharashtra is centrally located in peninsular India. Bordered by the Arabian Sea on its west coast, it shares boundaries with Gujarat, Madhya Pradesh, and Chhattisgarh to its northwest, east, and north, respectively. To the south, Maharashtra is bordered by Telangana, Goa, and Karnataka. The coastal districts of Thane, Mumbai City, Mumbai Suburban, Raigad, Ratnagiri, and Sindhudurg are geographically separated from the rest of Maharashtra by the northern Western Ghats (Sahyadri), which run in a north–south direction. This ridge creates a significant climatic division, intersecting the monsoon stream at a right angle. As a result, rainfall to the east of the ghats diminishes drastically within a short distance, whereas the western slopes and coastal districts experience heavy monsoon rains. The primary period of rainfall in the state is the southwest monsoon season (June to September). The coastal region receives substantial rainfall (approximately

Figure 3.1 Koppen-Geiger climate classification of Maharashtra



Source: Authors' adaption from Beck et al. 2019

2,000–3,000 mm), while the central rain shadow areas experience scanty rainfall (about 500 mm), and the eastern parts receive moderate rains (about 1,000 mm) within the state.

Maharashtra experiences a typical monsoon climate, characterised by hot, rainy, and cold weather seasons. The state's climatic patterns, based on Koppen's classification, are depicted in Figure 1 and are determined by temperature and rainfall variations. Most of the state falls under the tropical savannah (Aw) category, characterised by hot, seasonally dry weather, usually in winter. However, certain central regions, as well as the coastal belt and adjoining ghats, come under the tropical rainy monsoon with a short dry season (Am) and the dry, semi-arid, hot tropical (Bsh) climates, respectively.

Based on this broad classification and historical climatological data, Maharashtra is divided into four meteorological subdivisions: Konkan, Madhya Maharashtra, Marathwada, and Vidarbha. The state's climate can be primarily classified into the following main types:

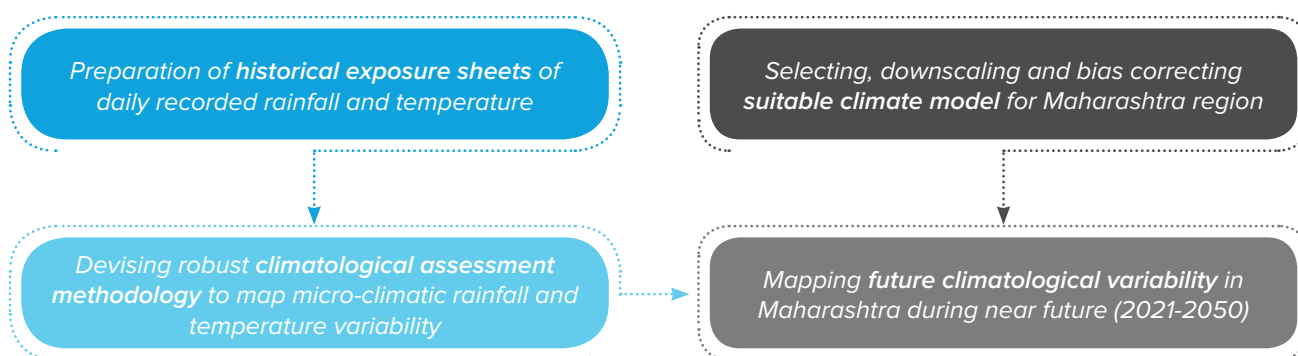
Monsoon climate: This type is observed in the coastal belt and adjoining ghats, encompassing districts such

as Thane, Raigad, Ratnagiri, Sindhudurg, Pune (western hilly parts), Satara, and Kolhapur. The coastal region experiences an annual rainfall of over 2,000 mm with a small range of temperature throughout the year, where mean daily temperatures remain above 22°C. The coastal belt has a hot and humid climate, receiving abundant rainfall during the southwest monsoon season.

Dry climate: This type covers semi-arid regions in districts like Jalgaon, Nashik, Aurangabad, Pune, Beed, Satara, Osmanabad, and Kolhapur, as well as most parts of Dhule, Nandurbar, Ahmednagar, Solapur, and Sangli. The average daily temperature ranges between 18°C and 22°C in winter and remains above 22°C during other months. The region receives low annual rainfall, ranging from 600–900 mm, mainly during the southwest monsoon season. Mean daily relative humidity remains below 50 per cent throughout the year, dropping to below 30 per cent for two to three months during the central region's summer.

Tropical rainy climate: This type is found in parts of the Nashik and Jalgaon districts, eastern areas of Aurangabad, Jalna, Beed, Osmanabad, and all remaining districts of Marathwada (Hingoli, Latur, Parbhani, and Nanded) and Vidarbha. Precipitation is limited to the monsoon season, with annual rainfall exceeding 700 mm. The average

Figure 3.2 Schematic representation of approach for climatological assessment



Source: Authors' compilation

relative humidity is above 60 per cent, except during summer when it drops to less than 30 per cent for one or two months. Mean daily temperatures range between 18°C and 22°C during winter and remain above 22°C during the other months (IMD 2005).

3.3 Approach and methodology for climatological assessment

Climate variability by the World Meteorological Organisation (WMO) has been defined as 'variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events'. While climate variabilities measured at a seasonal scale do provide a larger picture of changing climatic conditions, targeted adaptation and mitigation strategies also need nuanced micro-climatic assessments that capture the short-lived, high-intensity extremes such as heat waves, heavy rainfall, cold waves, etc. Hence, a robust climatological assessment methodology was devised for the analysis of current and future climate trends to capture the variabilities at different scales using indices pertinent to the Maharashtra state. This methodology draws lessons from common approaches followed by WMO, IMD, NOAA, and other relevant literature.

Scientists have employed climate models to comprehend the intricate interplay of Earth's various components within the system. These models possess the capability to forecast future changes in crucial climate factors – including temperature and rainfall – making them valuable

tools for informing climate adaptation strategies. While climate change is a global phenomenon, its impacts are acutely felt at local levels, underscoring the significance of addressing vulnerability to climate change in specific regions. This highlights the importance of regional climate projections. Therefore, in the context of this climate action plan, openly available regional climate model projections were utilised to analyse potential future climate variations. These projected trends hold significant importance in devising adaptation strategies for different sectors.

3.3.1 Methodology for mapping observed climate variability and trend analysis

While climate projections do provide insight into the future trends of climate variabilities and extremes, the focus of the SAPCC is to propose policies for the coming decade. Hence, it becomes important to understand the current climatological trends, especially the changes in the last decade (2011–20). Therefore, an assessment of climate trends in the last 50 years (1971–2020) as well as changes in the last decade has been carried out in this section, referred to as historical or observed trends. These historically observed trends were also used to validate the outputs from the regional climate models and subsequent bias correction.

According to the WMO's guidelines, for any climatological analysis to be performed, a minimum of a 30-year

Figure 3.3 Schematic representation for mapping observed climate variability and trends



Source: Authors' compilation

Table 3.1 List of models regionally downscaled by the IITM RegCM4 Cordex South Asia RCM used for this plan

Driving CMIP5 GCM	Contributing CMIP5 Modelling Centre
CCCma-CanESM2	Canadian Centre for Climate Modelling and Analysis (CCCma), Canada
NOAA-GFDL-GFDL ESM2M	National Oceanic and Atmospheric Administration (NOAA), Geophysical Fluid Dynamics Laboratory (GFDL), USA
CNRM-CM5	Centre National de Recherches Météorologiques (CNRM), France
MPI-ESM-MR	Max Planck Institute for Meteorology (MPI-M), Germany
IPSL-CM5A-LR	Institut Pierre-Simon Laplace (IPSL), France
CSIRO-Mk3.6	Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Source: Authors' compilation

climate normal is considered to capture the changing climatological trends effectively. Still, when variables like precipitation are considered, it is important to go beyond a 30-year time scale (WMO 2017).

Therefore, for the historical analysis, we obtained daily recorded rainfall and temperature data from the IMD. The daily precipitation at the 0.25° dataset from IMD was originally compiled by Pai et al. 2014 in 2014, utilising station observations from over 6,000 stations scattered across India. This dataset effectively captures crucial characteristics of the Indian summer monsoon, reflecting higher rainfall in the Western Ghats and north-eastern India, and lower rainfall in the semi-arid and arid regions of western India (Pai et al. 2014).

To analyse historical temperature trends, we utilised a high-resolution daily gridded temperature dataset at a 1° × 1° resolution. This dataset was developed based on temperature data from 395 quality-controlled stations, as described by Srivastava, Rajeevan, and Kshirsagar in 2009, and subsequently downscaled to a finer 25 km resolution grid using bilinear interpolation. These datasets underwent rigorous quality-assurance procedures, demonstrating a high correlation with other global gridded datasets, and exhibited spatial and temporal homogeneity (Srivastava, Rajeevan, and Kshirsagar 2009; Dash and Mamgain 2011; Mishra et al. 2020). They have been previously employed for validating climate model simulations and conducting trend analysis (Pingale et al. 2014; Mishra et al. 2020).

3.3.2 Modelling climate change projections for Maharashtra

To comprehend future climatic trends, we acquired high-resolution downscaled projections from the Coordinated Regional Climate Downscaling Experiment (CORDEX) South Asia programme, which is overseen by the Centre for Climate Change Research (CCCR) at the Indian Institute of Tropical Meteorology (IITM), Pune. These projections are derived from the CMIP5 (Coupled Model Intercomparison Projects, 5th generation) climate models. CMIP is a collaborative platform where various modelling groups coordinate their efforts, and the fifth assessment report (AR5) of the IPCC showcased the CMIP5. Under

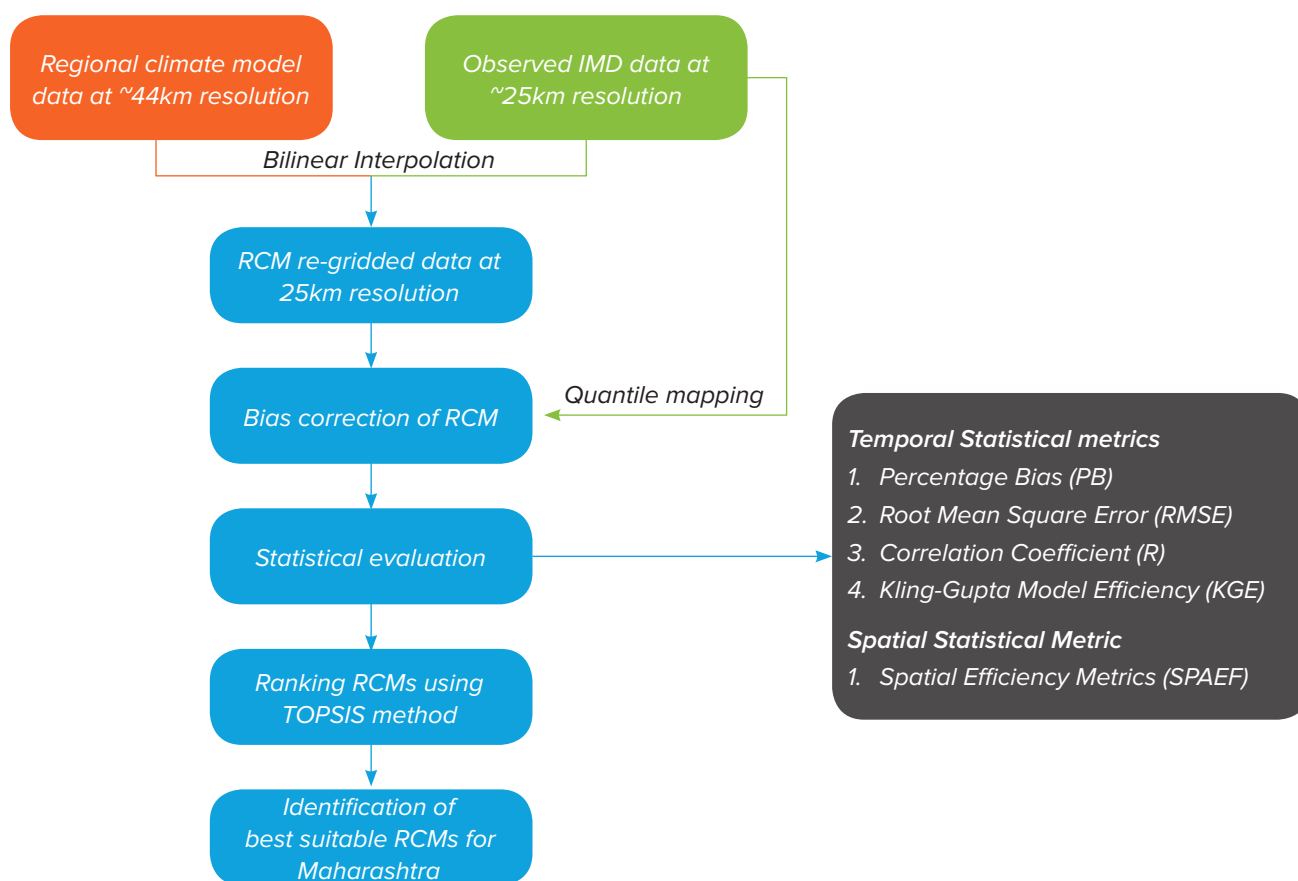
the CORDEX programme, regional models are driven by data from atmosphere-ocean coupled general circulation model runs conducted under CMIP5 for the representative concentration pathway (RCP) scenarios (Taylor, Stouffer, and Meehl 2012). For this assessment, the future projections in this report are based on two standardised forcing scenarios known as Representative Concentration Pathways (RCPs), specifically RCP 4.5 (mid-range emissions) and RCP 8.5 (high-end emissions) scenarios. Each scenario comprises a time series of emissions and concentrations of greenhouse gases (GHGs), aerosols, and chemically active gases, as well as land-use changes throughout the 21st century, characterised by the resulting radiative forcing in the year 2100. To elaborate further, RCP 4.5 represents an intermediate stabilisation pathway resulting in a radiative forcing of 4.5 W/m² in 2100, whereas RCP 8.5 corresponds to a high-concentration pathway leading to a radiative forcing of 8.5 W/m² in 2100.

However, these modelled projections are built with uncertainty and bias. The downscaled temperature projections are considered to be of high or moderate confidence, while rainfall projections are of low confidence. Hence, robust scientific statistical methods of model selection and bias correction were used to prepare the projected datasheets prior to analysis. Despite the statistical corrections, due to the coarse resolution of the models and the high inherent variability shown by the Indian climate, the results derived might be prone to some level of uncertainty.

The bias-corrected RCM outputs were statistically evaluated using temporal and spatial metrics to identify the best-suited RCM for Maharashtra. The models with high performance scores were then ensemble¹ to produce the daily projected outputs for rainfall and temperature datasheets. For precipitation CanESM2 and IPSL-CM5A-LR were found to be the best performing, whereas, for temperature, it was CanESM2 and CSIRO-Mk3.6. The projections were downscaled from an original 44 km spatial grid onto a finer 25 km resolution grid of the historical IMD data and

¹ A climate ensemble involves slightly different models of the climate system where the ensemble average is expected to perform better than individual model runs.

Figure 3.4 Schematic representation of methodology for RCM bias correction and ensemble model selection



Source: Authors' analysis

subsequently interpolated to districts of Maharashtra by averaging the values of the grids lying in a particular district. It should be noted that the analysis was done based on Census 2011 demarcated districts to maintain consistency for sectoral analysis. Hence, Thane encompasses both Palghar and Thane as of the latest demarcation. Moreover, it should be noted that the shapefile used for all analyses is based on Census 2011, where the district labels are given as Bid and Raigarh, wherein the inferences should be drawn for Beed and Raigad, respectively.

3.4 Temperature variability in Maharashtra

Atmospheric temperature is a crucial aspect of the climate system and serves as a significant indicator of climate change, both at regional and global levels. The most recent IPCC report titled *Climate Change 2022: Impacts, Adaptation, and Vulnerability* reveals a progressive increase in temperature over the past four decades, surpassing any

Table 3.2 Indicators and parameters analysed for temperature variability

Indicator	Definition
Mean day-time temperature	Seasonal or annual mean of daily maximum temperature.
Mean night-time temperature	Seasonal or annual mean of daily minimum temperature.
Mean average temperature	Seasonal or annual mean of daily average temperature.
Diurnal temperature range	Seasonal or annual mean difference between the maximum and minimum temperature.
Hot day frequency	Frequency of days when the recorded maximum temperature is > 90th percentile threshold. ²
Extreme heat day frequency	Frequency of days when the recorded maximum temperature is > 99th percentile threshold.
Warm night frequency	Frequency of days when the recorded minimum temperature is > 90th percentile threshold.
Extreme warm night frequency	Frequency of days when the recorded minimum temperature is > 99th percentile threshold.

Source: Authors' analysis

² The percentile thresholds were calculated for a climatological baseline of 1971–2010 centred on a five-day moving window.

previous records dating back to 1850. However, taking global warming into account, it becomes essential to focus on regional manifestations of temperature variations since warming is not uniform worldwide (Kothawale, Munot, and Kumar 2010). To assess temperature variability across Maharashtra and identify micro-climatic hotspots of extreme heat, an analysis based on indices utilising district-specific thresholds was conducted.

3.4.1 Historical and projected trends in annual average temperature variability

The analysis of temperature variability for the period 1971–2020 indicates a rising trend in annual average maximum temperature in Maharashtra. During this period, annually, the mean daytime temperature has increased at the rate of 0.013°C. While the annual average minimum temperature has not statistically increased in the 50 years, an increasing trend can be observed over the last 30 years (1991–2020) at the rate of 0.014°C annually. These increasing trends in both daytime and nighttime temperatures have also increased the mean annual temperature at the rate of 0.013°C annually. In terms

of the diurnal temperature range, a slightly decreasing trend is observed, however, the trend is not statistically significant.

The district-level pentad-decadal analysis of temperature variability indicates that nearly all districts are witnessing a rise in mean daytime temperatures, while the districts in Konkan, Pune, and parts of Aurangabad, i.e., Mumbai, Pune, Nashik, Jalgaon, Thane, are witnessing a rise in both daytime and nighttime temperatures. During this period, the highest annual average maximum and minimum temperatures were recorded in Ratnagiri at 38.054°C and 28.781°C, respectively, while the lowest were recorded in Kolhapur at 31.496°C and Ahmednagar at 19.139°C, respectively. However, the observed trend suggests that the mean daytime temperature has been increasing by an annual rate of 0.018°C in Kolhapur, which is the highest among all districts in Maharashtra.

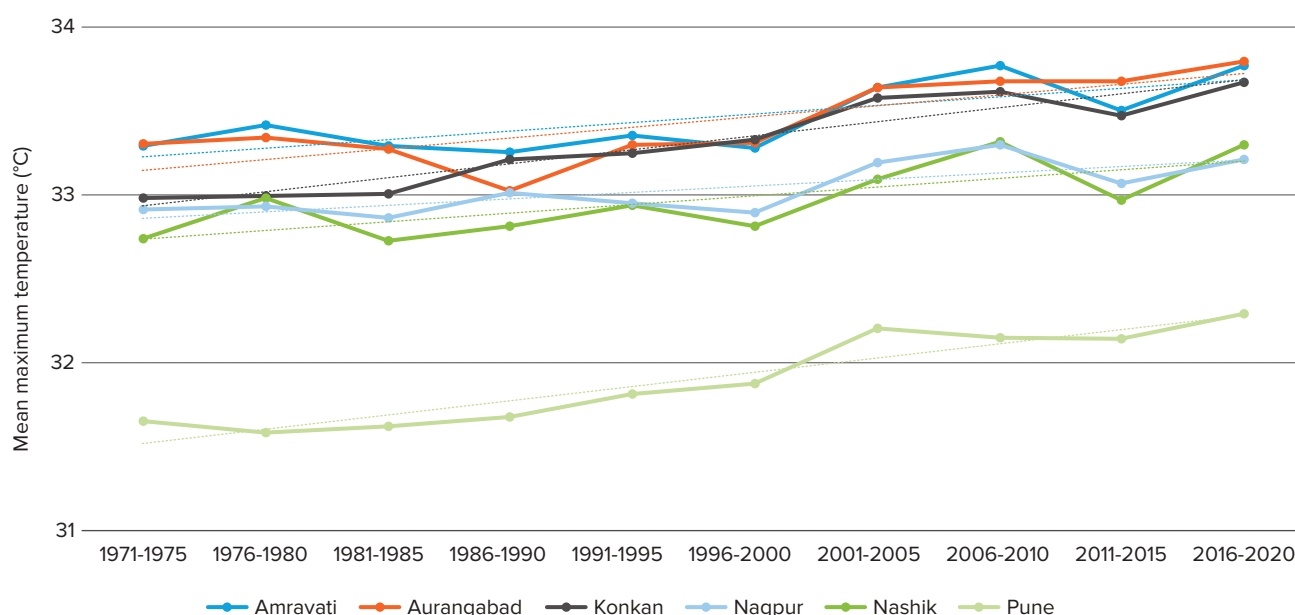
In continuation of these trends, analysis of projected annual average maximum and minimum temperature suggests that both daytime and nighttime temperatures will continue to increase linearly across all regions of Maharashtra under both RCP scenarios during the 2030s.

Table 3.3 Changes in annual average temperatures during the 2030s compared to the historical period (1971–2020)

Indicator	RCP 4.5 scenario	RCP 8.5 scenario
Mean day-time temperature	Increases in Maharashtra by 0.90°C	Increases in Maharashtra by 1.56°C
Mean night-time temperature	Increases in Maharashtra by 1.04°C	Increases in Maharashtra by 1.83°C
Mean average temperature	Increases in Maharashtra by 1.23°C	Increases in Maharashtra by 1.43°C
Annual average diurnal temperature range	Decreases in Maharashtra by –0.66°C	Decreases in Maharashtra by –0.78°C

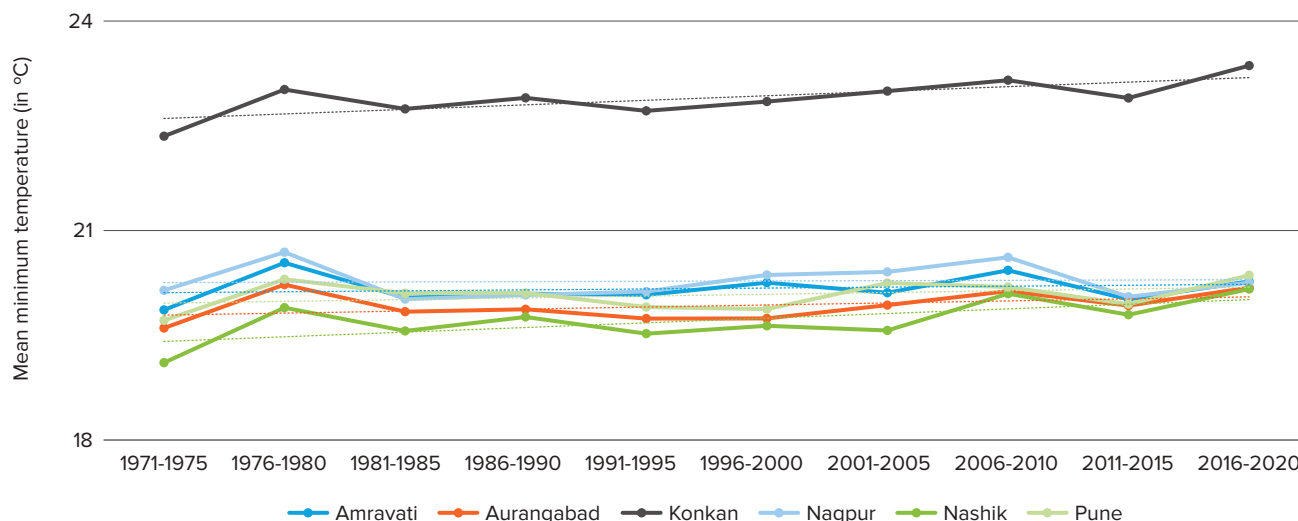
Source: Authors' analysis

Figure 3.5a Division-wise trends in average annual maximum temperature (1971–2020)



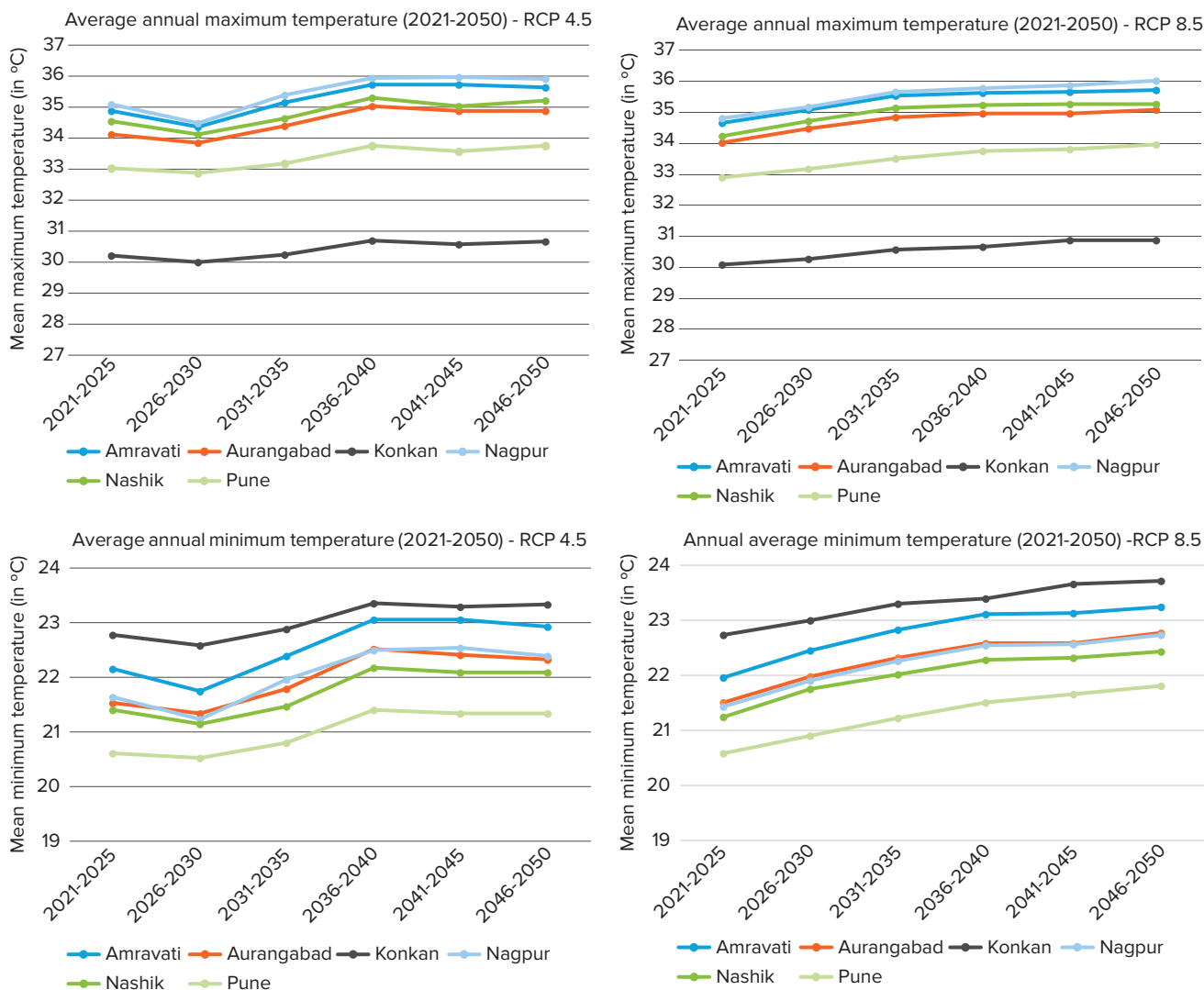
Source: Authors' analysis

Figure 3.5b Division-wise trends in average annual minimum temperature (1971–2020)



Source: Authors' analysis

Figure 3.6 Division-wise projections of annual minimum and maximum temperature in Maharashtra under RCP 4.5 and 8.5 scenarios in the 2030s



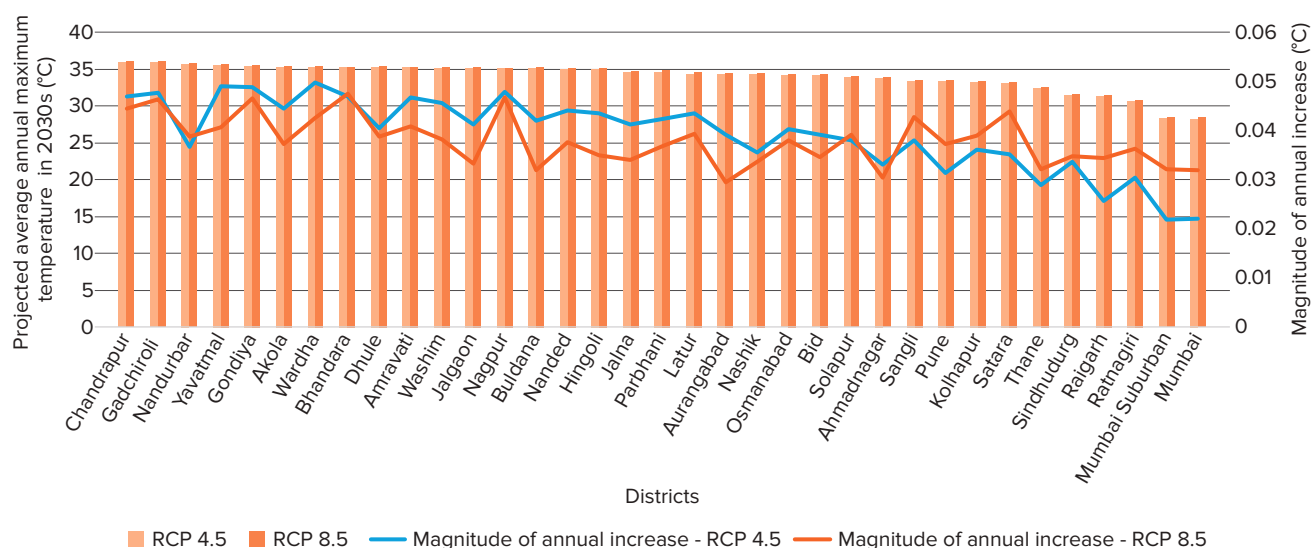
Source: Authors' analysis

To further decode these increasing trends, district-level projected temperature trends were analysed. Trend analysis based on the Mann Kendell test and the Sen's Slope projects the highest daytime temperatures in eastern Maharashtra, particularly in the Nagpur and Amravati divisions under both RCP scenarios. The potential five warmest districts in the 2030s will be Chandrapur, Gadchiroli, Nandurbar, Yamatval, and Gondia. These districts show the highest projected magnitude of increase in maximum temperatures. The projected trends match with the current scenario as eastern Maharashtra

is witnessing more extreme temperatures in recent years (Dhorde, Korade, and Dhorde 2017). The projected trends infer that there is a higher likelihood of more intense and frequent extreme heat events and heat waves in these regions.

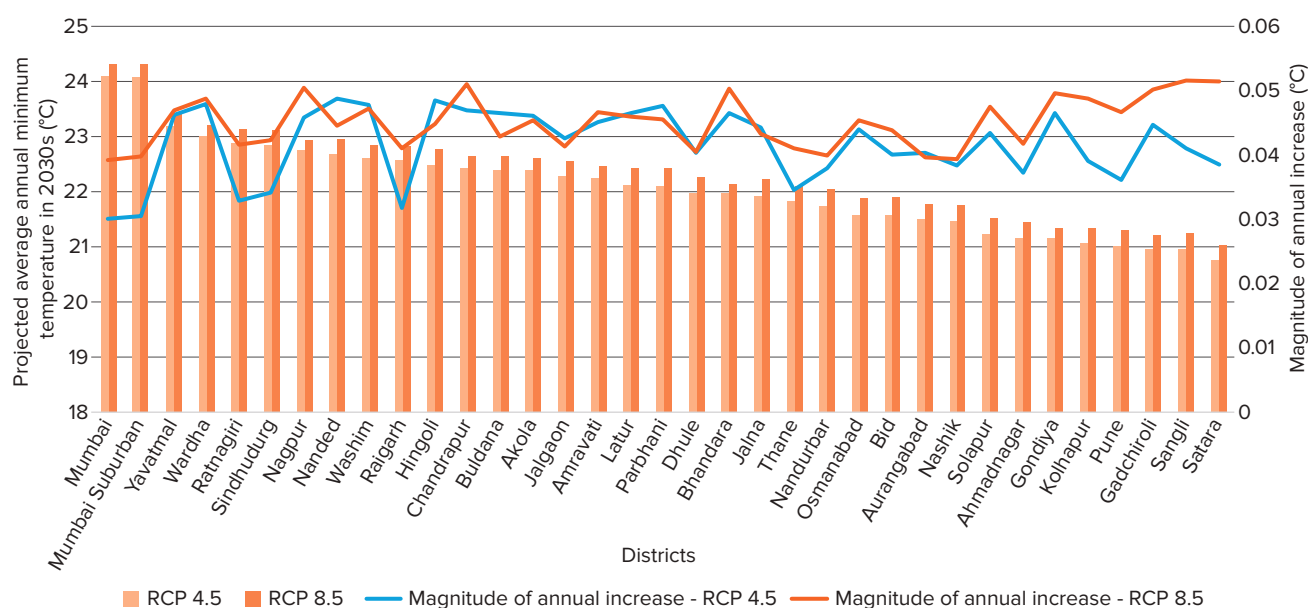
Likewise, a district-level examination of trends in nighttime temperatures indicates a significant projected increase across all districts of Maharashtra. Like the patterns observed in daytime temperatures, nighttime temperatures are anticipated to be highest in the eastern and Konkan regions.

Figure 3.7 District-wise projected mean daytime temperatures and annual magnitude of increase during the 2030s



Source: Authors' analysis

Figure 3.8 District-wise projected mean nighttime temperatures and annual magnitude of increase during the 2030s

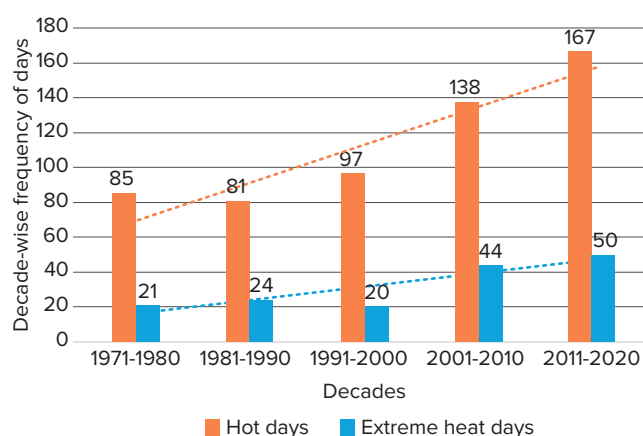


Source: Authors' analysis

3.4.2 Historical and projected trends in temperature extremes over Maharashtra

In light of recent heat waves and cold waves in India, extreme temperatures are now recognised as a significant health hazard. These temperature extremes occur when daily temperatures exceed certain tolerance limits, and their frequency is of great concern in terms of their impact on human well-being (Revadekar et al. 2012). Changes in temperature and the occurrence of extreme events carry substantial socio-economic implications, influencing aspects like water availability and usage, power generation and consumption, crop yields, human health, and comfort (Meehl et al. 2000). Additionally, rising temperatures – coupled with factors such as humidity – result in elevated heat stress on human health due to higher wet-bulb temperatures. Elevated wet-bulb temperatures, especially when combined with high dry-bulb temperatures, can pose severe risks, leading to heat-related illnesses and

Figure 3.9 Decadal total frequency of day-time heat extremes in Maharashtra during the historical period (1971–2020)



Source: Authors' analysis

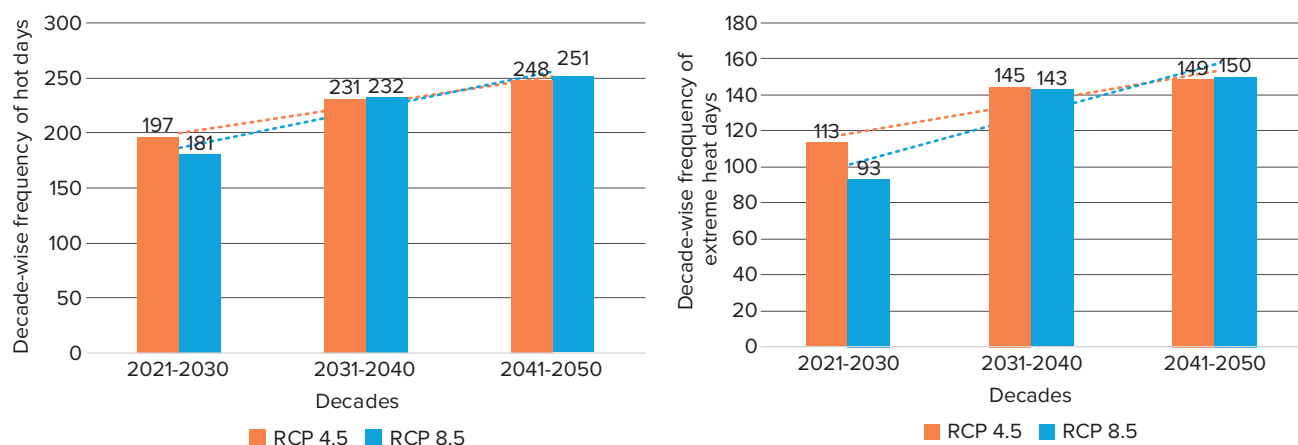
even mortality. As wet-bulb temperatures cross a certain threshold, typically around 35°C (95°F), the human body's natural cooling mechanisms are compromised, making it difficult to dissipate heat and potentially leading to heat stroke, even at lower dry temperatures. Although cold extremes are not relevant to the state of Maharashtra, this study analysed both daytime and nighttime daily temperature extremes using a set of indices for the historical and future periods up to the 2030s.

State-level analysis suggests that overall, in Maharashtra, there has been a nearly two-fold increase in the frequency of hot and extreme heat days for the last five decades. The increase is more evident during the last two decades. In continuation of this trend, the heat extremes are further projected to increase significantly under both RCP scenarios in the 2030s.

To understand the spatial pattern of this trend, a district-level analysis was carried out, which suggests that all the districts of Maharashtra are witnessing an increase in the frequency of daytime heat extremes during the summer season (March, April, and May); the trend is statistically significant in 84 per cent of these districts. The highest annual magnitude of increase is witnessed in Sindhudurg, followed closely by Ratnagiri, Kolhapur, Pune, Raigad, and Mumbai. These increasing extreme heat days have resulted in some of the deadly heat waves that have occurred in Maharashtra in the recent period. For e.g., in 2022, Maharashtra saw more than four prolonged heat waves in the state (IMD 2022) with districts such as Chandrapur and Pune among others breaking the single-day maximum temperature records.

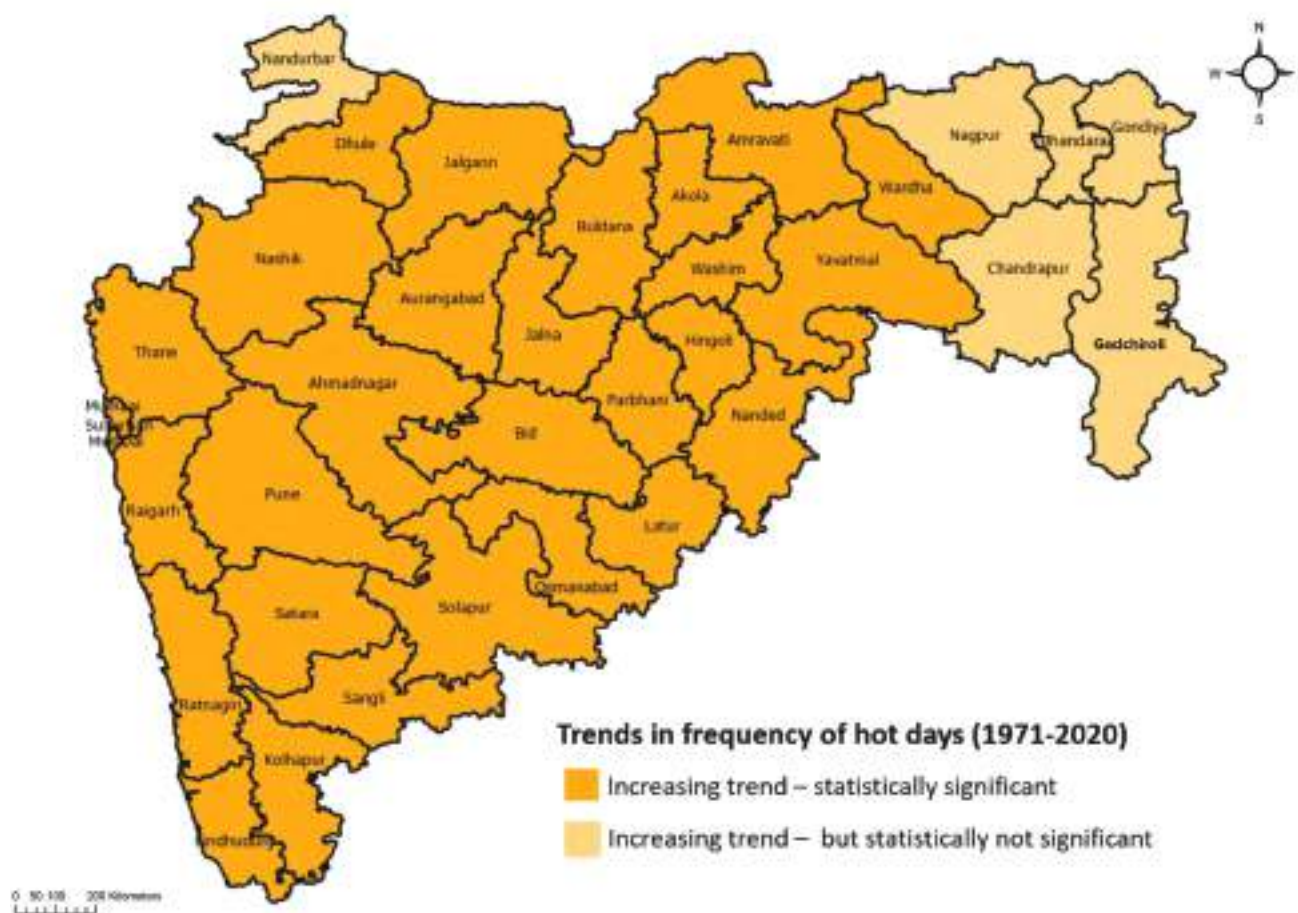
To further understand the variability in temperature extremes, the frequency of warm nights was analysed. Warm nights are said to occur when the daily recorded minimum temperature crosses the defined thresholds and are considered a major health risk as warmer nighttime temperatures do not allow people to recover from more frequent extremely hot days. Moreover, warmer nights

Figure 3.10 Projected decadal total frequency of hot days and extreme heat days in Maharashtra during the 2030s



Source: Authors' analysis

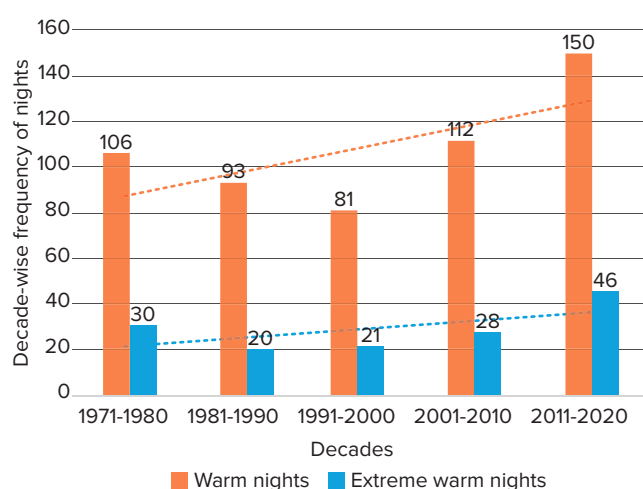
Figure 3.11 District-wise trends in frequency of hot days during the historical period (1971–2020)



Source: Authors' analysis

are found to be highly associated with urban heat-island effects in cities and suggest there will be a higher demand for air conditioning, affecting energy consumption patterns.

Figure 3.12 Decadal total frequency of night-time heat extremes in Maharashtra during the historical period (1971–2020)



Source: Authors' analysis

Similar to the trend witnessed in the daytime temperature extremes, warm nights have increased significantly in Maharashtra during the historical period and are projected to increase further under both RCP scenarios.

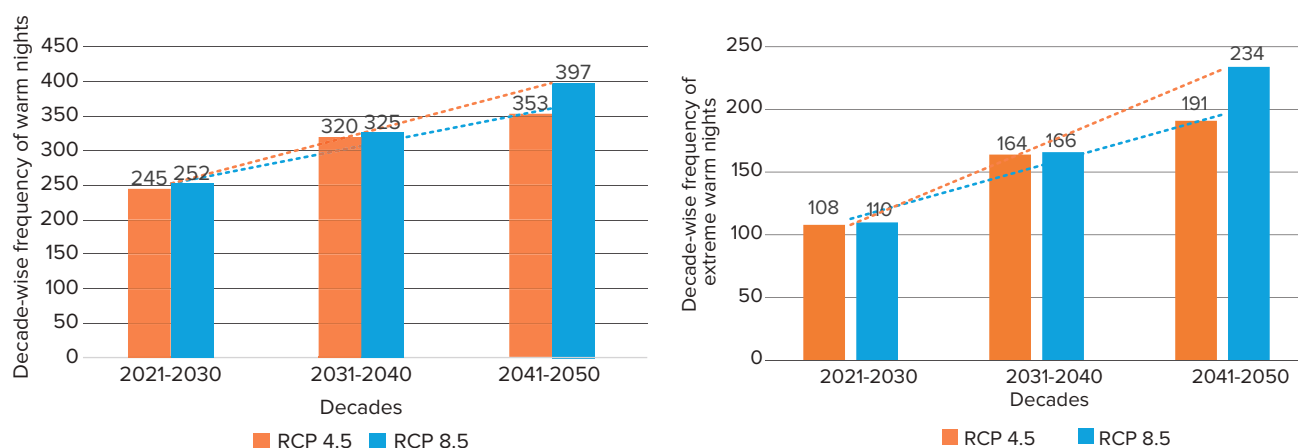
District-level analysis of warm nights suggests that more than 40 per cent of the districts are witnessing an increase in the frequency of warm nights, particularly in the divisions of Konkan, Pune, and parts of Aurangabad. The trend is significant in the northwestern part of Maharashtra, which includes urban areas such as Mumbai, Thane, Pune, and

Table 3.4 Projected changes in the average yearly frequency of days during summer (March, April, May)

Average yearly frequency of days during summer (March, April, May)			
Indicator	Observed	RCP 4.5	RCP 8.5
Hot days	11	22	23
Very hot days	3	13	14
Warm nights	10	31	32
Very warm nights	3	15	17

Source: Authors' analysis

Figure 3.13 Projected decadal total frequency of warm nights and extreme warm nights in Maharashtra during the 2030s



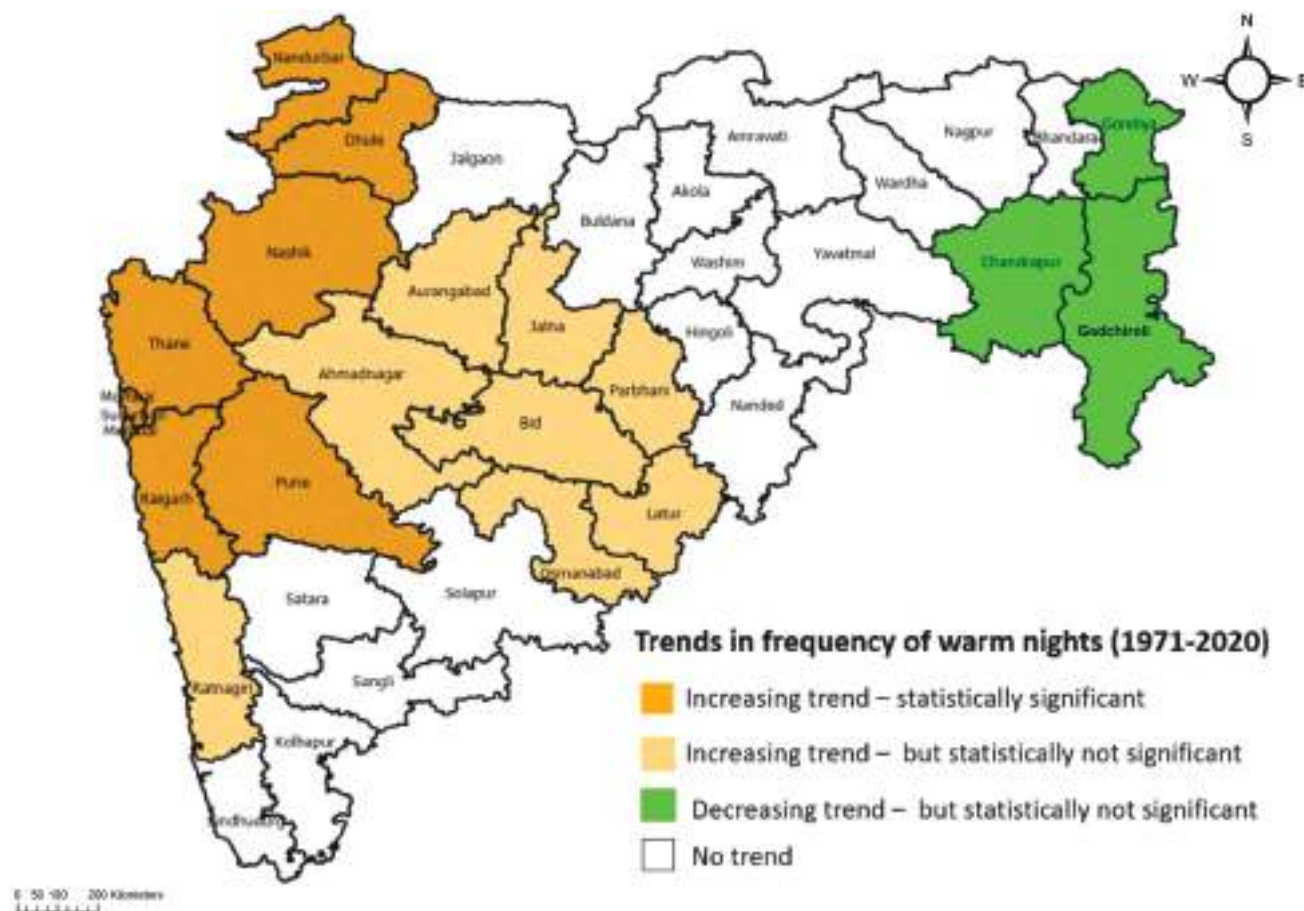
Source: Authors' analysis

Nashik. The increase in warm nights has been attributed to the effect of urban heat islands because buildings and other built-up areas block the heat from the ground from rising into the cold night sky. As the heat is trapped on lower levels, the temperature is warmer during the night (Parker 2010; Nichol 2005). The projected trends also suggest that these regions along with parts of eastern Maharashtra will see more frequency of nighttime temperature extremes.

This trend is in line with the projected increase in mean nighttime temperature increase in the 2030s.

The observed and projected rise in temperature and heat extremes renders Maharashtra particularly vulnerable, significantly increasing its exposure to climate risks. While temperature variability is relatively consistent across the state, the impact of heat extremes is more pronounced in

Figure 3.14 District-wise trends in the frequency of warm nights during the historical period (1971–2020)



Source: Authors' analysis

Table 3.5 Indicators and parameters analysed for mapping rainfall variability

Aspect of variability	Indicator	Criteria
Inter-annual variability	Annual or seasonal average rainfall	Average of total rainfall received during a year or season
	Annual or seasonal rainfall variability	Coefficient of variation
	Number of rainfall-deficient years	Years with rainfall departure of –20% from the Long Period Average (LPA)
	Number of normal rainfall years	Years with rainfall recorded between –19% to +19% of the LPA
	Number of excess rainfall years	Years with rainfall departure of +20% from the LPA
	Projected change in annual or seasonal rainfall	Percentage change in the projected annual or seasonal rainfall compared to the historical period
Intra-annual variability	Frequency of dry days	Frequency of days with rainfall recorded < 2 mm
	Frequency of moderate rainfall days	Frequency of days with rainfall recorded between 2mm and the 90 th percentile threshold
	Frequency of heavy rainfall days	Frequency of days with rainfall recorded > 90 th percentile threshold

Source: Authors' analysis

the eastern and certain northwestern areas of Maharashtra. As per the Annual Disaster Weather Reports released by the India Meteorological Department (IMD), which document cases of heat waves in India and their adverse effects on lives, districts such as Nagpur, Chandrapur, Amravati, Yavatmal, Gadchiroli, and Bhandara are among the most affected (IMD 2021). Furthermore, modelled projections indicate a future escalation in heat extremes within the state, with maximum temperatures expected to peak in the eastern region. Similarly, the impact of increasing nighttime temperatures, partly influenced by the urban heat island effect, will be more pronounced in the north-western urban districts. As a result, prioritising these regions according to their temperature profiles becomes crucial in the development of the state's heat action plans.

3.5 Rainfall variability over Maharashtra

The Indian monsoon in general shows high variability across space and time (Guhathakurta et al. 2015). Maharashtra moreover has a very diverse monsoon profile with regions such as the Konkan area receiving high rainfall and the adjoining parts facing deficient rainfall conditions. While changes in rainfall received from one year to another significantly impact policy making – particularly for the water and agriculture sectors – the changes in intra-annual patterns leading to extremely heavy rainfall events need robust disaster preparedness and management strategies. Hence, to capture this variability shown by various facets of the monsoon, the rainfall pattern of Maharashtra was analysed through various indices that capture the critical spatial, inter-annual, and intra-annual monsoon variability. The analysis was focused on the months of JJAS (June, July, August, and September) since Maharashtra receives most of its rainfall from the southwest monsoon (IMD 2005). Some of the pertinent indices were also calculated for pre-monsoon (March, April, and May) and post-monsoon season (October, November, and December).

To map the intra-annual rainfall variability, a percentile-based, district-specific thresholding approach was used, which considers the varying heterogeneity of the climate and topographical and geographical factors in Maharashtra (Ghosh et al. 2013). This approach aids in a more accurate representation of the monsoon trends and patterns spatially, considering the wide range of variability found across the state using an absolute threshold method (Krishnamurthy, Lall, and Kwon 2009).

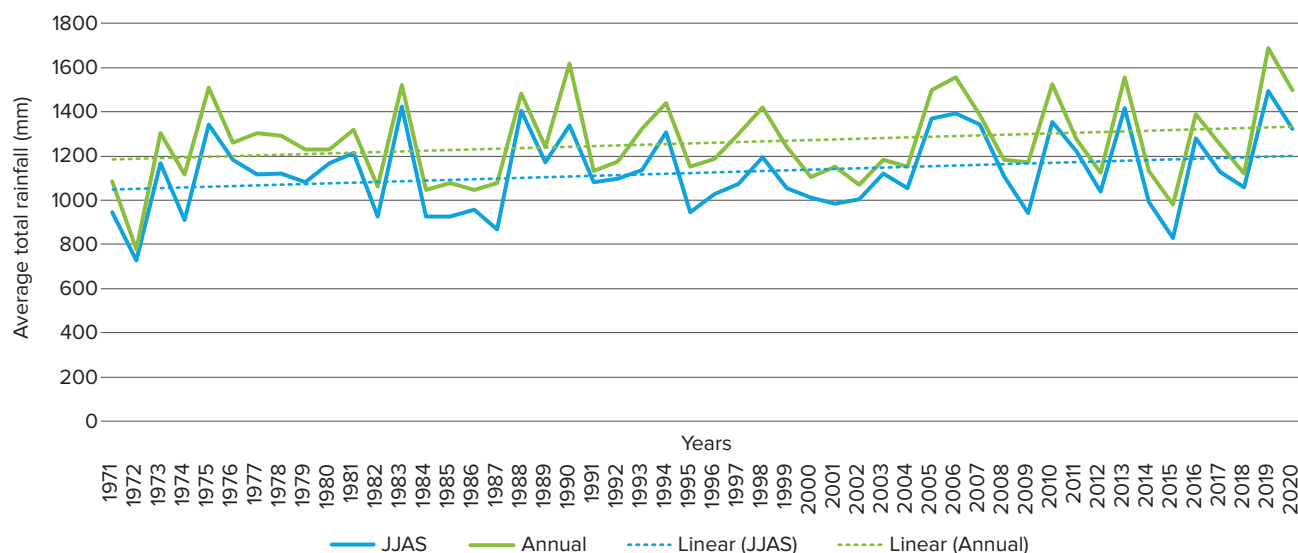
3.5.1 Inter-annual rainfall variability

Overall, state-level temporal analysis performed on rainfall data for 1971–2020 suggests that Maharashtra receives around 1,259 mm of rainfall annually on average. The years 2019 and 1971 received the highest (1687.5 mm) and lowest (779.8 mm) annual rainfall, respectively. The highest rainfall is received during the JJAS months from the southwest monsoon, followed by post-monsoon and pre-monsoon, respectively. The districts in the Konkan region receive the highest annual rainfall with Ratnagiri, Sindhudurg, Mumbai Suburban, Mumbai, Thane, and Raigad districts receiving more than 2,000 mm of average rainfall every year, whereas the lowest rainfall has been recorded in the Aurangabad region where districts receive an average of around 600 mm of rainfall every year.

Overall, state-level analysis shows a linear increasing trend in both annual and JJAS rainfall, whereas a decreasing rainfall trend is witnessed during the October, November, and December (OND) season from the post-monsoon (not significant). However, this is marked by high spatial variabilities and hence requires district-specific analysis of the trends and variabilities. District-wise total average rainfall during each season and the rainfall variability using district LPA were mapped, which has been enumerated in Figure 3.16. The statistical method of coefficient of variation³ was used to calculate the rainfall variability.

³ The coefficient of variation (CV) is the ratio of the standard deviation to the mean and shows the extent of variability in relation to the mean. The higher the CV, the greater the dispersion from the mean.

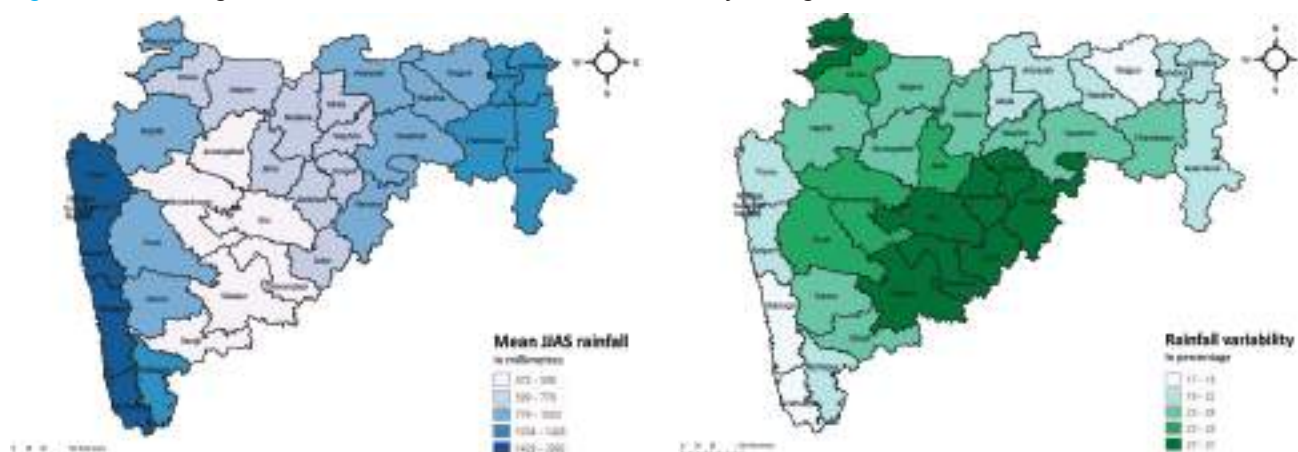
Figure 3.15 Trend in annual and southwest monsoon rainfall (JJAS) over Maharashtra from 1971–2020



Source: Authors' analysis

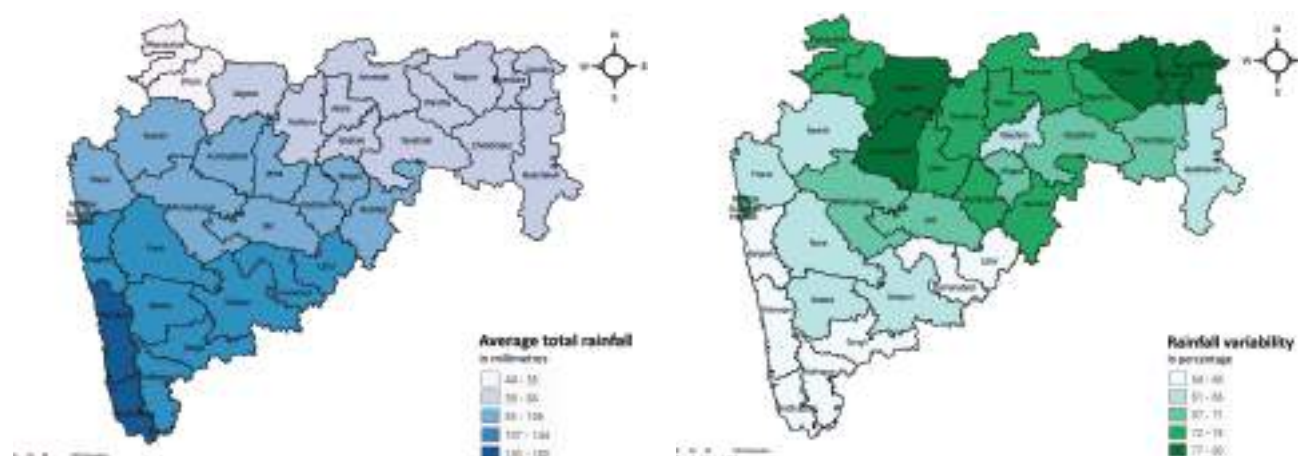
To visualise the data as maps, the **Jenks natural breaks method** was employed. This approach establishes ranges that group similar areas together, maximising the distinctions between classes. In contrast, the equal interval classification may lead to situations where certain datasets end up with most data values falling into just one or two classes, leaving very few or no values in the other classes (Campbell and Shin 2011).

Figure 3.16a Average total rainfall and observed rainfall variability during JJAS from 1971–2020



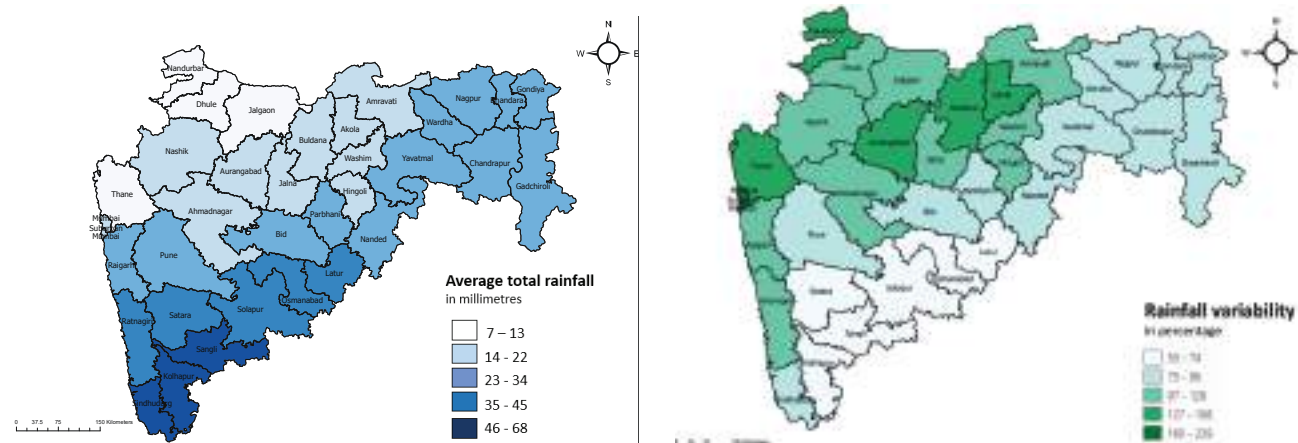
Source: Authors' analysis

Figure 3.16b Average total rainfall and observed rainfall variability during the post-monsoon season (OND) from 1971–2020



Source: Authors' analysis

Figure 3.16c Average total rainfall and observed rainfall variability during pre-monsoon season (MAM) from 1971–2020



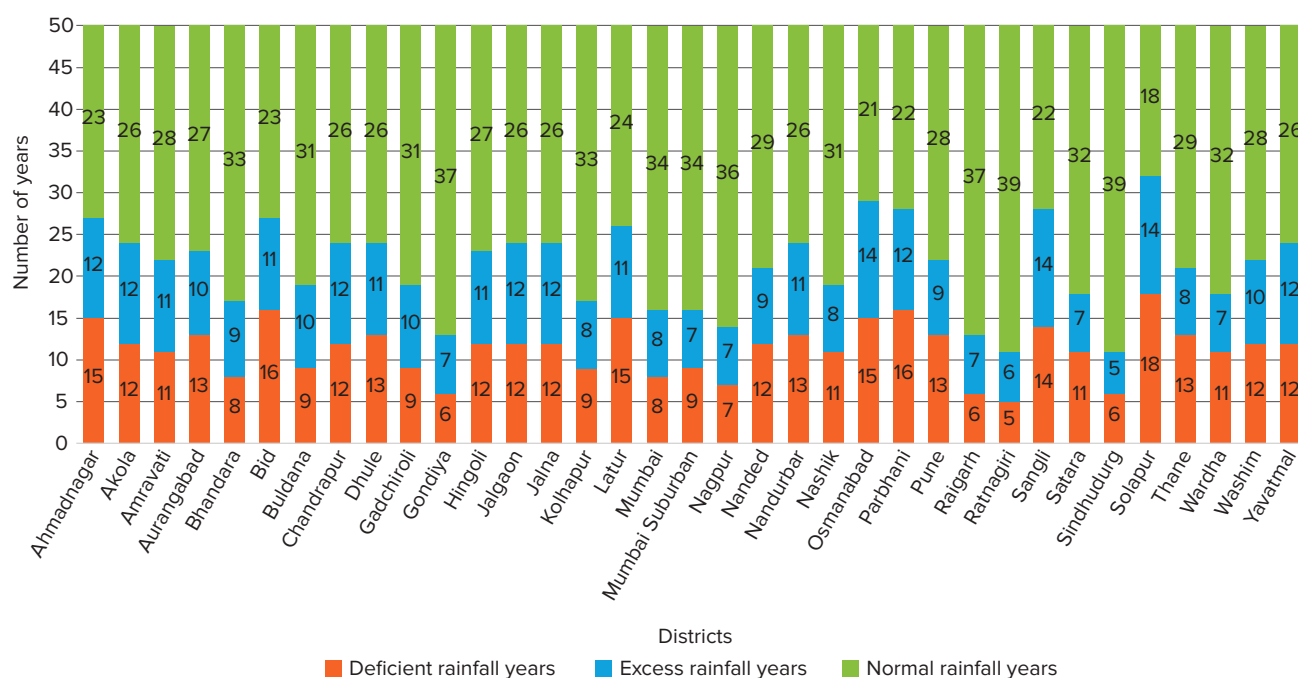
Source: Authors' analysis

The districts in the Konkan region receive the highest rainfall during the primary monsoon season, whereas the lowest rainfall is recorded in the districts of Aurangabad, Nashik, and parts of the Pune division. These are also the areas where the highest rainfall variability has been recorded. The generally observed trend was that districts receiving low rainfall were the ones with high rainfall variability. District-level trend analysis found that JJAS season rainfall is increasing in the Konkan region, along with the districts of Nashik, Pune, and Ahmednagar, whereas a slightly decreasing trend can be observed in the eastern region.

While the statistical method of coefficient of variation does provide the estimation of deviations from the mean, sectoral adaptation strategies require understanding this variability in a more nuanced way. For this purpose, the historical years were classified into deficient, excess, and normal rainfall years to understand the reason for the high rainfall variability based on the IMD criteria.

It was found that the districts, namely, Osmanabad, Solapur, Ahmednagar, Beed, Sangli, and a few districts of Pune and Aurangabad have alternatively witnessed a high number of both deficient and excess rainfall years

Figure 3.17 Inter-annual rainfall variability during JJAS from 1971–2020



Source: Authors' analysis

compared to other regions of Maharashtra. Solapur has witnessed the highest number of deficient rainfall years (18) and the highest excess rainfall years (14). Such a trend is followed closely by Osamanabad, Beed, Sangli, and districts of Nagpur, Wardha, and Amravati, whereas the districts in the Konkan division show the least rainfall inter-annual variability and have received majorly normal rainfall years. Ratnagiri, followed by Raigad, Nagpur, Mumbai, and Thane have witnessed the highest number of normal rainfall years.

Projected state and district-level trends in monsoon rainfall

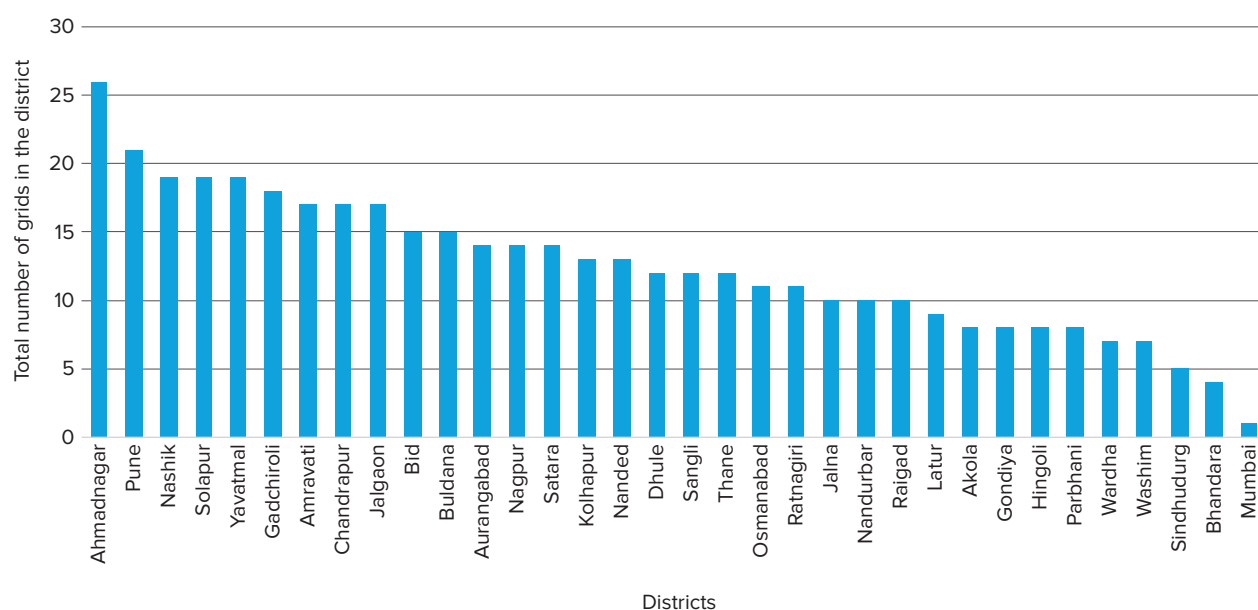
To understand how the rainfall patterns will change in the near future, the indices were analysed on rainfall projection data for the period of 2021–50 (referred to as the 2030s). The analysis of future rainfall variability was restricted to the primary monsoon season (JJAS) due to the inherent uncertainties in the RCMs for pre- and post-monsoon seasons. Under both scenarios, the rainfall in Maharashtra is projected to increase in most regions or remain similar under both RCP scenarios compared to the baseline in the 2030s, compared to the historical period. However, as shown in Figure 3.19, this trend is marked by

high spatial variabilities, and hence a division- and district-level analysis of projected rainfall trends was carried out.

Overall, it is projected that the highest rainfall will be witnessed in the Konkan region in continuation of the historically witnessed trends. Moreover, the rainfall will significantly increase in the central Maharashtra region, with parts of Pune and Ahmednagar districts – which are traditionally dry areas – being comparatively wetter than in the historical period. The eastern part of Maharashtra is projected to receive slightly less rainfall, especially in parts of Amravati and Nagpur.

Aggregating these projections to division level, rainfall is projected to increase in the Konkan and Pune divisions, remain comparatively similar in Nashik and Aurangabad, and decrease slightly in Nagpur and Amravati. While the projected changes in rainfall do match national- and regional-level studies, certain trends in the eastern part are opposite to the findings of Todmal (2021). This could be due to the different models used, since this assessment relied on IITM regionally downscaled models, compared to the usage of only REMO models as done by Todmal (2021). A report by Centre for Science and Technology in 2022 also found that rainfall will increase in the majority of

Figure 3.18 Total number of grids in each administrative boundary of a district

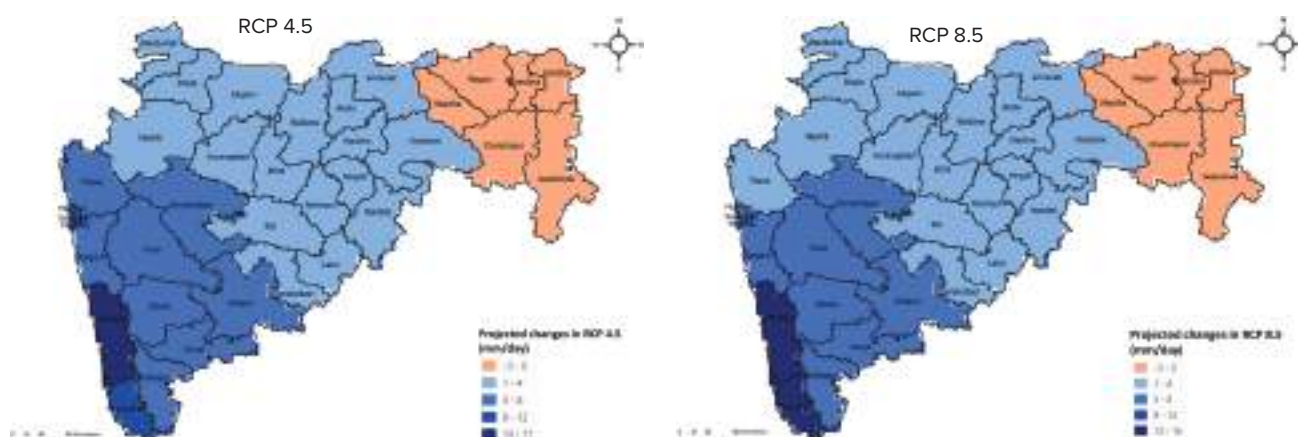


Source: Authors' analysis

It should be noted that the outputs from the CORDEX models are at a native coarse resolution of ~44 km, which is unsuitable for district-level analysis. This was further downscaled to a 25 km resolution grid to obtain district-level figures, but the information provided at a district level is of low confidence in the projections. Hence, there might be minor uncertainties in the outputs and key inferences should be drawn from the region-specific findings that have been provided.

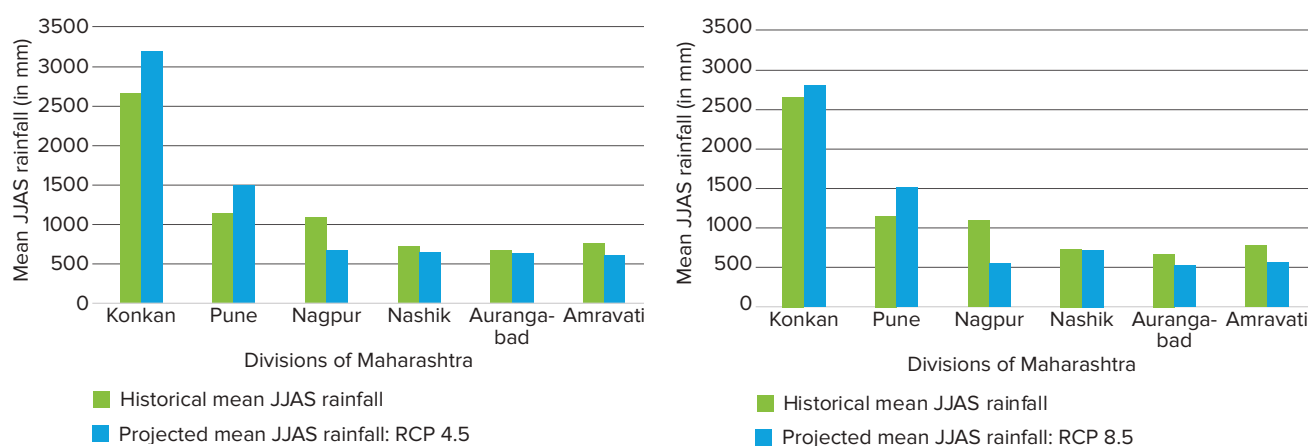
The inferences from districts having a high grid count can be considered of high confidence, whereas lower grid counts represent a minor level of uncertainty. Mumbai and Mumbai Suburban have been aggregated as Mumbai since no grid count fell in the Mumbai district.

Figure 3.19 District-wise projected changes in JJAS rainfall under both RCP scenarios



Source: Authors' analysis

Figure 3.20 Division-wise comparison of projected and historical monsoon season rainfall



Source: Authors' analysis

Maharashtra using an ensemble of 15 Cordex South Asia RCMs (CSTEP 2022). While the general trends are similar, it should be noted that the district-level analysis could have minor fluctuations due to differences in models and the coarse resolution of grids.

3.5.2 Intra-annual rainfall variability

The intra-annual observed and projected rainfall variability, i.e., changes in the frequency of days with different categories of rainfall intensity, was mapped using district-specific intensity thresholds as enumerated in Figure 3.21. This approach has been found to be more representative in capturing the spatial variabilities observed in highly heterogeneous climatological conditions as prevalent in Maharashtra.

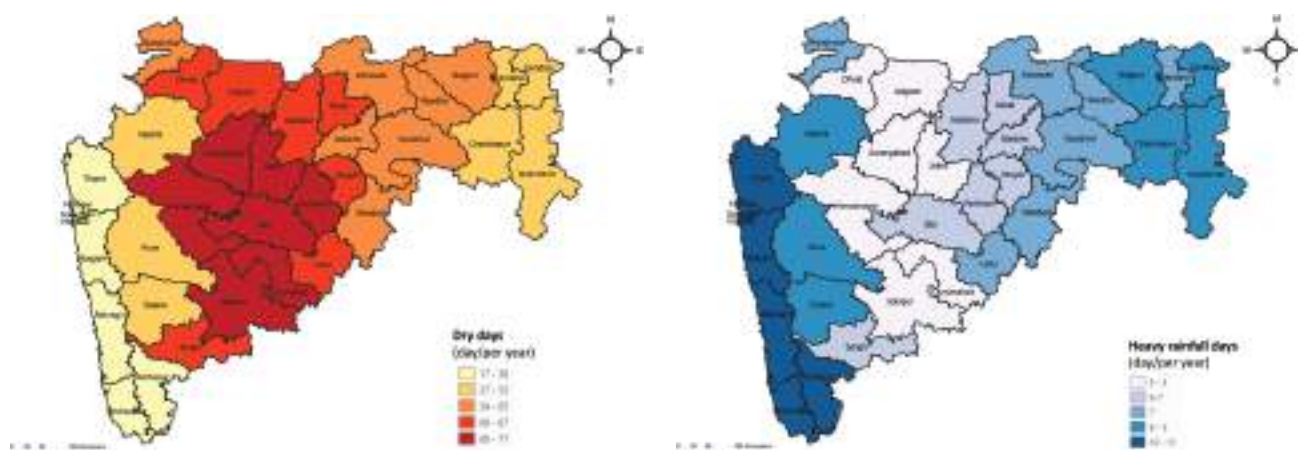
The observed pattern of rainfall days with different intensities: The Konkan region witnessed a high frequency of heavy rainfall days, whereas the dry days are highest in the central Maharashtra region. While the trend analysis performed does not show any statistically significant

trends in the frequency of dry and moderate-intensity rainfall days, the heavy rainfall events are found to be increasing in certain regions.

The analysis suggests that heavy rainfall events are increasing significantly in Konkan and parts of the Pune and Nashik regions of Maharashtra. The magnitude of increase as per the Sen's Slope was found to be the highest in the districts of Pune, Thane, Raigad, Sindhudurg, and Mumbai Suburban.

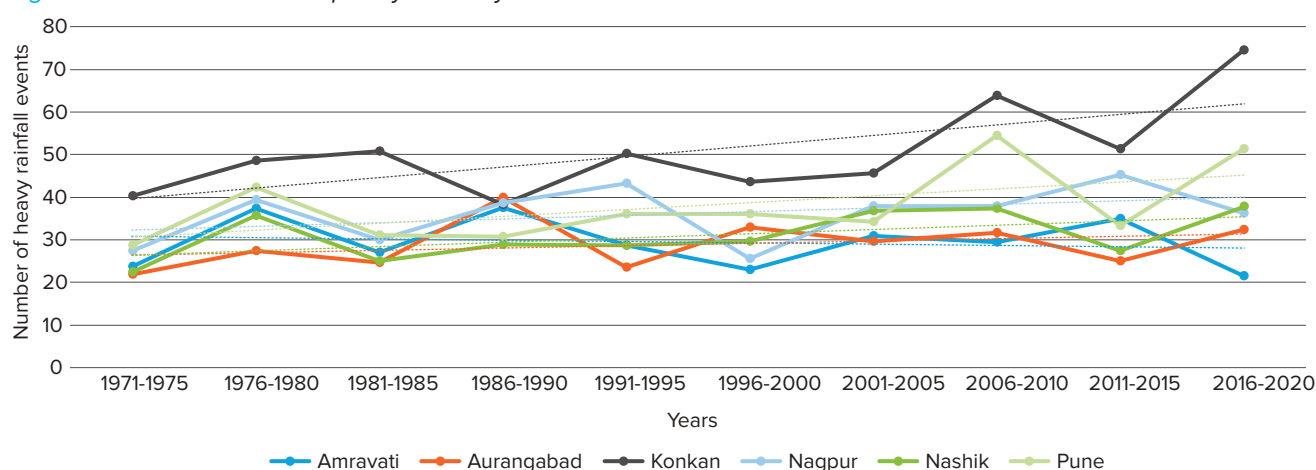
This increasing trend is partially attributed to the cyclonic disturbances in the Arabian Sea, which have become much stronger over the last two decades (2000–20) (Dave, James, and Ray 2017), with the frequency of extreme cyclones increasing by a near three-fold in the last decade (Mohanty and Wadhawan 2021). Modelled projections show that rainfall will increase in the Konkan region followed by parts of central Maharashtra under both RCP scenarios, which increases the probability of more intense and frequent heavy rainfall events in these regions.

Figure 3.21 Annual average district-wise frequency dry days and heavy rainfall days from 1971–2020 during JJAS



Source: Authors' analysis

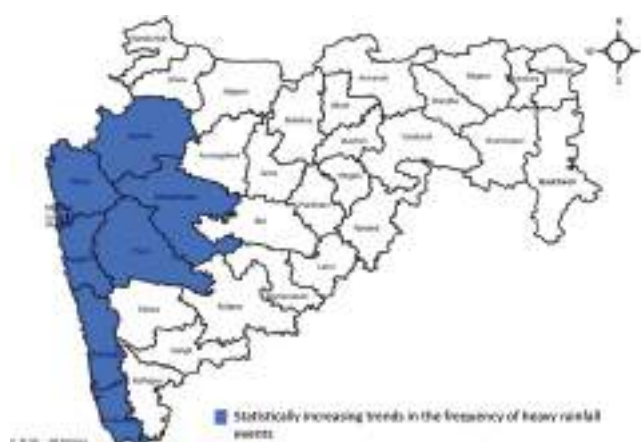
Figure 3.22 Trends in the frequency of heavy rainfall events across divisions of Maharashtra from 1971–2020



Source: Authors' analysis

Overall, the findings from the temperature and rainfall analysis suggest that Maharashtra will see higher temperatures and rainfall in most of its regions in the 2030s in continuation of the current observed trend. Moreover, the temperature extremes are projected to increase significantly uniformly in the state, while rainfall changes will be marked by high spatial variability. The findings and trends closely match with available national and regional literature, except for the slight decrease in the eastern region for rainfall and are in line with the findings of the Assessment of Climate Change over the Indian Region report on climate change by the Ministry of Earth Sciences (MoES 2020), which projected an overall increase in the temperature and rainfall in the country. The findings presented in this chapter play a critical role in drawing out the adaptation strategies for the sectors, and the indices have been used as input for the hazard component of sectoral vulnerability and risk assessments, i.e., for water, health, and agriculture.

Figure 3.23 Trends in frequency of heavy rainfall events from 1971–2020



Source: Authors' analysis

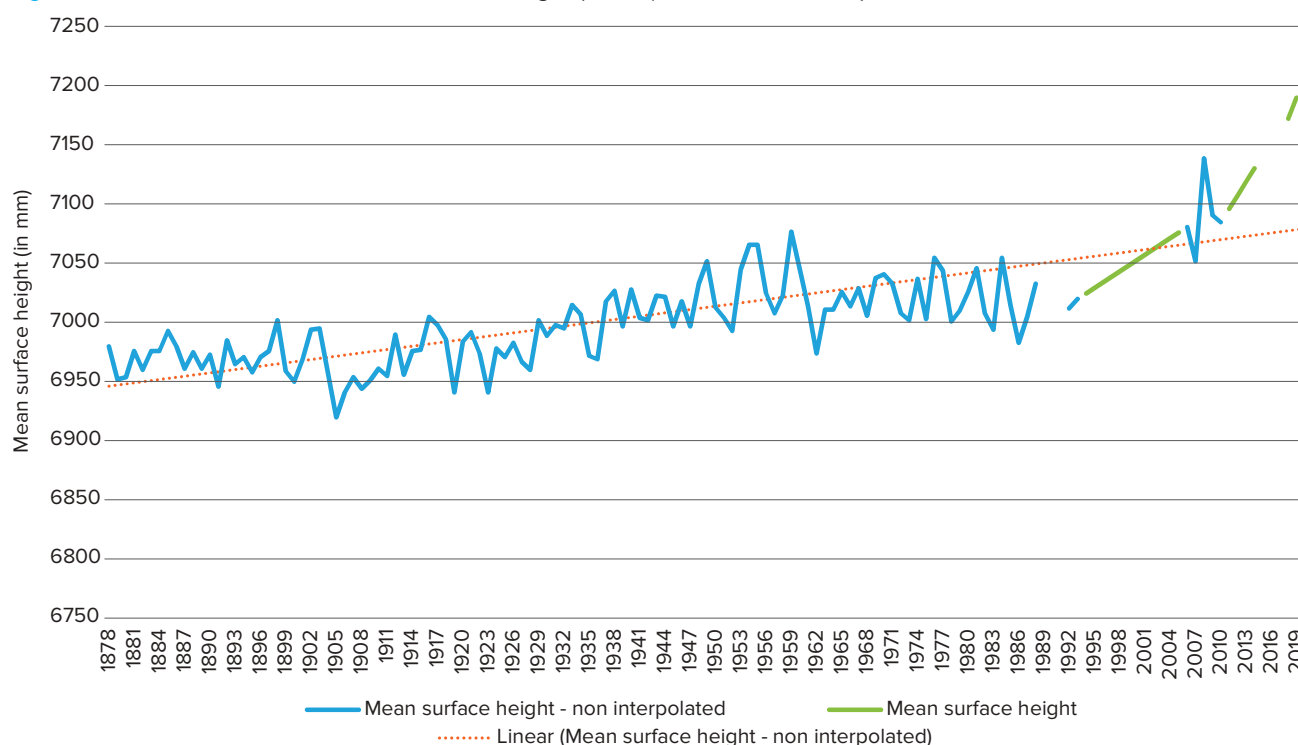
3.6 Sea-level rise in Maharashtra: Historical and projected trends

In the context of the warming climate, sea levels worldwide have been steadily rising, with projections indicating a continued increase in the future. The anticipation of future sea-level rise is of utmost importance for coastal planners and policymakers as they seek to comprehend and account for its impacts on communities, sectors, and infrastructures. Given Maharashtra's coastline extending approximately 720 km and its significant districts and cities situated near the Arabian Sea, it becomes imperative for the region to prepare for rising sea levels and their compounding effects. To examine historical and projected trends in sea-level rise, an analysis was conducted utilising open-source global- and regional-level datasets.

For the historical trend analysis, yearly mean surface height data for the Mumbai port spanning 143 years, from 1878–2020, was obtained from the Permanent Service for Mean Sea Level portal. Linear interpolation was employed to address missing data for certain years. The analysis reveals a notable linear increasing trend, with a rate of 0.91 mm rise in mean surface height per year.

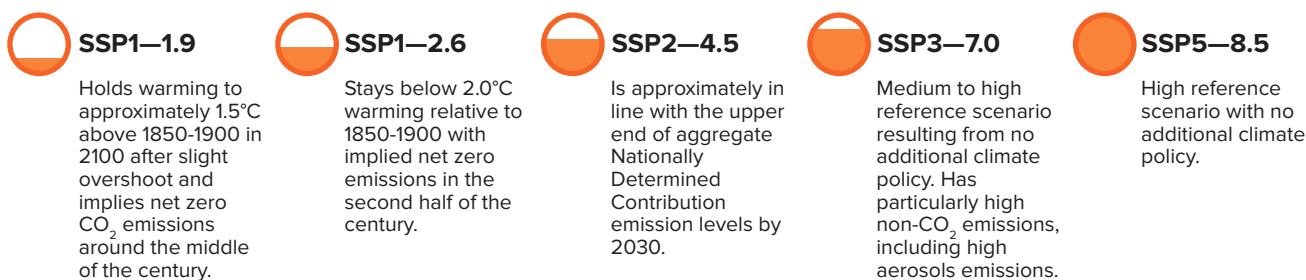
To project future sea-level rise along the coastline of Maharashtra, data from the IPCC Sixth Assessment Report (AR6) was utilised. This information is derived from the NASA sea-level projection tool. The AR6 report offers insights into the global mean sea level, incorporating regional sea-level projections and associated uncertainties. The projections are based on CMIP6 models, which account for the impact of socioeconomic conditions, such as population and economy, on GHG emissions by linking

Figure 3.24 Historical trend in mean surface height (in mm) over the Mumbai port



Source: Authors' analysis

Figure 3.25 Five shared socioeconomic pathway scenarios (SSP) used in projections



Source: Authors' compilation

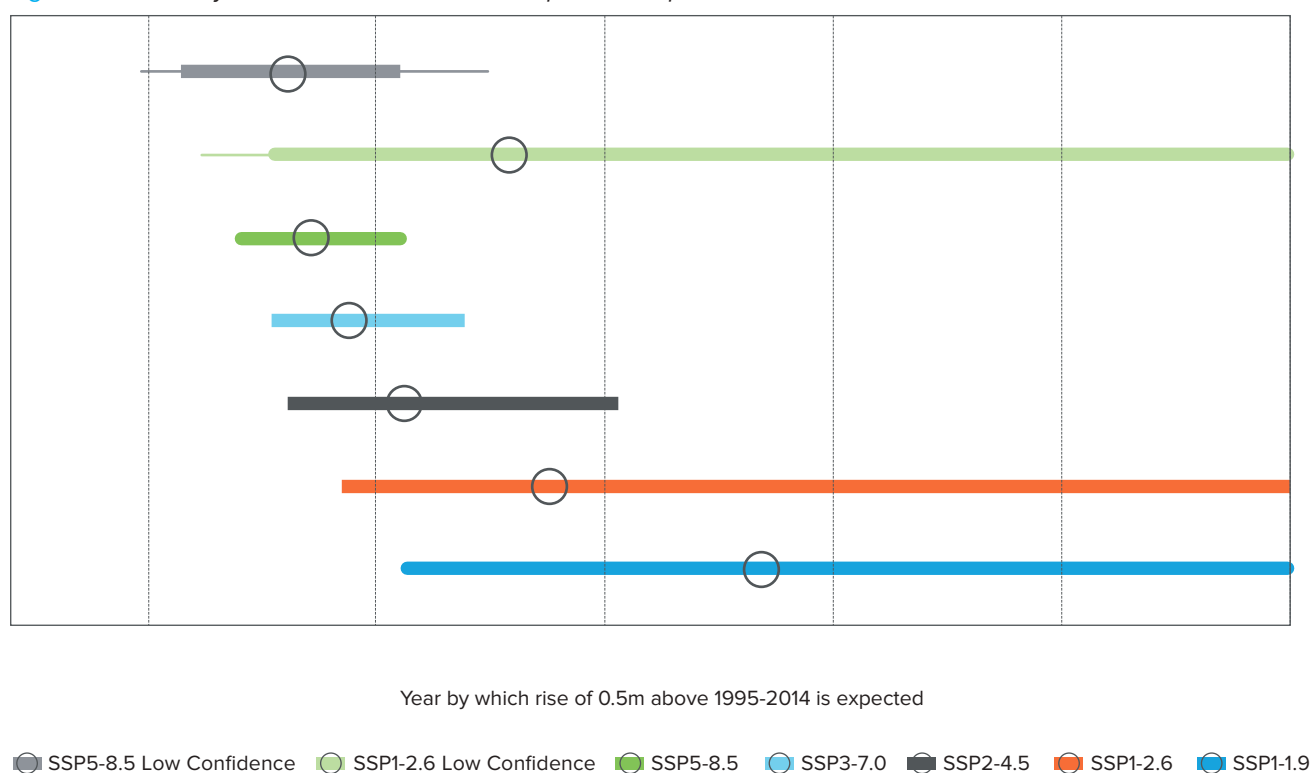
RCPs to Shared Socioeconomic Pathways (SSPs). This approach enhances the reliability of climate projections and provides better support for climate policies. The models in AR6 provide projections of absolute sea levels and the rate of change (measured in mm/year) under the five shared socio-economic pathways.

The sea-level projections encompass likely ranges that are evaluated by considering uncertainties related to temperature changes linked to emissions scenarios, as well as uncertainties in the connections between temperature and factors influencing projected sea-level changes, such as thermal expansion, ocean dynamics,

and glacier and ice-sheet mass loss. These likely ranges typically correspond to the 17th–83rd percentiles, indicating a probability of at least 66 per cent, as the term 'likely' is used to represent in this context.

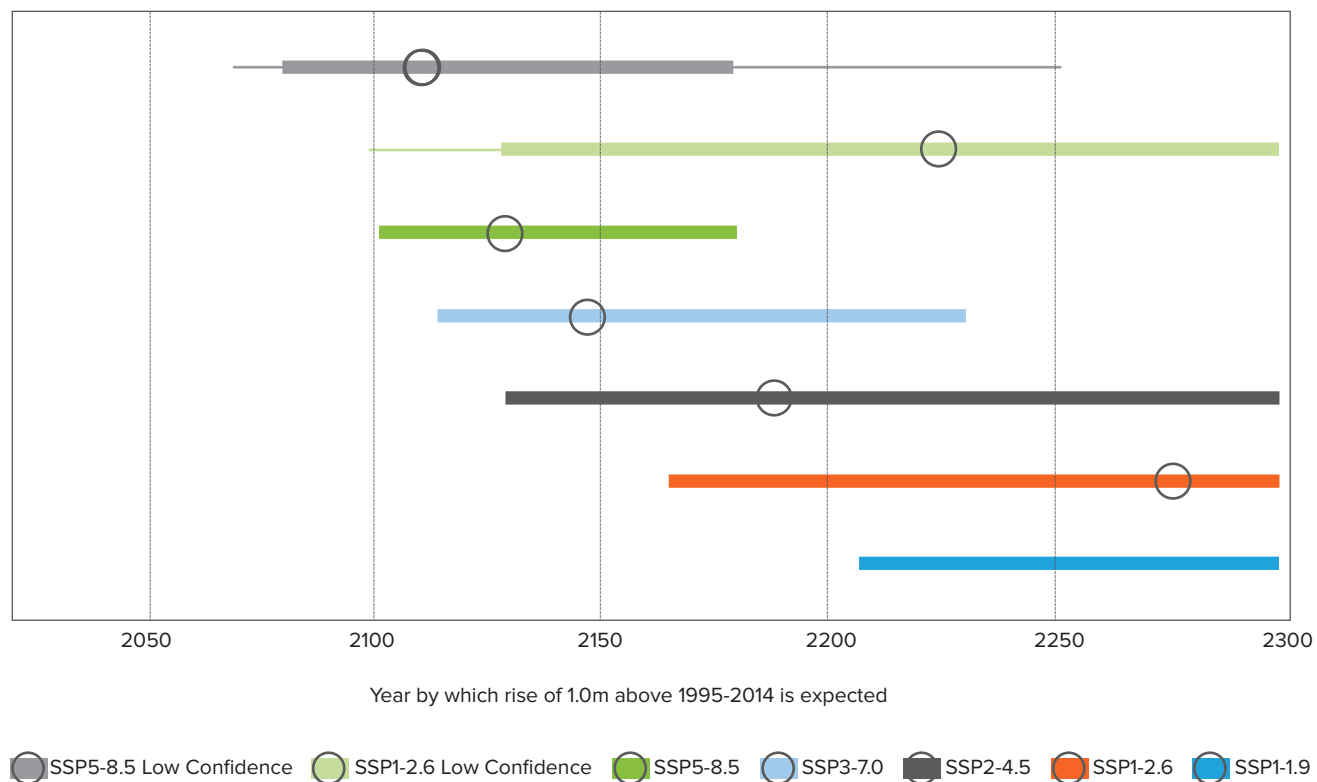
The projections suggest that under all scenarios, the sea levels are expected to rise by 0.1 m above baseline by 2050, while the rise of 0.5 m is expected to take place in the 2075 (SSP5-8.5) scenario and the sea level is expected to increase by 0.5 m after 2100 under the SSP2 4.5 scenario. The projections also indicate that the sea levels are expected to increase by 1 m by 2125 (SSP5-8.5 scenario) and by the year 2175 (SSP2-4.5 scenario).

Figure 3.26 Year by which sea levels at Mumbai port are expected to rise 0.5 m and above



Source: NASA Sea Level Change Toolkit

Figure 3.27 Year by which sea levels at Mumbai Port are expected to rise 1 m and above



Source: NASA Sea Level Change Toolkit

Comprehensive risk and vulnerability assessment of extreme climate events in Maharashtra

4.1 Introduction

As evidenced by the rise in frequency and intensity of extreme climate events that are devastating lives and livelihoods, climate change is no longer a distant concern but a harsh reality. Weather patterns are undergoing alterations and severely affecting infrastructure investments, especially in coastal regions. Unfortunately, vulnerable communities with limited adaptive capacity bear the brunt of these changes.

The increase in extreme weather events driven by climate change has led to a surge in human casualties and substantial economic losses on a global scale. In India alone, the annual cost of extreme climate events reaches a staggering USD 87 billion (INR 71000 crore): (WMO, 2021). The IPCC projects that extreme weather events will continue to rise in frequency and intensity throughout the 21st century, primarily due to human-induced climate change.

The Sixth Assessment Report by the IPCC emphasises the grave consequences of excessive GHG emissions and unsustainable land-use practices, which are pushing us towards surpassing the critical 1.5°C threshold. Such a scenario poses immense challenges and threats to emerging economies worldwide, as climate risks are intricately linked to economic growth and stability. The urgency to address and mitigate climate change is now more crucial than ever before.

4.2 The state of extreme climate events in India

India ranks as the seventh-most vulnerable country to climate extremes. It is crucial to scale up climate action at sub-national and district levels to mitigate the impacts of extreme events. The IPCC predicts a 3 per cent increase in precipitation and intensified cyclones and floods for every degree rise in temperature. Despite efforts to limit temperature rise to 2°C, storms, droughts, and unprecedented floods have already caused significant loss and damage in India. Therefore, it is necessary to consider the consequences of a 2°C target.

Rainfall patterns in India have significantly changed, with floods occurring during the Indian summer monsoon (ISM) season. Heavy rainfall, low-pressure systems, and high precipitation levels during the monsoon trigger disastrous floods, impacting over 40 million ha of land annually (Ray et al. 2019). Over 52 per cent of India's population depends on the agricultural sector (PIB 2020). Unfortunately, the agricultural sector is severely affected by droughts, which devastate livelihoods at an alarming rate. There are three main types of droughts: meteorological, hydrological, and agricultural.

According to a study by CEEW, India experienced a significant rise in extreme events from 1970–2019, particularly accelerating from 2000–19 (Mohanty 2020). This increase in floods and droughts affects various regions across different climatic zones, posing serious challenges to food and water security. Floods encompass overflow from stream channels, higher

coastal and lake levels, and flash floods. Droughts are characterised by extended periods of unusually low precipitation, leading to water shortages, with the severity varying by location and environmental sector (EM-DAT 2015).

Since 2002, there have been significant improvements in drought monitoring, but predicting monsoonal droughts on seasonal to decadal scales still presents challenges (Rajeevan et al. 2012). Changes in land use and precipitation levels have contributed to an increase in drought events. In 2001 and 2002, over 25 per cent and 29 per cent of the country, respectively, were affected by moderate drought, leading to country-level drought since 1987 (IMD, 2005).

India's eastern coasts have historically been more exposed to tropical cyclones, but in recent decades, extreme cyclonic events have surged along western coasts. The intensity of tropical cyclones is high in the northwestern Indian Ocean, which experiences fewer disturbances compared to the northeastern Indian Ocean (Mohapatra et al. 2012). Cyclones, classified as tropical storms, are characterised by warm-core, non-frontal synoptic-scale disturbances with a low-pressure centre and strong winds. The IPCC estimates a 2–11 per cent increase in maximum wind speed for tropical cyclones by the year 2100, including the north Indian Ocean region (IPCC 2013a,b; Mohapatra et al. 2012).

Tropical cyclones have a significant impact, compounded by associated events like heavy rainfall, floods, hailstorms, cold waves, and tornadoes. The number of storms with over 100 mm of rainfall in a day has increased by 10 per cent per decade (UNEP 2009). Rising sea-surface temperatures lead to larger cyclone diameters, intensifying cyclonic disturbances.

According to a CEEW study titled 'Preparing India for Extreme Climate Events, Mapping Hotspots and Response Mechanisms' (Mohanty 2020), more than 75 per cent of Indian districts are extreme climate–event hotspots, facing an increase in the frequency and intensity of floods, droughts, cyclones, and associated events. The study also indicates that over 40 per cent of districts are undergoing a swapping trend, with traditional flood-prone areas becoming drought-prone and vice versa.

To effectively manage climate risks, it is crucial to understand the underlying drivers of hazards, the exposure of regions and populations, their sensitivity and resulting vulnerability, and the interactions between these components, as highlighted by the IPCC. The impacts of extreme events can be non-linear, depending on the sensitivity and adaptive capacity of the affected systems. Identifying and mapping the vulnerability of geographies and communities should be a national imperative to address these challenges.

4.3 Mapping climate vulnerability of extreme events

Vulnerability and risk indices play a crucial role in hazard mitigation and planning, providing concrete scores (Jones and Andrey 2007; Tate 2012; Wood, Burton, and Cutter 2010). Composite index-based assessments offer valuable insights into why certain regions are riskier and more vulnerable than others despite similar landscape attributes and climate zones. Understanding these vulnerabilities is essential, as climate extremes can disrupt the Earth system's thresholds (Lenton et al. 2008). Spatial index-based vulnerability and risk assessments are effective tools to minimise loss and damage. Evaluating vulnerability and risk at the district level is essential for developing comprehensive climate risk–mitigation strategies. Over time, methodologies for conducting national and sub-national vulnerability and risk assessments have evolved.

For any risk or vulnerability assessment study, a comprehensive hazard assessment is crucial (IPCC, 2015). Sub-national micro-level vulnerability and exposure assessments focus on understanding the impacts of climate change, especially concerning climate extremes. The quality and quantity of data are vital for such studies, and recent assessments utilise the analytical hierarchy process (AHP), geographical information systems (GIS), and quantitative and qualitative indicators. Stakeholder groups often participate in hazard classification, but their scope is limited to sector-, region-, and state-specific assessments. However, recent studies integrate various approaches, including GIS, qualitative/quantitative metrics, and high-level stakeholder participation for robust empirical assessments. Dominant indices typically capture social and physical vulnerability factors at the national level (Jones and Andrey 2007; Wood, Burton, and Cutter 2010). In India, spatial mapping of social vulnerability primarily relies on census or household survey data. Including spatially explicit indicators in vulnerability assessments helps stakeholders and policymakers identify vulnerability drivers in specific districts concerning particular hazards (Frazier, Thompson, and Dezzani 2014).

- Exposure is defined in the same report as 'the nature and degree to which a system is exposed to significant climatic variations'.
- Sensitivity is 'the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)'.
- Adaptive capacity is 'the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences'.

The IPCC's special report in 2012, *Managing Risks from Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX 2012), introduced a disaster risk-management framework that considers risk arising from the interaction of weather and climate events (hazard), exposure, and vulnerability. In this framework, the focus lies on reducing exposure and vulnerability while increasing resilience (IPCC 2012). Notably, vulnerability is regarded as an internal property of the system, consisting of sensitivity and adaptive capacity, and is separated from hazard and exposure elements. According to the SREX 2012 report, vulnerability is considered independent of physical events (IPCC 2012, 1.1.2.1, 33).

The IPCC's Fifth Assessment Report (AR5) released in 2014 further elucidated the core concepts related to risk assessment. Risk arises from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems (IPCC 2014). As per the AR5, vulnerability is defined as the propensity or predisposition to be adversely affected, encompassing sensitivity or susceptibility to harm and a lack of capacity to cope and adapt (IPCC 2007). The United Nations International Strategy for Disaster Risk Reduction (UNISDR) specifies vulnerability as the characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard (UNISDR 2011).

Moreover, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Office for Disaster Risk Reduction (UNDRR), the United Nations Development Programme (UNDP), and the Department of Science & Technology (DST) have conducted several studies highlighting the importance of robust micro-level vulnerability assessments. In India, many studies integrate mapping of exposure (the extent and nature of system exposure), sensitivity (the degree of system impact), and adaptive capacity (the system's ability to adjust to climate change) to assess vulnerability at state and district levels with varying temporal and spatial scales. As per the

IPCC's AR6 and an in-depth literature review, evaluating the vulnerability of any system requires considering all three components of the vulnerability function: exposure, sensitivity, and adaptive capacity. Equation 4.1 outlines the vulnerability function.

$$\text{Vulnerability (f)} = \text{Exposure (E)} \times \text{Sensitivity (S)} / \text{Adaptive Capacity (AC)}$$

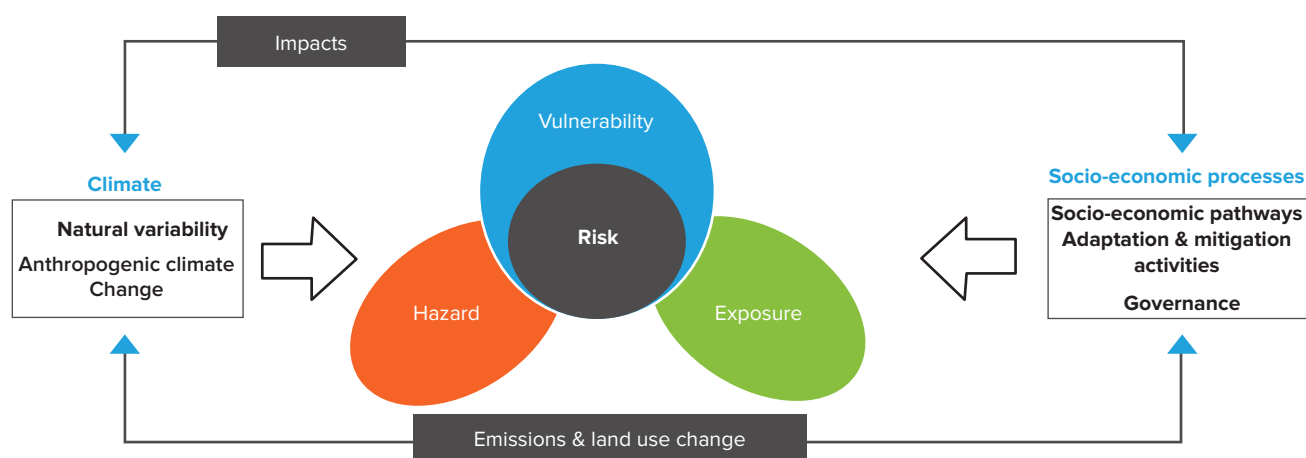
However, the concept of vulnerability may be operationalised in two ways (O'Brien 2007; Kelly 2000):

- Starting point/Contextual approach: The vulnerability of a system is considered a pre-existing condition in anticipation of a hazard.
- Endpoint/Outcome approach: The vulnerability of a system is assessed before and after exposure to a hazard.

The impact of climate change and climate hazards is not uniform across space and time, varying in different regions due to differences in exposure and vulnerability of ecosystems, economic sectors, and social groups (O'Brien 2008). Assessing system vulnerability is crucial in identifying suitable adaptation measures to address climate change and cope with current climate risks (DST 2020).

Using the AR4 SREX Framework, the DST and CEEW assessed the vulnerability of all states in India. The CEEW released a state-level ranking – the Climate Vulnerability Index (CVI) – based on vulnerability scores calculated for each district using Census 2011 data. Maharashtra ranked third on the CVI, indicating it as the third-most vulnerable state to extreme climate events in this study. However, the DST's 2020 ranking showed Maharashtra as 'low' on their vulnerability index, as it considered primarily socio-economic drivers and primary sector-based livelihood, along with some biophysical and institutional factors (DST 2020). On the other hand, the CEEW study mainly focused on exposure to extreme climate events such as floods,

Figure 4.1 Illustration of the IPCC SREX framework for components risk and vulnerability



Source: Intergovernmental Panel on Climate Change 2014

droughts, cyclones, and their compounding impacts, also considering district sensitivity to these extreme hydro-met disasters due to landscape attributes and socio-economic indicators.

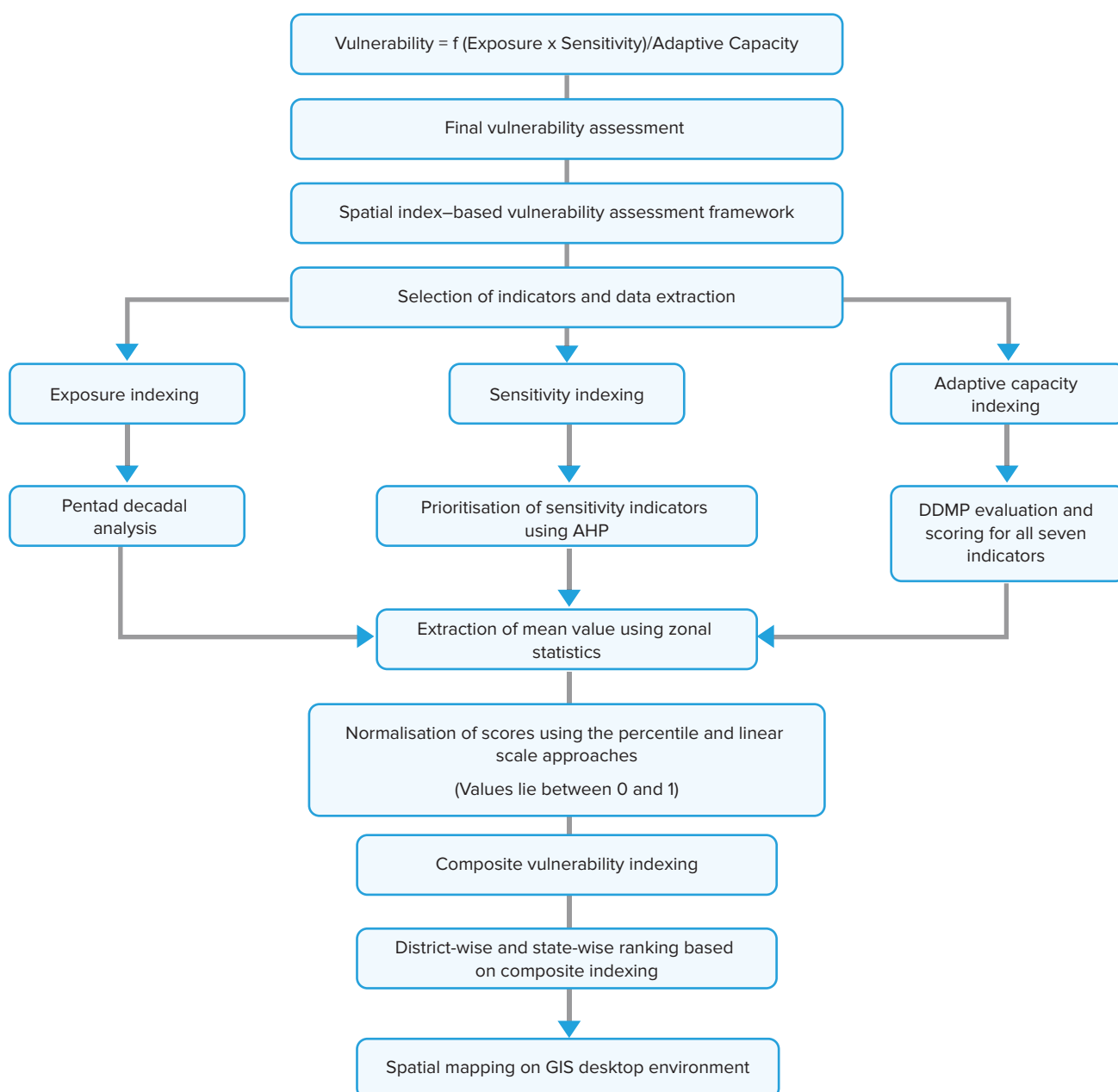
4.3.1 Mapping vulnerability of districts in Maharashtra to extreme hydro-met events

The CEEW conducted a micro-level vulnerability assessment titled 'Mapping India's Climate Vulnerability: A District-Level Assessment', mapping the climate vulnerability of districts in India. The vulnerability assessment utilises a composite

Climate Vulnerability Index (CVI) for Indian states and UTs, considering exposure, sensitivity, and adaptive capacity. Exposure is evaluated at the micro-level, sensitivity through spatiotemporal analysis, and adaptive capacity by assessing socio-economic and governance mechanisms. The framework used is based on the IPCC's AR4 SREX framework, also employed by DST for mapping vulnerability to climate change. By integrating spatial, temporal, and location-specific indicators, the CVI allows for mapping critical communities, sectors, and assets.

The assessment includes mapping the frequency and intensity of Indian districts' exposure to hydro-met extremes and associated events. These data are integrated

Figure 4.2 Step-wise approach for conducting a comprehensive vulnerability assessment



Source: Authors' compilation based on Mohanty and Wadhawan 2021

Table 4.1 Selected indicators for evaluating vulnerability

Component	Correlation with vulnerability	Selected Indicators	Sources
Exposure	Exposure is directly proportional to vulnerability. Higher exposure equates to increased vulnerability of the system to the impacts of climate change.	Frequency and intensity of extreme events and their associated events	Extreme-events catalogue developed by CEEW (Mohanty 2020)
Sensitivity	Vulnerability is directly proportional to the degree to which a system is affected (sensitivity). High sensitivity equates to high vulnerability to the impacts of climate change.	1. Land use and land cover 2. Elevation 3. Slope 4. Groundwater 5. Soil moisture	1. Bhuvan-Indian Space Research Organisation (ISRO) 2. United States Geological Survey (USGS) 3. USGS 4. Water Resources Information System (WRIS) 5. National Aeronautics and Space Administration (NASA)
Adaptive capacity	Vulnerability is inversely proportional to adaptive capacity. The higher the adaptive capacity, the lower the vulnerability of a system to the impacts of climate change.	1. District disaster management plans 2. Gross district domestic product 3. Literacy rate 4. Sex ratio 5. Availability and accessibility to critical infrastructure 6. Availability of disaster-ready shelters 7. Population density	1. Census 2011 2. Ministry of Statistics and Program Implementation, Government of India (MoSPI) 3. Ministry of Agriculture (MoA) 4. Farmers Welfare Press Information Bureau (PIB)

Source: Authors' compilation

with spatial mapping of landscape indicators' sensitivity (e.g., land-use-land-cover, soil moisture, groundwater, slope, and elevation) to climate extremes. The CEEW also assesses adaptive capacity by considering a wide range of socio-economic indicators, including population density, GDDP, literacy ratio, sex ratio, availability and accessibility of critical infrastructures, availability and accessibility of shelters, and robustness of district disaster management plans (DDMPs). Following the IPCC's SREX framework and the DST common vulnerability assessment approach, the study evaluates the combined risk of hydro-met disasters and their compounded impact on districts' climate vulnerability.

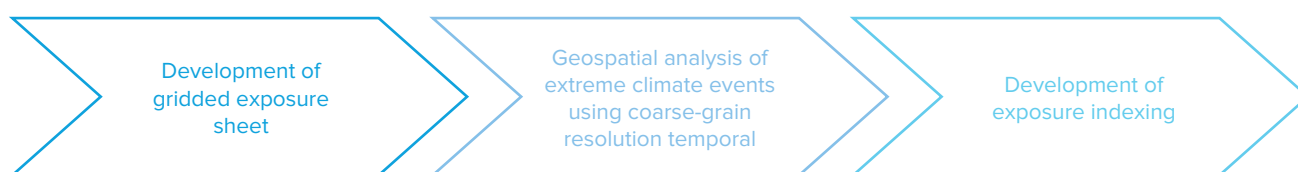
In assessing the vulnerability of districts in Maharashtra, each selected indicator plays a functional role in determining the component and overall vulnerability of a district. The assessment considers both biophysical and social indicators. Exposure indicators encompass the frequency and intensity of extremes, while sensitivity indicators consider landscape attributes. Adaptive capacity indicators include socio-economic factors and the evaluation of DDMPs. Refer to Table 4.1 for detailed information on the selected indicators.

4.3.1.1 Exposure assessment

For this assessment, exposure was defined as the occurrence of specific events within a particular grid representing a district boundary. This approach aimed to identify districts that are extreme event hotspots, using the classification of extreme events provided by EM-DAT, IMD, and WMO. The district-level assessment utilised spatial and temporal modelling, considering complexities and non-linear trends and patterns. It analysed the frequency and intensity of hydro-met disasters, the pattern of associated events, and their compounded impacts over 50 years (1970–2019). The assessment also examined shifts in climate-event trends across sub-regions.

To obtain pentad frequency scores, data on the frequency of extreme events by decade for each district from 1970–2019 were compiled. Aggregated values were normalised using a percentile approach. Since the analysis focuses solely on extreme hydro-met events, percentile-based indices provide a detailed statistical method for deriving a relative exposure index at the micro-level.

Figure 4.3 Approach and methodology for exposure assessment



Source: Authors' analysis

4.3.1.2 Sensitivity assessment

The initial step in any vulnerability assessment is a comprehensive evaluation of hazard-linked sensitivity (IPCC 2018). The sensitivity analysis provides crucial insights into landscape-based drivers of hydro-met extremes and how changes in landscape attributes have contributed to their intensification. The accuracy of climate-extreme assessments relies on the quality and quantity of spatial data (IPCC 2018). Gridded data sheets are effective for mapping climatological and meteorological inferences at a coarse-grain resolution (GAR 2017).

To begin, gridded spatial layers were created for various landscape indicators (elevation, slope, land use/land cover – LULC, groundwater, and soil moisture) from coarse-grain base-level maps with a 25 km × 25 km resolution. A downscaling approach was then employed to derive grid-level attribution data for each indicator at a higher resolution of 30 m × 30 m, using Q-GIS for re-gridding and clipping sensitivity spatial layers. These grid-level data could be easily overlaid on exposure-gridded sheets, which identify the frequency and intensity of primary events (cyclones, floods, and droughts) and their

Table 4.2 Indicators considered for evaluating sensitivity

Indicator	Correlation with Sensitivity		
	Flood	Cyclone	Drought
Elevation	Direct correlation As the precipitation and runoff increase with a decrease in elevation, the low-lying areas are prone to flood risks.	Indirect correlation Areas with the characteristics of low elevation and slope are considered highly vulnerable to tropical cyclones, whereas areas with high slope and elevation are considered less vulnerable (Rao et al., 2013).	No correlation
Slope	Direct correlation Higher slope leads to more velocity of water, resulting in runoff and contributes to more floods in low-lying areas.	Indirect correlation Areas with the characteristics of low elevation and slope are considered highly vulnerable to tropical cyclones, whereas areas with high slope and elevation are considered less vulnerable (Rao et al., 2013).	No correlation
Groundwater	Direct correlation Higher water tables indicate that the soil is already saturated with water, thus suggesting an overflow of water and leading to more intense floods.	No correlation	Indirect correlation The availability of more groundwater suggests the availability of more water resources as the groundwater rises the baseflow discharge to surface-water bodies, thus reducing the sensitivity to droughts.
Soil moisture	Direct correlation A decrease in the percolation capacity of the soil will lead to less absorption of water, resulting in more floods.	Indirect correlation	Indirect correlation More water content in the soil will lead to more water resources, thus resulting in fewer droughts.
LULC	Direct correlation Significant expansion of urban lands and depletion of agricultural lands, floodplains, and waterbodies have increased the frequency of floods.	Direct correlation Changes in LULC lead to higher temperatures and an increase in moisture, leading to the formation of cyclones.	Direct correlation Reduction in the amount of water resources available due to changes in LULC leads to more droughts.

Source: Authors' analysis

associated events. A district-level grid-based analysis was conducted for all indicators. Normalisation of data was necessary due to the use of base-level maps from various sources, which contained outliers. A unified raster was created, considering the correlations of landscape indicators with hydro-met disasters, based on a literature review.

Additionally, the indicators underwent prioritisation using the Analytic Hierarchy Process (AHP) model. The re-classified raster data was fed into the AHP model along with the assigned indicator weightages. Saaty's scale (Saaty 1994; Coyle 2004) was used to determine the indicator weightages and establish correlations. This process allowed the ranking of indicators on a scale of 1–5 based on their correlation with hydro-met disasters for the analysis. The results were further validated by computing the consistency ratio (CR) following standard practices. A CR value less than 0.1 indicates a valid AHP ranking (using the provided equation). These steps facilitated the development of gridded spatial layers for subsequent geospatial analysis and the derivation of a sensitivity index.

Consistency ratio (CR) equation:

$$\text{Consistency Ratio} = \frac{\text{Consistency Index}}{\text{Random Inconsistency Index}}$$

$$CI = \frac{\lambda - n}{n - 1}$$

Where, n = number of factors and λ = average value of the consistency vector

4.3.1.3 Adaptive capacity assessment

An adaptive capacity index, based on quantitative indicators, was developed for the analysis. Extensive literature surveys and stakeholder consultations were used to finalise seven indicators and their sub-indicators. The Delphi technique was employed to further refine these indicators and establish scoring ranges for adaptive capacity. The final scoring ranges are as follows: **0–0.2 = very low; 0.21–0.4 = low; 0.41–0.6 = moderate; 0.61–0.8 = high; 0.81–1.00 = very high**. These indicators were chosen based on their correlation to adaptive capacity, encompassing economic, social, infrastructural, and governance aspects crucial for a region's adaptive capacity. Table 4.3 illustrates the adaptive capacity indicators. To ensure a comprehensive assessment, an evaluation of the DDMPs was included, based on the NDMA guidelines (NDMA 2015).

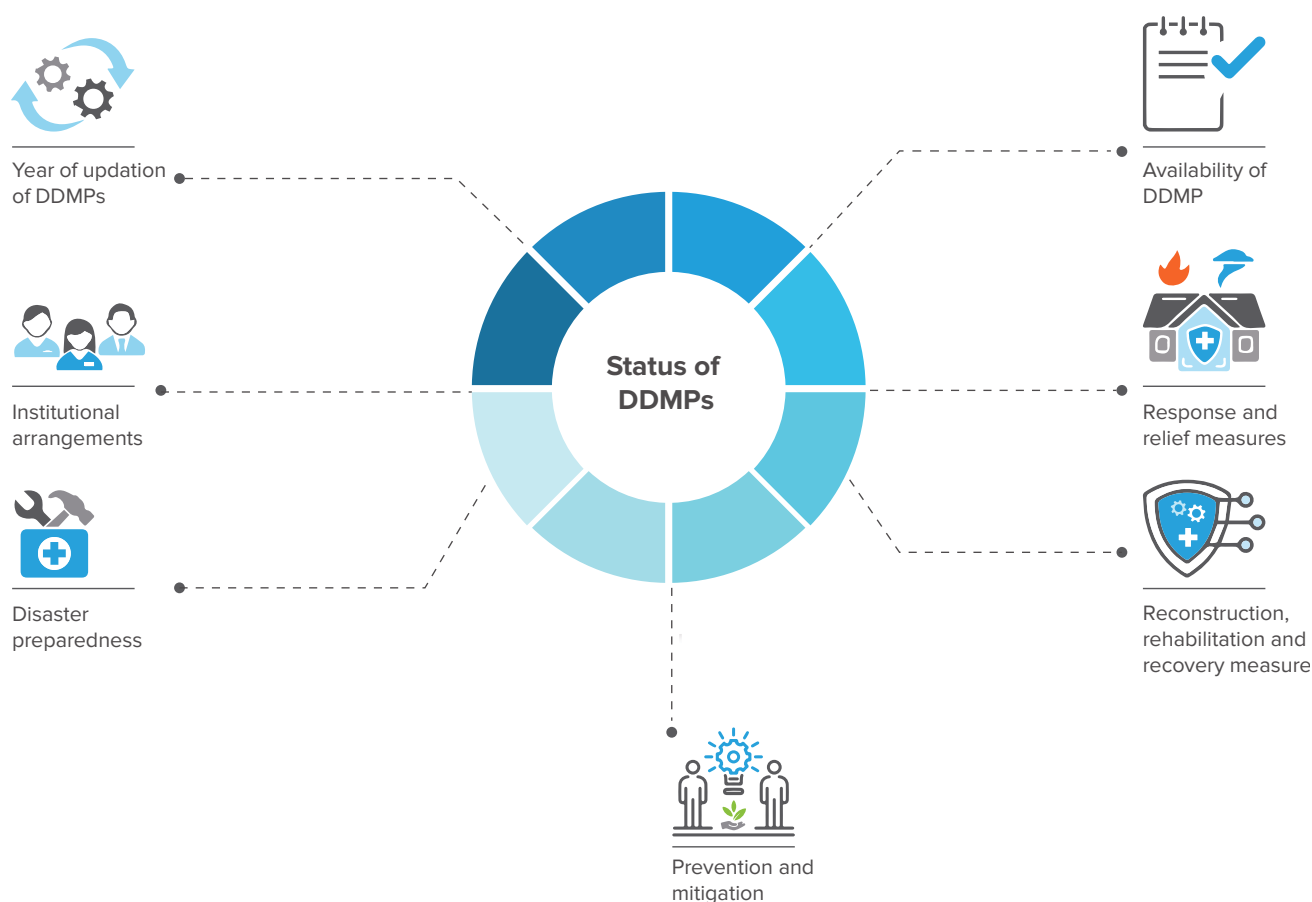
The data for mapping the adaptive capacity index of Indian districts was obtained from the Census of India (2011). For six indicators, excluding DDMPs, this served as the primary data source. As shown in Table 4.3, the selected indicators encompass economic, social, infrastructural, and governance aspects that influence a district's adaptive capacity directly or indirectly. To maintain consistency with DST (2019) and the Indian Himalayas Climate Adaptation Programme (IHCAP 2018) guidelines, equal weightage was assigned to all indicators. The weighted scores were then normalised to obtain mean values for the overall indexing of a district's adaptive capacity. The normalisation of the weighted scores was performed based on the functional correlation of indicators (IISD 2009).

Table 4.3 Indicators considered for evaluating adaptive capacity

Indicator	Correlation with adaptive capacity
Status of DDMPs	Every district in India is required to have a DDMP as per NDMA guidelines. Further, these DDMPs should be updated annually. They provide a detailed overview of the district's disaster preparedness state and often describe an institutional mechanism for building back better and developing strategies for effective preparedness. We consider an updated and effective DDMP to be positively correlated with adaptive capacity.
Population density	The population is a key demographic characteristic. A densely populated geography has higher exposure and lower adaptive capacity. Hence, population density is negatively correlated.
Literacy rate	A high literacy rate drives higher adaptive capacity because of better risk-management knowledge and disaster preparedness (Hoffman et al. 2020). The literacy rate is thus positively correlated.
GDDP	Economic development leads to higher adaptive capacity since communities become less vulnerable. Regions with a higher GDDP per capita are better able to deal with the consequences of climate change; hence, it is positively correlated with adaptive capacity.
Availability and access to critical infrastructure	Critical infrastructure protects communities from a variety of hazards and enables essential services to operate without disruption (World Risk Report 2016). We have considered educational and medical institutions as they are major disaster risk-reduction infrastructures, followed by all-weather roads and other critical infrastructures as stated in the DDMPs. This indicator is positively correlated.
Availability and accessibility to shelters	Shelters provide basic evacuation support during extreme events. This indicator is highly crucial for flood and cyclone adaptive capacity assessments, and we have considered cyclone and flood rescue shelters enumerated in the DDMPs as part of the evaluation.
Sex ratio	Gender is a key determinant of vulnerability to climate change, and women often bear the brunt of climate extremes (UNDP 2012). Marginalised women are the most affected, and the indicator negatively correlates with adaptive capacity.

Source: Authors' analysis

Figure 4.4 Variables considered for evaluating DDMPs



Source: Authors' analysis

Furthermore, the evaluation of DDMPs considered various variables, as mentioned in Figure 4.4, and multiple sub-indicators were utilised to assess the status of DDMPs (Table 4.4). This evaluation is a unique attempt to identify disaster preparedness gaps at an institutional level.

DDMPs play a crucial role as the first line of response mechanisms, and evaluating them provides insights into the robustness of financial and institutional support available for de-risking at a hyperlocal level.

Table 4.4 Sub-indicators considered for evaluating DDMPs

Sub-indicator	Correlation with DDMP evaluation
Updation year	Frequently updated DDMPs serve to strengthen disaster resilience and the capacity to recover from natural disasters.
Identification of hazards	This enhances the overall preparation strategy, policy, institutional structure, warning and forecasting capabilities, and helps to mitigate the situation beforehand and take appropriate action in the face of an immediate disaster.
Organisational hierarchy	Disaster management is more effective and sustainable if it is institutionalised.
Scope of resource inventory of man and material	Preparedness and mitigation measures towards disasters lower the risk of loss of life and damage to property. Various resources can be used from the inventory, thereby lessening the response time during a disaster.
Scope of hazard-specific response or crisis-management plans	The presence of hazard-specific response/crisis-management plans helps with dealing with a crisis within a limited period and with making optimum use of the available resources.
Roles and responsibilities of emergency services agencies	Effective emergency services help better cope in case of an emergency.
Scope of resilient reconstruction	Rehabilitation and reconstruction activities help in quick and efficient recovery in disaster-hit areas.
Availability of critical infrastructure	The availability of critical infrastructure in a DDMP helps carry out mitigation, response, relief, and rehabilitation activities.

Source: Authors' analysis

4.3.1.4 Vulnerability assessment

Vulnerability, a complex and multidimensional aspect of climate risk assessment, is often quantified using a composite index-based approach. For the integrated vulnerability assessment (IVA) of India, a composite index was adopted, considering three key components: exposure, sensitivity, and adaptive capacity. Exposure indicators encompassed extreme hydro-met disasters (floods, droughts, cyclones) and their associated events, while sensitivity indicators were landscape-based (LULC, elevation, slope, groundwater, and soil moisture). Adaptive capacity indicators included socio-economic factors and the effectiveness of DDMPs.

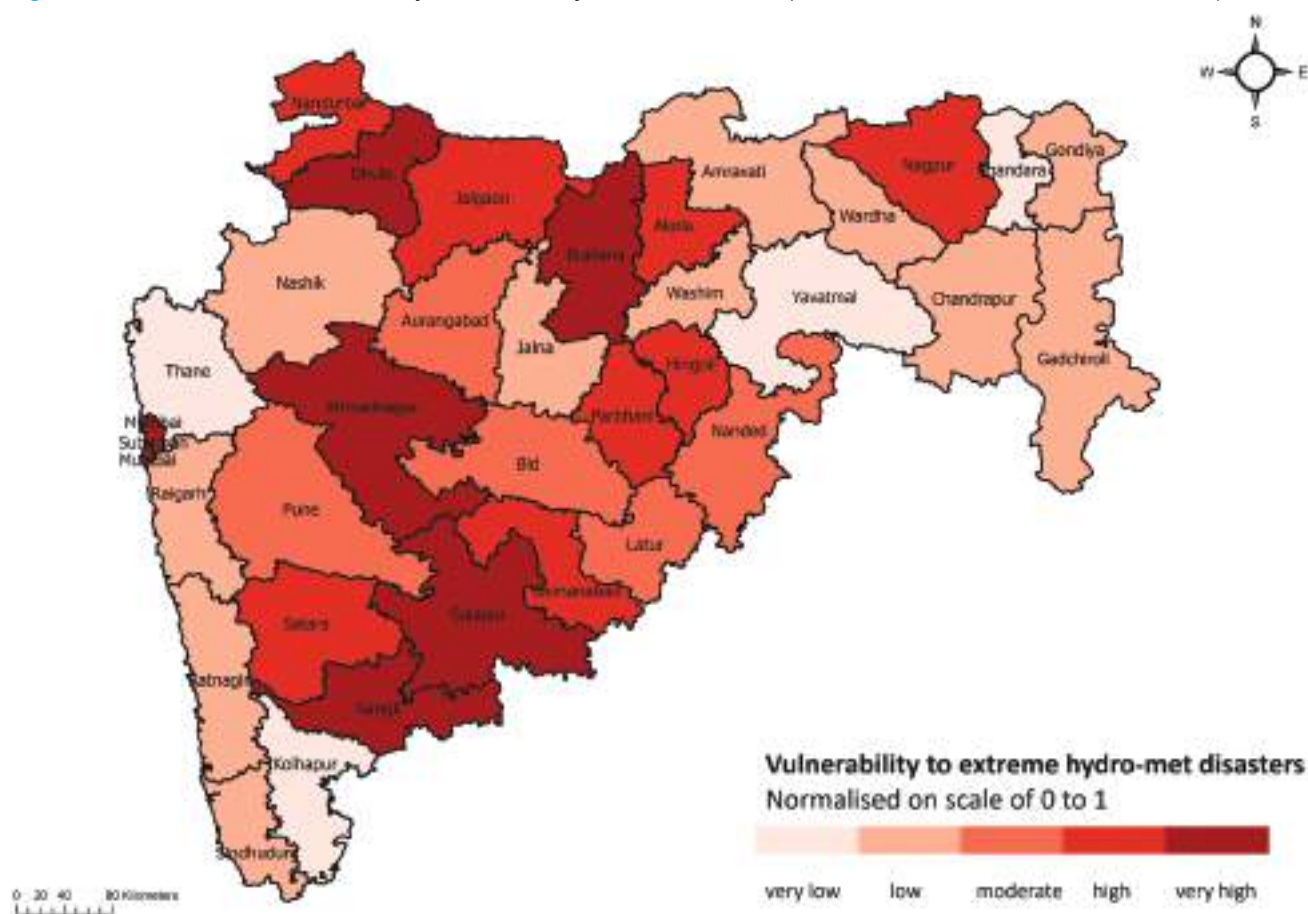
To create the composite vulnerability index, attribute scores for exposure, sensitivity, and adaptive capacity were normalised to ensure consistency across different indicators. As each indicator was measured on a different scale, normalising the aggregated values was essential for a robust index. The percentile method was used for exposure normalisation, while the linear scaling method was applied to sensitivity and adaptive capacity. The final composite vulnerability index was calculated by aggregating values from the three components. Exposure

and sensitivity showed a positive correlation with vulnerability, meaning higher values of these components increased vulnerability, while adaptive capacity exhibited a negative correlation, indicating that higher adaptive capacity reduced vulnerability.

4.4 Maharashtra's vulnerability to extreme climate events

As the Indian coastline is highly exposed to all three hydro-met disasters, certain districts adjacent to India's eastern and western coasts are vulnerable to all three extreme events. Maharashtra is one of the most vulnerable states to extreme hydro-met disasters in India and ranks third in CEEW's climate vulnerability index. The state is vulnerable to all three hydro-met disasters, i.e., floods, cyclones, droughts, and their associated events. This makes the impacts of such events highly compounded in the state, affecting lives, livelihoods, and economies at scale. The CEEW's analysis finds that 33 out of 35 districts, i.e., 94 per cent of districts are exposed to extreme floods, cyclones, droughts, and their associated events, making millions of people in the state vulnerable to extreme climate events.

Figure 4.5 Maharashtra's vulnerability to extreme hydro-met disasters (district list based on Census 2011 data)



Source: Authors' analysis

4.5 Maharashtra's exposure to extreme events

Exposure is 'the presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected' (IPCC 2014). It represents the susceptibility of a system to the adverse impacts of climate change. To effectively manage climate risks, it is crucial to understand the drivers of hazards, especially the exposure of regions and populations to extreme climate events. The CEEW analysis assesses district-level vulnerability by mapping the frequency and intensity of exposure to hydro-met extremes and associated events. This assessment considers the frequency and intensity of hydro-met disasters and their associated patterns, analysing the compounded impacts over 50 years (1970–2019).

4.5.1 Droughts

Maharashtra is one of the most drought-affected states in India, with over 85 per cent of its districts exposed to extreme droughts and associated events. Drought extremities in the state have tripled in the last 50 years. Studies indicate that the central and Vidarbha regions are more susceptible to droughts, while both Marathwada and Vidarbha regions are prone to floods. Factors like land-use change, urban heat island effect, and changes in precipitation levels contribute to the recent increase in drought events. The annual average rainfall has a linear relationship with drought events during 1990–99, according to CEEW's analysis. The IMD data shows that more than a quarter of the country in 2001 and 2002 was affected by moderate drought, with a significant impact on summer monsoons in 2002, causing a nationwide drought since 1987 in recent decades. These drought extremities pose a threat to critical economic sectors like agriculture, manufacturing, and MSMEs, and severely affect the food and water security of the country. Table A1 in the Annexure provides a list of districts exposed to extreme drought events.

4.5.2 Floods

Maharashtra faces significant exposure to extreme floods and associated events, with more than 30 per cent of its districts being vulnerable. Over the past decade, the state has witnessed a staggering four-fold increase in the occurrence and severity of extreme flood events. Historically, floods were often accompanied by the onset of ISM during earlier decades, triggered by favourable monsoonal conditions that brought heavy-to-very-heavy extreme rainfall. Low-pressure systems and high precipitation levels contributed to disastrous downpours at an unprecedented scale.

The impact of floods has been extensive, affecting ecosystems, lives, and livelihoods. Estimates reveal that

over 40 million ha of land are exposed to floods annually, with nearly 8 million ha of land being impacted. The surge in extreme flood events aligns with the warming of the Indian Ocean. As the Indian Ocean warms, it contributes to increased moisture, resulting in extreme rainfall events and subsequent floods. Unsustainable urbanisation, along with indiscriminate encroachment of natural drainage systems, has further exacerbated flood risks across the country. Annexure Table A2 provides a comprehensive list of districts that are exposed to extreme flood events.

4.5.3 Cyclones

In Maharashtra, five coastal districts are vulnerable to extreme cyclones and their associated events. Over the last decade, the state has experienced a significant three-fold increase in extreme cyclonic events. While India's eastern coasts have traditionally been more exposed to tropical cyclones, there has been a noticeable surge in extreme cyclonic events along the western coasts in recent decades. Although the Arabian Sea witnesses fewer cyclonic disturbances compared to the Bay of Bengal, the tropical cyclones' intensity remains remarkably high. Several factors have contributed to the rise in extreme cyclone events in recent years. Land-surface changes play a crucial role in triggering these cyclones, while increasing sea-surface temperatures further amplify their intensity. The diameter of cyclones has surged due to rising sea-surface temperatures, leading to heightened cyclonic disturbances.

Moreover, there has been a concerning increase in the number of storms with more than 100 mm of rainfall in a single day, rising by 10 per cent per decade. These extreme weather events pose significant challenges and risks to coastal regions, emphasising the need for effective adaptation and disaster preparedness strategies to safeguard lives, infrastructure, and ecosystems. The impacts of extreme cyclones and associated events call for comprehensive measures to enhance resilience and mitigate the adverse effects of climate change along India's coastal areas, particularly the western coasts in Maharashtra.

Moreover, the Mumbai and Mumbai Suburban districts in Maharashtra are situated on a narrow coastal plain between the Arabian Sea and the Western Ghats, making them highly vulnerable to the impacts of cyclones and storms originating in the Arabian Sea. Their low-lying coastal topography, with a significant portion built on reclaimed land, exacerbates their susceptibility to flooding from heavy rainfall and storm surges during cyclones. The flat terrain hampers the quick drainage of excess rainwater, leading to waterlogging and inundation during monsoon seasons – especially the southwest monsoon from June to September, which brings intense rainfall and heightened flood risk to the city.

Climate change further exacerbates these vulnerabilities, contributing to the increasing frequency and intensity of

extreme weather events like cyclones and heavy rainfall. Rising sea levels due to climate change pose the additional threat of coastal flooding in low-lying areas. Over the years, natural water bodies like rivers, creeks, and wetlands in and around Mumbai have faced encroachment or been filled up for construction purposes, disrupting the natural flow of water and aggravating flood risks.

In response to these challenges, various measures have been undertaken to mitigate flood and cyclone risks in Mumbai. These include the construction of flood-protection infrastructure, improved stormwater drainage systems, early warning systems, and the formulation of disaster management plans. Despite these efforts, the combination of geographical factors, rapid urbanisation, and climate change-related challenges continue to pose significant risks to Mumbai, making it susceptible to extreme weather events. Table A3 in the Annexure provides a list of districts exposed to extreme cyclone events.

4.6 Maharashtra's sensitivity to extreme events

Sensitivity refers to the degree to which a system is affected by exposure to risks. To derive a sensitivity index at the district level, landscape indicators were considered. A sensitivity analysis provides valuable insights into the landscape-based drivers of hydro-meteorological (hydro-met) extremes and their impacts on ecosystems. It helps forecast a country's resilience to climate change, considering geographical, social, cultural, financial, and political factors.

Based on the AHP ranking of landscape indicators, elevation and slope were identified as dominant drivers of sensitivity to flooding events. Land-use and land-cover (LULC) changes also significantly influence climate, leading to shifts in land-surface temperature and rainfall patterns in various districts (Gogoi et al. 2019). These changes have been linked to the recent trend of incessant rainfall across Indian districts. Land use and land cover indicate the types and uses of landforms, both natural and human-made, creating a mosaic structure with major and minor land-cover types (Bogner, 2018).

For droughts, the AHP analysis revealed that soil moisture and groundwater levels are key drivers of sensitivity. Meteorological droughts are influenced by micro-climatic changes, such as anomalies in land-surface temperature and precipitation, while agricultural droughts are connected to changes in LULC, soil moisture levels, and ground slope, impacting water availability and crop production (Sivakumar et al. 2020).

Regarding cyclones, LULC, elevation, and slope emerged as the dominant sensitivity drivers, with the latter two indirectly correlated with cyclonic events. Land use and land cover, particularly forest-management practices,

deforestation, and changes in forest cover, play a crucial role in influencing a district's sensitivity to cyclones. Unsustainable agricultural practices also exacerbate the impacts of cyclones, leading to associated hazardous events like inland flooding and landslides (Srinivas and Nakagawa, 2008).

The sensitivity analysis indicates that 80 per cent of the districts in Maharashtra are highly sensitive to extreme hydro-met events. Additionally, over 20 per cent of the state area has experienced rapid changes in landscape attributes, contributing to the occurrence of these extreme events. Even more concerning is that 25 per cent of districts in the state are exhibiting a swapping trend, where flood-prone areas are becoming drought-prone and vice versa. These findings highlight the significance of understanding sensitivity drivers for effective climate-risk mitigation and adaptation strategies. Table A4 in the Annexure provides the sensitivity of districts in Maharashtra to extreme events.

4.7 Maharashtra's adaptive capacity to extreme events

Adaptive capacity refers to the ability of a community to respond to evolving stresses and negative impacts of hazards. It is shaped by the socio-economic and infrastructural conditions prevailing in the community, making it essential to develop proper adaptation strategies that enhance their adaptive capacities. Formulating effective adaptation strategies requires meeting two fundamental requirements: i) the capacity to learn from past experiences, and ii) the application of these learnings to cope with future climate-related stresses. Successful implementation of such strategies depends on various factors, including financial and social capital, institutional setups, skills and knowledge, natural resources, and, crucially, the role of local government. The willingness and drive of those affected to take action are also critical for the successful execution of robust adaptation measures (Brooks and Adger, 2007).

Governments and decision-makers can adopt planned or reactive adaptive measures depending on the scale of exposure and the degree of sensitivity of states and districts. Planning and implementing adaptation strategies are essential to enhance the resilience of vulnerable communities to climate change impacts and extreme events. By addressing the socio-economic, infrastructural, and institutional aspects of adaptive capacity, communities can better adapt to the challenges posed by climate change and reduce their vulnerability to hazards. The collaboration and coordination of all stakeholders, including governments, local communities, and non-governmental organisations, are instrumental in building and strengthening adaptive capacities to safeguard livelihoods and enhance the overall well-being of communities in the face of changing climatic conditions.

In this analysis, the seven key indicators for adaptive capacity in the state suggest that Maharashtra has an overall moderate adaptive capacity towards extreme hydro-met disasters. However, due to its high exposure and sensitivity towards extreme hydro-met disasters, the state faces large socio-economic impacts. Further, individual scores for each indicator highlight the reason for low adaptive capacities for certain districts. For example, the Mumbai and Mumbai suburban districts of Maharashtra have relatively high population densities as compared to other districts in the state, decreasing the overall adaptive capacity of the districts. Further, Nandurbar, Jalna, Dhule, Parbhani, Gadchiroli, Nanded, Beed, Solapur, Latur, Hingoli, Jalgaon, Osmanabad, Aurangabad, and Ahmednagar have low literacy rates, contributing to the low adaptive capacities of these districts towards extreme hydro-met disasters.

Sindhudurg and Buldhana, Amravati, Aurangabad, Nanded, Parbhani, Jalna, Beed, Palghar, Ratnagiri, Kolhapur, Pune, Satara, Solapur, Nashik, and Raigad are some of the districts with availability of shelters/rescue homes, contributing to an increase in their adaptive capacity towards extreme hydro-met disasters like floods and cyclones. The availability of shelters/rescue homes ensures that preparedness mechanisms are already in place to safeguard people during the onset of a disaster.

Furthermore, an in-depth analysis of the DDMPs found that all the districts in the state have a DDMP except for the Jalgaon district, which is not available.

4.7.1 Status of district disaster management plans in the state

Availability, updation, and identification of hazards in DDMPs

All DDMPs in the state except Mumbai and Jalgaon have been updated till the year 2020–21, contributing to the state's disaster preparedness and response mechanisms. Further, more than 83 per cent of the district's disaster management plans identify all the disasters they are exposed to, as identification of hazards is the first step of any disaster preparedness and response system; this adds to the state's adaptive capacity against extreme hydro-met disasters.

Institutional arrangements

Institutional arrangements are essential components of a DDMP. They encompass policies, systems, processes, and structures used by organisations to efficiently legislate, plan, and manage their activities. These arrangements also facilitate effective coordination with others in fulfilling their mandates. So institutional arrangements for capacity building are the necessary policies, systems and structures used to plan and manage the process of capacity building for an organisation in a holistic manner. However, only

30 per cent of the DDMPs mention adequate institutional arrangements such as the incident response system (IRS), district disaster management cell (DDMC), district crisis management group (DCMG), and the emergency operations centre (EOC) essential for establishing the organisational hierarchy in the disaster management departments of all the districts. This highlights a lack of institutional structure required to manage disasters effectively.

Prevention and mitigation

The first component under prevention and mitigation measures for building disaster resilience is the presence or absence of structural and non-structural modules. Based on our analysis, 58 per cent of DDMPs mention structural measures and 72 per cent mention non-structural measures for increasing mitigation by investing in the prevention of the onset of disasters.

The second component under prevention and mitigation is mainstreaming DRR into development plans, and 42 per cent of the DDMPs mention the same. Mainstreaming DRR into development plans ensures that disaster risk-reduction measures are incorporated into all sectors, thereby reducing vulnerability and building resilience to disasters. Further, the Sindhudurg and Palghar DDMPs also mention and undertake special projects for preventing and mitigating disaster risk to build their resilience.

Preparedness

The first and the most essential component of building preparedness towards disasters is disaster risk analysis, which includes assessing the degree of disaster risk. This focuses on identifying the specific hazards, vulnerabilities, and risks faced by the community, which helps in prioritising and targeting risk-reduction measures. Second, it helps in understanding the potential impacts of disasters on the community, such as the number of people and assets at risk, the severity of the potential damage, and the potential economic and social consequences. This information is crucial for developing disaster preparedness and response plans, allocating resources, and building the capacity of emergency response teams. Finally, the disaster risk analysis helps in monitoring and evaluating the effectiveness of the risk-reduction measures implemented and in making necessary adjustments to ensure that the community remains resilient to future disasters. Our analysis finds that 70 per cent of DDMPs in the state have conducted a disaster-risk analysis in some or the other capacity.

The second-most important component of preparedness is the establishment of well-researched and designed evacuation procedures. A well-established evacuation procedure should majorly consist of three sub-components, namely: SOPs for hazard-specific evacuation, organisational mechanism of evacuation, and media outreach to expedite procedures. Our analysis

finds that 89 per cent of the DDMPs have laid out clear SOPs for hazard-specific evacuation, 72 per cent of districts have placed organisational mechanisms in place for timely evacuation, and a further 92 per cent of districts have highlighted the role of media outreach to expedite procedures and for better coordination during evacuation processes.

The third crucial component of preparing for disasters is the capacity building of institutions and communities. We find that 67 per cent of DDMPs mention the scope of institutional capacity building while 58 per cent of plans mention the scope of enhancing community participation in capacity building. However, no district has enlisted the adoption or promotion of traditional, resilience practices in their DDMPs yet.

Finally, to be well prepared for the onset of a disaster, it is essential to maintain a resource inventory of man and material. Our analysis suggests that 72 per cent of the plans highlight the scope and allocation of the resource inventory. However, only 47 per cent of the DDMPs explicitly mention the budgetary capacities in terms of the scope of funding for DRR activities.

Response and relief

Our analysis finds that only 50 per cent of the districts mention hazard-specific response or crisis management plans in their DDMPs. Hazard-specific response or crisis management plans help prepare for disaster risk by providing a framework for coordinated and effective response in the event of a disaster. These plans are tailored to specific hazards, such as earthquakes, floods, or cyclones, and outline the specific actions to be taken before, during, and after a disaster.

Further, our analysis finds that 75 per cent of the DDMPs highlight the importance and scope of access to early warning systems clearly mentioning the organisational structure to disseminate early warning systems till last mile connectivity. However, only 45 per cent of the districts mention the role and importance of community-based early warning systems in their disaster management plans. Furthermore, 64 per cent of the districts mention the scope of quick assessment teams and organisational and institutional arrangements for the assessment of loss and damage.

Another key component to conducting robust response and relief is to clearly establish the roles and responsibilities of emergency services agencies like civil protection authorities (fire and police). Our analysis finds that 94 per cent mention specific roles and responsibilities in their DDMPs. Moreover, community and volunteer participation plays a crucial role in response; 36 per cent highlight both NGOs and private agencies, while 56 per cent of plans mention just NGOs.

Reconstruction, rehabilitation, and recovery

Based on our analysis, 67 per cent of districts mention the need to conduct a detailed damage assessment in their DDMPs to assess the direct and indirect damages incurred due to a disaster. Further, 81 per cent of the DDMPs clearly highlight the mechanism and organisational structure for restoring basic services after the onset of a disaster. 78 per cent of the plans also mention the role of restoring critical infrastructure like transportation, telecommunication, health facilities, power, education facilities and water supply, while 64 per cent of the DDMPs highlight the necessity of restoring livelihoods and constructing resilient infrastructures to build back better after the onset of an extreme event.

Table 4.5 Overview of the status of DDMPs in Maharashtra

S. no.	Factor	Section	Sub-section	Performance
1	Availability, updation, and identification of hazards in DDMPs	Availability and updation		All districts except Mumbai and Jalgaon have updated their DDMPs till the year 2020–21
		Identification of disasters		83% of DDMPs identify all the disasters they are exposed to
2	Institutional arrangements	Adequate institutional arrangements		Mentioned by 30% of districts
3	Prevention and mitigation	Mitigation measures	Structural measures	Mentioned by 58% of districts
			Non-structural measures	Mentioned by 72% of districts
		Mainstreaming DRR into development plans		Mentioned by 42% of districts
		Special Projects		Sindhudurg and Palghar have done special projects to mitigate and prevent disaster risk

S. no.	Factor	Section	Sub-section	Performance
4	Preparedness	Disaster risk analysis		Mentioned by 70% of districts
		Evacuation procedures	SOPs for hazard-specific evacuation	Mentioned by 89% of districts
			Organisational mechanisms for timely evacuation	Mentioned by 72% of districts
			Media outreach	Mentioned by 92% of districts
		Capacity building	Scope of institutional capacity building	Mentioned by 67% of districts
			Scope of enhancing community participation	Mentioned by 58% of districts
			Adoption/Promotion of traditional, resilience practices	No district
		Resource inventory of man and material	Scope and allocation of the resource inventory	Mentioned by 72% of districts
		Budgetary capacities	Scope of funding for DRR Activities	Mentioned by 47% of districts
5	Response and relief	Hazard-specific response or crisis-management plans		Mentioned by 50% of districts
		Access to early warning systems	Scope of access to early warning systems	Mentioned by 75% of districts
			Role and importance of community-based early warning systems	Mentioned by 45% of districts
		Scope of a quick assessment team; organisational and institutional arrangement for the assessment of loss and damage		Mentioned by 64% of districts
		Roles and responsibilities of emergency services agencies		Mentioned by 94% of districts
		Roles of NGOs and private agencies		Mentioned both by 36% of districts and only NGOs by 56% of districts
6	Reconstruction, rehabilitation, and recovery	Detailed damage assessment		Mentioned by 67% of districts
		Scope for restoring basic services		Mentioned by 81% of districts
		Scope of restoring critical infrastructure		Mentioned by 78% of districts
		Necessity of restoring livelihoods and reconstructing resilient infrastructure		Mentioned by 64% of districts

Source: Authors' analysis

Now, based on the vulnerability analysis, the following most-vulnerable districts were identified in the state of Maharashtra that require targeted and prompt action

to build their resilience. Table 4.6 identifies the most vulnerable districts in the state and their vulnerability scores.

Table 4.6 Vulnerable districts of Maharashtra

District	Event	Vulnerability
Sangli	Drought	Very high
Ahmednagar	Drought	Very high
Solapur	Drought	Very high
Dhule	Drought	Very high
Mumbai City	Flood & cyclone	Very high
Mumbai Suburban	Flood & cyclone	Very high
Buldhana	Drought	Very high
Hingoli	Drought	Very high
Jalgaon	Flood & drought	Very high
Osmanabad	Drought	High
Parbhani	Drought	High
Nandurbar	Drought	High
Nagpur	Drought	High
Satara	Drought	High
Akola	Drought	High
Nanded	Drought	High
Beed	Drought	High
Aurangabad	Flood & drought	High
Latur	Drought	Moderate
Pune	Flood & drought	Moderate
Amravati	Flood & drought	Moderate
Nashik	Flood & drought	Moderate
Jalna	Drought	Moderate
Gadchiroli	Drought	Moderate
Ratnagiri	Flood & cyclone	Moderate
Sindhudurg	Flood & cyclone	Moderate
Washim	Drought	Moderate
Raigad	Drought	Moderate
Chandrapur	Drought	Moderate
Gondia	Drought	Moderate
Wardha	Flood & drought	Low
Yavatmal	Drought	Low
Thane	Flood & cyclone	Low
Bhandara	Drought	Very low
Kolhapur	Drought	Very low

Source: Authors' analysis

4.8 Sub-district vulnerability and risk assessment

Need for granular vulnerability and risk assessments

Climate change vulnerability assessments are vital tools for identifying areas most susceptible to the negative impacts of climate change and selecting appropriate adaptation strategies. These assessments rely on impact chains, which establish cause-and-effect linkages. Indicators related to exposure, sensitivity, and adaptive capability are used to gauge vulnerability. Our research involves both national and local assessments to identify climate change hotspots and suitable adaptation strategies (Schneiderbauer et al 2020).

The United Nations Framework Convention on Climate Change (UNFCCC) promotes the national adaptation plan (NAP) process to facilitate adaptation planning. The UNFCCC's 'LDC Expert Group' recognises the importance of vulnerability assessments for identifying adaptation options and integrating climate change into development policies. Such assessments aid in identifying vulnerable hotspots, assessing adaptation needs, and supporting policy integration.

4.8.1 Conducting a sub-district vulnerability and risk for Maharashtra

While previously, the IPCC AR4 framework looked at vulnerability as a component of exposure, sensitivity, and adaptive capacity, the modified AR5 risk-assessment framework considers vulnerability as an inherent characteristic of a system, independent of hazard and exposure, as illustrated in Figure 4.6.

In the framework, vulnerability is viewed as a system property encompassing sensitivity and adaptive capacity, representing a system's propensity to be negatively impacted, regardless of exposure.

The framework defines 'risk' as, 'The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from the potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species' (IPCC 2014).

In the AR5, IPCC highlights that the severity of impacts resulting from weather and climate events, both extreme and non-extreme, is strongly linked to the level of vulnerability and exposure to these events. Therefore, conducting an analysis of vulnerability and assessing the extent of exposure becomes essential for

Figure 4.6 The conceptual framework of the IPCC AR5 risk assessment



Source: Intergovernmental Panel on Climate Change 2014

effectively managing risks and enhancing resilience. This emphasises the importance of understanding the nature of vulnerability and the degree of exposure to mitigate and adapt to the challenges posed by climate change. The risk is hence calculated by the following equation.

The framework consists of three components which define the risk to the systems (in this analysis, the sectors). The sub-indices are exposure, vulnerability and hazards, the definitions of which are:

1. **Hazard:** The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term 'hazard' usually refers to climate-related physical events or trends or their physical impacts.
2. **Exposure:** The presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected.

3. **Vulnerability:** The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

The vulnerability component of the AR5 framework further encompasses two sub-indices:

1. **Sensitivity:** The degree to which a system or species is affected, either negatively or positively, by climate variability or change.
2. **Adaptive capacity:** The ability of systems, institutions, humans, and other organisms to adjust to potential damage, seize opportunities, or respond to consequences arising from climatic or anthropogenic causes.

4.8.2 Methodology

Conducting a risk assessment is a multistep exercise that requires the identification of clear goals and objectives. These determinations will guide the type of risk assessment, scale, tier, indicators, and methods to be employed. The concept of risk can be operationalised

Figure 4.7 Risk assessment equation



Source: IPCC Fifth Assessment Report (AR5) 2014

in two ways: the starting point/contextual approach and the endpoint/outcome approach. In the starting point/contextual approach, risk is regarded as a pre-existing condition in anticipation of a hazard. In contrast, the endpoint/outcome approach involves assessing risk before and after exposure to a hazard (Department of Science and Technology 2019; Kelly 2000).

For this action plan, a starting point/contextual approach was adopted, whereby risk was identified based on pre-existing conditions within the given context. The sectoral risk assessment conducted considering present climate hazards offers insights into the existing vulnerabilities of natural or socio-economic systems, as well as the factors contributing to these vulnerabilities. This information serves as a basis for developing strategies to address the identified weaknesses in the system and effectively respond to or adapt to these contributing factors.

The first step of the assessment included the identification of indicators for each component (hazard, exposure, and

vulnerability). Indicators are variables that are closely linked to the phenomenon or concept intended to be measured but are often challenging to quantify directly. Essentially, the values of these indicators, whether examined individually or in the form of an aggregate index, help us understand the relative position of a system or unit of interest compared to others in relation to the associated phenomenon. Therefore, indicators or the use of indicator methods are particularly valuable in planning development interventions. When tracked over time, indicators can also serve as a useful tool for monitoring and evaluating programmes, as highlighted by Crane et al. (2017) in the case of vulnerability assessment. In this analysis, we selected indicators that reflect the three dimensions of risk: hazard, exposure, and vulnerability. The selection process involved reviewing relevant literature considering theoretical aspects underlying different risk determinants, and engaging stakeholders in consultations.

Table 4.7 List of comprehensive indicators of taluka-level risk analysis

Component	Sub-component	Correlation with risk	Selected indicators	Sources
Hazard		Hazard refers to the potential occurrence of a natural or human-induced physical event or trend that may result in adverse effects.	Frequency and intensity of extreme events and their associated events	Extreme events catalogue developed by CEEW (Mohanty 2020)
Exposure		Exposure is directly proportional to risk. Higher exposure equates to an increased risk of the system to the impacts of climate change.	Population density	District Census Handbook I Population Census Abstract 2011
Vulnerability	Sensitivity	Vulnerability is directly proportional to the degree to which a system is affected (sensitivity). High sensitivity equates to high vulnerability to the impacts of climate change.	1. Land use and land cover 2. Elevation 3. Slope 4. Groundwater 5. Soil moisture	1. ESRI 2020 2. Bhuvan-Indian Space Research Organisation (ISRO) 3. United States Geological Survey (USGS) 4. Water Resources Information System (WRIS) 5. National Aeronautics and Space Administration (NASA)
	Adaptive capacity	Vulnerability is inversely proportional to adaptive capacity. The higher the adaptive capacity, the lower the vulnerability of a system to the impacts of climate change.	1. District disaster management plans 2. Gross district domestic product 3. Literacy rate 4. Sex ratio 5. Availability and accessibility to critical infrastructure 6. Availability of disaster-ready shelters	Census, 2011 Press Information Bureau (PIB) DDMPs District Census Handbook

Source: Authors' analysis

Second, to compute the indices of hazard, exposure, vulnerability, and finally risk, a database of all the indicators for the 35 districts of Maharashtra was developed. As many of the indicators were based on Census 2011 data, the Palghar district was excluded from the analysis. The indicators were normalised to bring all the indicators to a common scale and to make them unit-free by the min–max normalisation technique in case of indicators related to exposure, vulnerability, and hazard.

After normalising the indicators, to obtain the scores of each district for that particular indicator, they were classified into 10 classes based on equal interval distribution. The scores hence obtained were reclassified for indicators that were inversely related to the component of risk. After obtaining the scores, they were aggregated into the indices of hazard, exposure, vulnerability, and finally risk. Weights to indicators of each determinant of risk were obtained through a literature review and consultations with relevant state government departments and experts. Equal weightages for indicators were considered in the absence of existing literature on weightages. The whole process, right from the approach, methodology, indicator selection, weighting, etc., was presented and discussed in consultation meetings with representatives from different stakeholder departments and other organisations.

4.8.3 Mapping risk of talukas to extreme hydro-met events

4.8.3.1 Talukas prone to hazards

Talukas prone to extreme drought events

Seventy eight per cent of talukas in Maharashtra are prone to extreme droughts. Based on our analysis, talukas in the districts of Aurangabad, Ahmednagar, Osmanabad, Jalgaon, and Nashik are the most prone to extreme drought events. Table A5 in the Annexure shows the taluka-level exposure to extreme drought events.

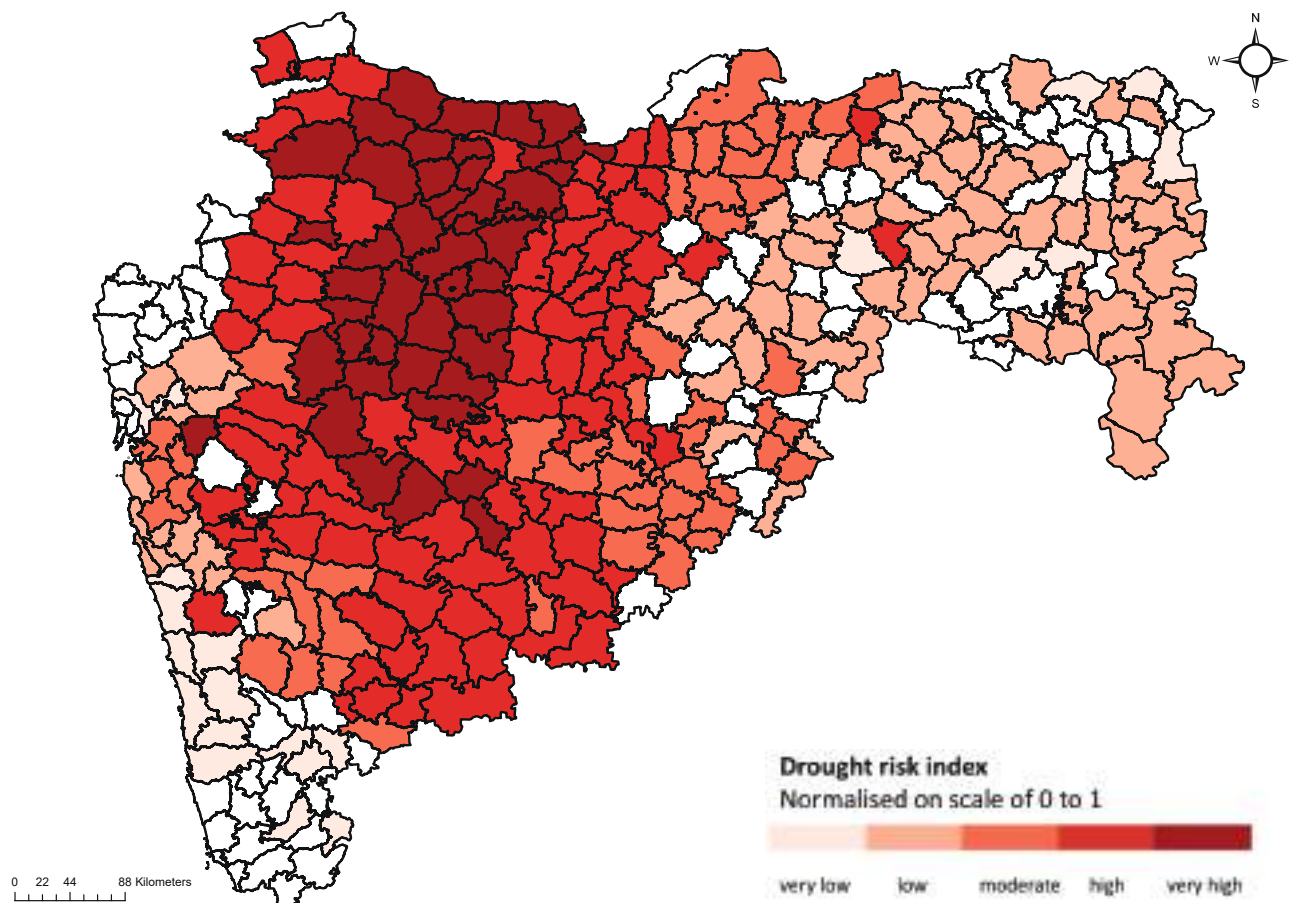
Talukas prone to extreme flood events

Twenty one per cent of talukas in Maharashtra are prone to extreme floods and their associated events. Based on our analysis, talukas in districts Mumbai, Mumbai Sub-urban, Ratnagiri, Pune, Jalgaon, Amravati, Wardha, Aurangabad, Thane, and Nashik are the most prone to extreme flood events. Table A6 in the Annexure shows the taluka-level exposure to extreme flood events.

Talukas prone to extreme cyclone events

Only 5 districts and 35 talukas in Maharashtra are prone to extreme cyclone events. However, the frequency and intensity of cyclones have increased across the western

Figure 4.8 Talukas at risk of extreme drought events



Source: Authors' analysis

coastal belt of India in recent years. Based on our analysis, talukas in the districts of Mumbai, Mumbai Suburban, Ratnagiri, Thane, and Sindhudurg are the most prone to extreme cyclone events. Table A7 in the Annexure shows the talukas prone to extreme cyclone events.

4.8.3.2 Exposure to extreme events

Around 40 per cent of talukas in Maharashtra have a relatively high population density and therefore have higher exposure to extreme events, whereas 21 per cent of talukas have moderate exposure and 39 per cent of talukas have low exposure due to the moderate and low population density of these areas. Higher exposure of the population means more people can be affected by the impacts of extreme climate events such as floods, droughts, cyclones, and their associated events.

4.8.3.3 Sensitivity towards extreme events

The sensitivity analysis suggests that 57 per cent of the drought-prone talukas in Maharashtra are also highly sensitive to extreme drought events due to low soil moisture and groundwater levels. Further, 50 per cent of the flood-prone talukas are also highly sensitive to extreme flood events due to their geographical location in low elevation and slope areas increasing chances of inundation during flood events. However, only 10 per cent of the cyclone-prone talukas have a high sensitivity towards extreme

cyclone events, while the rest have a moderate to low sensitivity towards extreme cyclone events.

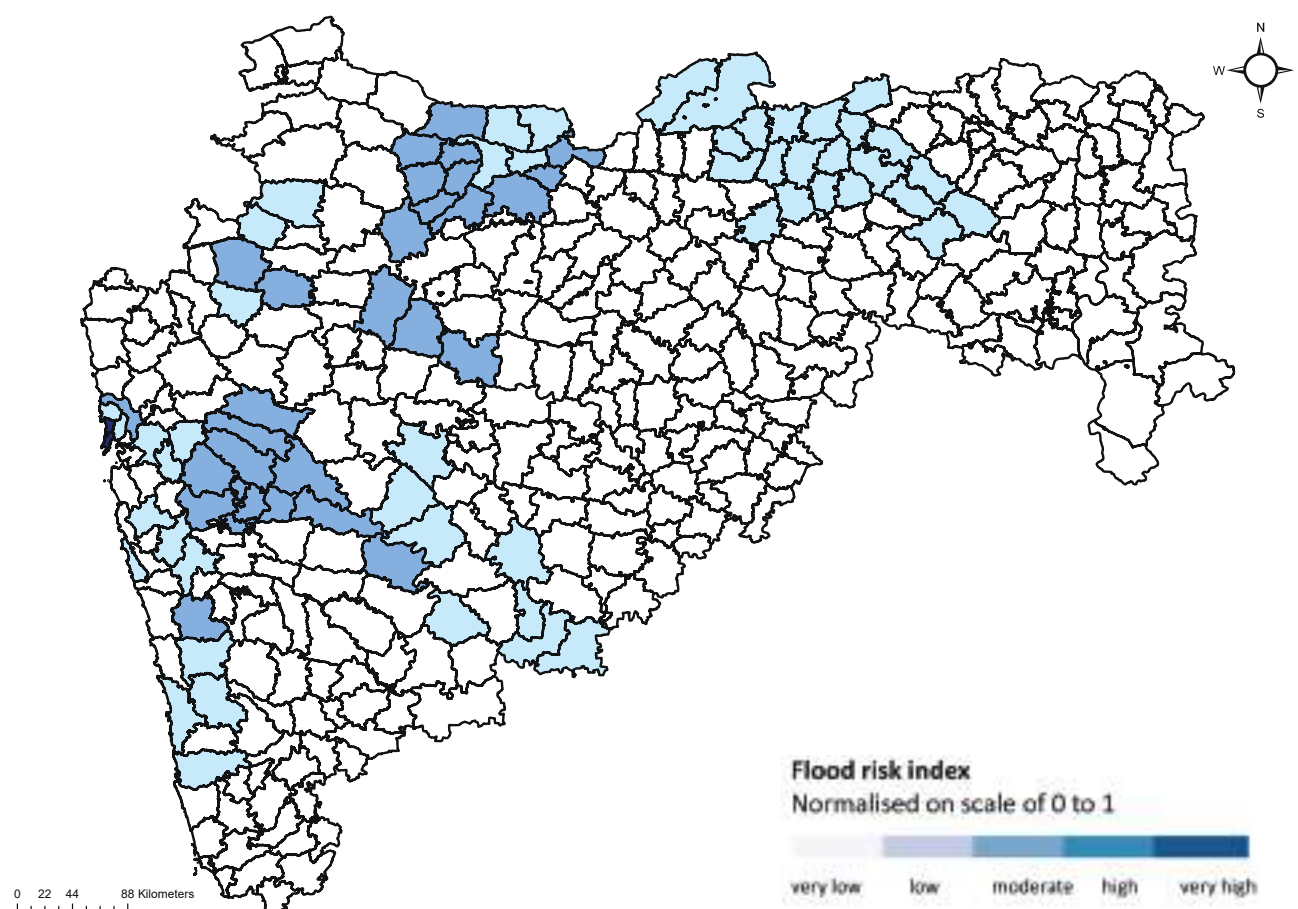
4.8.3.4 Adaptive capacity towards extreme events

71 per cent of talukas in the state have a high-to-moderate adaptive capacity, and 29 per cent have a low adaptive capacity towards extreme events. This high adaptive capacity can be attributed to the updated DDMPs in the state, which is a key step to laying out the first response towards disasters in any district. The major factor driving the low adaptive capacity in talukas is the lack of availability of critical infrastructures such as education centres, hospitals, and shelters. Further, the low adaptive capacity can also be attributed to a low literacy rate in the identified talukas, and high population densities compounding the talukas' vulnerability towards extreme events.

Risk of extreme events

Our analysis finds that 35 per cent of talukas in Maharashtra have a high risk of extreme droughts. Based on our analysis, talukas in the districts of Jalgaon, Buldhana, Washim, Jalna, Aurangabad, Nashik, Pune, Ahmednagar, Bid, Latur, Osmanabad, Solapur, Satara, and Sangli are the most vulnerable to extreme drought events. Figure 4.8 shows the taluka-level risk of extreme drought events.

Figure 4.9 Talukas at risk of extreme flood events



Source: Authors' analysis

Talukas in Maharashtra have an overall low risk towards extreme flood events. Only 3 per cent of talukas have a high to moderate risk towards extreme flood events. However, over the last decade, several talukas are facing an increase in the frequency and intensity of extreme flood events due to an increase in the western disturbances across the Arabian Sea, which is causing multiple drought-prone talukas to face frequent floods as well. Figure 4.9 shows the taluka-level risk of extreme flood events.

Further, it is essential to highlight here that the risk analysis for floods was quantified based on the data available in DDMPs of the various districts, most of which were in regional languages, making it hard to collect and quantify data. Further, there was no information on the frequency of events in these plans, making it a limitation of the analysis. Therefore, the flood risk analysis might under-present the current state of floods on the ground in the state.

Eleven talukas in Maharashtra have a high to moderate risk of extreme cyclones. Based on our analysis, talukas in the coastal districts of Mumbai, Raigarh, Ratnagiri, Sindhidarg, and Thane are the most at risk of extreme cyclone events. According to an analysis by CEEW, the western coast of India has witnessed a five-fold increase in the frequency of extreme cyclone events due to more depressions being

formed in the Arabian Sea, owing to climate change and an increase in the western disturbances (Mohanty 2020). Figure 4.10 shows the taluka-level risk of extreme cyclone events.

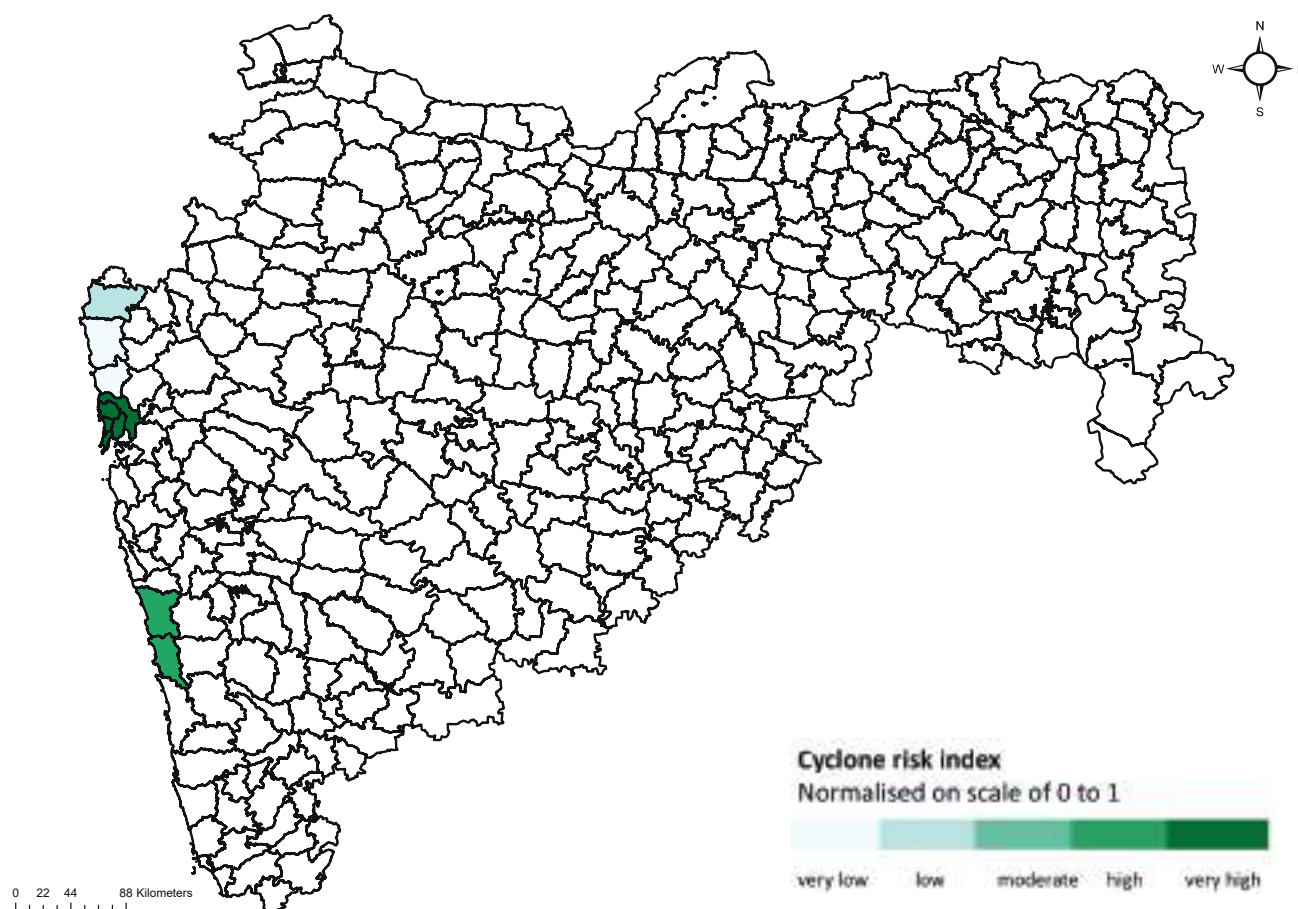
4.9 Adaptation strategies and key recommendations

4.9.1 Floods

Key action 1: Conducting basin-level flood zonation mapping.

Flood hazard assessment and mapping play a crucial role in identifying flood-prone areas and enhancing flood risk management and disaster-preparedness strategies. These assessments and maps predict the potential extent and depth of flooding under different scenarios, such as 100-year and 50-year events. To raise awareness about flooding risks, the government should actively promote basin-level flood-hazard maps among the public, local authorities, and other organisations. Additionally, integrating cutting-edge artificial intelligence (AI) and machine-learning tools for real-time flood-inundation models can be a significant

Figure 4.10 Talukas at risk of extreme cyclone events



Source: Authors' analysis

Table 4.8 Adaptation strategies and key recommendations

S. no.	Recommendations/ Targets	Actions to be undertaken	Geographical areas impacted	Implementing government departments	Financial implications	Outcome
1	Improved drought hazard mitigation by 2030	Promoting Zero-Budget Natural Farming with a focus on drought-resilient crops in 'highly vulnerable drought-affected talukas': a. Training and capacity building of farmers. b. Implementation of pilots for drought-resistant crops. c. Establishing a market for the promotion of crops.		Department of Agriculture	All components: Based on the estimates for the activities mentioned, the total budget for 7 years which will be utilised in promoting Zero-Budget Natural Farming, with a focus on small and marginal farmers, will be 160 crore. ¹	- Reduction in losses of marginal farmers. - Improvement of soil quality with the reduction in the use of pesticides and other chemical inputs.
2	Improved coastal flooding mitigation by 2030	Restoration and conservation of wetlands and mangroves: 1. Plantation of mangroves. 2. Maintaining the ecosystem (soil, nurseries, protection from tidal waves, etc.).		Department of Forest	All components: According to the estimates based on the expenditure of the Mangrove Foundation Cell of Maharashtra, the restoration of 100 ha involves a budget of 86 lakh. With the aim of restoring 100 ha per year by 2030, the total budget for 7 years is estimated at 6 crore.	- Promotion of alternative livelihoods. - Improvement in biodiversity and green cover. - Increase in the resilience of coastal belts.
3	Improving accessibility to EWS by 2025	Ensuring last-mile connectivity of EWS: 1. Conducting cyclone preparedness programmes for volunteers. 2. Dissemination of warnings in local languages.		State Disaster Management Authority (SDMA)	Component 1: The estimated budget of each cyclone preparedness program is INR 30,000. Component 2: The estimated budget for the salary for 4 language translators (Hindi, English, Marathi, and other local and vernacular languages) is 1 lakh.	- Last-mile connectivity will lead to a reduction in the number of affected people. - Increase in time-informed decisions leading to a reduction in loss and damage to assets.
4	Investing in EbA to build resilience towards floods	State- and district-level policy mandates for the construction of bio-dykes along the banks of rivers to prevent river flooding: 1. Slope maintenance. 2. Dyke and spur construction. 3. Soil filling and planting.	Flood- and cyclone-exposed talukas in coastal districts.	Department of Environment and Climate Change in association with SDMA and other relevant departments like Revenue, Agriculture and Forest Department	All components: The estimated budget for constructing and maintaining one bio-dyke is INR 7.3 lakh (Practical Action, 2018).	

¹ The total cropped area under marginal and small farmers in Maharashtra amounts to 1,03,23,167 ha (according to Agricultural Census 2015–16). This will lead to about 18 lakh ha of agricultural fields under marginal and small farmers in the 64 'highly' vulnerable sub-districts in Maharashtra. Based on the funds released by the central government for Zero Budget Natural Farming (ZBNF), it is estimated that the annual cost of promoting ZBNF in 10% of the mentioned total area will come out to be 22.8 crore.

S. no.	Recommendations/ Targets	Actions to be undertaken	Geographical areas impacted	Implementing government departments	Financial implications	Outcome
5	Construction of detention ponds for urban flood resilience	Construction of detention ponds in low-lying areas of cities for collecting excessive stormwater: 1. Technical support to identify the optimum location for construction. (Hiring of external experts/consultants). 2. Construction of detention ponds. 3. Capacity building and maintenance.	Flood-exposed talukas in urban areas.	Municipal corporations	All components: The estimated cost of constructing a dry detention basin is around INR 800 per sq m (Naturally Resilient Communities n.d.).	• Improvement in water quality. • Reduction in risk to assets. • Increase in recreational activities.

initiative. For example, the collaboration between the Central Water Commission (CWC) and Google resulted in the Google Flood Alert System, an AI-based flood forecasting tool that provides flood forecasts with at least 48 hours of advanced notice.

Key action 2: Installing flood monitoring stations.

Maintaining regular, timely, and accurate flood monitoring is vital for effective flood management. By establishing flood monitoring stations near water bodies and waterways, crucial information can be gathered to protect lives and property. To achieve this, collaboration between state and central government authorities like the CWC is essential to install flood monitoring stations across major flood-prone areas in Maharashtra.

According to the 2019 CWC Flood Forecast Monitoring Directorate, the flood forecasting activity expanded to include 12 additional level forecast stations and 11 inflow forecast stations in Maharashtra. As per CWC data, by 2019, there were 22 flood forecasting sites in the state (8 level and 14 inflow). However, as of 2022, CWC upgraded 27 level monitoring sites to level forecast sites and added 20 new sites (4 level and 3 inflow forecast sites) based on data from South Asia Network on Dams, Rivers and People (SANDRP). As of September 2022, Maharashtra has a total of 113 flood monitoring sites, comprising 42 level forecasts, 54 level monitoring, and 17 inflow forecast sites.

Key action 3: Installation and implementation of multi-hazard early warning systems (MHEWS).

To establish an effective flood warning system, key considerations include data collection through gauging, data processing, necessary hardware and software, and timely dissemination of flood warning information. Implementing automatic weather stations (AWS) with multi-hazard early warning systems (MHEWS) can significantly enhance flood monitoring, impact assessment, and the

timely issuance of accurate warnings, thus saving lives and minimising losses.

In Maharashtra, efforts are underway to address cyclone risk through the NCRMP-Phase II project, especially concerning the increasing frequency and intensity of cyclones along the west coast of India. In 2017, Maharashtra became the first state in India to install an AWS in Dongargaon, Nagpur. The AWS provides crucial weather data such as wind direction, wind speed, air temperature, relative humidity, and rainfall amounts, shared with farmers through the Mahavedh portal and a mobile application in collaboration with private organisations. These AWSs enable micro-level weather forecasts up to the taluka level, and when integrated with MHEWS, they enhance disaster monitoring and forecasting efficiency, enabling timely and accurate warnings for floods, cyclones, tsunamis, and extreme rainfall events.

Key action 4: Incorporating ecosystem-based adaptation (EbA) approach for improved flood management.

Ecosystem-based adaptation such as restoring wetlands, developing water-retention areas, removing obstacles, and reviving mangroves can complement conventional infrastructure to improve flood protection and create additional environmental and social benefits. The Maharashtra government already has an established mangrove protection cell that focuses on rebuilding the fragmented mangrove plantations around the state and restoring damaged mangrove areas. The government should invest more in the conservation and protection of urban ponds, mangroves, floodplains, and other wetlands that act as natural buffers during extreme flooding events, safeguarding communities and infrastructure. Planting and conserving mangroves in the coastal Konkan districts of Mumbai City, Mumbai Suburban, Palghar, Thane, Raigad, Ratnagiri, and Sindhudurg will help decrease the impacts of extreme floods and cyclones in these regions.

Key action 5: Encouraging community-led information and risk identification.

Effective and inclusive community engagement is essential for successful risk identification, risk zonation, and MHEWS initiatives. When programme implementers engage regularly and inclusively with communities, trust and positive relationships are fostered. Inclusive engagement ensures initiatives are sustainable and aligned with the needs and priorities of all community members, including women and vulnerable groups. Leveraging existing community networks, particularly those of local women, can enhance community cohesion and access valuable local knowledge. By involving these women through their established networks, specific support can be provided to marginalised groups whose needs and risks might otherwise be overlooked, leading to a more efficient allocation of time and resources.

4.9.2 Droughts

Key action 1: Robust and continuous monitoring of the meteorological drought in the state.

A composite risk and vulnerability assessment such as CEEW's Climate Vulnerability Index (CVI) would aid in formulating effective strategies for filling crucial gaps during drought relief as well as long-term policies and programmes for reducing drought risk at the state level. However, there is a lot of ambiguity among climate scientists and experts regarding the root causes of droughts. Apart from considering droughts to be a larger natural disaster, the government should take into consideration the risks associated with extreme drought events (Wilhite and Svoboda 2015).

As a first step in monitoring these extreme events, the quantification of risk is essential. Further, the drought-management division under the disaster management department in the state as per the DM Act, 2005 should initiate a comprehensive drought risk assessment for the meteorological droughts in the state. The department may coordinate with research institutions like Indian Institute for Tropical Meteorology (IITM) Pune, IMD, and IIT Bombay for the same. The CEEW's analysis suggests that proper meteorological drought risk assessments of the Marathwada and Vidarbha regions in the state should be conducted by considering the intensity and frequency of meteorological droughts and the vulnerability of the population. When the risk of the region is quantified, specific adaptation strategies and targeted solutions such as ecosystem-based adaptation (EbA) can be further developed through risk-informed disaster risk-reduction techniques.

Key action 2: Adopting a proactive preparedness approach for drought mitigation.

The state government should identify the existing drought management policies such as *Mahatma Gandhi National*

Rural Employment Guarantee Scheme (MGNREGS), Integrated Watershed Management Programme (IWMP), Drought Prone Area Programme (DPAP), National Rural Drinking Water Programme (NRDWP), Swarna-Jayanthi Grameen Swarozgar Yojana (SGSY), Rashtriya Krishi Vikas Yojana (RKVY), Fodder & Feed Development Scheme, etc and promote their implementation at a local level. However, such policies might render the farmers and other communities too dependent on the release of funds, thereby reducing their individual adaptive capacity. Since most drought policies and drought management strategies have a response-oriented approach, it is imperative that there be a paradigm shift from the traditional response-oriented approach to a proactive preparedness approach, thereby empowering victims of drought to independently deal with the effects of drought. This shift to a proactive preparedness approach will prepare the communities to face the impacts of the disaster and help build their resilience against such extreme events.

Key action 3: Implementing regional drought early warning systems (DEWS).

A robust drought mitigation plan comprises three key components: monitoring and early warning, risk assessment and mitigation, and response. Establishing monitoring and early warning systems is essential for effective drought mitigation as droughts are slow-onset events. Timely and accurate warnings are critical to trigger emergency response systems. Providing reliable climate information – including seasonal forecasts – supports decision-makers in managing the impacts of drought. Understanding the unique characteristics of droughts is crucial for an effective monitoring and early warning system as part of a comprehensive drought preparedness plan.

Key action 4: Developing targeted insurance products to build the resilience of farmers against drought risk.

According to the Manual for Drought Management (2009), state insurance policies that provide coverage against drought must be designed for various agro-climatic zones. The central and state governments must support agricultural insurance programmes, make sure farmers are aware of the goods that can be used for insurance, and inform them of the importance of using insurance to reduce their yield and income risks. In addition to the *Pradhan Mantri Fasal Bima Yojana (PMFBY)* – a central government-sponsored scheme that integrates multiple stakeholders on a single platform – the state should also formulate independent region-specific insurance products to promote the safeguarding of small-scale farmers against crop losses caused due to drought events. Further, developing and incorporating comprehensive insurance and financial strategies should be based upon granular risk assessments to ensure proper fund allocation for the implementation of drought mitigation plans.

4.9.3 Cyclones

Key action 1: Implementing multi-hazard impact-based forecast and warning services.

The CEEW's analysis suggests that the frequency of cyclones on the western coast of India has increased five-fold. The coastal districts of Maharashtra like Mumbai, Sindhudurg, Thane, Ratnagiri, Raigad, and Palghar will be severely affected by such extreme cyclone events. Tropical cyclones and other meteorological, climate, and water extremes cause numerous fatalities, major property damage, and infrastructure failure, with long-lasting negative economic effects on communities. All of this occurs even though many of these severe occurrences have been accurately predicted and timely warning information has been disseminated.

The lack of awareness of the potential effects of hydro-met event forecasts and warnings by both the authorities in charge of civil protection and disaster management, as well as by the general public, is what causes this seeming disconnect. Therefore, the dissemination of impact-based information in a palatable format is essential for effective DRR. Thus, the state government needs to complement the *National Cyclone Risk Mitigation Project* (NCRMP) by ensuring the dissemination of accurate, impact-based information that is easily understood by the public, especially the communities such as fishermen that will face the maximum impacts from such extreme events.

Key action 2: Integrating cyclone-specific emergency response procedures in the district disaster management plans (DDMPs).

The state and district officials should thoroughly review the emergency response protocols established by the central and state governments in detail during the design and implementation phases of the DDMPs. The main risks that are specific to that particular region, such as cyclones, wind threats, and other risks must be considered in these methods. Further, the state officers should utilise regionally established response plans while adopting their own emergency response protocol. The district plans should outline the specific circumstances under which they will be activated, a clear chain of command and responsibility assignments, a list of the specific emergency tasks to be performed and who will carry them out, evacuation procedures – including routes and whether an emergency

exists – and appropriate procedures to account for staff, customers, and visitors. The plans should also ensure that the staff have access to appropriate emergency supplies, such as medical kits and other relevant equipment.

Key action 3: Conducting hazard risk zonation mapping.

Prior to formulating effective mitigation strategies, conducting risk assessments for physical assets is crucial. On-ground mapping exercises are necessary to prioritise areas most vulnerable to extreme events. The government should focus on mainstreaming sub-district and block-level assessments by collecting granular data and making it available to end users to enhance targeted mitigation strategies for climate change impacts.

Although the direct impacts of tropical cyclones cannot be reduced, mitigation strategies to lessen their effects can be developed. Measures such as timely communication of warnings, land-use planning, and enforcement of cyclone-resistant construction can reduce vulnerability and the resulting losses. Emphasising institutional capacity building will enable knowledge updating to handle unforeseen hazards (R. K. Panda 2019).

Key action 4: Strengthening community-based disaster risk reduction (CBDRR) strategies in coastal districts.

The DDMPs should prioritise the DRR action plans based on CBDRR. There should be initiatives that incorporate community participation through various inter-governmental interventions and programmes. Further, organising and coordinating public-awareness campaigns is a crucial part of disaster risk reduction. Any initiative for reducing disaster risk must involve the community that is being threatened. The community is better prepared to handle a disaster if they are aware of the warning system's capabilities and limits as well as the source of the alerts. There are mechanisms in place, such as the dissemination of circulars, do's and don'ts, posters, and media coverage about precautionary measures. However, historical experience indicates that these activities are implemented insufficiently and more must be done. For an awareness campaign to be successful, there must be man-to-man interaction. Such activities must not only be maintained, but they must also be frequent and ongoing. A comprehensive awareness campaign involving the community is crucial for building resilience from the bottom.

Sector-wise climate change impacts and adaptation strategies

Given the observed and projected climate variabilities, along with Maharashtra's climate risk landscape, enhancing community resilience and safeguarding key sectors is imperative. Maharashtra State Action Plan on Climate Change (MHSAPCC 2.0) comprehensively addresses sector-specific climate impacts and adaptation strategies. This chapter evaluates the effects of climate variations and extremes and outlines adaptation measures across pivotal sectors in the state, namely Agriculture, Water Resources, Forest and Biodiversity, Health, Habitat, Tribal Development, Decentralised Renewable Energy, and Disaster Management.

5.1 Climate change impacts on agriculture and allied sectors and adaptation strategies

5.1.1 Current status of agriculture in Maharashtra

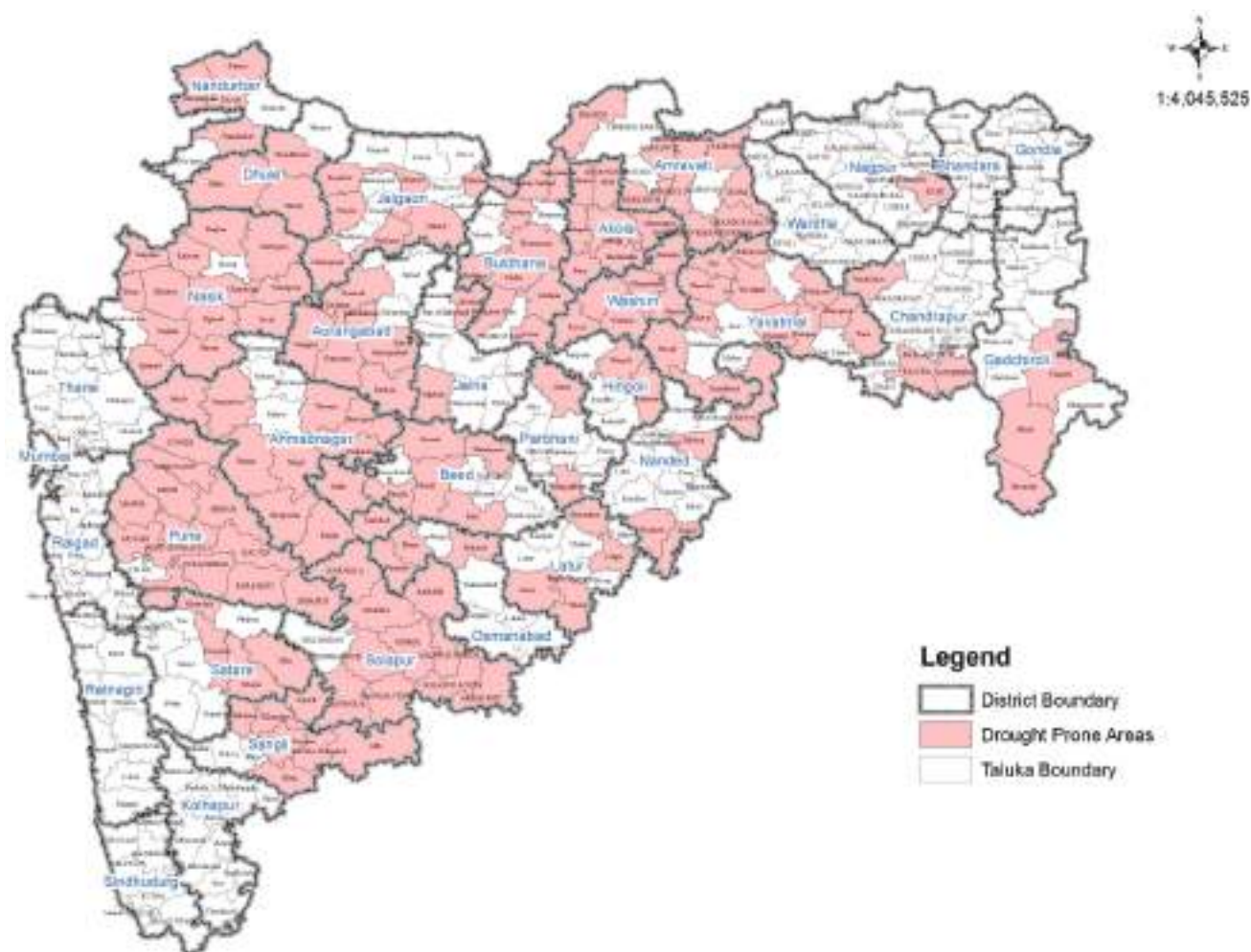
The service sector's share in Maharashtra's economy is the highest (56.1%), followed by industries (32%) and agriculture and allied activities (11.9%). Within the agriculture sector, the percentage share of crops is 7.6 per cent, livestock 2.6 per cent, forestry and logging 1.4 per cent, and fishing and aquaculture 0.3 per cent. Approximately half of the state's population relies on agriculture for their livelihoods, even though this sector contributes just 11.9 per cent to the state's economy. The state's total geographical area is 307.58 lakh ha, with a gross cropped area of 235.70 lakh ha and a net sown area

of 167.22 lakh ha (approximately 54.4% of the state's total geographical area) (Planning Department 2022).

With only 18.2 per cent of the crop area being irrigated, Maharashtra predominantly has rainfed agriculture (Sen, Bhagawat, and Nazareth 2021), indicating the heavy reliance on rainfall conditions in this sector. Of the total 358 talukas in the state, nearly 145 are rainfed talukas located in 25 districts (Soil and Water Conservation Department 2020) (Figure 5.1.1). There are 13.6 million farmers in the state, of whom 48.9 per cent are marginal and 29.5 per cent are small farmers. With an average operational land holding of 1.34 ha (down from 4.28 ha in 1970-71), smallholder agriculture constitutes 45.2 per cent of the total cropping area (ADB 2021b). Broadly, cereals (such as jowar, bajra, rice, maize, and wheat), pulses (such as gram, tur, moong, and urad), oilseeds (soybean and groundnut), cotton, and sugarcane are grown in the state (Sen, Bhagawat, and Nazareth 2021).

Over the decades, the state's production base has diversified from coarse cereals to crops such as cotton, sugarcane, fruits, flowers, vegetables, maize, and soybean, which are high in value. Furthermore, in terms of organic farm production, the state ranks second in India with a 22 per cent share; approximately 1.26 lakh MT of organic farm produce was exported from the state in 2021-22. In the case of allied activities in the agricultural sector, the state ranked second in terms of meat production and seventh in terms of milk and egg production in 2019-20. In addition, the state has a 1.12 lakh sq km area suitable for marine fishing and a further 4.18 lakh ha and 0.10 lakh ha for inland and brackish water fishing, respectively (Planning Department 2022).

Figure 5.11 Of the 348 talukas, nearly 145 are rainfed in Maharashtra



Source: Soil and Water Conservation Department, Government of Maharashtra

5.1.2 Agriculture risk assessment

According to a recent study by the Indian Council of Agricultural Research (ICAR), almost 77 per cent of Maharashtra's cropped area is highly vulnerable to the impact of climate change, droughts, and reduced water security (Adhav et al. 2021). These extreme climate events can potentially have a detrimental effect on the agricultural economy of Maharashtra as climate fluctuations impact crop yields, significantly affect the availability of natural resources, disrupt cropping patterns, and make market conditions volatile for farmers. With agriculture being predominantly rainfed and regions such as Vidarbha and Marathwada being historically drought-prone, the state faces severe agricultural development challenges. This has led to rural distress and significant indicators of increasing vulnerability towards climate stressors, such as cyclones, floods, and droughts.

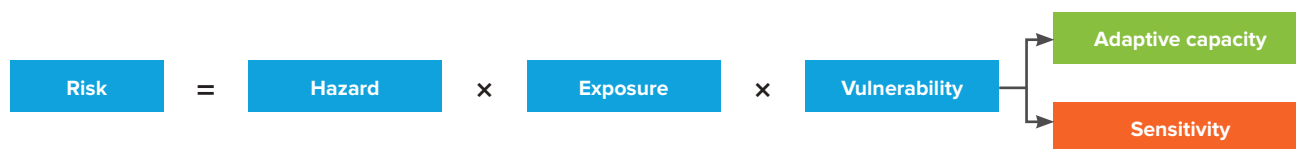
State Action Plans and policies on agriculture that are formulated at the state level often fail to consider intra-regional and district-level variabilities on resource

distribution, agroecological conditions, and exposure and sensitivity parameters. Assessing risks and vulnerabilities at the district level is extremely important to measure the degrees of impacts at a ground level and understand their drivers to plan and prioritise adaptation and investment accordingly.

An agriculture risk index (ARI) was developed and computed at the district level to evaluate their vulnerability and risk to climate variability and stresses. The ARI is based on the definition of risk developed by the IPCC (Brooks 2003), which defines it as a function of the system's exposure to climate variation, where sensitivity refers to agriculture being adversely affected by climate change, and adaptive capacity is the ability of the agriculture production system to better adjust to climate variability and extremes. It can be represented as:

A set of 36 indicators of risk was used in the assessment capturing the 'historical hazards', 'current hazards', 'exposure', and 'vulnerability' of the state. These indicators were chosen based on a review of literature

Figure 5.1.2 Risk assessment equation



Source: Authors' compilation

and stakeholder consultations with the Government of Maharashtra's Agriculture Department and the *Project on Climate Resilient Agriculture* (PoCRA). The report by the Central Research Institute for Dryland Agriculture (CRIDA) on mapping the agriculture vulnerability of Indian districts was used as a guideline for the assessment. The indicators chosen, their data sources, and their impact on various components of the ARI are presented in Table 5.1.1. The majority of indicators have a direct correlation with the components of the vulnerability, i.e., the higher the value of the indicator, the higher will be the value of the component. Only some of the indicators were indirectly correlated, i.e., the higher the value of the indicator, the lower the value of that component.

The data for the indicators were obtained from various sources, ranging from geospatial raster datasets to census-derived values. The geospatial datasets were aggregated at the district level using statistical methods to maintain consistency. Thus, a uniform district-wise roster datasheet was prepared for each component.

Second, to compute the indices of hazard, exposure, vulnerability, and finally, risk, a database of all the indicators for Maharashtra's 35 districts was developed. Since many of the indicators were based on census 2011 data by which Palghar district was not yet formed, Palghar district was excluded from this analysis. All indicators were normalised through the use of the min-max normalisation technique

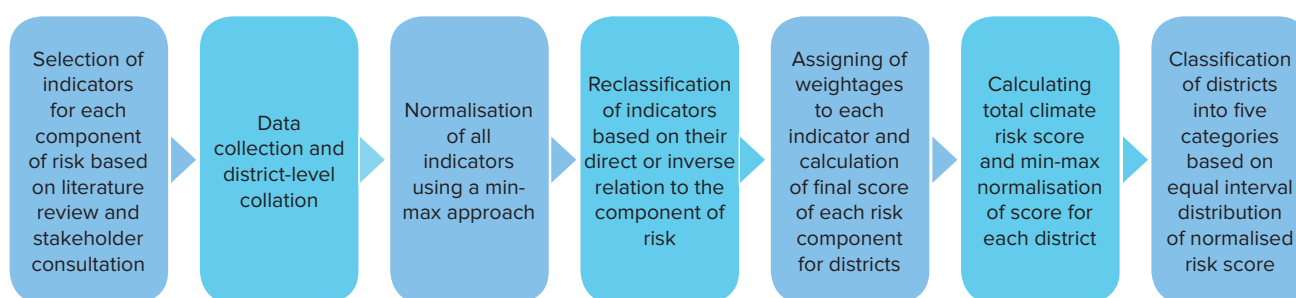
Table 5.1.1 A set of 36 indicators were chosen to assess each component of risk

Component of risk	Indicator	Relation to risk	Weightage
Historical hazards (1971–2020)	Flood proneness	Direct	20
	Drought proneness	Direct	30
	Cyclone proneness	Direct	5
	Number of deficient monsoon years	Direct	15
	Number of excessive monsoon years	Direct	15
	Annual rainfall variability	Direct	15
Current hazards (changes in 2011–20 compared to baseline of 1971–2010)	Change in annual rainfall	Inverse	10
	Change in June rainfall	Inverse	5
	Change in July rainfall	Inverse	10
	Change in rainy days	Inverse	10
	Change in summer temperatures	Direct	10
	Change in winter temperatures	Direct	10
	Change in frequency of hot days	Direct	10
	Change in frequency of dry days	Direct	10
	Change in frequency of very hot days	Direct	10
	Change in frequency of heavy rainfall days	Direct	10
	Change in frequency of warm nights	Direct	5
Exposure	Net sown area	Direct	40
	Rural population density	Direct	15
	Small and marginal farmers' land holdings	Direct	20
	SC and ST population	Direct	15
	Crossbreed cattle	Direct	10

Component of risk	Indicator	Relation to risk	Weightage
Vulnerability	Annual rainfall	Inverse	12
	Degraded and wasteland	Direct	5
	Soil moisture	Inverse	8
	Groundwater availability	Inverse	10
	Livestock density	Inverse	8
	Literacy (% literate)	Inverse	4
	Literacy gender gap (difference between total literacy and female literacy)	Direct	3
	Self-help groups	Inverse	4
	Net irrigated area	Inverse	20
	Market access	Inverse	4
	Fertiliser use (kg/gross sown ha)	Inverse	5
	Gross Per Capita DDP (in crore)	Inverse	5
	Percentage of forest area to total area	Inverse	4
	Crop area insured	Inverse	8

Source: Authors' compilation

Figure 5.1.3 Process of assessing agriculture risk using the agriculture risk index

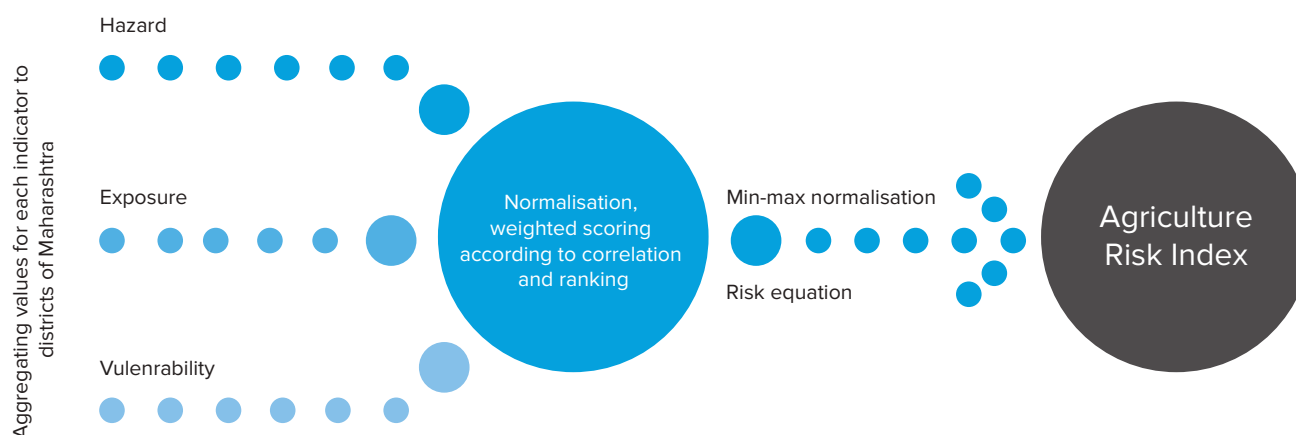


Source: Authors' compilation

to bring them to a common scale and make them unit-free. After normalising the indicators, they were classified into ten classes based on equal interval distribution to obtain the scores of each district for the specific indicator.

The scores of indicators that were inversely related to the component of risk were reclassified. The scores were then aggregated into the indices of hazard, exposure, vulnerability, and risk. The weights to indicators of each

Figure 5.1.4 Schematic representation of approach for computing Agriculture Risk Index



Source: Authors' compilation

determinant of risk were obtained through a literature review and consultations with relevant state government departments and experts. Weights of 20 each were assigned to historical hazards, current hazards, and exposure, and weight of 40 was assigned to vulnerability for the final risk calculation as per the CRIDA report. The whole process — including the approach, methodology, selection of indicators, weightage allocation, etc. — was presented and discussed in consultative meetings with representatives from different stakeholder departments and other organisations and the results were presented and validated in the consultations.

The computed index for the historical and current hazard, exposure, and vulnerability (including sensitivity and adaptive capacity) is presented in Figures 5.1.5 to 5.1.8.

The state's district-level analysis based on the historical and current hazards for the agriculture sector suggests that most of the districts are highly prone to the impacts of severe climate events, i.e., floods, droughts, cyclones, and related events. These events have a direct impact on agriculture, increasing the risk for the sector. Districts in the central Maharashtra region, such as Nashik, Jalgaon, Aurangabad, Ahmednagar, Pune, Solapur, and Osmanabad, along with Nandurbar in the northern region, are highly prone to the impacts of extreme weather events. Further, the current hazard scenario suggests that indicators such as changes in heavy rainfall days and hot days also directly increase the risk of the sector to changing climate. The districts in the Marathwada region, namely Bid, Parbhani, Nanded, Latur, and Osmanabad, are highly hazard prone.

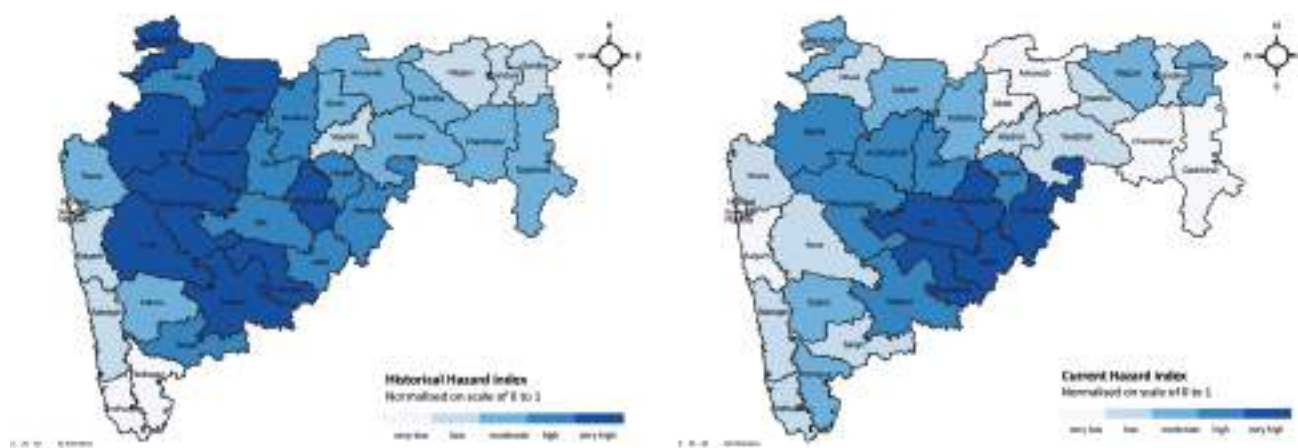
Figure 5.1.6 reveals that districts in the central (Aurangabad, Jalna, Buldhana, Akola, etc.) and southwestern regions (Satara, Sangli, and Kolhapur) have the highest exposure. A higher presence of the rural population, with more than 50 per cent of small and marginal farmers and a

majority of cattle being crossbred in the high-exposure southwestern districts, increases the vulnerability of the population here as they face excessive challenges in coping with climate fluctuations. In contrast, Yavatmal and Chandrapur districts in the eastern region and Sindhudurg along the coastline have lower exposure as they have low population density, less proportion of crossbred cattle, and a smaller share of small and marginal farmers. Thus, focussed policy measures must be taken to support small and marginal farmers and meet the needs of crossbred cattle in different regions.

However, the vulnerability is higher along the Konkan belt and the Vidarbha region, which includes districts such as Washim and Yavatmal. The key reason for high vulnerability in the Konkan region is that these areas have historically been less agriculturally vulnerable and hence, have a comparatively low adaptive capacity since they are not agriculturally dominant regions. Therefore, adaptation strategies could consider future vulnerabilities to climate change when planning to prevent further agricultural distress.

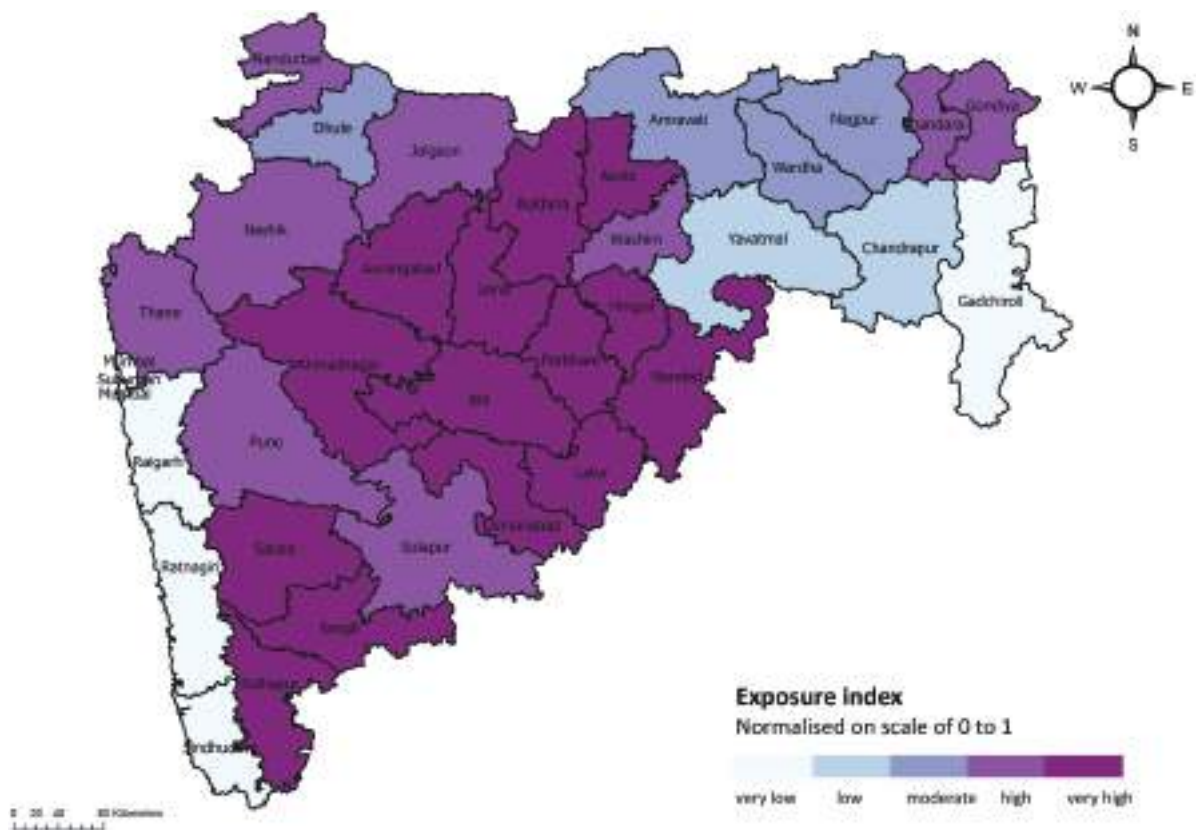
Geographically, a relatively very high risk was observed in Bid, Latur, Hingoli, Parbhani, and Osmanabad (Figure 5.1.8). Since these districts are also drought-prone, they might experience a pronounced effect on crop productivity, placing the agrarian economy at high risk. Therefore, adaptation strategies should consider the impact of future climate changes in these districts in judiciously planning to prevent further agricultural distress. These districts are also most at risk due to varying rainfall patterns, floods, droughts, and extreme temperatures that would heavily affect crop productivity. Districts such as Pune, Solapur, Ahmednagar, Aurangabad, Jalna, Nanded, Jalgaon, and Nandurbar fall in the high-risk category, while Nashik, Satara, Sangli, and Buldhana are in the moderate-risk category.

Figure 5.1.5 District-wise Hazard sub-index value for the agriculture sector in Maharashtra



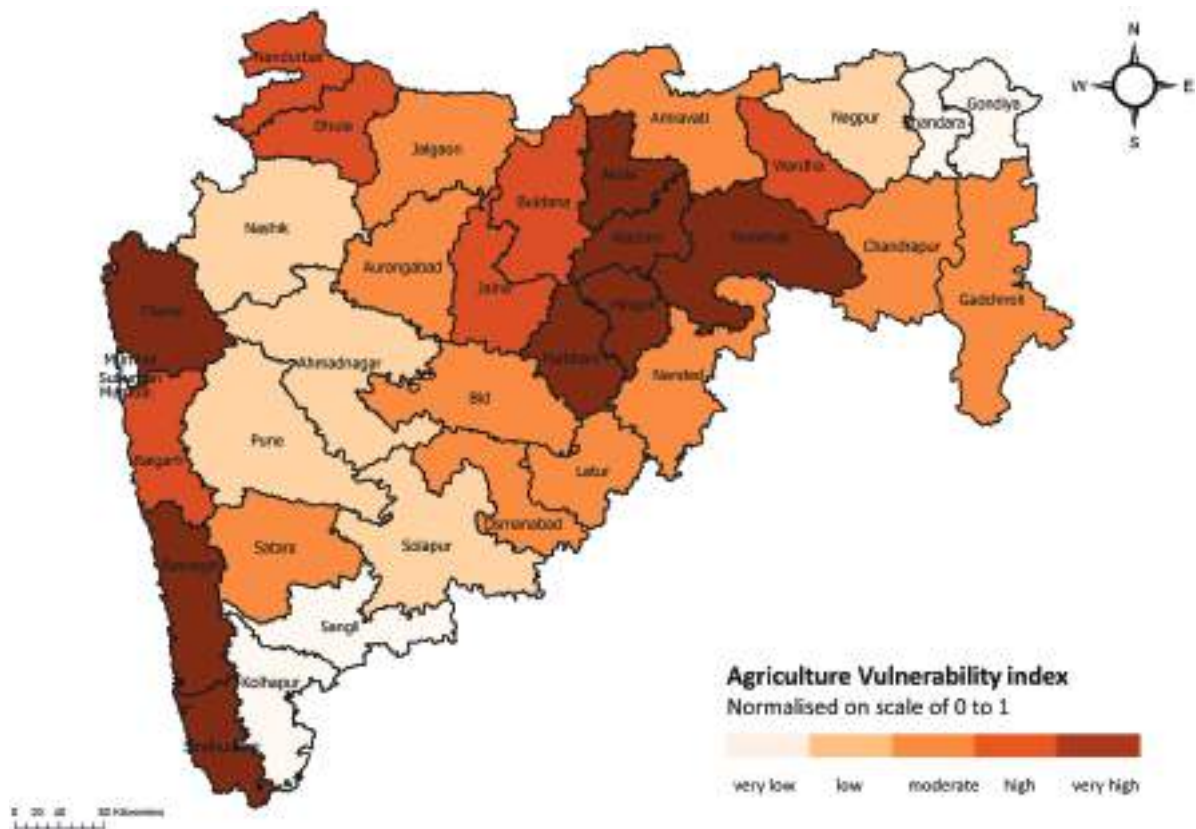
Source: Authors' analysis

Figure 5.1.6 District-wise Exposure sub-index value for the agriculture sector in Maharashtra



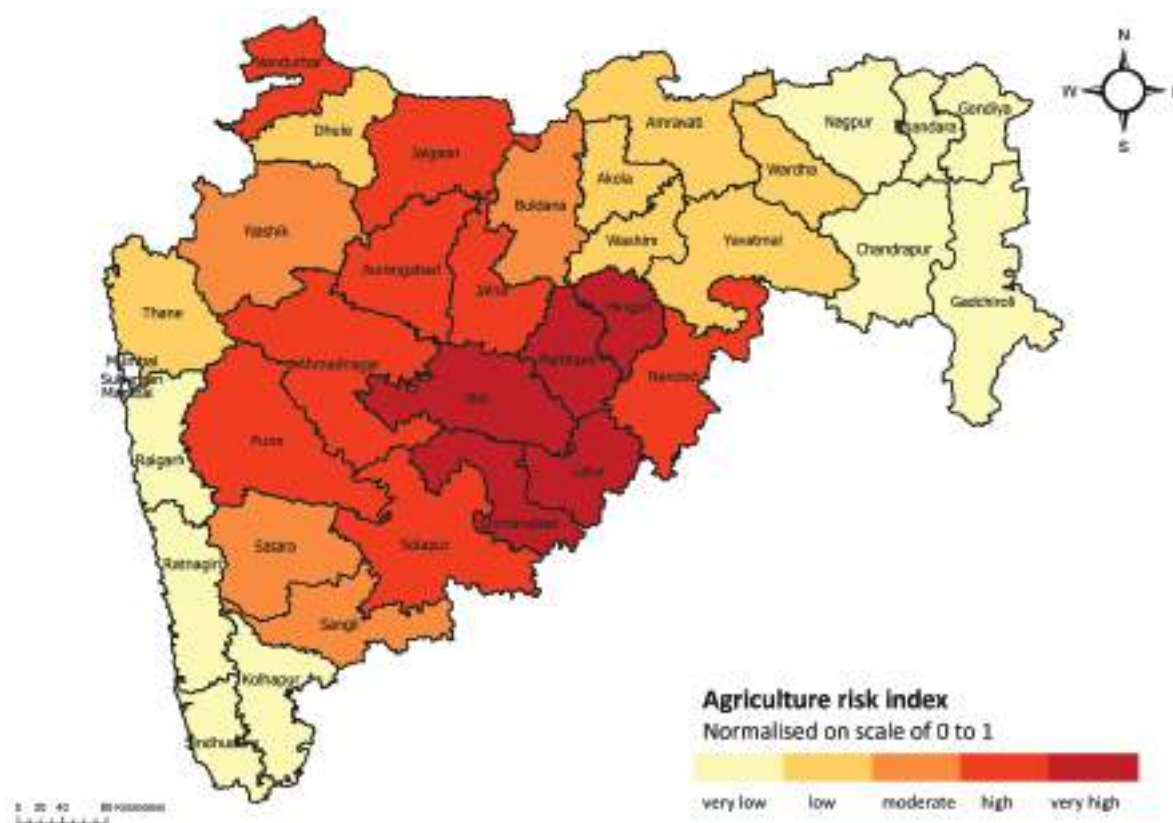
Source: Authors' analysis

Figure 5.1.7 District-wise Vulnerability sub-index value for the agriculture sector in Maharashtra



Source: Authors' analysis

Figure 5.1.8 District-wise Agriculture Risk index value for Maharashtra



Source: Authors' analysis

Table 5.1.2 Key drivers of risk for the very vulnerable districts in the agriculture sector

Major drivers	Districts with the highest risk in the agriculture sector				
	Parbhani	Osmanabad	Latur	Hingoli	Ahmadnagar
Exposure					
Net sown area				x	x
Rural population density	x	x		x	x
Small and marginal land holding farmers	x	x	x	x	x
SC/ST population	x	x	x	x	x
Crossbreed cattle	x	x	x	x	
Vulnerability					
Annual rainfall	x	x	x	x	x
Degraded and wasteland	x	x	x	x	x
Soil moisture	x		x	x	
Groundwater availability	x	x	x		x
Livestock density	x	x	x	x	
Literacy	x	x	x	x	x
Literacy gender gap		x	x		x
Self-help groups	x	x	x	x	x
Net irrigated area	x	x	x	x	

Major drivers	Districts with the highest risk in the agriculture sector				
	Parbhani	Osmanabad	Latur	Hingoli	Ahmadnagar
Market access	x				x
Fertiliser use	x	x	x	x	x
Gross Per Capita DDP	x	x	x	x	x
% forest area	x	x	x	x	x
Crop area insured				x	x

Source: Authors' analysis

5.1.3 Impacts of climate change on the agriculture sector

Agricultural systems are a complex function of physical, physiological, chemical, and biological processes. Agriculture production and productivity are dependent on external drivers such as hydrometeorological variables, soil biochemistry, and geomorphology, thus making agriculture a climate-dependent sector.

The agrarian economy of Maharashtra predominantly practises rain-fed agricultural production with rain-fed crops such as sorghum, pearl millet, pulses, and oilseeds collectively covering about 60 per cent of the sown area (Todmal 2021). Major cash crops produced in the state, including sugarcane, rice, cotton, and maize account for about 27 per cent of the cropped area (Todmal 2021). The impact of changing climatic conditions is expected to affect the productivity of key crops. For instance, in soybean and cotton, excess rainfall can affect pod development and maturity, boll formation, and boll bursting stage, impacting crop production and quality. The following section provides a brief overview of the impact of climate change on major crops.

Cotton

Cotton, a major crop in western Vidarbha and parts of Marathwada is mainly affected by temperature and rainfall. The ideal temperature range for the crop is 21°–27°C, but it can also grow in temperatures as high as 43°C given that there is adequate moisture in the soil. However, its growth slows down or ceases below 21°C. It requires nearly 600–1000 mm of rainfall when the crop is growing, and heavy rainfall and excess moisture at the budding stage and boll shedding reduces productivity substantially (Kelkar et al. 2020). Climate projections indicate an increase in production by 20–30 per cent in the 2040s in most districts due to an increase in maximum temperature. Due to rainfall changes, the average maximum temperature exceeding the ideal temperature will damage the cotton buds (Kelkar et al. 2020).

Soybean

Soybean cultivation requires temperatures between 22°C and 35°C along with rainfall of 100 mm before and 50–80

mm after sowing. A rise in temperature can reduce the yield by harming the reproductive system and changing the timeline of different stages. A temperature increase of 1°C may result in a reduction of the yield of soybean by 3–7 per cent (Mahato 2014). Rainfall patterns directly impact soybean yields. While a delayed monsoon can result in fungal infestations, excessive rainfall could lead to root rot due to flooded fields, and untimely rains during the harvest period can damage the matured crop. Future predictions till 2050 show that the majority of Maharashtra will see higher rainfall. However, specifically for Soybean, Vidarbha may experience higher than ideal rainfall levels during harvest and other phases, while the Khandesh and Marathwada regions are expected to experience less than required rainfall (Bhagawat and Nazareth 2021).

Sugarcane

For sugarcane, a rise in temperature during the day is detrimental. On the other hand, the crop thrives on an increase in rainfall, as sugarcane requires large amounts of water for its growth. Being a tropical crop, a temperature range of 27°–38°C during every phase of growth is crucial; above this range, the rate of photosynthesis drops. By 2040, increasing temperatures could reduce the output of sugarcane by 40–80 per cent in the Marathwada region (Latur, Nanded, Parbhani, and Jalna), while an increase in minimum temperature can reduce production by 20–40 per cent in central Maharashtra (Madhya Maharashtra). On the other hand, a few districts, such as Osmanabad, Solapur, Jalna, and Parbhani, show a 20–40 per cent production rise due to an increase in seasonal rainfall (Kelkar et al. 2020).

Sorghum

Sorghum thrives in temperatures between 26°C and 30°C and can tolerate temperatures as high as 45°C; however, temperatures below 8°C can harm flowering and pollination. Extremely high temperatures can cause flower initiation to be delayed and reduce yields, and a rainfall shortage of more than 50 per cent can result in crop failures (VM and Rao 2019). The projected increase in the annual mean temperature in regions of Maharashtra (north Satara Bhor Taluka (Pune), Pune (Mulshi, Maval, and Rajgurunagar), north Solapur, east Osmanabad, central Maharashtra and Marathwada) will decline yields by 6–18 per cent in these areas (Todmal 2021).

Impact of climate change on horticulture crops and production: The horticulture sector in Maharashtra also faces increasing risk from climate change, which will potentially impact the productivity of key fruits and vegetables.

Mango

Perennial fruits such as mangoes respond differently to temperature changes than annual crops. While a rainfall between 890–1,015 mm in a year is ideal, the projected rise in drought and vapour pressure deficit (VPD) would adversely impact photosynthesis. This is due to the rapid closure of stomata in mango trees when water stress increases (Normand et al. 2015). The Chausa variety of mangoes is susceptible to becoming hotbeds for fruit flies (Choudhary et al. 2018), which suggests that similar trends could also be observed in other mango varieties such as Alphonso, Mankurad, Mulgoa, Pairi, Rajapuri, Kesar, Gulabi, and Vanraj cultivated in the state. Rising temperatures (10–31°C) and relative humidity (60–90%) also make it favourable for powdery mildew, a disease caused by *Oidium mangiferae* Berthet. This can result in output losses of up to 80–90 per cent in severe cases (Misra 2001). With changing climate patterns, climate models suggest that Alphonso's production may shift from Ratnagiri, where it is currently being grown.

Pomegranate

Pomegranate can be successfully grown in areas with semi-arid conditions with an ideal temperature of 25–35°C and annual rainfall levels between 500–800 mm. It can tolerate temperatures of up to 44°C and as low as -12°C. It thrives in arid and semi-arid regions with 500 to 1000 mm of annual rainfall, hot and dry summers, and mild winters. An increase in temperature (20°C–30°C) and relative humidity (80–95%) creates a conducive environment for anthracnose disease, which can result in a 10–80 per cent reduction in marketable yield of total crop production (Jain et al. 2020).

Onions

Onions can thrive in temperatures ranging between 27°C to 32°C and rainfall between 50 to 100 cm. Soil-water stress at early stages can lead to a crop loss of up to 26 per cent. However, temperatures above 40°C can reduce the size of the bulb. An increase of approximately 3.5°C above 38°C will reduce productivity by 10–20 per cent. In Nashik alone, unpredictable rainfall patterns and a rise in temperature have already led to a fall in the output of Kharif onion yield by 30–40 per cent over the last decade (Pawar, 2019; Chahal and Mishra, 2021). Further, an increase in temperature (21–30°C) and relative humidity (80–90%) facilitates the spreading of purple blotch *Stemphylium* Blight with the potential to reduce seed yield by 60–90 per cent (Mandal et al., 2022).

With about 28.4 per cent of contribution to Maharashtra's Gross State Value Added (GSVA) and high significance for exports, climate challenges have repercussions for the farmer's livelihoods and the state economy.

Impact on soil health and water availability for agriculture: Effects of climate change on soil are apparent in soil salinisation resulting from excessive groundwater irrigation and flooding, adversely impacting agricultural production and stability. This is predominantly observed in the sugarcane belts of western Maharashtra. Salinity in the soil also influences the uptake of nutrients by the crops. As climate change intensifies, salt-affected areas are likely to increase, which will hinder the production of crops (such as cotton, sugarcane, sorghum, wheat, maize, and horticulture crops) as salinity affects germination, vegetative growth, and reproductive development phases of plant growth (Kochewad SA et al. 2021). With projections signalling an increase in rainfall intensities and extreme rainfall days, soil erosion and loss of critical soil nutrients will directly be responsible for low soil fertility and crop yields.

The agriculture sector in Maharashtra is the highest user of freshwater, withdrawing more than 80 per cent of the water (blue water). Moreover, almost 80 per cent of the agricultural land in the state is rainfed. Such circumstances make a few regions severely water stressed. The state has an estimated annual availability of water resources of nearly 198 bn cubic metres (BCM), of which 164 BCM are surface water and 34 BCM groundwater, in addition to more than 21 lakh wells (Kale and Kulkarni 2022). Climate change has reduced the number of rainy events, induced erratic rainfall, and increased average temperatures leading to groundwater depletion and causing water scarcity for irrigation. This will eventually affect agricultural production and cause water availability issues for allied activities and livelihood purposes. Besides, climate stress in areas producing water-demanding crops such as sugarcane can further reduce the water availability for other crops and cause water scarcity.

Impact on vulnerable communities such as marginal farmers, landless families, labour, and tribal farmers:

In Maharashtra, climate change poses differentiated vulnerabilities to groups depending on caste, occupation, demography, and land ownership (Kuchimanchi et al. 2019). Studies point out, in particular, certain groups (marginal farmers, landless families, labour, and tribal farmers) are at more risk due to lesser access to resources and government support (subsidies), leading to high vulnerability and low adaptive capacity.

Economic impact

Scheduled tribes and scheduled castes generally have marginal landholdings and rely more on wage labour, which can fluctuate with demand. The forest-dwelling tribal communities in Yavatmal, Gondia, and Gadchiroli districts in eastern Vidarbha rely heavily on natural resources as their primary source of livelihood. With extreme temperatures and unpredictable rainfall, they face a likely decline in incomes as the yield of non-timber forest produce (NTFP) is impacted by climate change (Chari 2022).

Socio-economic impact

Insufficient access to knowledge and technology makes landless and marginal tribal farmers more vulnerable to climate shocks, as seen in tribal districts such as Nandurbar, Chandrapur, and Gondia. Most of the state's small farmers depend entirely on rainfed farming, increasing their vulnerability to droughts, rainfall variability, and associated problems such as crop diseases and pests that follow these events. Temperature rise will lead to marginal and small farmers facing more difficulties, especially in storing perishable produce, as they have limited access to existing cold storage facilities.

Impact on the agriculture sector: In addition to the particular impacts discussed above, climate change has a significant overall impact on the agriculture sector.

Pest infestations and fungal diseases

The alterations in temperature, moisture regimes, and day lengths significantly increase the risk of invasive pest infestations in the state. A serious threat from increasing populations of pests such as woolly aphid (*Ceratovacuna lanigera*), pink bollworm, *Spodoptera litura*, *Helicoverpa armigera*, and other leaf-eating pests have been recorded across Maharashtra (Singh and Yadav 2021). High atmospheric humidity, longer wet seasons, and high temperatures also create a conducive environment for fungal diseases (Chauhan et al. 2014). In recent years an increase in reports of fungal infection from fungi such as *Fusarium udum* and *Alternaria porri* (Shrivatsav 2018).

Increase in mean temperatures

Temperature rise has the potential to significantly reduce the yields of many crops popularly grown in Maharashtra. This includes a potential decline of 6–18 per cent for sorghum, 6–22 per cent for sugarcane, 0–49 per cent for rice, and a 268 kg/ha decline for cotton (Todmal 2021). Climate change can reduce crop duration, increase crop respiration rates, alter photosynthate movement from source to sink and thus result in reduced crop productivity (Chauhan et al. 2014).

Changes in precipitation trends, exposure to cyclones and storm events, and floods

The inevitable increase in rainfall across Maharashtra can reduce the productivity of food grains and commercial crops. The increase in the rainfall during monsoon in Vidarbha and western Ghats may lead to increased leaching (i.e., nitrates) in soils that are well-drained. Moreover, it can have an adverse impact on the decomposition of organic matter (Kelkar et al. 2020; Chauhan et al. 2014). The distribution of rainfall and the increase in rainfall from extreme weather events will affect agricultural productivity in Maharashtra by delaying the sowing and harvesting seasons, water saturation, agricultural loss from storm events, increase in run-off, and irreversible loss of soil quality.

Droughts

Hydrological droughts translate to agricultural droughts in the state (Katalakute et al. 2016). Rainfall deficit years, delayed onset of monsoon leading to dry lean agricultural periods and fall in groundwater levels create an imbalance in the agricultural ecosystem that results in substantial crop failures (Katalakute et al. 2016). In 2012, droughts caused an estimated 21 per cent yield reduction in cereals, 5 per cent in pulses and an 18 per cent decline in total food grain production (Bhagawat and Nazareth 2021). The vulnerability of water-intensive cash crops such as cotton, sugarcane, and rice is high.

Elevated levels of CO₂

An increase in CO₂ levels to 450–600 ppm will decrease the yields of crops such as rice, maize, and sorghum (Reddy and Sreenivas 2016). Further, increased CO₂ concentrations can decrease leaf nitrogen and increase phenolics (Reddy and Sreenivas 2016), which affect the quality of crops.

Rising cost of cultivation

Crop failures lead to a loss in revenue, which have huge economic impacts on an agrarian state such as Maharashtra. Various factors push for the need for adaptation strategies to climate change, such as a decrease in soil fertility necessitating higher use of agricultural inputs; an increase in the cost of agricultural inputs leads to an increase in the cost of cultivation. Post-harvest operations, especially for horticulture crops, are highly sensitive to climate change impacts. Further, infrastructure that complements activities such as harvesting, grading, drying, packaging, transport, and storing is also impacted and needs to be financed via investments. For instance, an increase in temperature expedites the process of natural degradation leading to crop loss and wastage (ADB 2021b).

5.1.4 Climate change impact on animal husbandry (livestock)

The complex relationship between the livestock sector and climate change is often overlooked, but it plays an important role in poverty alleviation and rural development in Maharashtra. The livestock sector in Maharashtra has a significant bovine population of 19.50 million (livestock census 2019). Livestock reared in Maharashtra includes cattle, buffalo, goats, sheep, poultry, horses, and ponies. This sector has a significant contribution to the GDP of the state. During the financial year 2018–19 alone, 11.66 million tonnes of milk, 1.08 million tonnes of meat, 5.96 billion eggs, and 1385.78 thousand kg of wool were produced (Das 2022). The varied impact of climate change on livestock production is elaborated below.

Feed resources

There is a shortage of green and dry fodder in the state due to various climate-induced stresses. A large part of the sown area is under food crops, and just 3.06 per cent of

the cultivated area is utilised for fodder crops. Shortage of dry fodder is about 31.3 per cent, and that of green fodder is 59.4 per cent (ICAR-IGFRI 2020). Fodder shortage is pronounced in the drought-prone and water-scarce regions of Marathwada and Vidarbha. To deal with fodder shortages, the government has had to support dairy farmers with free fodder camps and a ban on the sale of fodder outside the districts where it is produced (Kalamkar, Sharma, and Atkare 2021). The expanding livestock population will be at severe risk of malnutrition under conditions of climate change that will disrupt fodder production in the state.

Water resources

Erratic rainfall, extreme weather events, and increasing mean temperature have led to cycles of water shortage resulting in water scarcity for fodder production and drinking water for livestock. As a relief measure, the government organises free fodder camps every year in rainfall-deficit areas. Dry matter resulting from crop residue is considerably lower in Ahmednagar, Pune, Kolhapur, Satara, and Sangli because of the high density of dairy animals in these districts (NDDDB 2015).

Livestock productivity

Rise in temperature reduces feed consumption, lowers production, and leads to fatigue that may decrease the fertility, fitness, and life span of milch animals (Katalakute et al. 2016). Climatic changes have a high impact on animal behaviour due to alterations in their neuroendocrine responses to climate. This affects production as well as the health of the animals (Shelton 2000; Sejian et al. 2010a; Baumgard et al. 2012). Moisture and heat from air and thermal radiation can cause heat stress impacting livestock in terms of performance, health, and well-being (Kochewad et al. 2021). The genetic erosion of certain species of livestock is also being exacerbated by climate change, with drought-tolerant species surviving extreme weather conditions (Kochewad et al. 2021). Livestock provides a significant cushion for small landholding farmers against crop failure and augments their income. A fall in livestock productivity has a significant impact on farmers' incomes and livelihoods.

Livestock diseases and vectors

Higher temperatures increase the number of new pathogens that directly or indirectly harm poultry, cattle, and other agricultural animals, causing them to suffer as a result of climate change. For instance, cattle exposed to drought, extreme humidity, or heat are more susceptible to illness. In addition, alternating drought and high rainfall cycles offer a favourable habitat for vectors of vector-borne cattle illnesses, such as midges and mosquitoes. Changes in rainfall patterns also increase vector populations in the monsoon season (Kochewad et al. 2021).

Indirect impact on human health: As a direct impact of climate change, livestock populations are left more prone and vulnerable to livestock diseases. These diseases are increasingly jumping from livestock species to humans

and posing a major threat to human health. For example, avian flu cases have been reported in poultry farms across Maharashtra for the past many years (PIB 2021e).

5.1.5 Climate change impact on marine fisheries

Changes in wind patterns, the occurrence of severe storms, changes in temperature, and irregular rainfall patterns are likely to have an impact on fish production, distribution, and species composition (Girkar et al. 2017). Maharashtra has a 720 km long coastline, and according to the Marine Fish Landings in India (2019), the state has a fishermen population of 15,18,228. With marine fisheries playing such an important role in the economy of Maharashtra, the impact of climate change on this sector would have a significant effect on the state's economy.

Lower fish landing

The state witnessed the lowest fish catch in 45 years in 2019 (Bhalerao 2020). This alarming decrease is attributed to various climatic factors such as rising sea temperatures, overharvesting, pollution, increased precipitation, winds, and extreme sea-level events associated with some tropical cyclones. The rise in sea temperatures has increased cyclonic events, which, in turn, are further affecting fish yield (Boraiah KM 2021).

Reduction in phytoplankton population

The rise in sea levels and changes in solar radiation is affecting the phytoplankton population. A 30 per cent decline in the phytoplankton population in the western Indian Ocean has led to imbalances in the patterns of fish migration and consequently affecting the state's marine fisheries sector (Roxy et al. 2015). The food chains in the Arabian Sea are sustained by a species of phytoplankton called diatoms. The rise in surface sea temperatures in the Arabian Sea has resulted in massive blooms of other species of phytoplankton, such as *Trichodesmium erythraeum* and *Noctiluca scintillans*. This change in vegetation puts the regional fish populations at risk as their food chains are disrupted (Sahu, Pati, and Panigrahy 2016). Moreover, with the melting of snow in the Himalayas and a decrease in the temperature differential between the land and sea, the winds are much calmer, which prevents the sea from churning the required nutrients to the surface. Without these nutrients, the growth of diatoms is impacted, which in turn, disrupts the food chain of finfish. The growth of phytoplankton such as *Noctiluca scintillans* has already been observed near the coast of Maharashtra, which makes it imperative for the state to take necessary adaptation measures (Bisht 2021).

Loss of lives and livelihoods

Environmental conditions such as extreme weather conditions, along with vessel-related problems such as instability and physical fatigue, affect the lives and livelihoods of the fishermen community (Rai 2016).

5.1.6. Mapping the existing policies

Table 5.1.3 Policy mapping

S. no.	Title of policy or scheme	Nodal/Implementing agency	Launch/ Time period	Budget allocated (in INR)	NDC	SDG
1	Agriculture Export Policy	Maharashtra State Agricultural Marketing Board	2018	NA	NDC 1	SDG 1, 2, and 8
2	Agricultural Technology Management Agency (ATMA)	State-level sanctioning committee comprising of: Chief Secretary of the state and departmental heads of Finance, Planning, Fisheries, Animal Husbandry, Environment and Forests, Panchayati Raj, Rural Development, Water Resources and Irrigation, Agriculture, Horticulture etc.	The ATMA scheme was implemented in 2005.	Expenditure in Maharashtra under the scheme (up to January 2022): 419.2 million (41.92 crore). (Planning Department 2022)	NDC 1	SDG 1, 2, and 12
3	Formation and Promotion of 10,000 Farmer Producer Organisations (FPOs)	Implementing agencies: • Small Farmers Agri-Business Consortium (SFAC) • National Cooperative Development Corporation (NCDC) • National Bank for Agriculture and Rural Development (NABARD) • National Agricultural Cooperative Marketing Federation of India (NAFED) • Foundation for Development of Rural Value Chains (FDRVC) • Ministry of Rural Development (MoRD)	2020–21	Total national level budgetary outlay of the scheme: 68.65 billion (6865 crore) (till 2027–28) (PIB 2021b)	NDC 1	SDG 1, 8, and 12
4	Mission for Integrated Development of Horticulture (MIDH)	Maharashtra State Horticulture and Medicinal Plants Board (MSHMPB)	2014–15	The financial outlay for Maharashtra (2022–23): 20 billion (2000 crore) (Directorate of Economics and Statistics 2022)	NDC 1	SDG 1, 2, 9, 17 (NITI Aayog 2020), and SDG 13
5	National Beekeeping and Honey Mission	National Bee Board (NBB) and Honey and Pollinators Board of India (HPBI) under the Department of Agriculture and Farmers' Welfare, Ministry of Agriculture and Farmers Welfare	2020	Approved national level allocation under the mission (2020–2023) 5 billion (500 crore) (PIB 2021a)	NDC 1	SDG 1, 2, 8, and 15
6	National Mission for Sustainable Agriculture	State Level Committee (SLC) under Agriculture Production Commissioner (APC)/Principal Secretary/Secretary (Agriculture/Horticulture). Other departments such as Revenue, Animal Husbandry, Fisheries, and Forests. State agricultural universities (SAUs) and Indian Council of Agricultural Research (ICAR) centres can be represented.	2014–15	Financial outlay for Maharashtra (2022–23) Rainfed Area Development component: 3.2 million (32 lakh) Soil Health Management component: 50 million (5 crore) (Directorate of Economics and Statistics 2022)	NDC 1, 6	SDG1, 2, 13, and 17 (NITI Aayog 2020)

S. no.	Title of policy or scheme	Nodal/Implementing agency	Launch/ Time period	Budget allocated (in INR)	NDC	SDG
7	Paramparagat Krishi Vikas Yojana (PKVY)	Department of Agriculture, Maharashtra and the regional councils registered under the Participatory Guarantee System of India Certification Programme.	2015	The financial outlay for Maharashtra (2022–23): 156.1 million (15.61 crore) (Directorate of Economics and Statistics 2022)	NDC 1	SDG 2 and 15
8	Pradhan Mantri Fasal Bima Yojana (PMFBY)	State Level Coordination Committee on Crop Insurance (SLCCCI), including departments of the state government, Reserve Bank of India (RBI), National Bank for Agriculture and Rural Development (NABARD), etc.	2016	Total national-level financial outlay for the scheme (2022–23): 155 billion (15,500 crore) (Ministry of Finance 2022)		SDG 1
9	Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)	Department of Agriculture, Maharashtra	2015–16	The financial outlay for Maharashtra (2022–23): Under Agriculture Department: Per drop more crop: 5.62 billion (562 crore) Under Water Resources Department (state share): 17.29 billion (1,729 crore) Under Water Resources Department (central share): 4.27 billion (427 crore) (Directorate of Economics and Statistics 2022)	NDC 1, 6	SDG 1, 2, 6, 12, and 13
10	Rashtriya Krishi Vikas Yojana — Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (RKVY-RAFTAAR)	Department of Agriculture, Maharashtra	2007	The financial outlay for Maharashtra (2022–23): 4.0031 billion (400.31 crore) (Directorate of Economics and Statistics 2022)		SDG 1, 2, 8, 9, and 17 (NITI Aayog 2018)
11	Restructured Weather Based Crop Insurance Scheme (RWBCIS)	State Level Coordination Committee on Crop Insurance headed by the Agricultural Production Commissioner (APC) or by an official of an equal rank of the state	2016			SDG 1
12	National Food Security Mission	The Executive Committee of the <i>State Food Security Mission</i> , under the chairmanship of the Chief Secretary, oversees the activities of the mission in the state. The committee includes secretaries of relevant departments such as Agriculture, Irrigation, and Panchayati Raj.	2007	The financial outlay for Maharashtra (2022–23): Rice, wheat, pulses, coarse cereals: 3.03 billion (303 crore) Sugarcane: 43.2 million (4.32 crore) Cotton: 34.6 million (3.46 crore) (Directorate of Economics and Statistics 2022)	NDC 1	SDG 1, 2, 12 SDG 5, 10, and 13 (NITI Aayog 2020)

S. no.	Title of policy or scheme	Nodal/Implementing agency	Launch/ Time period	Budget allocated (in INR)	NDC	SDG
13	Soil Health Card Scheme	Department of Agriculture, Maharashtra	2015	Total allocation under the scheme for Maharashtra for the year 2018–19: 396 million (39.67 crore) (MoAFW 2017)	NDC 1	SDG 1, 2, 13, and 17 (NITI Aayog 2020)
14	Sub Mission on Agricultural Mechanisation (SMAM)	Department of Agriculture, Maharashtra	2014–15	The financial outlay for Maharashtra (2022–23): 1.1 billion (110 crore) (Directorate of Economics and Statistics 2022)		SDG 1, 2, 8, and 17 (NITI Aayog 2020)
15	Sub Mission on Plant Protection and Plant Quarantine (SMPPQ)	National level nodal agency: Department of Agriculture and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare Implementation agency: Project Coordinating Cell of All India Network Project (AINP) on Pesticide Residues (NITI Aayog 2020)		Budget: for three years, i.e., 2017–18 to 2019–2020 13.15 billion (1,315.02 crore) (NITI Aayog 2020)	NDC 1	SDG 2, 12, and 13 (NITI Aayog 2018)
16	State of Maharashtra's Agri-business Rural Transformation Project (SMART)	Department of Agriculture, Maharashtra	2019–2027	The financial outlay for Maharashtra (2022–23): 1 billion (100 crore) (Directorate of Economics and Statistics 2022)		SDG 1, 8, and 13
17	Nanaji Deshmukh Krushi Sanjivani Prakalp (PoCRA)	Department of Agriculture, Maharashtra	2018	Total cost of the project: 40 billion (4,000 crore) (Funded by the Government of Maharashtra (30%) and the World Bank (70 %))	NDC 1, 5	SDG1, 2, 12, and 13
18	Magel Tyala Shet Tale Yojana (Farm Pond on Demand)	Planning Department, Employment Guarantee Schemes	2016	The outlay for 2022–23: 1 million (10 lakh) (Directorate of Economics and Statistics)	NDC 1	SDG 1, 2, and 6
19	Chief Minister Sustainable Agriculture Irrigation Scheme	Department of Agriculture, Maharashtra	2017	The outlay for 2022–23: 60 billion (6,000 crore) (Directorate of Economics and Statistics 2022)	NDC 1	SDG 1, 10, and 12

Source: Authors' compilation

*NDC – Nationally Determined Contributions

*SDG – Sustainable Development Goal



Konkan region produces largest share of rice in Maharashtra.

5.1.7. Adaptation strategies and recommendations for agriculture and livestock sector

Table 5.1.4: Recommendations for making agriculture resilient to the impact of climate change

S. no.	Recommendations/Targets	Actions to be undertaken	Relevant regions
1	Improve the research capacity on key areas pertaining to climate change adaptation in the agriculture sector.	1. Create a comprehensive database cataloging cultivars of crops grown in the state, focusing on those with climate-resilient traits. Additionally, initiate the development of new varieties as required. For instance, ensure that crop varieties like millet, sorghum, groundnut, and pulses, commonly cultivated in regions prone to drought, are equipped with features promoting resistance to drought and heat.	State-level focus but prioritise research for drought-prone regions like Dhule, Nasik, Aurangabad, Ahmednagar, Pune, Satara, Solapur, and Sangli.
		2. Establish decision support systems (DSS) specifically designed for utilisation by the extension system, aiding farmers in individual districts to adapt agricultural and allied sector practices to climate change.	State-level focus but prioritised research for the most vulnerable districts such as Ahmednagar, Solapur, Bid, Nandurbar, and Jalgaon.
		3. Create a database detailing village-level soil fertility, particularly focusing on major micronutrients, to enhance precision in assessing soil quality and optimise fertilizer use efficiency for enhanced productivity.	State-level focus but action could be prioritised in areas where horticulture and cash crop cultivation are prominent such as Ahmednagar, Thane, Pune, Nashik, and Satara.
		4. Enhance financial allocations to State Agricultural Universities (SAUs), animal husbandry universities, and veterinary universities, directing resources toward research and development in the specified research-for-action domains.	State-level
2	Improve the capacity of stakeholders (farmers, CSOs, farmer-interfacing government institutions) to take up climate change adaptation measures.	1. Enhance the collaboration capabilities of the KVK and the extension system with relevant institutions, including SAUs, animal husbandry, and veterinary universities: - Facilitate collaboration for piloting initiatives with the farming community to generate essential data and evidence required for well-informed and targeted action. - Task KVKs with identifying 3–5 critical issues in their district based on factors such as cultivated crops, livestock, and socio-economic, bio-physical, and climatic conditions. - Direct KVKs to conduct experiments, collect data, and analyze information to provide up-to-date insights into challenges. - Encourage a bottom-up approach, where KVKs work in collaboration with SAUs to identify potential solutions to the identified challenges. - Strengthening KVKs as focal point for dissemination of Climate Resilient Technologies for farmers.	State-level
		2. Set up demonstration plots at KVKs to showcase success stories of micro-irrigation and build capacity for its uptake in the farming community.	State-level focus but prioritise capacity building in drought-prone regions such as Dhule, Nasik, Aurangabad, Ahmednagar, Pune, Satara, Solapur and Sangli.

Participating government departments	Relevant policies	Proposed budget (INR)	Justification	Outcomes
ICAR, SAU, central agricultural university (CAU), and ATMA, with PoCRA being the nodal governing body. Integrate with National Mission on Sustainable Agriculture.	This could be aided by <i>National Innovations on Climate Resilient Agriculture</i> (NICRA) through its strategic research component, which focuses on genetic enhancements, among other things, and ATMA, which is responsible for disseminating technological inputs to promote research.	18.5 billion (1,850 crore)	As per the 2022–23 annual budget, INR 17.61 billion (1,761 crore) was allocated for agricultural research and education. With an assumption of 15% of this budget to be used annually for seven years for research on climate-resilient agriculture, INR 18.50 billion (1,850 crore) would be required till 2030.	Strengthened and improved research-for-action capabilities in the state's agriculture system to adapt to climate change in a targeted manner.
ICAR, SAU, CAU, and KVKs, with PoCRA being the nodal governing body.	NICRA has the mandate to formulate agro-advisories, contingency plans, and identification of best-suited management practices. The NMSA has Climate Change and Sustainable Agriculture: Monitoring, Modelling, and Networking (CCSAMMN) as one of its major components, which could be instrumental in creating a decision-support system to counteract the effects of climate change. It is the objective of the CCSAMMN (NMSA) to provide information and knowledge on climate change through piloting climate change adaptation and mitigation projects.			
Department of Agriculture, KVKs, and SAU.	The <i>Soil Health Card</i> scheme under NMSA is meant to monitor the macronutrient status of the soil from farmers' landholdings. This scheme can be leveraged to further develop a database of village-level soil fertility status of micronutrients for horticulture and cash crops.			
SAU, animal husbandry universities, and veterinary universities.	NA			
ICAR, SAU, ATMA, and KVKs of all districts	The RKVY's objective is to understand risk mitigation better. The objective of ATMA is to train to improve data generation abilities. The objective of NICRA includes a strategic research component which looks at monitoring and evaluation.	350 million (35 crore)		Strengthened and improved capacity in the state's agriculture system to adapt to climate change
State Water Resource Department, State, District Resource Organisations, NS CSOs such as WOTR and KVKs	The policies of NICRA and RKVY, along with PoCRA, play a crucial role in setting up demonstration plots at KVKs, particularly for food grains and cash crops, to showcase success stories of micro-irrigation. These policies provide funding, technical support, and resources to establish these			

S. no.	Recommendations/Targets	Actions to be undertaken	Relevant regions
		3. Educate farmers via Krishi Vigyan Kendras (KVKs) regarding alterations in cropping calendars, the enhanced outcomes of improved seed varieties, and potential pests and pathogens in diverse climate change scenarios. 3.1 Seed Variety Awareness: • Inform farmers about the improved results associated with the use of advanced seed varieties. • Address potential pests and pathogens, providing insights for different climate change scenarios. 3.2 Promoting Practices: • Sensitise farmers on the advantages of adopting intercropping practices. • Encourage diversification by including hardy crops in farming practices. 3.3 Integrated Farming Systems: • Advocate for the adoption of integrated farming system approaches. • Highlight the benefits, including multiple yields, risk reduction, and increased incomes for farmers.	State-level focus but prioritise capacity building in the most vulnerable districts such as Ahmednagar, Solapur, Bid, Nandurbar, and Jalgaon.
		4. Build training modules that can be imparted through MANAGE to the extension systems to use the decision support systems to provide customised and timely information to the farmers.	State-level focus but prioritise capacity building for the villages in the most vulnerable districts such as Ahmednagar, Solapur, Bid, Nandurbar and Jalgaon
		5.1. Establish a mobile-driven disease surveillance infrastructure to detect and monitor emerging pests and pathogens in diverse agro-climatic zones for both crops and livestock. 5.2. Implement early warning systems to swiftly identify and respond to potential threats in collaboration with agriculture universities and research stations. 5.3. Develop customised advisories for farmers based on the surveillance data, fostering partnerships with agricultural institutions to enhance the quality and relevance of the information.	State-level

Participating government departments	Relevant policies	Proposed budget (INR)	Justification	Outcomes
	demonstration plots where micro-irrigation techniques such as drip irrigation or sprinkler systems are implemented. By highlighting the positive outcomes and benefits of micro-irrigation, these demonstration plots serve as practical examples for farmers, promoting wider adoption of this water-efficient technique and contributing to sustainable agriculture and improved crop yields.			
KVKs (National Mission on Sustainable Agriculture)	NICRA and RKVY can significantly contribute to educating farmers through KVKs on various aspects related to climate change. These initiatives can allocate resources and support KVKs to conduct awareness programmes, training sessions, and capacity-building activities focused on changes in cropping calendars, the benefits of improved seed varieties, and the potential risks associated with pests and pathogens under different climate change scenarios. By disseminating this knowledge, KVKs can empower farmers with the necessary information and tools to adapt their agricultural practices, make informed decisions about crop selection and planting timings, and effectively manage pests and diseases in the face of changing climatic conditions.			
Department of Agriculture, MANAGE, and KVKs	ATMA focuses on awareness and availability of resources on good farming practices through the dissemination of technological inputs. MANAGE specialises in training, consultancy, and research services on the same issues. PoCRA focuses on enhancing small landholding farmers' capacity for adaptation, institutions' and stakeholders' transformative potential, and stakeholders' absorptive appetite in selected value chains; this motive could be leveraged to build appropriate training modules.			
Department of Agriculture, India Meteorological Department (IMD), and SAU	<i>Crop Pest Surveillance and Advisory Project (CROPSAP) and Sub Mission on Plant Protection and Plant Quarantine (SMPPQ)</i> can use mobile technology for disease surveillance, collecting real-time data on pests and diseases from farmers in the field. This data can be analysed to detect emerging pests and diseases early, establishing an early warning system. By collaborating with agriculture universities and research stations, customised advisories can be developed based on regional challenges. Capacity-building programmes can educate stakeholders on pest management. Such collaborations can also support research and development for innovative solutions. Overall, these projects enable timely interventions, improved crop protection, and sustainable agriculture in different regions.			

S. no.	Recommendations/Targets	Actions to be undertaken	Relevant regions
		6. Encourage the adoption of a consortium-based approach to enhance the climate resilience of the agricultural system. Incorporate civil society in the innovation process, specifically by involving climate innovation centers within departments to engage with start-ups. Supplement this by promoting participatory action-research by actively involving innovative farmers. Leverage the innovation capabilities of these start-ups to advance the research-for-action agenda focused on achieving climate resilience.	State-level
3	Make interventions in a holistic manner to mainstream climate-resilient agricultural practices and improve water use efficiency and post-harvest management.	1. Increase the uptake of precision agriculture practices among farmers through the use of micronutrient analysis. 2. Develop a network of seed-saving communities through state and community participation to maintain and proliferate resistant varieties. 3. Spread the adoption of heat-tolerant and short-duration varieties of pulses and minor millets, alongside high-yielding varieties of millets. 3.b. Support in promoting alternative livelihood opportunities in the allied sector by also enhancing co-benefits such as; promote pisciculture, floriculture, cattle farming, improve cattle variety with heat-tolerant indigenous cattle breeds.	Horticulture districts: Ahmadnagar, Thane, Pune, Nashik, and Satara. State-level focus but prioritise interventions in rainfed regions with small landholding farmers such as Chandrapur, Nandurbar, Solapur, Gadchiroli, and Hingoli. State-level focus but prioritise intervention in districts with the highest annual maximum temperature, such as Sindhudurg, Ratnagiri, Kolhapur, Satara, and Sangli.

Participating government departments	Relevant policies	Proposed budget (INR)	Justification	Outcomes
Department of Agriculture and CSOs.	NA			
Department of Agriculture and KVKs of the relevant districts Integrate with National Mission for Sustainable Agriculture	RKVY has a mandate to fund initiatives that focus on soil health management and nutritional diversity by augmenting existing soil test laboratories with micro-nutrient testing facilities. NMSA (soil health management) focuses on establishing soil testing facilities by connecting macro and micro-nutrient management with soil fertility maps.	144 billion (14,400 crore)	As per PoCRA's budget expenditure, approximately INR 7.2 million (72 lakh) was disbursed on average per village for various development-related interventions on water, support to horticulture, post-harvest infrastructure development, and natural resource management as per farmers' needs and applications. Using these estimates, to cover 20,000 vulnerable villages by 2030 (out of a total of 40,000 villages), a budget of approximately INR 144 billion (14,400 crore) would be needed.	Improved climate adaptation of the farming community through a series of interventions in water use efficiency, post-harvest management, and climate-resilient agricultural practices in a holistic manner.
Department of Agriculture, ATMA and extension systems	The policy <i>Seeds Mini Kits Distribution</i> under NFSM and ATMA can be effectively leveraged to organise funds and resources to develop a network of seed-saving communities through state and community participation. These initiatives can support the establishment and maintenance of seed banks and encourage the preservation and proliferation of resistant crop varieties. By providing financial support and technical assistance, these policies enable the formation of seed-saving communities that actively engage in seed conservation, multiplication, and distribution, ensuring the availability of resilient seed varieties and promoting sustainable agriculture practices at the local level.			
ICAR, SAU, CAU, and KVKs	PoCRA and <i>Rashtriya Gokul Mission</i> can be effectively leveraged to disseminate heat-tolerant and short-duration varieties of pulses and minor millets, as well as high-yielding millet varieties along with indigenous cattle breeds which are known to be heat tolerant. These initiatives can provide the necessary funding, technical support, and resources to promote the cultivation and adoption of climate-resilient crop varieties and the conservation and breeding of indigenous cattle breeds. By organising awareness campaigns, training programmes, and distribution networks, these projects enable farmers to access and benefit from heat-tolerant crop varieties, ensure food security, and contribute to the conservation and improvement of indigenous cattle breeds, supporting sustainable livestock farming practices.			

S. no.	Recommendations/Targets	Actions to be undertaken	Relevant regions
		4. Broaden the network of farmers with access to climate services and weather advisories. This information could be made available at the Gram Panchayat level. Promote the establishment of community resource persons, empowering farmers to take the lead in forming networks that act as a bridge between the government's extension system and the larger farming community.	Most vulnerable districts with: Ahmadnagar, Solapur, Bid, Nandurbar, and Jalgaon.
		5. Introduce Group Micro Irrigation (GMI) initiatives in collaboration with smallholder farmers to expand irrigation coverage without compromising water security. Enhance subsidy delivery mechanisms to facilitate increased access to micro-irrigation for smallholder farmers.	Drought-prone regions: Dhule, Nashik, Aurangabad, Ahmednagar, Pune, Satara, Solapur, Sangli
		6.1 Establish agricultural processing clusters in districts susceptible to vulnerabilities, particularly those cultivating major and minor millets. 6.2 Conduct training programs aimed at fostering local entrepreneurship and forming self-help groups (SHGs).	Millet growing districts with: Ahmadnagar, Solapur, Bid, Jalgaon, Sangli, and Pune.
		7. Revitalise defunct cold storage units at the block or village level to enhance local storage capacity. Further, establish new government-owned cold storage facilities (especially for perishables and fruit crops) at the block level in a 50–50 public-private partnership model.	Most vulnerable horticulture-heavy districts with: Ahmadnagar, Jalgaon, Thane, Pune, Satara, Ratnagiri, and Raigad.

Participating government departments	Relevant policies	Proposed budget (INR)	Justification	Outcomes
Department of Agriculture, extension systems and ATMA.	RKVY-RAFTAAR can be effectively leveraged to expand the network of farmers with access to climate services and weather advisories while promoting the creation of community resource persons and championing farmers to lead such networks and bridge the gap between the government's extension system and the farming community. Under RKVY-RAFTAAR, funds and resources can be allocated to establish and strengthen the dissemination of climate services and weather advisories through various channels, including mobile applications, SMS services, and community meetings. Additionally, the policy can support training and capacity-building programmes to identify and empower community resource persons and champion farmers who possess knowledge and expertise in climate-resilient agriculture. These individuals can serve as intermediaries, effectively connecting the government's extension system with the broader farming community, disseminating valuable information, and facilitating the adoption of climate-resilient practices at the grassroots level.			
State Water Resource Department, State/ District Resource Organisations, CSOs like WOTR	The policies <i>Pradhan Mantri Krishi Sinchayee Yojana</i> (PMKSY), <i>Per Drop More Crop</i> (Micro Irrigation), and Chief Minister Sustainable Agriculture Irrigation Scheme can be leveraged to implement Group Micro Irrigation (GMI) with smallholder farmers. By providing financial support, raising awareness, strengthening Farmer Producer Organisations (FPOs), promoting sustainable water management practices, and establishing monitoring mechanisms, these policies can enable the expansion of irrigation coverage while ensuring water security and enhancing agricultural productivity for smallholder farmers.			
Department of Agriculture and State Agriculture Marketing Board	RKVY-RAFTAAR <i>PM Formalisation of Micro Food Processing Enterprises</i> can be implemented to encourage setting up food and agro-processing units by subsidising potential owners.			
Department of Agriculture, State Agriculture Marketing Board, and State Horticulture Board	Under MIDH, cold storage (long-term storage and distribution hubs) up to 5,000 MT capacity will be promoted under NHM/ HMNEH sub-schemes. Hubs with a capacity above 5,000 MT up to 10,000 MT will be promoted under the NHB sub-scheme. Under the scheme <i>Formation and Promotion of 10,000 Farmer Producer Organisations</i> (FPOs), one of the objectives is to create 'producer clusters' where a particular crop is produced. This can enable efficient marketing and economies of scale.			

S. no.	Recommendations/Targets	Actions to be undertaken	Relevant regions
		8. Facilitate market linkages for registered Farmer Producer Organisations (FPOs), particularly with urban and export markets for organic produce. Foster connections between FPOs and the poultry feed industry and the health food manufacturers, specifically targeting millet products.	State-level focus but prioritise intervention in regions with the least adaptive capacity in terms of markets and SHGs, such as Aurangabad, Nanded, Osmanabad, Pune, and Chandrapur.
4	Increase the coverage of crop insurance programmes to small and marginal farmers in the most vulnerable districts in the state.	1. Bring small and marginal farmers under crop insurance coverage in the most vulnerable districts.	Most vulnerable districts such as Ahmadnagar, Solapur, Bid, Nandurbar, and Jalgaon.
5	Provide hand-holding support and build capacities of the tribal communities to improve the agri-allied-based livelihood opportunities in the region to enhance their income and build their resilience in overcoming future challenges caused due to climate.	1. Offer targeted assistance to farmers by supporting commercially viable crops. • Focus on tribal-populated regions like Nandurbar (69%) and Nashik (25%) for promoting commercial cultivation. • Initiate Phase 1 support for the commercial cultivation of onion and garlic, benefiting 1,000 farmers. Expand the program in Phase 2 to encompass 2,000 farmers through ICAR. 2. Provide 150 solar cold storages to farmers from Nashik, Vidarbha, and Marathwada divisions (there is >6,000 deployment potential of solar cold storage in the state). 3. Provide 5,000 (1–2 HP), 3,000 (3–5 HP) solar micro-pumps to tribal farmers of an entire district under PM-KUSUM/ <i>Mukhyamantri Saur Krushi Pump Yojana</i> (there is >1,50,000 deployment potential of solar micro-pumps in the state). 4. Establish and strengthen 360 tribal cooperatives (in each Talukas) for marketing, grading, and packing products and sensitising cooperatives on climate-proofing production and marketing via TRIFED, KVKs.	Entire state with a special focus on Nashik, Vidarbha, and Marathwada region.

Participating government departments	Relevant policies	Proposed budget (INR)	Justification	Outcomes
Department of Agriculture and State Agriculture Marketing Board	SMART and <i>Formation and Promotion of 10,000 Farmer Producer Organisations</i> (FPOs) have the mandate to enhance market linkages to FPO-led initiatives for up to five years of FPO formation.			
Department of Agriculture, District KVKs, District Central Cooperative Bank, Bank of Maharashtra, and insurance companies.	PMFBY and RWBCIS provide the mechanism for crop insurance.	10.99 billion (1,099 crore)	As per the latest PMFBY statistics from Kharif 2022 season, the state paid an average insurance premium of INR 2,165 per farmer for approximately 41 lakh small and marginal farmers. To cover the remaining 43 lakh small and marginal farmers in the state (considering their total population of 92 lakh according to the 2015–16 Agriculture Census), an additional INR 10.99 billion (1,099 crores) will be needed from the state. The state government can prioritise coverage in vulnerable districts.	Improved resilience and adaptive capacity of the farming community.
Department of Agriculture.	PoCRA can be leveraged as it aims to make agriculture profitable for small farmers.	INR 50 million (5 crore)	The total support cost of farmers for cultivating onion and garlic, including training, capacity building, hand-holding support for the first crop, and the cost of trainers for Phase 1 and Phase 2, is approximately INR 20 million (2 crore).	Improved agricultural production, which in turn improves the livelihoods of the local tribal community.
Department of Agriculture, and Maharashtra Energy Development Agency.		90 million (9 crore)	The provision of 150 cold storage is approximately INR 80-90 million (8–9 crore) (at 30% capital subsidy).	
Integration National Solar Mission.				
Department of Agriculture and Maharashtra Energy Development Agency.	<i>Mukhyamantri Saur Krushi Pump Yojana</i> / PM KUSUM.	450 million (45 crore)	The provision of 8,000 solar pumps for tribals in Nashik under PM KUSUM/ <i>Maharashtra Saur Krishi Pump Yojana</i> will cost approximately INR 450 million (45 crore) (at 30% capital subsidy).	
Integrate with existing scheme; National Solar Mission.				
Department of Agriculture and Department of Tribal Development.	PoCRA can enhance climate resilience for farming systems and thereby climate-proof production.	INR 50 million (5 crore)	Capacity building of tribal cooperatives includes training, knowledge dissemination, and technological interventions costing approximately INR 20 million (2 crore).	

S. no.	Recommendations/Targets	Actions to be undertaken	Relevant regions
6	Support and strengthen the livelihood activities of the tribals residing near the forest peripheral areas and dependent on non-timber forest products (NTFPs) and other tribal forest communities to overcome climate change challenges and uplift their livelihoods and diversify them.	Establish or reinforce the capacities of 1,000 Self-Help Groups (SHGs), producer companies, and cooperatives to facilitate market access for tribal women involved in processing and selling commodities derived from Non-Timber Forest Produce (NTFPs). Utilise the SHABRI Adivasi Scheme, Krishi Vigyan Kendras (KVKs), and SRLM-Umeed to play a crucial role in providing training, building capacities, and financing for SHGs and Farmers' Producer Organizations (FPOs). 2. Promote the deployment of 500 small horticulture processor units (50 L) to strengthen the collection and storage of NTFPs for an initial phase of 5 years. 3. Provision of an affordable and sustainable solar drying device of 100 kg capacity that adds value to the marketing and collection of NTFP. About 300 units of dryers could be provided. 4. Provide 6,000 units of solar animal-repellent light and sound systems to 2,000 farmers from forested regions (set of 3 units to 2,000 farmers; 1 acre of land requires 3 units).	All tribal districts with a special focus on Gadchiroli, Chandrapur, Gondia, Yavatmal, and Nashik.

Source: Authors' Analysis

The total overall financial outlay needed for implementing the recommendations for agriculture and allied sector is INR 37099.17 crore.

Participating government departments	Relevant policies	Proposed budget (INR)	Justification	Outcomes
Department of Tribal Development in collaboration with ICAR, Department of Agriculture, and SRLM- Umeed, Ministry of Rural Development.	PoCRA can be utilised as the project aims to create and develop women's self-help groups.	50 million (5 crore)	For institutionalising 1,000 SHGs and cooperatives, the cost comprises awareness of new technologies, value addition, marketing, and entrepreneurial skills. Along with the cost of trainers, the total cost is estimated at INR 20 million (2 crore).	Improved livelihood opportunities for forest-dependent tribal communities and forest conservation activities leading to restoration of biodiversity.
Department of Agriculture and Maharashtra Energy Development Agency		30 million (3 crore)	For the initial phase, 500 multi-purpose food processors are to be provided. The cost of one unit (50 L) is INR 150 thousand (1.5 lakh) and a total cost of approximately INR 30 million (3 crore) (at 30% capital subsidy)	
Department of Agriculture and Maharashtra Energy Development Agency		20 million (2 crore)	The approximate cost of a solar drying device of 100 kg capacity is INR 150 thousand (1.5 lakhs). For the 300 units in the initial phase, the total cost is about INR 20 million (2 crore) (at 30% capital subsidy).	
Department of Agriculture and Maharashtra Energy Development Agency.		30 million (3 crore)	1 unit costs approximately INR 10,000–15,000. Total cost would be INR 30 million (3 crore) (at 30% capital subsidy)	

Agriculture Export Policy

Objective: The policy focuses on promoting agricultural exports and export-oriented agriculture production. The vision of the policy is to raise the farmers' income and help India harness its export potential.

Performance of the policy: Maharashtra is one of the leading states in the country with respect to the export of agricultural produce. It ranks first in producing fruits such as grapes and bananas and is among the top states producing pulses, cereals, oilseeds, dairy, fisheries, and other animal products. With more integrated efforts, the state has the potential to become the export hub of agricultural produce. Therefore, based on the national *Agriculture Export Policy*, the *Maharashtra State Agriculture Export Policy* was developed to help the state in realising its potential (MSAMB 2019).

Mission for Integrated Development of Horticulture (MIDH)

Objective: This scheme promotes the holistic growth of horticulture, including fruits, mushrooms, flowers, spices, tuber crops, vegetables, coconut, aromatic plants, cocoa, and bamboo.

Performance of the policy: According to NITI Aayog, as a result of the mission, there has been an increase in productivity, and gross cropped area under horticulture crops, which has also helped increase farmers' income. The primary beneficiaries (approximately 86%) of the scheme are small and marginal farmers (NITI Aayog 2020). Under the MIDH, provisions have been made for the construction of green and shade net houses and for selecting a variety of construction materials for their construction. To minimise the cost of construction, locally available materials have been given preference. According to the Annual Action Plan of Maharashtra (2022–23) for MIDH, beneficiaries have been provided 50 per cent assistance towards the construction of shade nets limited to 4,000 sq m (with a maximum permissible cost limited to INR 710 per sq m). Similar assistance has also been provided to the beneficiaries for cultivating high-value vegetables in poly houses (maximum permissible cost limited to INR 140 per sq m) and cultivation of orchids and anthurium in poly houses or shade nets (with a maximum permissible cost limited to INR 700 per sq m) (Department of Agriculture and Farmers' Welfare 2023).

The overall performance of the policy within Maharashtra has been impressive. The expenditure-to-target ratio of Maharashtra is more than one (NITI Aayog 2020). Further, according to an impact evaluation report, the state witnessed the highest increase in average household income INR 331 thousand (3.31 lakh) in 2017 from INR 126 thousand (1.26 lakh in 2016)) under the National Horticulture component of MIDH (Manjunatha et al. 2017) for all the households that are cultivating fruits, vegetables, flowers, plantation crops, spices, and medicinal plants.

National Mission for Sustainable Agriculture (NMSA)

Objective: NMSA is one of the eight missions under NAPCC through which it aims to make Indian agriculture

more sustainable, productive, and resilient to climate change. The scheme has three major components:

- a. Rainfed Area Development (RAD)
- b. Soil Health Management (SHM)
- c. Climate Change and Sustainable Agriculture: Monitoring, Modelling, and Networking (CCSAMMN).

Performance of the policy: The RAD component of the mission focuses even on horticulture, agroforestry activities, poultry, dairy and fisheries. Under this component, one of the strategies is to support each farm family up to a 2 Ha farm size and offer financial assistance limited to INR 100 thousand (1 lakh). But the construction and renovation of infrastructure such as farm ponds and poly houses are not constricted by these limits.

Paramparagat Krishi Vikas Yojana (PKVY)

Objective: The scheme aims to support and further organic farming in the country to produce agricultural products devoid of chemicals and pesticides.

Performance of the policy: This scheme aligns with the need to support sustainable growth and is very relevant for the development of the agriculture sector. Since the beneficiaries do not purchase fertilisers and pesticides, it has resulted in a reduction in the cost of cultivation (10–20%) and an increase in net returns (20–50%) (Reddy 2017a). Maharashtra is one of the top three states with respect to the total allocation of funds under PKVY (NITI Aayog 2020). For the first three-year period, Maharashtra was allocated the highest budget of INR 844.3 million (84.43 crore) for 932 clusters (Reddy 2017a). Exposure visits and training programmes on organic production practices have been effective in the state due to the involvement of ATMs in the implementation of PKVY.

Pradhan Mantri Fasal Bima Yojana (PMFBY) and Restructured Weather-Based Crop Insurance Scheme (RWBCIS)

Objective: PMFBY provides financial assistance to farmers that suffer crop damage or loss due to unforeseeable circumstances. RWBCIS aims to reduce the burden of financial loss on (insured) farmers resulting from low crop yield due to adverse weather conditions.

Performance of the policy: According to the Maharashtra state officials, the number of perils (in agriculture) included under PMFBY is much more than in previous schemes. For example, it covers both pre-sowing and post-harvest losses. This broad risk coverage has benefitted several farmers (Shroff and Phadke 2018).

Rashtriya Krishi Vikas Yojana—Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (RKVY-RAFTAAR)

Objective: With various measures directed towards strengthening farmers' efforts, encouraging agri-business entrepreneurship, and risk mitigation, RKVY-RAFTAAR aims to make farming a remunerative activity. Among the various kinds of activities that can be funded under RKVY-

RAFTAAR, shade net and poly house infrastructure can be constructed for protected cultivation.

Performance of the policy: RKVY-RAFTAAR's primary beneficiaries across all the states are small and marginal farmers. It also supports infrastructure and value chain development to support animal husbandry, milk processing, and fisheries. In the case of Maharashtra, since 2017–18, the scheme has been focusing on rural and post-harvest infrastructure development (this component was missing earlier) and is in line with the State Agriculture Plan (NITI Aayog 2020).

National Food Security Mission (NFSM)

Objective: NFSM aims to increase the production of rice, wheat, pulses, coarse cereals, and nutri-cereals by covering more area under the said crops and augmenting their productivity.

Performance of the policy: According to a 2018 study on the effect of NFSM on pulses in Maharashtra, it was observed that there was an increase in the cultivated area under rice, along with production and productivity. The reason for this could be attributed to the various facilities made available under the mission, such as assistance on integrated nutrient and pest management, availability of an improved variety of seeds, and various equipment such as sprinklers and seed drills. Further, compared to other programmes, NFSM focuses much more on building capacity, planning, and monitoring (Shah 2018).

Soil Health Card Scheme (SHC)

Objective: The scheme is being implemented in states across India to conduct periodic testing of soil and recommend the management of nutrients accordingly.

Performance of the policy: According to a report by the National Centre for Management of Agricultural Extension (MANAGE), Maharashtra is among those states where the scheme is progressing better (Reddy 2017b).

Sub Mission on Agricultural Mechanisation (SMAM)

Objective: SMAM aims to promote agricultural mechanisation, especially focusing on small and marginal farmers and regions with low availability of farm labour.

Performance of the policy: SMAM has contributed to a 30 per cent decrease in labour requirements and reduced diesel consumption and fertiliser requirements by 22.4 per cent and 12.7 per cent, respectively. It also contributed to an increase in productivity by 17.9 per cent. Within the scheme, a higher percentage of subsidy has been allocated for women and SC/ST beneficiaries (NITI Aayog 2020). However, despite the progress in financial and physical achievements of SMAM, the adoption of technology can be improved.

Sub Mission on Plant Protection and Plant Quarantine (SMPPQ)

Objective: SMPPQ aims to minimise loss of crop yield and quality owing to factors such as pests, diseases,

and rodents and prevent the spread of alien species. The objectives of SMPPQ are also very similar to that of other prevailing schemes such as PKVY (NITI Aayog 2020).

Performance of the policy: One of the major achievements of SMPPQ has been the fixation of the maximum residue limit on spices. This will help in ensuring food safety and acceptable pesticide levels, especially with regard to international trade.

Agricultural Technology Management Agency (ATMA)

Objective: The aim of the *Support to State Extension Programmes for Extension Reforms* (or ATMA scheme) is to foster decentralised farmer-friendly extension systems in the country. It provides support to the efforts of the state government. Through various extension activities (such as training, demonstrations, and kisan mela), the scheme focuses on the availability of good agricultural practices and technologies to the farmers (PIB 2021c).

Performance of the policy: At the district level, ATMA synergises and converges with the agencies responsible for the development of agriculture in the district, such as line departments, NGOs, and research organisations.

Formation and Promotion of 10,000 Farmer Producer Organisations (FPOs)

Objective: This scheme aims to develop FPOs in production clusters at places where agriculture or horticulture produce is grown or cultivated to make value chains efficient and provide improved access to the market for their members.

Performance of the policy: Under this scheme, there is a provision to provide each FPO with financial assistance of up to INR 1.8 million (18 lakh) for three years. There are also provisions for matching equity grants up to INR 2,000 per farmer who is a member of an FPO (which has a limit of INR 1.5 million (15 lakh) per FPO). The FPOs also have access to one credit guarantee facility in the form of a project loan (up to 20 million (INR 2 crore)) from an eligible lending institution. An evaluation of the *Maharashtra Agricultural Competitiveness Project* (MCAP) by PricewaterhouseCoopers (PwC) shows that price realisation by members increased by 22 per cent as a result of sales through Farmer Producer Companies (FPCs). Moreover, when compared to other channels, the cost of marketing was 31 per cent lower (PIB 2021d).

National Beekeeping and Honey Mission (NBHM)

Objective: The aim of this programme is to promote the development of scientific beekeeping and produce quality honey and other beehive products such as beeswax, bee pollen, and comb honey.

Performance of the policy: Technological interventions can contribute to the scaling up of the sector and promote

entrepreneurship. By scaling up beekeeping, NBHM also aims to help in doubling farmers' income, employment generation, ensuring food security, bee conservation, and enhancing pollination and crop productivity (NITI Aayog 2020).

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)

Objective: PMKSY aims to increase the area under irrigation, reduce water wastage by enhancing efficiency in on-farm utilisation, and promote the adoption of water-saving technologies and water conservation practices. Launched in 2015, PMKSY integrated micro-irrigation (such as drip and sprinkler irrigation systems) as an essential component of the scheme (NITI Aayog 2020).

Performance of the policy: According to an evaluation by the Indian Council of Food and Agriculture, the adoption of micro-irrigation systems resulted in a 24–70.5 per cent (with an average of 46.8%) increase in income in various states (NITI Aayog 2020). A significant share of funds under PMKSY are allocated to Maharashtra. Of the 99 irrigation projects under PMKSY, 26 are in Maharashtra (Mahajan 2019). It plays a crucial role in furthering micro-irrigation in the state (Pokale and Divekar 2019).

State of Maharashtra's Agri-business Rural Transformation Project (SMART)

Objective: By focusing on small and marginal farmers and agri-entrepreneurs, this project aims to develop inclusive and competitive value chains.

Performance of the policy: Under this project, producers and enterprises will be given access to new and organised markets, thereby facilitating market-driven transition and enhancing the role of the private sector (in production, processing etc.). Further, risk mitigation measures will be strengthened along with the development of timely access to market updates and production trends and producers' access to instruments that can facilitate financing and hedging. The project also aims to contribute to fulfilling the state's larger vision of "agriculture-based rural transformation" (PIB 2020).

Project on Climate Resilient Agriculture (PoCRA) - Nanaji Deshmukh Krushi Sanjivani Prakalp

Objective: In order to enhance the climate resilience of agriculture in the state, the Government of Maharashtra conceptualised the Project on Climate Resilient Agriculture (PoCRA) along with the World Bank for approximately 5000 villages spread across the 15 districts (Government of Maharashtra and The World Bank n.d.). The project focuses on improving the adaptive capacity of smallholder farmers, along with strengthening the transformative potential of institutions and stakeholders and developing the absorptive capacity of stakeholders in the chosen value chains (Project Management Unit 2021). The project has four components through which it is implementing measures such as the development of mini-watershed plans, promotion of farmer field schools

to facilitate the transfer of climate resilient technology, protected cultivation using infrastructure such as shade-nets and poly houses, micro-irrigation, construction of water harvesting structures etc.

Performance of the Policy: As per the mid-term review progress report (from May 2018 to September 2021), the project has been able to reach out directly to one million farmers. For instance, under the protected cultivation initiative, a grant of INR 1.12 billion (112 crore) has benefited 1237 farmers resulting in an increase of 40–80 per cent in their income. To improve saline and sodic-affected villages, 3781 farmers benefited from a grant of INR 373.1 million (37.31 crore). Major activities under this intervention included farm ponds, sprinkler irrigation, water pumps etc. It has supported more than 300,000 farmers with climate-resilient investments on their farms. In order to increase the profitability of the farming systems, more than 6980 FPOs are being supported to undertake different agri-business activities. Moreover, to further water security in the state, water conservation measures are also being focused on. Over the course of three and a half years, the project has supported various stakeholders with the financial support of INR 15.81 billion (1581.47 crore) through direct benefit transfer (Project Management Unit 2021).

Magel Tyala Shet Tale Yojana (Farm Pond on Demand)

Objective: In order to provide farmers with sustainable and secure irrigation facilities, the Government of Maharashtra launched the *Magel Tyala Shet Tale Yojana* (Farm Pond on Demand) in 2016.

Performance of the scheme: This initiative has assisted farmers in dealing with dry spells by capturing run-off water on their own farms, thereby contributing to enhancing overall productivity. Subsidies are provided to farmers based on the dimensions of the pond. Until December 2019, nearly 137,447 farm ponds were completed in the state (Planning Department 2020).

Chief Minister Sustainable Agriculture Irrigation Scheme

Objective: The scheme is being implemented in 251 talukas of drought-prone areas and naxal-affected and suicide-prone districts within the state. The aim is to provide farmers with sustainable irrigation facilities and help in doubling their income.

Performance of the scheme: For individual farms, the farmers are provided with 50 per cent of the actual cost of plastic and other materials or INR 75,000 in the form of subsidies (whichever is less) (Maharashtra Times 2019). Various activities such as micro-irrigation, the plastic lining of individual farms, and the construction of shade net houses and greenhouses are included in the scheme (Directorate of Economics and Statistics 2022).

5.2 Climate change impacts on water resources and adaptation strategies

5.2.1 Introduction

Maharashtra has a tropical climate. The state is divided into four meteorological subdivisions, namely Konkan, Vidarbha, central Maharashtra, and Marathwada, in the order of decreasing rainfall (Figure 5.2.1). Between 1901–2017, the mean average annual rainfall for Konkan was 2,988 mm, Vidarbha 1,094 mm, Central Maharashtra 881 mm, and Marathwada 792 mm. Overall, the mean average annual rainfall in the state was 1,360 mm.

The Sahyadri hill ranges running in the north-south direction parallel to the Arabian Sea divide the state into two parts — Konkan on the western side, which receives heavy rainfall, and the Deccan plateau (Desh) on the eastern side, which is a rain shadow area. The rivers originating from Sahyadri and flowing east have abundant water, while those flowing west comparatively have less water.

The maximum temperature recorded in the history of the state is 49.8°C (Government of Maharashtra 2018). March, April, and May experience very high temperatures. The minimum recorded temperature is 1°C. Low temperatures are experienced in December and January. The average daily sunshine is 7 hours, and the annual average humidity is about 67 per cent. The average maximum wind velocity reaches up to 66.2 km ph, and the annual average evaporation varies from 1,437 mm to 2,159 mm.

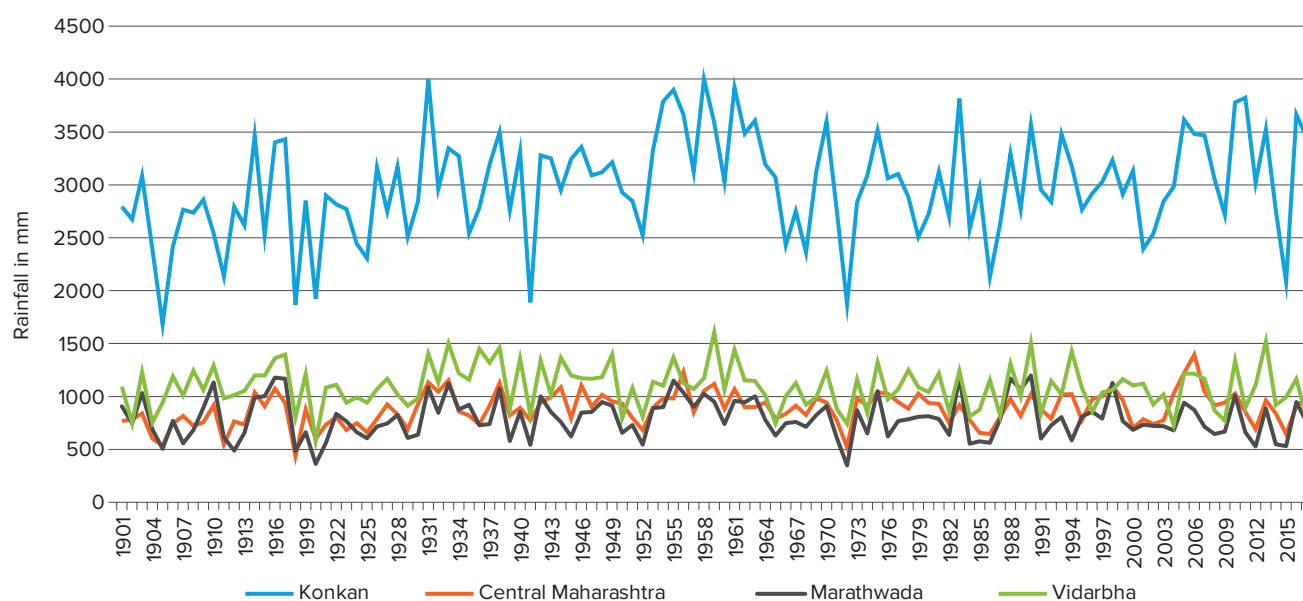
The state has a geographical area of about 30.8 million ha. About 73 per cent of the area has black soil, yellowish-brown to reddish soil, and lateritic soil. The rest of the area is covered by alluvial soil and grey-pinkish soil. About 66 per cent of the state's land is arable, and the soils are suitable for growing all types of crops, including cereals, pulses, oil seeds, vegetables, fruits, cotton, and sugarcane (Government of Maharashtra 2018). In 2019–20, the cropped area in the state was about 19 million ha, out of which only 23.6 per cent was irrigated; the overall cropping intensity was about 114 per cent (Directorate of Economics and Statistics (DES) 2019).

5.2.2 Current status of water resources

The geographical area of the state falls under six different river basins — Godavari, Tapi, Krishna, Narmada, Mahanadi, and west-flowing rivers (Figure 5.2.2). Out of the total 30.8 million ha, 49 per cent is in Godavari, 22 per cent in Krishna, 17 per cent in Tapi, 10 per cent in west-flowing rivers, and only 2 per cent in Narmada and Mahanadi river basins. Except for the west-flowing rivers, all others are inter-state river basins.

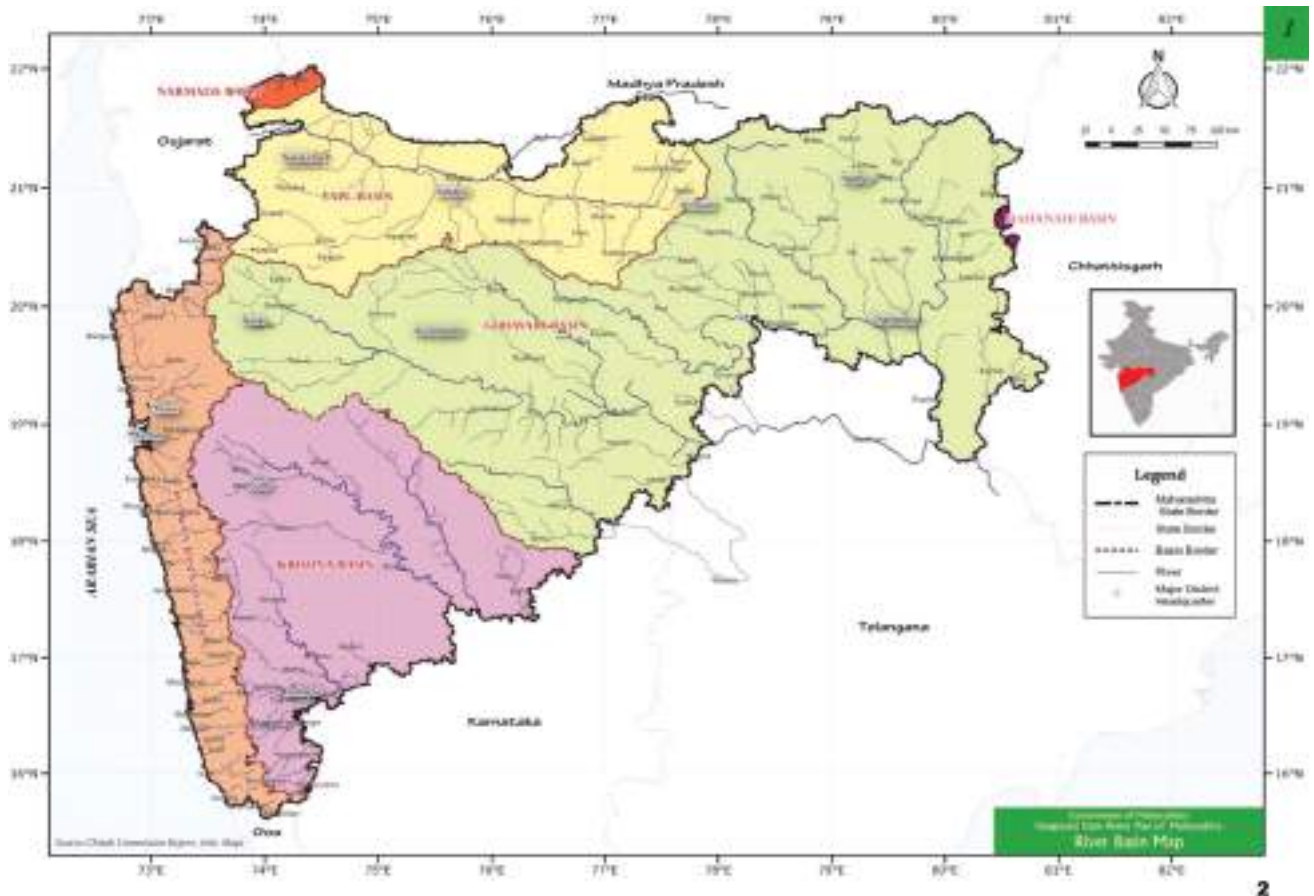
Under the hydrology project, a well-spread network of hydro-meteorological stations has been set up in Maharashtra. This includes 641 standard rain gauges, 340 autographic rain gauges, 153 full climatological stations, and 264 gauge discharge sites (Government of Maharashtra 2018). Additionally, there are groundwater monitoring stations. A gauging station, site on a stream, canal, lake, or reservoir where systematic observations of gauge height (water level) or discharge are obtained.

Figure 5.2.1 Rainfall variability in Maharashtra



Source: Authors' analysis using IMD data set

Figure 5.2.2 River basins in Maharashtra



Source: Government of Maharashtra 2018a

Approximately 75 per cent of dependable annual water availability in Maharashtra, assessed using the 2019 estimates of the Central Water Commission (CWC) for different river basins, is about 135.5 billion cu m. The estimated district-wise per capita annual water availability is presented in Figure 5.2.3. Accordingly, the highest per capita annual water availability is in Sindhudurg, and the lowest is in Mumbai suburban district. Further, of the 35 districts in the state, 11 districts are water-stressed, which is defined as having less than 1,700 cu m of water availability per capita per annum, and 18 districts are water-scarce, defined as having less than 1,000 cu m of water availability per capita per annum.

Further, Maharashtra experiences seasonal groundwater scarcity, especially in Vidarbha and Marathwada regions (Kumar, Bassi, and Kumar 2022). The main reason is that the groundwater in Maharashtra is confined to hard rock aquifers that have limited storage and low-yield potential (Figure 5.2.4).

5.2.3 Water risk assessment

A 2013 study found that over 100 years (1901–2000), annual rainfall has increased significantly in the districts of the Konkan region and southern and western parts of

the state (Guhathakurta and Saji 2013). The state receives most of its rainfall over 2–3 months during the monsoon. However, in the Marathwada and Vidarbha regions, there is a significant decrease in the quantum of annual rainfall, but with better distribution across the monsoon months.

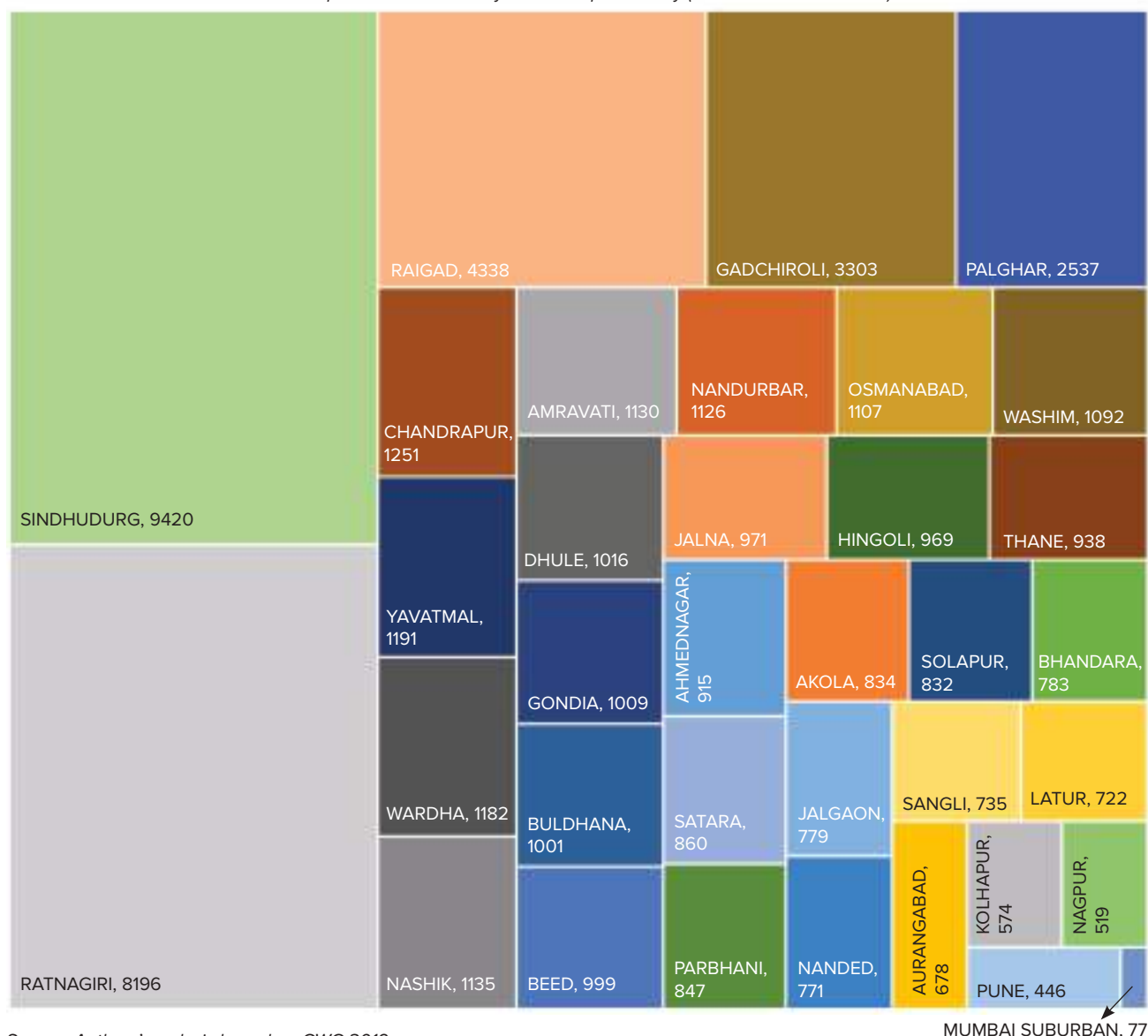
The rainfall extremes have a substantial impact on water availability, especially during the dry rainfall years. A water risk index (WRI) was developed and computed at the district level to evaluate the reliability of the water system to the adverse impacts of climate stresses and shocks. It was based on the IPCC's Fifth Assessment Report (AR5) published in 2014, which states that risk is a function of three components: (i) 'hazard' that are climate-related physical events and have the potential to damage the systems (natural and built water systems in the case of WRI); (ii) 'exposure' of the system and humans to climate variation; and (iii) 'vulnerability' of the systems, institutions, and humans to adjust to potential damage. It can be represented as:

$$\text{Risk} = (\text{Hazard}) \times (\text{Exposure}) \times (\text{Vulnerability})$$

A broad range of indicators for each of the three risk components was selected based on a literature review and discussion with the stakeholders, which included the water-related departments of the Government of

Figure 5.2.3 Variability in annual renewable water resource availability in Maharashtra

Per capita water availability at 75% dependability (cu m/annum in 2019-20)



Source: Authors' analysis based on CWC 2019

Maharashtra. The indicators, their data sources, and their impact on various components of the WRI are presented in Table 5.2.1. The majority of indicators have a direct correlation with the hazard and vulnerability components of risk, i.e., the higher the value of the indicator, the higher the value of the component. On the other hand, most of the vulnerability indicators are inversely correlated, i.e., the higher the value of the indicator, the lower the value of that component. For instance, a district with a high per capita gross storage capacity of reservoirs will be less vulnerable to the impacts of floods or drought; during the wet years, they will absorb the flood waters reducing the flood impact, and during the dry years, they will harvest and store the limited rainwater which can be used during the non-monsoon months to ensure water supply.

The data for indicators, obtained from various sources, ranged from geospatial raster datasets to census-derived

values. The geospatial datasets were aggregated at the district level using statistical methods to maintain consistency. Thus, a uniform district-wise raster data sheet was prepared for each of the components. As many of the indicators were based on the 2011 census data, the Palghar district was excluded from the analysis, and a total of 35 districts were considered for risk assessment.

The indicators were normalised to bring them to a common scale and to make them unit-free using the min-max normalisation technique. After normalisation, the indicators were scored by classifying them into ten classes based on equal interval distribution. The scores obtained were reclassified for indicators that were inversely related to the component of risk. After obtaining the scores, they were aggregated into the three sub-indices of hazard, exposure, and vulnerability. In addition, the obtained scores were multiplied by the weights for each indicator, which were

Figure 5.2.4 Distribution of aquifer types in Maharashtra



Source: Central Ground Water Board (CGWB) 2021

Table 5.2.1 Indicators chosen for each component of risk

Component	Indicator	Data source	Impact on WRI
Historic Hazards (1971–2020)	Annual rainfall variability	CEEW analysis based on IMD 25km resolution data (1971–2020)	Direct
	Number of deficient rainfall years	CEEW analysis based on IMD 25km resolution data (1971–2020)	Direct
	Number of excess rainfall years	CEEW analysis based on IMD 25km resolution data (1971–2020)	Direct
Current hazards (changes in 2011–2020 compared to baseline of 1971–2010)	Change in frequency of hot days	CEEW analysis based on IMD 25km resolution data (1971–2020)	Direct
	Change in frequency of dry days	CEEW analysis based on IMD 25km resolution data (1971–2020)	Direct
	Change in frequency of heavy rainfall days	CEEW analysis based on IMD 25km resolution data (1971–2020)	Direct
Exposure	Percentage of built-up area to the total geographic area	ESRI (2020). Land use land cover data at 10m resolution	Direct
	Percentage of the area under water bodies to the total geographical area	ESRI (2020). Land use land cover data at 10m resolution	Inverse
	Percentage of the below-poverty line (BPL) population	Economic Survey of Maharashtra 2011–12 (DES 2012)	Direct

Component	Indicator	Data source	Impact on WRI
	Percentage of the gross irrigated area to the gross cropped area	Agriculture Census 2015 (Department of Agriculture 2020b)	Direct
	Population density	Economic Survey of Maharashtra 2011–12 (DES 2012)	Direct
Vulnerability Adaptive Capacity	Ratio of annual groundwater extraction to annual net groundwater recharge (stage of groundwater extraction)	Dynamic Ground Water Resources of India, 2020 (Central Ground Water Board 2021)	Direct
	Surface water monitoring stations per 1,000 sq km	India Water Resources Information System (India-WRIS)	Inverse
	IMD monitoring stations per 1,000 sq km	Regional Meteorological Centre, Mumbai	Inverse
	Percentage of households with access to improved water resources within the premises	Processed and compiled from micro data catalogue, NSSO Survey Round 76	Inverse
	Percentage of households with improved sanitary facilities	Processed and compiled from micro data catalogue, NSSO Survey Round 76	Inverse
	Updated District Disaster Management Plan (DDMP)	CEEW analysis based on the compilation of DDMPs reviewed (2020)	Inverse
	Per capita gross storage capacity of reservoirs	Water audit of irrigation projects in Maharashtra (2019–20) (Government of Maharashtra 2020)	Inverse
	Surface water quality index	Water Quality Status of Maharashtra 2020–21 (The Energy and Resources Institute (TERI) 2021)	Inverse
	Groundwater quality index	Water Quality Status of Maharashtra 2020–21 (TERI 2021)	Inverse

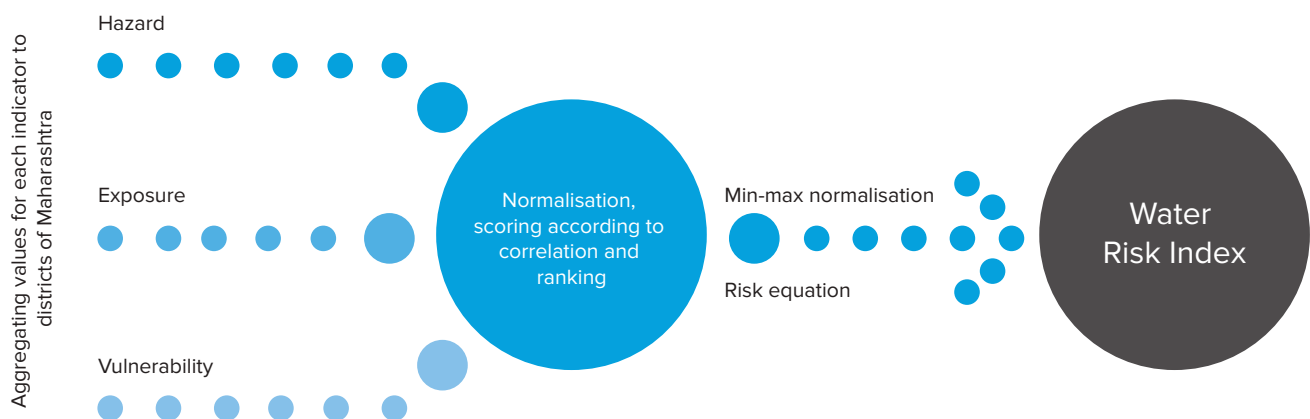
Source: Authors' compilation

assigned through a literature review and consultations with officials from relevant state government departments and experts. Equal weightage was considered for indicators for which supporting literature was unavailable, or weightage could not be assigned during the consultation process. Finally, the water risk index was computed by placing the value of the sub-indices in the risk equation. Districts were classified into five categories based on equal interval distribution, where '0' represented 'very low risk' and '1' represented 'very high risk'. The summary of the approach is presented in Figure 5.2.5. The whole approach, including

the methodology, indicator selection, weightage, etc., was presented and discussed in consultative meetings with representatives from water-related departments in the state and other development and non-government organisations.

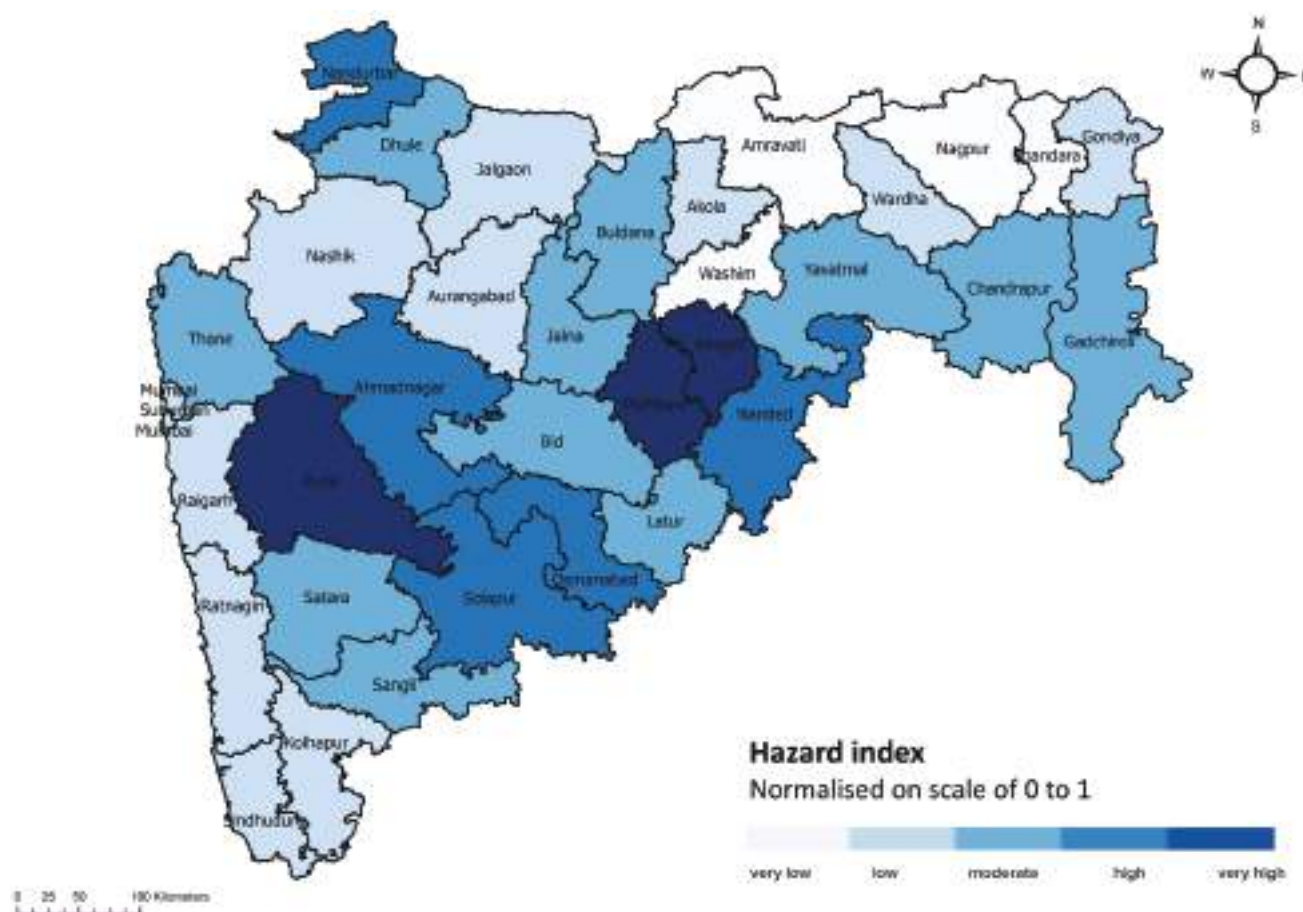
The computed sub-index values for the hazard, exposure, and vulnerability are presented in Figures 5.2.6–5.2.8. The results indicate that the hazard sub-index is high for many districts in central Maharashtra and Marathwada (Figure 5.2.6). These are the regions that receive low rainfall,

Figure 5.2.5 Schematic representation of approach for computing Water Risk Index



Source: Authors' compilation

Figure 5.2.6 District-wise Hazard sub-index value for Maharashtra



Source: Authors' analysis

which is highly variable compared to other regions in the state, such as Konkan and Vidarbha, that have low-to-moderate hazards. The hazard sub-index value is very high for Hingoli, Parbhani, and Pune. In these districts, the level of rainfall fluctuates by over 25 per cent, and nearly half of the last 50 years (1971–2020), were marked by extreme climate conditions (dry or wet rainfall years).

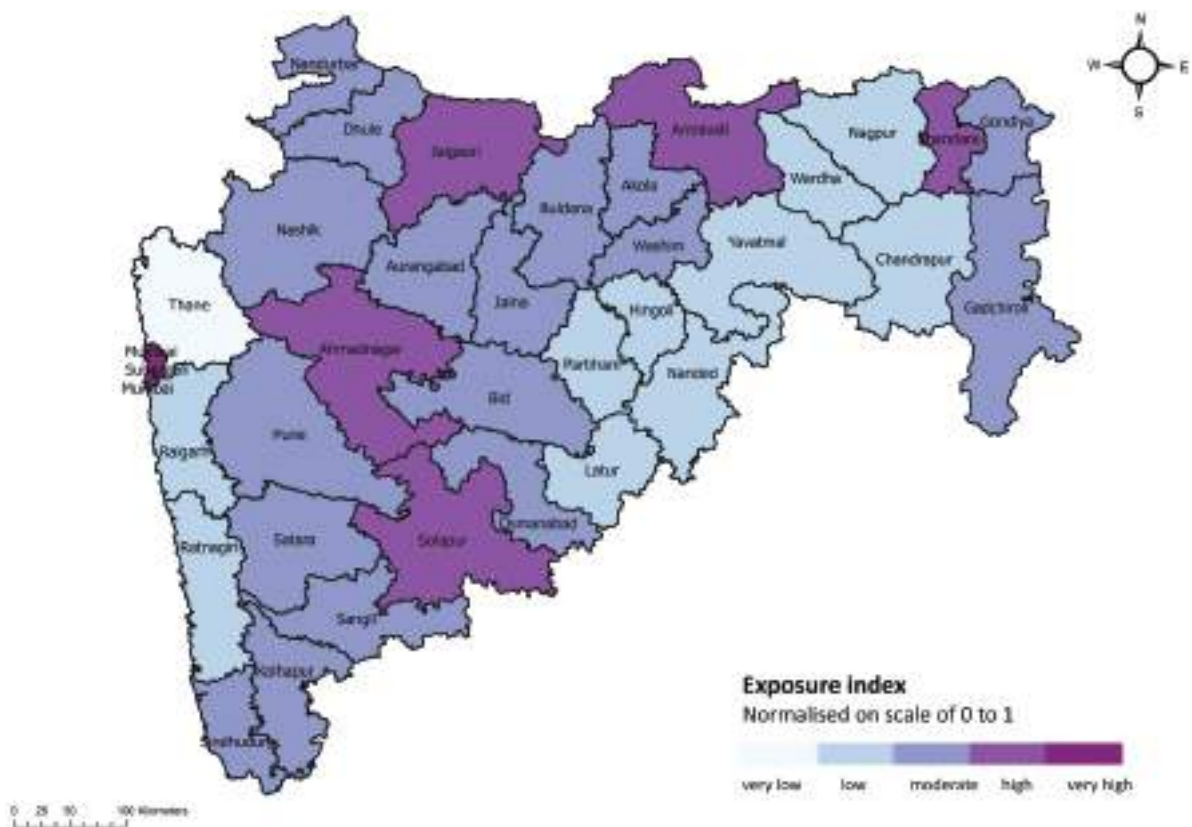
The exposure sub-index value is high for the districts in central Maharashtra and Vidarbha and a few districts in Marathwada (Figure 5.2.7). In the case of central Maharashtra and Bhandara district in Vidarbha, the main driver for this high value in the exposure sub-index is the high proportion of cropped area under irrigation. In the other districts of Vidarbha and Marathwada (especially in Amravati, Aurangabad, Buldhana, and Jalgaon districts), it is due to a high rate of groundwater extraction. Both conditions increase exposure during an extreme event, whether a flood or drought. Similarly, the exposure sub-index value is also very high for Ahmednagar, Amravati, Bhandara, Jalgaon, and Solapur districts. While in Ahmednagar, Amravati, Jalgaon, and Solapur, it is because of the high rate of groundwater extraction (more than 78%), in Bhandara, it is due to the highest

proportion of cropped area under irrigation (more than 65%).

The vulnerability sub-index value is high for most districts in central Maharashtra, Marathwada, and Vidarbha, which increases their overall risk (Figure 5.2.8). The main reasons are that, in most of these districts, there is low per capita reservoir storage, which is crucial to provide a buffer during dry years, and low density of hydro-meteorological monitoring stations, which are crucial for observing changes in the hydrological regimes during a period of drought or floods. The vulnerability sub-index value is very high for Bid, Jalna, Gadchiroli, Gondia, Hingoli, Nanded, Parbhani, and Washim districts. The adaptive capacity is best in the districts of the Konkan region.

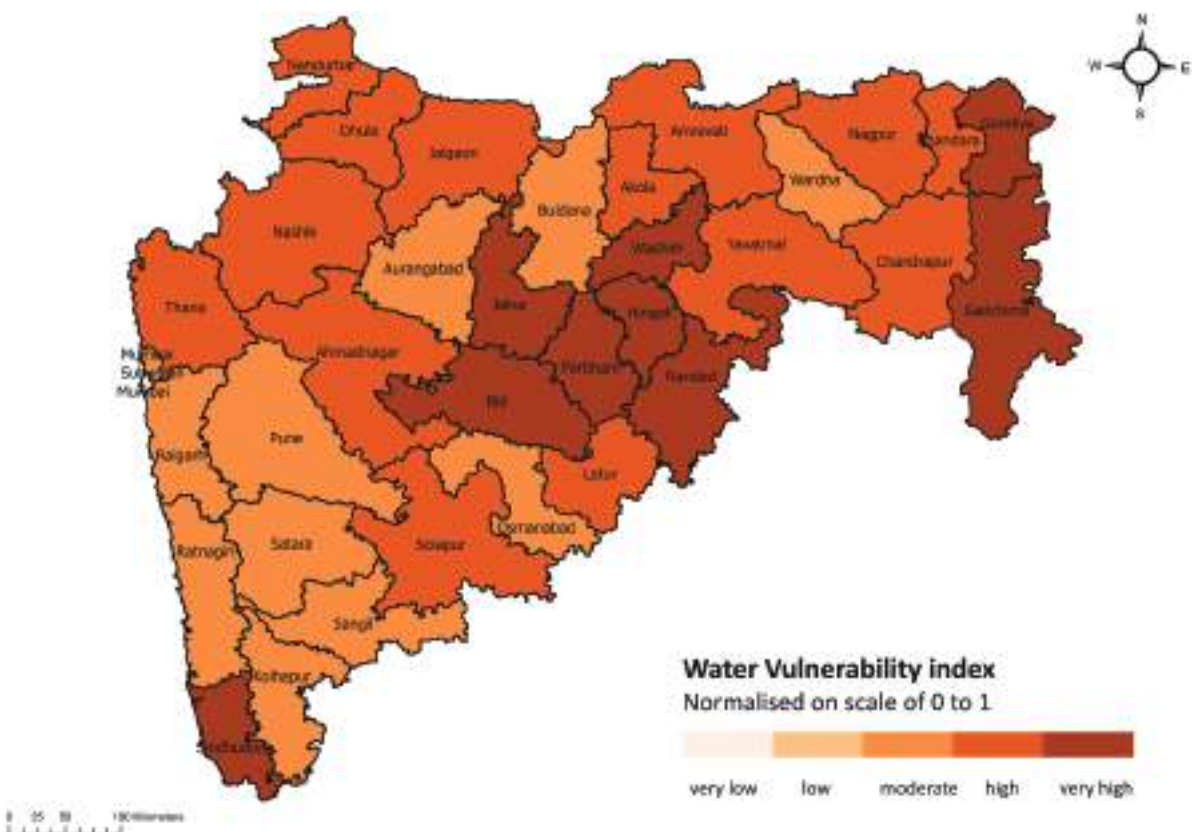
The overall water risk is highest for districts in central Maharashtra and Marathwada (Figure 5.2.9), particularly Ahmednagar, Nandurbar, Parbhani, and Solapur. A few districts in the Vidarbha region have a moderate level of water risk. On the other hand, the districts in the Konkan belt, such as Raigad, Ratnagiri, and Thane, have a very low water risk. The major drivers of very high risk are presented in Table 5.2.2.

Figure 5.2.7 District-wise exposure sub-index value for Maharashtra



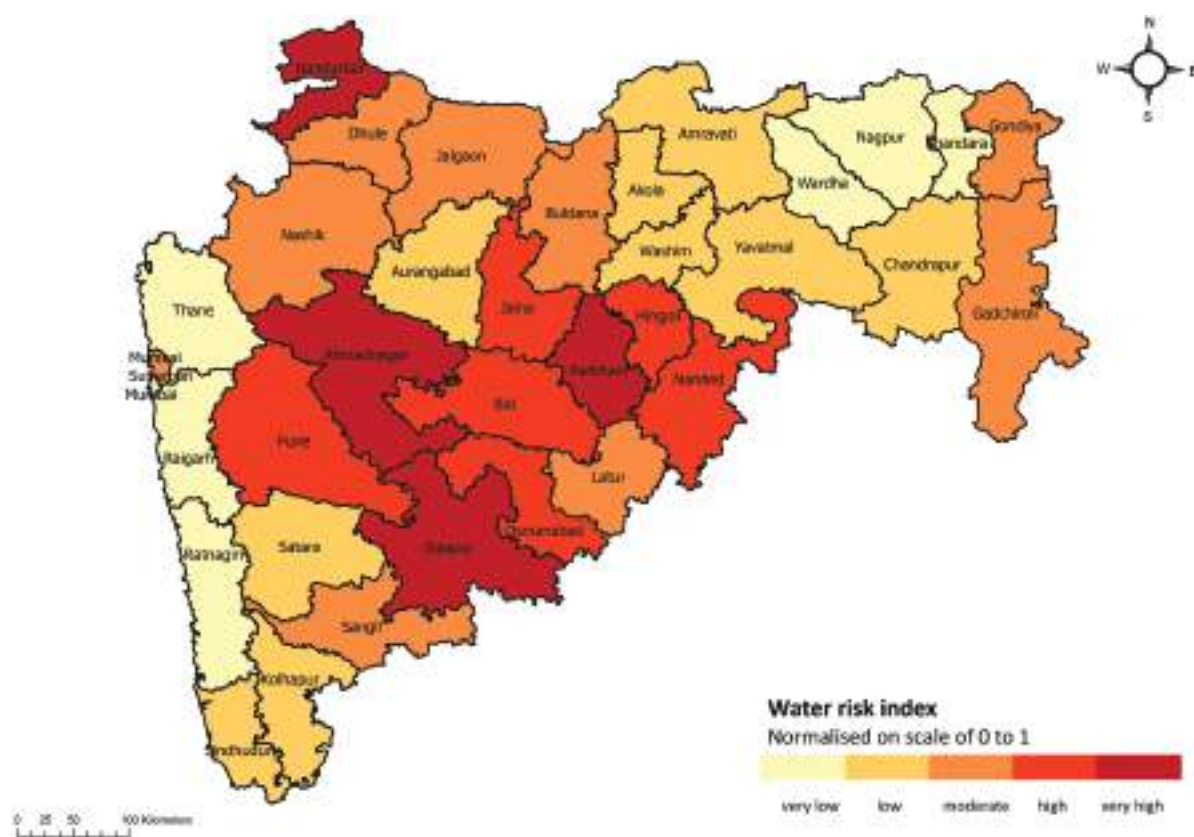
Source: Authors' analysis

Figure 5.2.8 District-wise vulnerability sub-index value for Maharashtra



Source: Authors' analysis

Figure 5.2.9 District-wise water risk index value for Maharashtra



Source: Authors' analysis

Table 5.2.2 Key drivers in very high water risk districts

Major drivers	Districts with very high water risk			
	Ahmadnagar	Nandurbar	Parbhani	Solapur
Hazard				
High rainfall variability	x	x	x	x
High number of deficient rainfall years	x	x	x	x
Exposure				
High percentage of the BPL population	x	x		x
High percentage of the gross irrigated area to cropped area	x			x
High stage of groundwater extraction	x			x
Vulnerability				
Non-updated DDMPs	x			
Low per capita reservoir storage capacity	x	x	x	
Less number of meteorological monitoring stations per unit area	x	x		x
Less number of surface water monitoring stations per unit area				x
Less number of groundwater monitoring stations per unit area	x			x
Low percentage of households with access to improved water resources within the premises		x	x	
Low percentage of households with access to sanitary facilities within the premises		x	x	

Source: Authors' analysis

5.2.4 Impacts of climate change on water resources

According to working group II of the IPCC AR6 (2021), it is now well established that one of the main reasons for the exacerbation of climate change is anthropogenic influences. Evidence suggests that the Indian sub-continent is witnessing a higher intensity of precipitation (especially in coastal areas) and increased duration of dry spells (Pörtner et al. 2021). In the context of Maharashtra, projections presented in Chapter 3 of this report show that in the 2030s, average total rainfall from south-west or summer monsoon will vary across almost all districts of Maharashtra compared to its long-term average, under RCP 4.5 and 8.5 scenarios. Further, it is estimated that by 2050, parts of the Vidarbha sub-division and western Ghats will experience an increase in rainfall by 82–225 mm (Todmal 2021). Meanwhile, other parts of the state expect a decreased frequency of low intensity rainfall events (TERI 2014). Thus, Maharashtra will be susceptible to flooding and drought in the future. Such rainfall patterns will have a substantial impact on recharging groundwater in the basaltic hard rock dominant geology of the state (Raut et al. 2021).

The projections of the latest coastal digital elevation models (DEMs) predict that by 2100, 28–50 million people in India, Bangladesh, and Vietnam will be exposed to the impacts of the rise in seawater levels even under low emission scenarios (Kulp and Strauss 2019). Thus, Maharashtra, with its 720 km long coastline, is more vulnerable than has been thought previously. Also, a rise in sea level will lead to salt-water intrusion in the aquifers along the coast, endangering the supply of fresh water from the wells in such areas.

Further, climate projections show that the Godavari River basin will be prone to flooding in the future (NITI Aayog 2021a). The basin is set to experience a highly altered flow regime resulting in an increase in overall water yield by 2050 under the business-as-usual scenario (Singh, Jain, and Gupta 2022). Compared to 2011, the increase in surface runoff in the Godavari river basin is estimated to range between 5.4 per cent and 10.72 per cent in 2040 and 2071, respectively (Hengade, Eldho, and Ghosh 2018).

On the other hand, a substantial area in the state (about 42.5%) lies in deficit or highly deficit sub-basins (GoM 2019b). Around 12 per cent of the population lives in drought-prone areas, and 60 per cent of the cultivated area lies predominantly in drought-affected districts that include Ahmednagar, Solapur, Nashik, Pune, Sangli, Satara, Aurangabad, Beed, Osmanabad, Dhule, Jalgaon, and Buldhana (TERI 2014). As per the Indian Government's estimates, the per capita annual water availability by 2050 in Godavari, Krishna, and Tapi river basins (i.e., 3 out of 5 river basins of Maharashtra, which covers the majority of the state) will be 1,122, 754, and 913 cu m respectively, which are much below the water stress threshold of 1,700 cu m (NITI Aayog 2021b).

Further, the evapotranspiration in the Godavari basin is projected to increase by 6.19 per cent in 2040 and by 10.6 per cent in 2070 (Hengade, Eldho, and Ghosh 2018). In the Tapi basin, evaporation is projected to increase in the winter season (Kale 2021). The evapotranspiration will increase due to climate change–induced rise in temperature, which is projected to be in the range of 0.5 to 2.5°C across the state (Todmal 2021). As per the projections presented in Chapter 3 of this report, annual average maximum and minimum temperatures, and consequently, the annual average mean temperature, are expected to rise for all districts in Maharashtra under both RCP 4.5 and RCP 8.5 scenarios in the 2030s.¹ Chandrapur, Gadchiroli, Nandurbar, Yamatval and Gondia have been projected to be the warmest districts in Maharashtra in the 2030s. The annual average mean temperature, which is impacted by the annual average maximum and minimum temperatures, will rise significantly across Maharashtra by 1.23°C and 1.43°C under RCP 4.5 and RCP 8.5 scenarios, respectively. The rise in temperature and evapotranspiration will result in higher consumption of water and further exacerbate the water risk in different districts across the state.

The increase in temperature will also impact the physicochemical properties of water. An increase in the temperature of water bodies can lead to a decrease in dissolved oxygen levels, increasing eutrophication levels, and hence worsening water quality. Even surface hydraulic boundary conditions of aquifers can change in response to changing temperatures and precipitation levels, thus changing the water balance of aquifers (TERI 2014).

5.2.5 Institutional structure for water resources development and management

Rural Development and Panchayat Raj and Soil and Water Conservation Department (RDPR & SWCD) of the GoM are responsible for the planning and development of irrigation facilities. While WRD is responsible for the survey, planning, design, construction, and management of major, medium, and minor projects in the state, RDPR & SWCD does the same for projects having a culturable command area below 250 ha.

The Water Supply and Sanitation Department (WSSD) is the state nodal agency for formulating, implementing, operating, and maintaining regional water supply schemes in both rural and urban areas of Maharashtra. The Groundwater Surveys and Development Agency (GSDA), the Maharashtra Jeevan Pradhikaran (MJP), and the Water Supply and Sanitation Organisation (WSSO) are the three-line agencies supporting WSSD. Further, some of the functions and functionaries of GSDA and MJP are entrusted to zilla parishads (ZP). The Water

¹ 2030s is a term which denotes time period 2021–2050

Supply Department of Zilla Parishads mainly comprises the transferred functionaries from the GSDA and MJP and is responsible for implementing water supply and sanitation reform programmes. A Reform Support and Project Management Unit (RSPMU) facilitates the rural water supply and sanitation reforms process. The RSPMU operates at the state and district levels.

Further, the Maharashtra Water Resources Regulatory Authority (MWRRA) was established in 2005 by virtue of an act with an aim to establish a regulatory mechanism for overseeing the relationship between the service provider and water user entities in terms of

determination, enforcement, and dispute resolution of entitlements and fixation of water charges. It also has the power to regulate the state's groundwater resources under the Maharashtra Groundwater (Development and Management) Act 2009.

5.2.6 Existing policies and schemes in the water sector

Some specific policies and programmes on water in the state were reviewed to determine their effectiveness in ensuring water security during climate extremes.

Table 5.2.3 Key features of existing policies and schemes in the water sector

S. no.	Title of the scheme/policy	Level of government	Nodal/Implementing agency	Launch/Time period	Budget Allocated	NDCs allocated	SDGs addressed
1	State Water Policy	State	Water Resources Department	Framed in 2003, revised in 2011 and 2019	NA	NDC 2, 3, 4, and 6	SDG 6, 12, and 15
2	Atal Bhujal Yojana	Centre (performance-based funding to states by centre)	Central Ground Water Board under the Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR, RD&GR) Central level	2020–21 to 2024–25	FY 2021–22: INR 10.20 crore (as on 22 July 2021)	NDC 6 and 7	SDG 6, 12, 13, and 16
3	Gaalmukt Dharan and Gaalyukt Shivar and Mahatma Jyotiba Phule Jal Bhumi Sandharan Abhiyan (2002-2017)	State	Implementation: State Revenue Department / Technical Assistance: State Water Conservation Department	2017– Ongoing (A part of the revised <i>State Water Policy</i> of 2019)	NA	NDC 6	SDG 6
4	Jal Jeevan Mission	Centre	State Water Supply and Sanitation Department	2019–24	INR 3.60 lakh crore (central funding: state funding = 50:50)	NDC 2 and 6	SDG 1, 5, 6, and 16
5	Kharland Development Scheme	State	State Water Resource Department	1979 – Ongoing	6,000 lakh in 2020	NDC 6	SDG 2, 8, 6, 16
6	Pradhan Mantri Krishi Sinchayi Yojana	Centre	Different departments for different components	2021–26	Central funding: state funding = 60:40	NDC 2, 3, and 6	SDG 1, 2, 6, and 13
(i)	Har Khet ko Paani	Centre	State Water Resource Department	2021–26			
(ii)	Per Drop More Crop	Centre	Department of Agriculture, Maharashtra	2021–26	FY 2018–19: central assistance released: INR 98 crore		
(iii)	Accelerated Irrigation Benefit Programme	Centre	State Water Resource Department	2021–26	FY 2020–21: central assistance Released: INR 348.08 crore		
(iv)	Watershed Development	Centre	Department of Land Resources, Maharashtra	2021–26			

S. no.	Title of the scheme/policy	Level of government	Nodal/Implementing agency	Launch/Time period	Budget Allocated	NDCs allocated	SDGs addressed
7	Magel-Tyala Shettale (Farm Pond Subsidy Scheme)	State	Government of Maharashtra	2017–18 – Ongoing	INR 204 crore	NDC 6	SDG 1,2, and 10
8	Chief Minister Water Conservation Programme (CMWCP)	State	Soil and Water Conservation Department of Maharashtra	2020–23	INR 1340 crore	NDC 6	SDG 1, 2, 6, and 13

Source: Authors' compilation

State Water Policy 2019

Maharashtra revised its existing state water policy for the second time in 2019 (GoM 2019b) after releasing the first version in 2003 and the first revised version in 2011. The policy provides an essential framework for transforming overall water governance in the state through strategic planning and prioritising investments. For this, the policy embodies the spirit of the National Water Policy 2012 (NWP) and recognises the basin as a unit for water management, identifies groundwater as a common resource held in public trust, and advocates for a scientific approach to flood management and watershed development. Further, it suggests developing decision support systems and flood forecasting models using advanced scientific tools. The policy has a substantial focus on suggesting water demand management in different sectors, improving water use efficiency in sectors, and maximising the value of water. It proposes creating a 'Centre of Excellence' in the water sector as an autonomous centre with international collaborations to promote soft skills, research water issues, and evaluate policy decisions. Section 17 of the policy entrusts the Maharashtra Water Resources Regulatory Authority (MWRRA) with the responsibility of setting volumetric pricing based on the principles of equity, efficiency, and economic principles. However, the policy needs further strengthening, given that many districts in the state are vulnerable to the impact of climate extremes. Though the policy calls for designing new water resource projects as multi-purpose projects, it does not explicitly state its position on climate proofing the existing water storage and supply infrastructure as an adaptive measure. Further, the ecosystem's need for water has been prioritised second last in water allocation priorities; drinking water and the agriculture sector have been given first and second priority, respectively. The order of water use may be modified in a particular project at the discretion of the competent authority. Kale and Kulkarni (2022), in their analysis of the State Water Policy, propose allocating inter-sectoral water based on the availability of water during the typical hydrological year (annual rainfall may be a deficit, average, or surplus). This is an important consideration for the years that experience

climate extremes. They also call for recognising the clear role of civil society organisations in micro catchment development and groundwater governance.

Atal Bhujal Yojana

This programme aims at preparing water budget and water security plans at the Gram Panchayat level and implementing various interventions at the village scale as an essential step towards arresting groundwater depletion. The programme recognises convergence with different schemes, such as the Jal Jeevan Mission, Swachh Bharat Mission, and MGNREGS, for sustainable management of groundwater with the help of community participation.

The efforts of this scheme can be supplemented by the National Aquifer Mapping and Management Programme (NAQUIM) in India, which provides information on the aquifer characteristics such as hydraulic properties, resource behaviour, water level regime, and chemical quality. To make NAQUIM more relevant at the local level, Kale and Kulkarni (2022) suggest mapping groundwater at a more granular resolution than the 1:50,000 currently being followed. They believe this could help improve decision-making on groundwater management at the Gram Panchayat level. Towards this, the involvement of representatives from local NGOs and experts working in groundwater management would be very useful.

Gaalmukt Dharan Gaalyukt Shivar Yojana

The main objective of the programme is to drought-proof agriculture by enhancing the water storage capacity of existing tanks through desilting. The excavated nutrient-rich silt is used as fertiliser, thereby offering the potential for higher agricultural production and reduced use of chemical fertilisers. Further, these farmlands would be able to have a higher water-holding capacity and improved soil organic carbon compared to other farmlands.

Kale and Kulkarni (2022) suggest that the selection of irrigation tanks for desilting should consider the region's groundwater recharge potential in order to make the best

use of harvested water, especially when it is not used for irrigation. If the groundwater recharge potential of the region is low, more water could be lost to evaporation. Further, the storage capacity should only be increased to the extent that it should not create adverse impacts downstream.

Jal Jeevan mission

The objective of the Jal Jeevan Mission (JJM) is to provide functional household tap connections to every rural household in India by 2024. As on 1 December 2022, about 72 per cent of the rural households in Maharashtra had tap connections within their premises (JJM Dashboard). Further, 80 per cent of the schools, Aanganwadis, and Community Health Centres had tap water connections within their premises. Under JJM, the annual action plans and village action plans that included activities such as water source strengthening, retrofitting of existing tap water connections, greywater management and maintenance of the infrastructure for the entire design cycle were developed.

Though the progress of the creation of drinking water supply infrastructure under JJM is satisfactory, it now needs to move to the next level to ensure reliable and safe drinking water services. In addition, investments are required to strengthen the existing data and information system on safely managed drinking water services (Bassi, Ganesan, and Dangi 2022).

Kharland Development Scheme

The objective of this scheme is to reclaim tidal lands by constructing and maintaining embankments and other works to increase the availability of arable land to grow more crops. The embankments help prevent the ingress of saline water into agricultural fields and hence prevent crop damage. Additionally, the embankments protect against floods during high tides.

However, the construction of tidal bunds is not recognised as a scientific measure to control the ingress of seawater as it may impact the mangrove ecosystem that is dependent on saline water. For instance, it was observed in the mangroves near Ratnagiri that regulating the flow of tidal water led to siltation and a decline in mangrove cover (Apte 2013).

Pradhan Mantri Krishi Sinchaayi Yojana (PMKSY)

The *Pradhan Mantri Krishi Sinchaayi Yojana* (PMKSY) is an umbrella scheme launched by the central government in 2021 with the goal of delivering the following four objectives: (i) enhancing the physical access to water on farms and expand cultivable area under assured irrigation under its *Har Khet Ko Paani* (HKKP) scheme; (ii) maximising water use efficiency at farm level by adopting micro irrigation techniques

including drips, sprinklers, and micro sprinklers, and by promoting supplementary water management activities under its *Per Drop More Crop* (PDMC) scheme; (iii) faster completion of ongoing major and medium irrigation projects through financial support, under its *Accelerated Irrigation Benefit Programme* (AIBP); and, (iv) effective management of runoff water and improved soil and moisture conservation activities such as ridge area treatment, drainage line treatment, rainwater harvesting, in-situ moisture conservation, and other allied activities on watershed basis, under its *Watershed Development* component. For the implementation of these schemes in Maharashtra, the Department of Agriculture, the Soil and Water Conservation Department of Maharashtra have been entrusted with varied responsibilities and tasks.

Maharashtra is a forerunner in the implementation of micro-irrigation (MI) programmes in the country, with cost-saving benefits of MI ranging from 7 to 35 per cent and gains in net return varying from 21 to 59 per cent (Chand et al. 2020). However, there is a poor understanding among farmers of spatial and temporal variation in soil moisture, crop-specific irrigation and fertigation schedules, availability of low-cost water-soluble fertilisers, etc. Further, farmers' perception of the transparency of the subsidy distribution component of PMKSY showed less than 50 per cent satisfaction. With just about 7 per cent of potential micro irrigation realised (ibid.), the state has immense potential to set even higher benchmarks for the rest of the country.

5.2.7 Adaptation strategies and key recommendations for improving climate adaptation and resilience in the water sector

Considering the water risk index and the expected water stress in the river basins of Maharashtra in the near future, water supply augmentation and water demand management interventions will be needed to make the water supply system resilient to the impact of climate change. Further, there is a need to climate-proof existing water supply infrastructure to ensure that they are able to operate even during climate extremes, such as during dry and wet years.

Table 5.2.4 Recommendations for improving climate adaptation and resilience in the water sector

S. no.	Recommendations/Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments and existing schemes that can be leveraged	Financial implications	Outcome	Remarks
Key action points and strategies for water supply augmentation							
1	Build conveyance to transfer 50% of the unutilised water stored in reservoirs in the Godavari river basin.	1) We have provided estimates for the present. 2) Scientific assessment must be undertaken to estimate water availability for the future under various climate change scenarios.	Entire state. Further, the scope for water development exists in middle Godavari, Sudha-Swarna, Wardha, Venna, Erai, Andhari, Nag,Kolar, Wainganga, Bagh, Khobragadi, Pranhita, Indrawati, and Kanhan (GoM 2017).	Water Resources Department Existing schemes that can be leveraged: National River Linking Project.	The estimated cost of water conveyance through lined canals is about INR 207 per cu m. (National Water Development Agency 2018) The total cost works out to INR 1,117 billion (INR 1,11,700 crore).	Augmentation of surface water-based supply.	Annual surface water allocation from the Godavari basin to Maharashtra, based on 75% dependability, is about 29,000 MCM (GoM 2017). Approximately 21,390 MCM of live storage is either created or under construction (GoM 2023). Out of this, only 10,600 MCM is utilised through major, medium, and minor irrigation projects (2017–18). This might be due to a lack of diversion or conveyance infrastructure. We assume that 50% of the unutilised water can be transferred.
2	Scope exists for harvesting 8,109 MCM of runoff per annum in a normal rainfall year.	1) Construction of water harvesting structures (following watershed management ridge to valley approach) such as check dams, and others. 2) Robust scientific assessments on hydrological, sociological, and economic feasibility are to be undertaken prior to the construction of check dams to ensure that there are no adverse impacts downstream.	Region: Vidarbha —Amravati division (Buldhana, Akola, Washim, Amravati and Yavatmal districts) and Nagpur division (Wardha, Nagpur, Bhandara, Gondia, Chandrapur and Gadchiroli districts).	Water Conservation and Rural Development departments. Existing schemes that can be leveraged: Jalyukt Shivar Abhiyaan, Jal Shakti Abhiyaan-Catch The Rain, PMKSY-watershed development component, and Majhi Vasundhara Abhiyaan.	The cost of Gabion check dams can vary from INR 13 per cu m of water harvested (Dashora et al. 2019), like in Rajasthan, to INR 55 per cu m, like in Telangana (Mishra and Babu 2020), depending on the design, geography, and whether they are located upstream or downstream. The total estimated cost for this intervention is INR 430 billion (INR 43,000 crore).	Capturing the monsoon runoff in Vidarbha leads to improved water security for irrigation and domestic consumption.	As per our estimates, 16,218 MCM of surface runoff remains uncommitted in the Vidarbha region (CGWB 2021). This is based on a 75% dependable yield and considering the water usage for 2019. We assume that 50% of it can be harvested.
3	754 MCM of treated used water to be availed for reuse per year.	Promote reuse of treated used water in areas indicated in the final draft of the Maharashtra Policy on Treated Water Use and	Entire state	State Water Resource Department, in conjunction with the Department of Urban Development.	We assume that the cost of creating conveyance infrastructure for transferring treated used water to the demand site will	Reduced pressure on freshwater sources and additional sources of government funding.	As per the National Inventory of Sewage Treatment Plant 2021, Maharashtra has a treatment capacity of 2,514.8 MCM (Central Pollution Control Board 2021). If the Maharashtra government can reuse

S. no.	Recommendations/Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments and existing schemes that can be leveraged	Financial implications	Outcome	Remarks
		Management 2023. These reuse areas are thermal power plants and power generation / energy sector; industries; urban areas such as railways, bus depots, and commercial complexes; municipal uses such as landscaping, parks, public toilets and washing/ sprinkling on roads; agriculture (including agro-forestry, forestry, aquaculture); and environment including discharge into surface water bodies after meeting the specified standards by the CPCB/SPCB, maintenance of wetlands and environmental flows.		Existing schemes which can be leveraged: AMRUT 2.0 and Smart Cities Mission.	be 50% of that required for the conveyance of surface water using irrigation canals (suggested in recommendation 1). This works out to INR 103.5 per cu m (Bassi et al. 2022). The total estimated cost is INR 78 billion (INR 7,800 crore).		30% of this treatment capacity as obligated by the state water policy, it would amount to 754 MCM of treated used water available for reuse each year.

Key action points and strategies for water demand management

4	2–10 km wide coastal belt	Regulate groundwater use from aquifers in the coastal areas by: 1) Assessing the total area that can experience seawater intrusion in the future. 2) Formulating a specific policy for the regulation of coastal aquifers.	Sindhudurg, Ratnagiri, Raigad, Palghar, and Greater Mumbai.	State Water Supply and Sanitation Department and Maharashtra Water Resources Regulatory Authority. Existing schemes which can be leveraged: National Water Mission.	Financial allocation for undertaking such assessments would be required.	It is found that approximately 2–10 km wide coastal belt and the inland tidal backwaters are affected by salinity intrusion in Maharashtra. The maximum effect is observed in Sindhudurg district, followed by Ratnagiri, Raigad, Palghar, and Greater Mumbai (Hegde et al. 2022).	

S. no.	Recommendations/Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments and existing schemes that can be leveraged	Financial implications	Outcome	Remarks
		3) Exploring options other than groundwater to meet water demand in the coastal areas.				It is projected that the coastal aquifers will experience increasing intrusion of seawater in the future. By taking measures to reduce dependence on groundwater in these areas, the state government can arrest salinity ingress and increase their adaptive capacity to combat climate change.	
5	In 2017–18, 52.54 lakh ha of area was under cash cropping in Maharashtra. Transitioning to micro-irrigation (MI) systems in sugarcane can be a starting point. 3,33,737 ha of the area under sugarcane cultivation can be brought under drip technology.	1) Scale up MI systems for cash crops in Maharashtra starting with sugarcane cultivation in Marathwada and central Maharashtra. 2) Water user associations (WUAs) to encourage farmers to adopt MI technologies for irrigation. WUAs must be established where they are not present, and the existing ones should be strengthened and made self-sufficient.	Region: Marathwada (Aurangabad, Beed, Hingoli, Jalna, Latur, Nanded, Osmanabad, and Parbhani) and central Maharashtra (Solapur, Ahmednagar, and Nandurbar).	Soil and Water Conservation Department in conjunction with the Department of Agriculture. Existing schemes which can be leveraged: RKVY - PDMC, and Command Area Development and Water Management Programme.	The indicative rates are INR 1.07 lakhs for 1 ha for close spacing of 1.5*1.5 m (GOI 2017). The total cost estimate is INR 36 billion (INR 3,600 crore).	Scaling up micro irrigation in Marathwada, by first prioritising it for sugarcane, will increase water use efficiency at the farm level and hence reduce water demand in the region. This will decrease the exposure of the region to climate change impacts and ultimately reduce its climate-related water risk.	The total area under sugarcane cultivation in the indicated districts was about 4,33,463 ha in 2017–18 (GOI 2021). Out of this, only 23% is under drip irrigation (Ghadyalpatil 2017).
6	29,52,000 ha (DES 2023) of the area in Maharashtra that was under river and canal	1) Introduce a volumetric basis of pricing for water supply in the canal command areas.	Entire state	Water Resources Department and Maharashtra Water Resources Regulatory Authority.	The number of V-notches weirs that will be needed will have to be established. As per GoM (2019a), an FRP V notch having a discharge	1) Efficient use of water in the culturable command area. 2) Reduction in the need for land acquisition	According to the State Water Policy 2019, the MWRRA is responsible for setting tariffs based on volumetric pricing. Future price revisions should ensure that the irrigation water is priced on a volumetric basis. Further, WRD

S. no.	Recommendations/Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments and existing schemes that can be leveraged	Financial implications	Outcome	Remarks
	irrigation in 2022–23 can be brought under volumetric pricing for irrigation water supply.	2) Install pressurised (piped) water supply below all tertiary (minor) canals of the irrigation infrastructure. 3) Build capacity of existing WUAs to ensure water is supplied on a volumetric basis and create WUAs in areas where they currently do not exist.		Existing schemes to leverage: PMKSY and National Water Mission.	capacity of 15 l/sec of section 20 x 40 cm with upstream and downstream channels costs INR 15,541.3/piece and an FRP V notch having a discharge capacity of 120 l/sec of section 42 x 84 cm with upstream and downstream channel is priced at INR 48,267.56/piece. Labour costs are included.	for laying field channels.	should ensure the implementation of volumetric pricing-based supply and engage WUAs for the same.

Key action points and strategies for climate proofing of water supply and its infrastructure

7	Potential to utilise 672 MCM of uncommitted internal surface water in the Marathwada and Vidarbha regions during a normal rainfall year that can be used as a source of drinking water for rural areas. As per our projections for 2022 based on the 2011 census data, the Marathwada and Vidarbha rural population is 3,34,69,385 and the number of households is about 73,39,207.	Increase surface water-based drinking water schemes, especially in rural areas. Recharge of the groundwater sources such as wells and borewells.	Marathwada and Vidarbha regions (hard rock areas).	Water Resources Department and Water Supply and Sanitation Department. The state's Water Supply Department has prepared the Marathwada Water Grid proposal for drinking water purposes for all 8 districts of Marathwada at an estimated cost of INR 270 billion (INR 27,000 crore). Existing schemes to leverage: Jal Jeevan Mission and MGNREGA.	The estimated cost of setting up surface water-based multiple village schemes is about INR 56,427/household. This is based on a surface-water scheme providing drinking water via metered piped connections to 156 villages and two towns in the Amravati district which is developed and run by the Maharashtra Jeevan Pradhikaran (Chary Vedala, Jasthi, and Uddaraju 2015). The total estimated cost is INR 414 billion (INR 41,400 crore). It is assumed that the cost will be the same for households in small towns and villages.	Multi-village surface water-based drinking water schemes are important because the hard rock aquifers in the state witness a sharp dip in water levels by the end of the winter season and are unable to supply water during the summer months. By promoting surface water for drinking water, the adaptive capacity of Maharashtra to climate change will increase.	As per our estimates using CWC data, about 24,980 MCM of internal surface water remains uncommitted in Marathwada and Vidarbha regions at 75% dependable yield. After portions of this are transferred from the Godavari sub-basin to other parts of the state, and some amounts are captured in water harvesting structures, the leftover volume of water can be explored to facilitate drinking water schemes and reduce the dependency on groundwater. We estimate about 672 MCM of water (about 3% of the uncommitted internal surface water in Vidarbha and Marathwada regions) would be needed annually to supply rural households in these regions, considering a water supply norm of 55 litres per capita per day.

S. no.	Recommendations/Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments and existing schemes that can be leveraged	Financial implications	Outcome	Remarks
8	Target to install and assess the potential of bulk water meter in the urban areas of Maharashtra, to be extended to rural areas after preliminary assessment.	Install bulk water meter to save water. Non-revenue Water management, ensure equitable distribution and avoid loss of water.	Entire state.	The State Water Supply and Sanitation Department, along with its subsidiary Maharashtra Jeevan Pradhikaran and Urban Development Department. Existing schemes which can be leveraged: Smart Cities Mission and Maharashtra Sujal Nirmal Abhiyan (MSNA).	The capital cost of an ultrasonic bulk water meter (recommended over a mechanical water meter) is about INR 50,000 to 80,000/meter (average of 65,000/meter). Cost estimates for rural areas can be worked out as each village will need only one such meter. There are 40,959 inhabited villages in the state, as per Maharashtra Economic Survey 2022–23. It is assumed that one bulk water meter would need to be installed at the inlet of the village level storage reservoir in each village. The total estimated cost is INR 2.6 billion (INR 260 crore).	Reduction in water losses from the public domestic water conveyance infrastructure.	NA
9	2,227 of large dams in Maharashtra need to be assessed for rehabilitation and improvement.	Assessment of dams for climate proofing. Remove encroachments on flood plains	Entire state.	Water Resources Department. Existing schemes which can be leveraged: Goal 1 of National Water Mission.	Financial allocation for undertaking such assessments would be required.	Improved resilience to the impacts of climate change.	Maharashtra has 2,394 large dams (CWC 2018), out of which only 167 have been considered for Phase 2 of the Dam Rehabilitation and Improvement Project (DRIP) for climate proofing (CWC 2020).

Source: Authors' analysis

The total overall financial outlay needed for implementing the recommendations for the water sector is INR 207760 crore.

5.3 Climate change impacts on forest and biodiversity and adaptation strategies

5.3.1 Current status of forest and mangroves in Maharashtra

Maharashtra, with a geographical area of 3,07,713 sq km, and 3,07,71,300 hectare, is the second-largest state in the country. The state is divided into six administrative divisions, namely, Konkan, Nashik, Pune, Amravati, Aurangabad, and Nagpur, spanning the five regional divisions of Konkan, Khandesh, Desh, Marathwada, and Vidarbha. Physiographic or biogeographic zones divide Maharashtra into three zones — the west coastal plains, the Western Ghats (also known as Sahyadris), and the Deccan tableland — varying in topography, slope, soil, temperature, rainfall, and availability of water. As many as six forest types are identified in these three divisions: tropical semi-evergreen forests, tropical moist deciduous forests, littoral and swamp forests, tropical dry deciduous forests, tropical thorn forests, and subtropical broadleaved hill forests (Champion and Seth 1968).

Forests in the Konkan region

The forests in the Konkan region are located along the coastline of Maharashtra, which is about 720 km long and

27–48 km wide. These forests are spread across seven districts, including Thane, Palghar, Mumbai, Mumbai suburban, Raigad, Ratnagiri, and Sindhudurg. The region receives high rainfall, generally about 2,000 mm, with high humidity and enjoys a maritime climate. The vegetation observed in these forests includes swampy forests, semi-evergreen forests, and deciduous forests. Even though in less quantity, small grassland and scrublands are also found in the forests located in this region.

Forests in the Khandesh region

Formed from the Deccan traps and its soils, the Khandesh region is located in the northwestern corner of Maharashtra. The region lies in the valley of the Tapi River, located between the Ajantha and Satpura ranges in the south and north, respectively. The climate in Khandesh is extreme, with winters being cold and summers very hot. Rainfall is confined to monsoons, with annual rainfall varying from place to place from 4.6 to 780.7 mm. The forests in the Khandesh region are typically tropical dry deciduous forests and mixed deciduous forests consisting of commercially valuable species such as teak.

Forests in western Maharashtra (Desh region)

Western Maharashtra, also known as the Desh region, is located between the Godavari and Krishna rivers. The climate in this region is hot and dry, with relatively poor

Figure 5.3.1 Map showing the regional divisions of Maharashtra



Source: Government of Maharashtra

humidity, barely exceeding 60 per cent throughout the year. Although the vegetation in western Maharashtra varies in composition, forests are mostly of dry deciduous type, along with scrub jungles and semi-evergreen trees. Floral and faunal wealth in this region is rich and preserved in ten wildlife sanctuaries.

Forests in the Marathwada region

The Marathwada region of Maharashtra is a part of the Deccan plateau. This region experiences significant variations in temperature, with the highest temperature crossing 45°C during the summers. The region is also characterised by low and erratic rainfall, with an annual average rainfall of approximately 720 mm. The region is predominantly covered with dry grassland ecosystems and dry deciduous forests.

Forests in the Vidarbha region

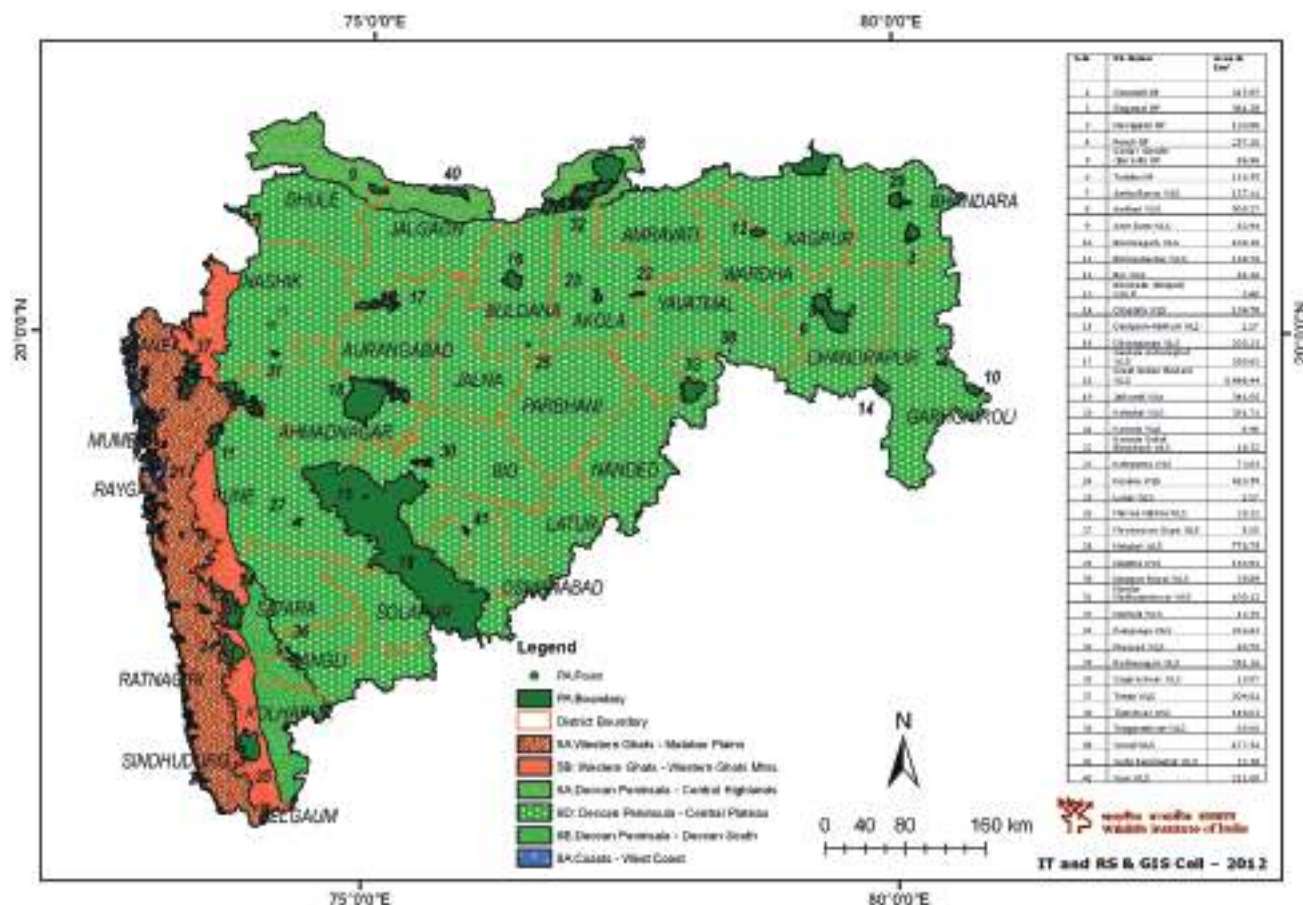
The Vidarbha region is located in northeastern Maharashtra with two divisions, namely Amravati (western Vidarbha) and Nagpur (eastern Vidarbha). Unlike other regions of Maharashtra, Vidarbha has no major hilly areas and experiences hot and dry climates with temperatures soaring beyond 45°C in summers and rainfall of 790–1,470

mm. The predominant forest type in the Vidarbha region is dry deciduous, but in some districts, such as Chandrapur, Gadchiroli, Amravati, and Yavatmal, luxuriant growth of moist evergreen and moist dry forest vegetation is found. Four out of the total six tiger reserves of Maharashtra are located in these five districts.

5.3.1.1 Distribution of biodiversity and protected areas of Maharashtra

Climatic and topographical variations bring great forest biodiversity to the state. The different kinds of habitats include scrubs, woodlands, less distributed forests, thickets, and grasslands. Additionally, there are a variety of wetlands extending over 8,06,872 sq km as per the National Wetland and Inventory Assessment conducted using the Resources at 2/2A LISS-III satellite data. The part of the state, which coincides with the Western Ghats is regarded as a hotspot of biodiversity and contains a wide variety of species, both flora and fauna. The Western Ghats Biodiversity Information System reported 4,500 plant species, out of which 35 per cent are endemic. The information system further lists more than 80 species (each) of fishes, amphibians, and reptiles, 15 species of birds, and 12 species of mammals local to the

Figure 5.3.2 Wildlife protected areas in Maharashtra



Source: ENVIS Centre on Wildlife and Protected Areas

Western Ghats. Maharashtra has classified an area of approximately 6,433 sq km as protected forests, along with approximately 10,282 sq km in protected areas, which includes national parks, wildlife sanctuaries, and conservation reserves to safeguard its biodiversity. As of 2021, the state had 6 national parks, 50 sanctuaries, and 15 conservation reserves. Maharashtra has six tiger projects providing legal protection to its tiger population under the Project Tiger Initiative of the National Tiger Conservation Authority.

Mangroves of Maharashtra

Mangrove forests constitute highly productive ecosystems found in the intertidal mudflats fringing sheltered coastal, estuarine, creeks, canals, lagoons, salt pans, backwaters, riverine, and island areas mostly in tropical and subtropical latitudes. Often highly saline and frequently inundated by tides, these forests support various types of flora and fauna. These ecosystems mostly comprise evergreen forests with traces of deciduous trees and perennial grasses, shrubs, and ferns. Mangroves inhabit a wide variety of fauna, spanning jackals, leopards, tigers, crocodiles, deer, etc. Conservation of mangroves is critical as they provide a wide variety of ecosystem services. They

provide food, fodder, fuel wood, honey, wax, and shelter for many marine species and protect against natural disasters and extreme events such as cyclones, tsunamis, and coastal erosion. These forests are also important for pisciculture, serving as a nursery, feeding, and breeding ground for many fishes and shellfish. In addition, they act as carbon sinks essential for the mitigation of climate change impacts and have the potential to store up to five times as much organic carbon as tropical upland forests. The major mangrove sites in Maharashtra are Thane, Mumbai, Raigad, Ratnagiri, and Sindhudurg.

According to a study by the Indian Institute of Space Science and Technology (2019), 70 per cent of the coast length of Maharashtra (720 km) has patches of mangrove vegetation spreading inwards around 44 creeks with the major extent in Thane Creek, followed by ten major rivers. As per the annual administration report by the Forest Department in 2021, Raigad district has the maximum mangrove cover (about 39%) of the total mangrove cover of the state, followed by Thane and Mumbai (including Mumbai suburban district) with 29 per cent and 20 per cent, respectively.

Table 5.3.1 Major sites of mangroves in Maharashtra

Name of district	Major areas of Mangroves: estuary/creek/river/sites
Thane	Vasai, Vaitarna River, Dandi, and Dahanu Creek
Mumbai	Thane Creek, Mahim, Malad Creek, and Manori Creek
Raigad	Hareshwar, Shrivardhan, Murud Korlai, and Uran
Ratnagiri	Vijaydurg, Purnagad, Bhatye, Mirya, Jaigad, Dabhol, Anjarle, and Kelshi
Sindhudurg	Phanaswadi, Wadatar, Mith Mumbri, Mithbav, Achara, Kolamb, Karli, Vengurla, Kelus, Mochamad, Reddi, and Terekhol

Source: Indian Institute of Space Science and Technology 2019

Figure 5.3.3 Location of the Mangroves (given in green) in Maharashtra



Source: Indian Institute of Space and Science Technology 2019

5.3.1.2 Trends in forest cover and distribution

Regardless of ownership (the legal status of the property) or the species composition of the trees, forest cover broadly refers to all lands with more than one hectare of trees and a tree canopy density of more than 10 per cent (FSI 2019). According to the Forest Survey of India (FSI), a dense forest is defined as having a tree canopy density of over 40 per cent. All lands having a tree canopy density of 70 per cent or higher are categorised as very thick forests, and all lands with a tree canopy density between 40–70 per cent are classed as moderately dense forests. Degraded forests are broadly defined as forest areas with a canopy cover of less than 40 per cent, including open forests (canopy cover of less than 40%) or scrubs with a canopy cover of less than 10 per cent (Reddy et al. 2001). An assessment of the spatial distribution of forests in

Table: 5.3.2 Dominant mangrove species in Maharashtra

S. no.	Scientific name of mangrove	Common name	Distribution
1	<i>Avicennia marina</i>	Tivar	All over Maharashtra
2	<i>Avicennia officinalis</i>	Tivar	Widely distributed in Maharashtra but not as common as <i>A. marina</i>
3	<i>Rhizophora mucronata</i>	Kandal	Throughout Maharashtra
4	<i>Rhizophora apiculata</i>	Kandal	Raigad, Ratnagiri, and Sindhudurg districts
5	<i>Bruguiera cylindrica</i>	Kandal	Mumbai, Thane, Raigad, and Sindhudurg Rare in Ratnagiri
6	<i>Bruguiera gymnorhiza</i>	Kankar, Ekmane	Rare in Sindhudurg, Ratnagiri, and Mumbai
7	<i>Kandelia candel</i>	Kandal-guriya	Sindhudurg and Ratnagiri districts
8	<i>Ceriops tagal</i>	Kirkiri	All along the Maharashtra coast
9	<i>Sonneratia alba</i>	Pandhari, chipi	Found in all coastal districts of Maharashtra
10	<i>Sonneratia apetala</i>	Chipi	Thane, Mumbai, and Raigad districts. Are rarely found in the southern districts of Ratnagiri and Sindhudurg (south of Alibaug)
11	<i>Sonneratia caseolaris</i>	Chipi	Found in Sindhudurg district. Rare in Ratnagiri
12	<i>Lumnitzera racemosa</i>	–	Mostly in Sindhudurg and Ratnagiri districts
13	<i>Xylocarpus granatum</i>	Bhelanda, Samudraphal	Found only in a few estuaries in Sindhudurg and Ratnagiri districts (Aachra, Vijaydurg, Purnagar and Jaitapur)
14	<i>Excoecaria agallocha</i>	Huri, Geva, Phungi	Coastal districts of Maharashtra
15	<i>Aegiceras corniculatum</i>	Kajala, Karti, Sugandha	Found in all coastal districts of Maharashtra
16	<i>Cynometra iripa</i>	Irapu	Very rare species found only in Sindhudurg district
17	<i>Heritiera littoralis</i>	Sundri	Sindhudurg district
18	<i>Dolichandrone spathacea</i>	Gorshingiah	Sindhudurg district
19	<i>Acanthus ilicifolius</i>	Marandi, Kateri	Throughout Maharashtra
20	<i>Acrostichum aureum</i>	–	Reported from Sindhudurg district

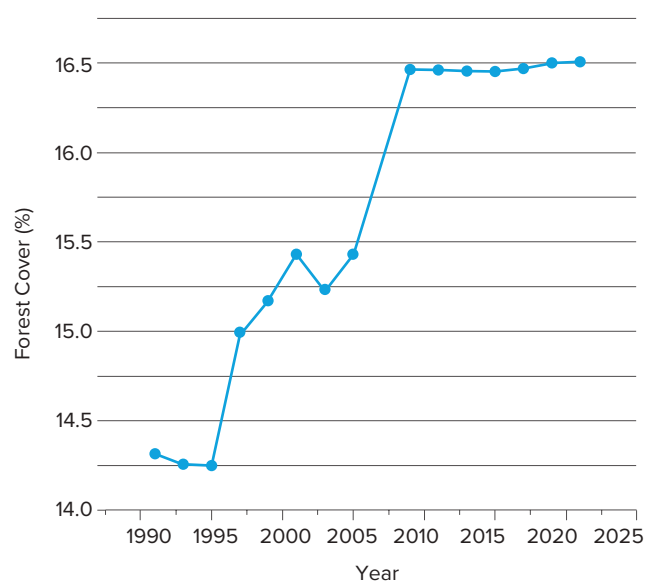
Source: Mugade and Sapkale 2014

Maharashtra provides a trend of the changing forest cover from 1990 to 2020 (Figure 5.3.4).

According to the Indian State of Forest Report 2021, about 50,798 sq km in Maharashtra is under forest cover, which is 16.51 per cent of the state's geographical area. Of this, 8,734 sq km has very dense forests, where the canopy cover is higher than 70 per cent; 20,589 sq km has moderately dense forests with canopy cover between 40–70 per cent; 21,475 sq km has open forests, where canopy cover is between 10–40 per cent; and 4,247 sq km has scrub vegetation with a canopy cover less than 10 per cent. The data obtained from the state forest reports (FSI) reveal that the area under forest cover has increased from 14.31 per cent (1991) to 16.51 per cent (2021).

Furthermore, total forest cover and tree cover have increased by 20 sq km and 1302 sq km, respectively, compared to the previous assessment in 2019. The state has witnessed a net increase of forest cover by 13 sq km and 17 sq km in very dense forests and moderately dense forests, respectively. In addition, tree cover (patches of size less than 1 ha outside the recorded forest area) has increased by 26.67 per cent (2,550 sq km) since 2015.

Figure 5.3.4 Forest cover area as a percentage of the total area in Maharashtra

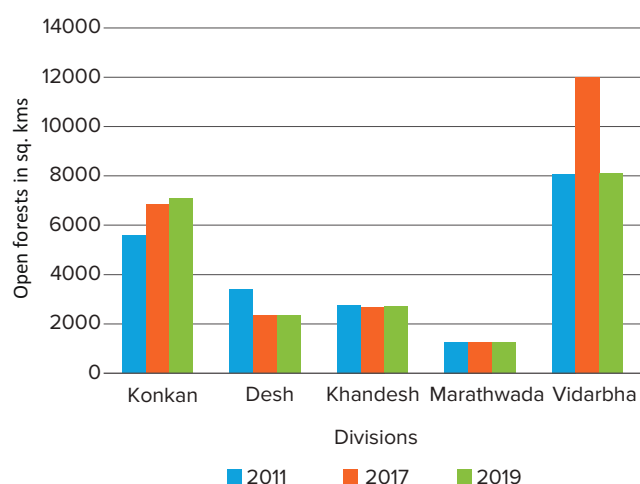


Source: Authors' compilation

Relative changes in the forest cover within the five regions

In the Konkan region, scrub forests have shown a slight increase to 374 sq km in 2019 from 344 sq km in 2011, while open forests have increased to 7,085 sq km in 2019 from 5,588 sq km in 2011. Conversely, in Khandesh or northern Maharashtra, the open forests slightly decreased to 2,701 sq km in 2019 from 2,772 sq km in 2011, and the scrublands marginally increased from 1076 sq km in 2011 to 1,131 sq km in 2019. In western Maharashtra (Desh region), the open forests decreased from 3,400 sq km in 2011 to 2,342 sq km, while the scrublands showed a marginal increase from 1,140 sq km in 2011 to 1,208 sq km in 2019. In Marathwada, the scrublands registered a slight decrease from 903 sq km in 2011 to 872 sq km in 2019. Similarly, the open forests in the region registered a very slight decrease from 1,262 sq km in 2011 to 1,253 sq km in 2019. In Vidarbha, the open forests reduced significantly to 8,102 sq km from 11,993 sq km in 2017; but overall, there was a slight increase compared to 2011, when it was 8,073 sq km. The scrublands in the region, however, showed minor variations.

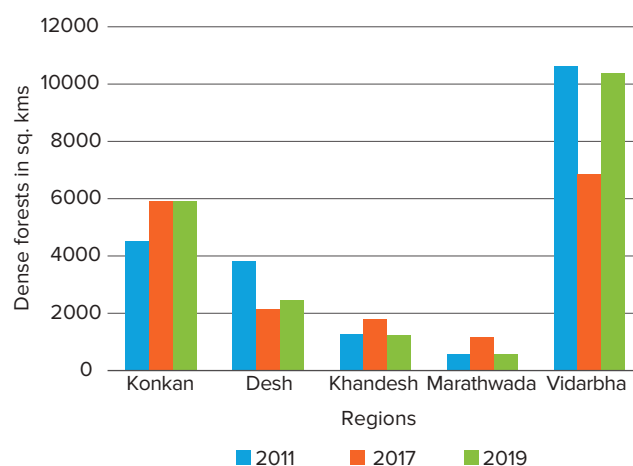
Figure: 5.3.5 Trends in the open forest cover in the five regions



Source: Forest Survey of India 2019

In the dense forest category, there have been notable increases in moderately dense forests, particularly in the Konkan and Marathwada regions, albeit to a small extent. Notably, when compared to 2011, there has been significant growth in moderately dense forests, apart from Desh region in western Maharashtra. Additionally, it's worth mentioning that there has been a positive trend in the expansion of very dense forests in the Konkan region.

Figure 5.3.6 Changes in dense forest areas across different regions of Maharashtra



Source: Forest Survey of India 2019

This analysis of the forest cover reveals a positive trend in Maharashtra's overall forest area, which has notably increased. More than half of the districts have recorded encouraging growth in forest cover. A few districts, including Gadchiroli, Chandrapur, and Thane, have experienced some changes in forest cover compared to the 2019 assessment conducted by the Forest Department of Maharashtra. The transformation in very dense and moderately dense forests can be attributed to a variety of factors, including both non-biotic elements and human activities. These activities are often linked to demands for agricultural land, mining operations, construction projects like irrigation channels and dams, as well as urban expansion and changes in land use. These multifaceted factors can sometimes contribute to habitat alteration and

Table 5.3.3 Districts in Maharashtra with varying degrees of forests area

Area under forests (% of geographical area)	Degree	Districts
Less than 10	Very low	Latur, Solapur, Jalna, Parbhani, Osmanabad, Beed, Jalgaon, Ahmednagar, Sangli, Mumbai, Hingoli, Dhule, Akola, Aurangabad, Washim, Buldhana, Nashik, and Nanded
11–22	Low	Pune, Satara, Wardha, Yavatmal, Nandurbar, and Nagpur
22–33	Medium	Kolhapur, Bhandara, Amravati, Mumbai suburban, and Thane
33–44	High	Chandrapur, Gondia, and Raigad
More than 44	Very High	Ratnagiri, Sindhudurg, and Gadchiroli

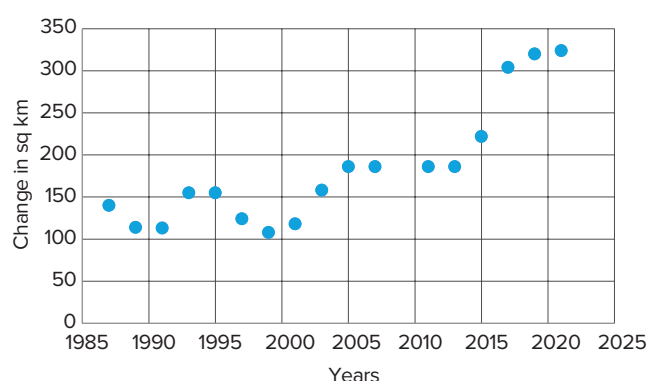
Source: Authors' compilation

fragmentation within biogeographic zones, along with changes in primary forests.

Changes in forest cover of mangroves

Maharashtra has the fifth largest area of mangroves in the country, and the past five years have seen a gradual increase. The mangrove cover in the state has increased by 4 sq km compared to the 2019 assessment. By 2021, the mangrove cover had increased by 45.94 per cent (102 sq. km) since 2015. Based on the 2019 FSI report, the mangroves in Maharashtra are spread over about 304 sq km. According to the study undertaken by the Indian Institute of Space Science and Technology (2019), the increasing cover of the mangroves is attributed mainly to stricter law enforcement, increased awareness among the public about the importance of mangroves, and protection mechanisms employed by the state government in recent years. A total of 161.5 ha of degraded mangrove land was restored in 2020 under the mangrove afforestation initiative spread over 28 locations along the coastal districts of Maharashtra, and 7,15,353 mangrove saplings were planted, according to the Annual Report of the Mangrove Foundation 2020-2021.

Figure 5.3.7 Graph showing changes in the forest cover of Mangroves (1987–2021)



Source: Authors' compilation

5.3.2 Impacts of climate change on forest and biodiversity

Overall, Maharashtra receives an annual mean rainfall of 1,363 mm with an 8.7 per cent coefficient of variability. Although the maximum annual rainfall in the state is due to the southwest monsoons between June and October, extraordinary variations are found across various regions.

According to analyses of temperature trends up until 2050, the annual mean temperature (AMT) in the entire state is projected to increase by 1–2°C. Additionally, the state is set to experience much warmer conditions, with significant warming of 1–2.5 °C expected in Konkan, Desh (Pune division), and Khandesh (Nashik division) regions. In the near future, it is predicted that the

majority of the state may face a significant increase in rainfall. The variability in the patterns of rainfall and temperature is likely to have impacts on the state's forests and implications on its product flows, trade, and management practices.

Using climate projections of regional climate models

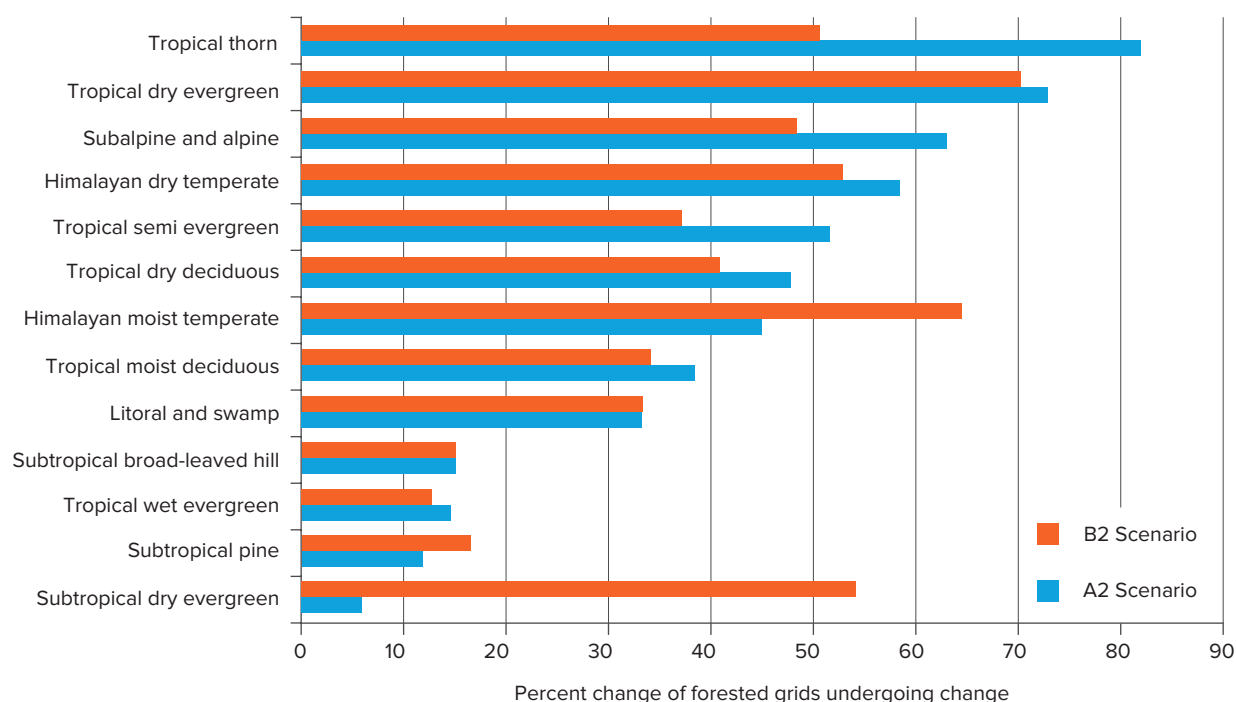
Scholars have used IBIS (Input/ Output Buffer Information Specification) and BIOME vegetation models to study projections for climate change and their impacts on forest types under two SRES scenarios, namely A2, where atmospheric CO₂ concentration reaches 740 ppm by 2085 and B2 scenario, where atmospheric CO₂ concentration reaches 575 ppm by 2085 (Chaturvedi et al. 2010; Ravindranath et al. 2006). The projections revealed a shift in most forest types under the A2 and B2 scenarios. With increased rainfall coupled with elevated CO₂ and soil moisture, moist deciduous and wet evergreen may expand farther east, and species adapted to warmer and lower elevations might migrate to higher altitudes. A reduction in rainfall, on the other hand, could cause evergreen forests to turn into deciduous forests in the Western Ghats. A study by Gopalakrishnan et al. (2011) suggests that due to lesser precipitation levels, northern and central parts of the Western Ghats, containing a significant extent of open forests, are more vulnerable to climate change impacts. Furthermore, an increase in the dry season due to increasing temperatures may put certain forest types, particularly dry deciduous trees, at risk of forest fires. Low tree density, low biodiversity status, as well as higher levels of fragmentation, contribute to the existing vulnerability of the forests; existing trees and plant species could face dieback and die or decline prematurely and rapidly. A recent Forest Survey Report (2021) revealed that by 2030, in Maharashtra, about 34,170 sq km of forest cover will be climatic hotspots with increasing degrees of severity from high to critical.

5.3.3 Adaptation strategies and key recommendations for the forest sector

Adaptation strategies for forests in the context of climate change are important because the impacts of climate change on forests, such as biodiversity loss, are long-term and often irreversible. It is important to carefully monitor and anticipate changes in climatic conditions and how they may affect forests. This knowledge should be incorporated into management decisions to develop adaptation strategies for climate-resilient forest ecosystems.

In Maharashtra, it is predicted that climate change is increasing the vulnerability of the forests. Droughts are projected to become more intense and frequent in these regions, and forests are likely to be exposed to fire, pests,

Figure 5.3.8 Percentage of the forested grids that the IBIS model source predicts will be affected in A2 and B2 SRES scenarios



Source: Chaturvedi et al. 2010

and pathogens. In biodiversity hotspots, endemic species may show a steep decline in population and may even get extinct (Gera, 2014). Similarly, moist deciduous and evergreen forests spread across Vidarbha and northern parts of the Konkan region are vulnerable to climate change. Due to the significant reliance on forests for livelihoods, non-timber forest products, fuelwood, and feed, it is crucial to take climate change consequences into account when planning and implementing any forest development projects.

5.3.3.1 Mapping existing policies

The Government of Maharashtra has several policies and programmes ensuring sustainable forest management and reducing the climate change impacts on forests and biodiversity. Working closely with national policies, the state government has taken proactive steps to strengthen mitigation and adaptation measures to ensure healthy forest ecosystems in the state. For instance, the Maharashtra government is working on the Green India Mission (GIM) under the National Action Plan for Climate Change (NAPCC), a national programme launched in 2008 to design, plan, and implement climate adaptation and mitigation across sectors and regions. In response to climate change, the GIM aims to protect and enhance India's green cover, enhancing ecosystem services, carbon sequestration and storage, protecting biodiversity, and increasing forest-based

livelihood income of the households living in and around the forests. In fact, Maharashtra became the only state in India to receive the Inspiring Regional Leadership Award and commendations for Climate Partnerships and Creative Climate Solutions at COP 26 held in Scotland in 2021.

There are various schemes, policies, and acts that are implemented in the forest sector that have adaptation relevance. Several of these policies and schemes targeting the conservation and development of forests and biodiversity have strong interlinkages with Sustainable Development Goals (SDGs) and contribute to achieving them in myriad ways. Addressing the issues of afforestation, biodiversity conservation, and ecosystem restoration brings forest management to the fore of SDG 15: Life on Land, along with many others such as SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 5: Gender Equality; SDG 6: Clean Water and Sanitation; SDG 13: Climate Action, and SDG 10: Reduced Inequalities. Table 5.3.5 outlines some of the major acts, policies and schemes the state has in place in the forestry sector to address climate change risks and enhance biodiversity conservation along with their interlinkages with the 17 SDGs and 8 Nationally Determined Contributions (NDCs). India, at COP 28, announced green credit scheme, which can be leveraged to enhance the funding in the forestry sector and achieve climate action.

Table 5.3.4 Acts and policies aiming protection, management, and conservation of forest ecosystems and biodiversity

Acts			
Acts	Objectives	SDG addressed	NDC addressed
The Indian Forest Act, 1927	To consolidate the forests, control, and reserve them for conservation, and regulate the use of timber and non-timber produce.	13, 15.1, and 15.2	1 and 5
The Forest Conservation Act, 1980	To protect and preserve the forest environment, stop destruction in all types of forests, regardless of ownership, and stop the conversion of forest lands for grazing, agriculture, or other commercial uses.	13, 15.1, and 15.2	1 and 5
The Wildlife Protection Act, 1972	It offers a fundamental framework to assure the management and conservation of wildlife, including wild animals, bird species, and plant species, in order to maintain ecological and environmental security.	13 and 15.7	1 and 6
Environmental Protection Act, 1986	It gives the government the authority to create agencies with the mission of preventing environmental pollution in all of its manifestations and addressing particular environmental issues unique to various regions of the nation.	15.1	1 and 6
Biological Diversity Act, 2002	To safeguard biodiversity, make sustainable management of biological resources easier, and safeguard local populations' understanding of nature.	13, 14, 15.4, and 15.5	1 and 6
Environmental Impact Assessment Notification of 2006	Notification mandating major economic and development activities in the country to clear the environmental impact assessment before commissioning the project.	12, 15, and 15.9	1 and 6
Forest Rights Act, 2006	It affirms the right to own and occupy forest land for personal or communal dwelling or for self-cultivation for subsistence.	1, 3, 10, 15.1, 15.6, and 16	1
Compensatory Afforestation Fund and Planning Authority (CAMPA) Act, 2016	In order to make up for forest area that was diverted to non-forest uses, the Act encourages afforestation and regeneration initiatives.	13, 15.2, and 15.9	1 and 5
Policies and schemes			
National Forest Policy, 1988	Environmental stability, ecological balance, biological diversity preservation, soil erosion control, and an increase in tree cover are all policies that are in place.	13, 15.3, 15.5, and 15.6	1, 2, 5, and 6
National Conservation Strategy and Policy on Environment and Development, 1992	Policy laying down guidelines to weave environmental considerations into the development process and reorienting policies and actions in sync with the environmental perspective	11, 12, 13, and 15.9	1, 2, and 6
National Environment Policy, 2006	In order to incorporate environmental concerns into all development activities, this policy expands coverage and closes any gaps in environmental management by aiming at the conservation of environmental resources.	13, 15.1, and 15.2	1
Wetlands (Conservation and Management Rules), 2017	Rules laying down a basic framework for the conservation and management of wetlands in India with the help of state authorities.	5, 13, 14, and 15.1	1 and 6
National Agroforestry Policy, 2014	A policy framework designed to improve agricultural livelihoods by maximising agricultural productivity for mitigating climate change.	2, 8, 10, 11, 12, and 13	1, 2, and 8
Green Highways (Plantation, Transplantation, Beautification, and Maintenance) Policy, 2015	A policy to encourage the greening of national highway corridors nationwide while preserving the environment and providing local people with economic opportunities through tree plantations.	13, 15.1, and 15.2	1
Green India Mission, 2008	The mission's objectives include preserving, enhancing, and reforestation of India's declining forest cover as well as adaptation and mitigation to climate change.	3, 5, 7, 11, 13, 15, 16, and 17	1 and 5

Acts			
Acts	Objectives	SDG addressed	NDC addressed
National Biodiversity Mission, 2008	The mission aims at generating comprehensive documentation of India's biodiversity involving cataloguing and mapping all life forms, cultural and traditional practices, and assessing the conservation status of biodiversity in India.	13, 14, 15.4, and 15.5	1, 2, 6, and 7
Intensification of Forest Management Scheme (IFMS), 2017	A programme run by the federal government with funding distributed in accordance with a 60:40 ratio of centre-state cost sharing to help all the states combat forest fires.	3, 4, 13, 15.5, 15.6, and 15.7	1, 5, and 6
National Action Plan on Forest Fires, 2018	The objective underlining the plan is to minimise forest fires from taking place by informing, enabling, and empowering forest fringe communities and incentivising them to work in tandem with the forest department. This would be done through fire risk zonation and mapping, developing an effective communication strategy for awareness generation, empowering communities to participate in fire management, biomass management, weed management, forest fire preparedness, digitisation of forest boundaries etc	3, 4, 13, 15.5, 15.6, and 15.7	1, 5, and 6
Integrated Development of Wildlife Habitat (IDWH), 2008	A programme that aids protected areas (national parks, wildlife sanctuaries, conservation reserves, and community reserves, excluding tiger reserves), protects wildlife outside the protected areas, and supports recovery programmes for protecting critically endangered species and habitats.	4, 13, 15.5, and 15.7	1 and 6
Project Tiger, 1973	A tiger conservation programme that aims to ensure a viable population of tigers in their natural habitats, protecting them from extinction, and preserving ecosystems across the tiger's range in the country.	4, 15.5, and 15.7	1 and 6
Project Elephant, 1992	An elephant conservation programme that aims to ensure the protection of elephant corridors and elephant habitats for the survival of the elephant population in the wild.	4, 15.5, and 15.7	1 and 6

Source: Authors' compilation

The state government has several specific schemes that are being implemented that have adaptation relevance for forests and biodiversity. Some of the major state-led policies and schemes include the following:

Maharashtra Felling of Trees (Regulation) Act, 1964

This act aims to make better provisions for regulating the felling of certain trees in the state for the purpose of preservation.

Maharashtra State Forest Policy, 2008

This policy aims at raising forest cover in the state to a minimum of 33 per cent (101.54 lakh ha) of total land, as per the recommendations of the Planning Commission and the National Forest Policy, 1988.

Maharashtra Forest Rules, 2014

These Rules lay down the process for the protection of reserved and protected forests from fire. They also contain provisions for hunting and shooting of animals in forest areas. In addition, they clarify the rights and privileges granted to persons who live or work in reserved forest areas, the regulations for the felling of trees, transit of forest produce, conversion of timber of certain species and the offences and penalties related to the provisions of these Rules.

Har Medh Par Ped Scheme, 2016

This agro-forestry scheme was launched to encourage tree plantation on farmland along with crops and cropping systems to help farmers get additional income and make their farming systems more climate resilient and adaptive. Under the scheme, assistance is given to farmers through the state government for nursery development, boundary plantation, and block plantation of prominent tree species to promote fruit-bearing trees, oilseeds, medicinal and aromatic plants, silk and lac-rearing host plants, in addition to timber species, so that farmers get early returns.

Van Mahotsav, 2017

In 2017, the forest department announced a drive to plant 4 crore saplings throughout the state involving 33 government departments along with students from schools and colleges, NGOs, CSR, railways, defence, NABARD, and other stakeholders.

Harit Sena Yojana 2017

The Maharashtra Forest Department initiated the Harit Sena (Green Army), a body of dedicated volunteers to participate in the plantation, protection, and activities in the forest and wildlife sectors over the years.

Hello Forest, 2017

A 24-hour toll-free helpline number 1926 called Hello Forest was set up to provide information regarding plantation and protection and for mass awareness of forest conservation and its benefits.

My Plants App, 2017

The forest department also created a mobile application called My Plants to record details of the plantation, such as numbers, species, and locations, to build a digital inventory of flora and fauna typical to the state. All volunteers at individual, collective, and organisational levels download and use this application to record their tree plantation work through the application, which became operational in July 2017.

Kanya Van Samruddhi Yojana, 2018

In 2018, the Maharashtra government announced the Kanya Van Samruddhi Yojana, where farmers' families where girl children are born are given saplings for plantation. These saplings are of different varieties, including teak, mango, jackfruit, black plum, and tamarind. It was expected through this policy that the income from these trees would be utilised for safeguarding the future of the girls.

Bhauasheb Fundkar Horticulture Scheme, 2018

This scheme was started under the MGNREGA scheme of the central government, where those beneficiaries who could not avail of the benefit of orchard cultivation would be given benefits.

Atal Bamboo Samruddhi Yojana, 2019

In 2019, the Maharashtra government introduced Atal Bamboo Samruddhi Yojana to promote the cultivation of bamboo tissue culture seedlings in the agricultural fields and at boundaries. Considered green gold and timber for the poor, the scheme envisaged economic security for poor farmers. The main objective of the scheme was to promote bamboo cultivation by farmers to earn their livelihood. The beneficiaries would directly purchase bamboo tissue culture seedlings at INR 25 per piece from the agency. The plantation authorities would oversee the cultivation, beneficiaries having less than 4 ha of land would get an 80 per cent subsidy, and farmers having more than four ha would get a 50 per cent subsidy. As many as 25,500 beneficiaries from all over the state (750 from each district) would be given bamboo seedlings for popularising bamboo plantations at the field and boundaries of their farms.

Forest-based Industry Policy, 2019

In 2019, the Maharashtra government was the first in the country that proposed to formulate a policy on forest-

based industry involving multiple stakeholders, including tribals, small entrepreneurs, manufacturers of herbal and ayurvedic medicines, timber industry, timber importers, and other state government departments such as Agriculture, Rural Development, Tribal Development and Industry.

Climate Action Plan for Mumbai, 2021

In 2021, the Maharashtra government released the country's first climate action plan for the city of Mumbai. The plan is a 30-year roadmap for the coastal city to tackle the challenges of climate change. The climate action plan has 6 focus areas and 24 priority actions. The plan will be reviewed and updated every five years. A similar initiative is also undertaken for Nashik with a focus on improving green cover, water, sustainable transport, green energy and buildings, air quality, and waste management. Additionally, a climate action cell was also institutionalised in the Nashik municipal corporation. The state has also made efforts to address climate change by notifying over 9,800 hectares of mangroves as protected areas and launching the first state-wide programme in the country on climate change mitigation and adaptation.

Forest Policy for Green Cover, 2022

In 2022, the Maharashtra government formulated a new forestry policy to increase the green cover in the non-forest areas of the state. The Social Forestry Department has decided to provide green cover to 80 per cent of non-forest areas and will elicit cooperation from the local self-government bodies in this endeavour. A study group comprising 18 members from Revenue, Forest, and Agriculture departments, along with Social Forestry, Pollution Control Board, and Municipal Corporations of Pune, Nagpur, Mumbai, private enterprises, and environment consultants under the leadership of former Chief Secretary was formed for the implementation of the policy. The study group that formulated the new policy, included concepts of community forestry; village parks; urban forestry such as tree plantations along the roads, ponds and all public spots; green belts by beautification of industrial areas; farm and agro-forestry such as tree plantations near farm ponds, roadside plantation; tree credit; and bamboo plantation, development, and marketing among others.

Council for Climate Change, 2022

The state also formed a Council for Climate Change based on a report by the Intergovernmental Panel on Climate Change (IPCC) about carbon impact.

Maharashtra State Tree Authority, 2022

The government constituted a Maharashtra State Tree Authority with the aim of increasing the tree cover in the urban areas and protecting the existing ones. The

authority envisages monitoring the functioning of local tree authorities constituted by the local civic bodies and councils. Besides, the authority will also ensure the protection and conservation of heritage trees for about 50 years or more. The authority is chaired by the secretary of the Department of Environment and Climate Change, and secretaries from the Urban Development, Forest Departments will be the members and an expert member.

Fencing in the Kas Plateau, 2022

The Kas plateau spans 1,600 ha and is home to at least 450 flowering plant species, of which 39 are endemic. Following UNESCO's suggestion to protect the blooms from trampling, the whole plateau was cordoned off in 2011. However, the fence reduced the entry of cattle to graze and restricted the interactions of flora and fauna that supports pollination and regeneration, therefore it was taken down in 2022. In 2023, the forest department decided to put up a seasonal fence from July to September so as to protect the flower buds from high pressure due to anthropogenic drivers.

Some of the other policies and programmes adopted by the state are the *Joint Forest Management Mangrove and Coral Reef Conservation Programme* launched by the Mangrove Cell Foundation of the state, *Nagar Van Udyan Yojana and Vasantharao Naik Scheme* for afforestation, and *Dr. Shyama Prasad Mukherjee Jan Van Vikas Yojana Scheme*. All these government-driven

planned adaptation measures, policy frameworks, and strategies and their subsequent implementation place particular emphasis on balancing GHG emissions by sources and removals by sinks, reducing deforestation and degradation, as well as sustainable forest management. The Maharashtra government signed an MOU with the United Nations Environment Programme (UNEP) to support its *Majhi Vasundhara Abhiyan* (MVA) to converge energy and environmental dimensions of sustainable development. The government also initiated its flagship *Jalyukt Shivar Abhiyaan* programme aimed at making the state drought-free. Further, the Maharashtra Project on Climate Resilient Agriculture (PoCRA) aims to enhance the climate resilience and profitability of small landholding farming systems in selected districts of Maharashtra. Table 5.3.6 maps the linkages of the above-mentioned state acts and policies for forest management with the SDGs and the NDCs.

State Climate Action Cell, 2023

The State Climate Action Cell (SCAC) focuses on prevention, adaptation and mitigation related to climate change. The cell provides guidance on implementation of the State Action Plan and Climate Change (SAPCC) and National Action Plan on Climate Change (NPACC) in the state. The cell also coordinates between the Union government, local governing bodies, NGOs, institutions working in the state.

Table 5.3.5 Linkages of the state level acts and policies with SDGs and NDCs

State level acts and policies	SDGs addressed	NDCs addressed
Maharashtra Felling of Trees Regulation Act	13, 15.1, and 15.2	1 and 3
Maharashtra State Forest Policy	13, 15.1, and 15.2	1 and 3
Maharashtra Forest Rules	13, 15.1, and 15.2	1 and 3
Har Medh Par Ped Scheme	4, 11, and 13	1, 2, 3, and 7
Van Mahotsav	4, 13, and 15	1, 5, and 6
My Plant App	4, 13, and 15	8
Kanya Van Samruddhi Yojana	4, 5, 10, 13, and 15	5 and 6
Bhausahab Fundkar Horticulture Scheme	1, 2, 9, 10, 13, and 15	2, 5, 7, and 8
Atal Bamboo Samruddhi Yojana	1, 2, 8, 10, 13, and 15	5, 6, and 8
Forest Based Industry Policy	8, 9, 10, and 15.9	1, 5, 7, and 8
Climate Action Plan for Mumbai	1, 2, 3, 5, 7, 8, 13, 15, 16, and 17	8
Forest Policy for Green Cover	13 and 15	1, 5, and 6
Council for Climate Change	13, 15, 16, and 17	1, 2, 3, 4, 5, 6, and 7
Coral Reef Conservation Programme	13 and 14	1 and 6
Nagar Van Udyan Yojana	4, 11, 13, and 15	1, 3, and 5
Vasantharao Naik Scheme for Afforestation	4, 11, 13, and 15	1, 3, and 5

Source: Authors' compilation

Box - 1

Bamboo: Harnessing the Untapped Potential

National Bamboo Mission:

The restructured National Bamboo Mission was launched by the Ministry of Agriculture and Farmers' Welfare, Government of India in 2018 as a centrally sponsored scheme; the mission aims to foster the holistic growth of the bamboo sector through an area-based, regionally differentiated strategy with a focus on expanding bamboo cultivation and marketing. To achieve this, the mission supports the establishment of new nurseries and strengthens existing ones to enhance the availability of quality planting material.

Maharashtra Bamboo Development Board:

Playing a pivotal role in mission implementation, the Maharashtra Bamboo Development Board, under the Forest Department, has capitalised on the state's abundant bamboo growth, covering approximately 21 per cent of its area, notably on the Konkan coast, Vidarbha and other tribal areas of the state. According to the Bamboo Resources of the Country prepared by the Forest Survey of India, 11,465 sq. km of the state is reported to be under substantial bamboo cover, with widespread cultivation in farm bunds across rural Maharashtra. This abundant bamboo presence creates opportunities for artisans, farmers, and entrepreneurs in goods, handicrafts, and livelihoods. Collaborating with the mission, the Maharashtra Bamboo Development Board actively leverages these opportunities, contributing to the sustainable development of the bamboo sector.

Chief Minister's Task Force for Environment and Sustainable Development:

Sensing the immense potential that bamboo holds in combating climate change through carbon sequestration and its utility in enhancing livelihood opportunities, the Government of Maharashtra has established the **'Chief Minister's Task Force for Environment and Sustainable Development'**. Its members consist of Ministers and Secretaries from relevant departments of the Government of Maharashtra. The Task Force is working towards encouraging farmers to undertake sustainable bamboo cultivation on a large scale in the state and promoting the use of bamboo as an alternative to fossil fuel. The Task Force aims at building awareness about uses of bamboo in food, medicine, textiles, artefacts, furniture, construction and consumer goods, skill development and forging marketing linkages to develop the entire value chain.

The Task Force has set out a target of cultivating bamboo (along with other plants) **over one lakh hectares of land in the state for FY 2024-25**, increasing it further to five lakh hectares in the next two years. District-wise targets have been specified for bamboo cultivation in order to achieve the state target. The cultivation is to be undertaken particularly on barren and fallow lands, CFR and IFR lands, on the banks of the rivers, lakes and dams, along the roadsides and on private agricultural lands. Farmers will be encouraged to plant bamboo through MGNREGA under which eligible farmers can get up to Rs 7 lakhs per hectare.

In order to implement the decisions of the Task Force, an **Executive Committee** has been constituted under the chairmanship of the Chairman, State Agricultural Price Commission (Ministerial Rank) and co-chairmanship of the Principal Secretary, Environment and Climate Change Department and Director General, MGNREGA. Similarly, a **Technical Committee** consisting of expert representatives from leading international/national/state-level research organisations and Agricultural Universities has been constituted under the chairmanship of Director General, MGNREGA to provide recommendations to the Executive Committee on various technical issues pertaining to bamboo cultivation. In order to propagate bamboo cultivation at the grassroots level, campaign vans have been deployed and review meetings are being conducted at the Divisional Commissioners' Offices at all the six administrative divisions of Maharashtra. Training programmes will be arranged to build capacities of the implementing agencies as well as farmers. With such large-scale bamboo plantation planned across the state, Maharashtra has potential to emerge as a prominent Bamboo based economy in the country.

Power generation through Bamboo biomass:

Bamboo has large biomass that can be used as raw material for energy production. Use of biomass can help in achieving the new standards laid out under the revised Biomass Policy (2023) by the Union Ministry of Power, which mandates 5% biomass co-firing in Thermal Power Plants (TPPs) from FY 2024-25. This obligation is planned to increase to 7% from FY 2025-26, creating further demand for biomass.

Bamboo has also been proven to be one of the most sustainable sources for ethanol production. India's first biorefinery producing ethanol from bamboo has been established in Numaligarh, Assam. Following the Government of India's initiative, Maharashtra is set to develop its own bamboo-to-ethanol biorefineries in the Nandurbar and Gadchiroli districts.

Harit Maharashtra Programme:

In alignment with the objective set out by the Union Ministry of Rural Development and PRI, to enhance green cover in the state over private lands by 20% on a mission mode, **'Harit Maharashtra'** programme has been launched under the Task Force to promote plantation of various trees besides bamboo, such as vetiver, moringa, horticulture, floriculture, mulberry, other trees and pastures in various regions of the state. The objective of 'Harit Maharashtra' program is to achieve equitable, eco-friendly growth and prosperity. Under this initiative, people will be encouraged to undertake plantation of local and indigenous species of plants and grass on a large scale. Implementation of this initiative through MGNREGA will ensure that cultivation is profitable to the farmers and the communities.

Source: Authors' compilation based on Forest Department, Government of Maharashtra. 2017. Report of the committee to strengthen the Bamboo sector in Maharashtra. Mumbai: Department of Forest, Government of Maharashtra; Ministry of Agriculture & Farmer Welfare, Government of India. 2023. National Bamboo Mission. Ministry of Agriculture & Farmer Welfare, Government of India. <https://nbm.nic.in/Home>

Box - 2

Significance of Ecosystem-based adaptation (EbA) in Maharashtra

Ecosystem-based adaptation (EbA) solutions that integrate biodiversity and ecosystem services into an overall strategy that promotes development and enables people adapt to the adverse impacts of climate change (Convention on Biological Diversity, 2009). It consists of 3 pillars or components: (1) Ecosystem Services and biodiversity; (2) Participatory Governance; and (3) Adaptive Capacities (based on FEBA, 2017). EbA strategies can contribute significantly to India's Nationally Determined Contributions (NDCs) and are instrumental in achieving the Sustainable Development Goals (SDGs).

EbA is vital for the state of Maharashtra as it addresses region-specific challenges, ranging from water scarcity and agricultural resilience to biodiversity conservation and disaster risk reduction. With a large population reliant on natural resources, implementing EbA-compliant developmental policies, programs, and practices in Maharashtra will safeguard livelihoods, enhance resilience, and promote sustainable development and economic growth (IUCN, 2019). With this objective, the Department of Environment and Climate Change, Government of Maharashtra has signed Memorandum of Understanding (MoU) with Watershed Organization Trust (WOTR) / WOTR Centre for Resilience Studies (W-CReS) to develop a policy to integrate EbA approach into the State's policies, programs, and projects.

Source: Authors' compilation based on CBD. 2009. Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Montreal, Technical Series No. 41. <https://www.cbd.int/do/publications/cbd-ts-41-en.pdf>; FEBA (Friends of Ecosystem-based Adaptation). 2017. Making Ecosystem-based Adaptation Effective: A Framework for Defining Qualification Criteria and Quality Standards (FEBA technical paper developed for UNFCCC-SBSTA 46). <https://www.iied.org/sites/default/files/pdfs/migrate/G04167.pdf>; International Union for Conservation of Nature. 2019. Annual Report. <https://portals.iucn.org/library/sites/library/files/documents/2020-025-En.pdf>

An aerial photograph showing a vast, lush green landscape. A river flows through the center, with a large dam structure visible in the lower right. The surrounding area is covered in dense vegetation and trees, with some cleared land visible near the riverbank.

The plan for accelerating EbA will provide a tangible chance to rebuild better — for more sustainable and resilient communities and ecosystems.

Box - 3

Significance of National Biodiversity Strategies and Action Plan (NBSAP) for Ecosystem Restoration

The Government of Maharashtra, in alignment with India's global commitment to tackling climate change, is dedicated to integrating the Kunming-Montreal Global Biodiversity Framework (KMGBF) and India's National Biodiversity Strategies and Action Plan (NBSAP) into the implementation of the Maharashtra State Action Plan on Climate Change (MH-SAPCC 2.0). The Action Plan aligns the KMGBF (23 action-oriented global) targets for the following: a) Reducing threats to biodiversity; b) Meeting people's needs through sustainable use and benefit-sharing; c) Tools and solutions for implementation; and mainstreaming the national biodiversity in the action plan. All the implementing departments will address these targets, ensuring that actions are undertaken promptly and completed on priority by 2030.

The following are India's NBSAP targets aligned with KMGBF focusing on national priorities and specific challenges. Major targets include:

1. **Protected Areas (30x30 Goal):** Protect and effectively manage 30% of terrestrial, inland water, coastal, and marine ecosystems.
2. **Ecosystem Restoration:** Restore at least 30% of degraded ecosystems to improve ecosystem services and enhance biodiversity.
3. **Reducing Biodiversity Threats:** Address significant threats such as:
 - a. Land-use change
 - b. Pollution
 - c. Invasive alien species
 - d. Overexploitation of resources in forestry, agriculture, and fisheries.
4. **Sustainable Use:** Promote sustainable management of agriculture, fisheries, and forestry to support rural livelihoods and maintain biodiversity.
5. **Fair and Equitable Sharing:** Ensure equitable benefit-sharing by utilising biological resources and prioritising indigenous and local communities.
6. **Policy Integration:** Embed biodiversity conservation into broader development planning, resource allocation, and decision-making processes.
7. **Resource Mobilisation:** Develop domestic funding strategies and public-private partnerships to support biodiversity conservation.

Source: Author's compilation based on the Ministry of Environment, Forest and Climate Change.



5.3.4 Key action points for adaptation and recommendations

Table 5.3.6 Recommendations for improving climate adaptation and resilience in the forest and biodiversity sector

S. no.	Recommendations/Targets	Actions to be undertaken
1	Protection of existing forests and increase the green cover of the state, including trees outside forest (TOF).	1. Ensure targeted assisted and artificial regeneration of degraded patches within very dense and moderately dense forests. 2. Increase the area under TOF • Trees with settlements (urban AMRUT vans; rural) • Trees with agricultural lands (agroforestry) • Trees along manmade or natural features (beside railways, roads, and canals/ rivers) • Raising plantation for forests species for industrial and commercial use • Other institutional lands. 3. Combine sustainable forest management criteria and indicators with remote sensing techniques to estimate forest degradation. 4. Prevent forest fires through a combination of methods, such as • Upgrade existing fire detection mechanisms • Devise fire danger rating systems for the state to assess the impact of climatic variables on the fire potential of an area • Adopt effective communication strategy for awareness generation • Use advanced drone technology for fire detection and mitigation • Empower communities to deliver on their responsibilities • Build capacity in communities through Joint Forest Management Committee and Eco-Development Councils. • Coordinate with other agencies. 5. Increase the resilience of forests to fires through • Moisture and water conservation • Forest floor biomass management • Weed management. 6. Suppress fire through • Training of field staff, fire watchers, and firefighters • Equipping firefighters • Development of adequate infrastructure for fire suppression • Arrangement of adequate manpower for fire suppression
2	Conservation of biodiversity, forest ecosystem, and protection of habitats.	1. Undertake climate-sensitive biodiversity research, policy and planning through • Research and explore the feasibility of innovative ecosystem financing and their modalities application in the state • Valuation of forest ecosystem services (Western Ghats) • Evaluation of feasible, innovative financing options (Green Bonds, Carbon Bonds, etc.) to protect ecosystems and habitats in Maharashtra.

Geographic areas impacted	Implementing government departments	Financial implications (INR, crore) 2023–2030	Outcome
Solapur, Amravati, Chandrapur, Gadchiroli, Kolhapur, Ratnagiri, Jalgaon, Nandurbar, Gondia, Nagpur, and Washim.	Maharashtra Forest Department, Department of Rural Development and Panchayati Raj, and Department of Tribal Development	12,400.5	Increased forest cover and creation of additional carbon sink for effective climate change mitigation
State level	Nodal agency: Maharashtra Forest Department Implementing agency: Revenue and Forest Department, Urban Development Department, Department of Rural Development and Panchayati Raj, Maharashtra Forest Department, Railways, Public Works Department, Government Of Maharashtra, Maharashtra State Horticulture & Medicinal Plant Board, private lands. Integrate with National Mission on Green India.		
State level	Maharashtra Forest Department.		
State level	Maharashtra Forest Department, State Disaster Management Authority, and Directorate of Information Technology.		
State level	Nodal agency: Additional Principal Chief Conservator of Forests (APCCF) -Protection, Maharashtra Forest Department. Implementing agency: Conservator of Forests (CF) - Forest Regulation, all circles and divisions.		
All districts	Nodal agency: Maharashtra Forest Department. Implementing agency: Maharashtra Forest Department (all circles), State Biodiversity Board, Brihanmumbai Municipal Corporation, Urban Local Bodies, Gram Panchayats, agriculture research institutions.	572.9	Identified synergy between mitigation and adaptation, and resilience and improving ecosystem services

S. no.	Recommendations/Targets	Actions to be undertaken
		2. Prepare guidelines for mainstreaming climate risks and impacts information in State Biodiversity Strategy and Action Plan by - Integrating climate risk, which includes a list of species impacted by climate change - Recognising the micro-climate of various habitat types to understand climate thresholds of the key species. 3. Map risks and vulnerability linkages of all Biodiversity Heritage Sites (BHS) - Prepare Local Biodiversity Strategy and Action Plans across all Gram Panchayats and Urban Local Bodies - Identify climate-vulnerability in protected areas - Prepare contingency plans for floods, droughts, heat waves, and sea level rise to protect wildlife and their habitats. 4. Set up new (and strengthen existing) gene banks, including plant and animal genetic resources - Identify, promote, and conserve traditional and indigenous knowledge of ecosystem services of forests (e.g., medicinal plants) 5. Build capacity of master trainers and officers - Conduct training of at least ten individuals in a GP and ULBs. 6. Map the most vulnerable areas where trash enters the creeks and devise effective waste management strategies, expanding the use of metal nets, deflector screens, mesh skirts, and sediment removal technologies to help collect floating debris from rivers and creeks and appointing flying squads to prevent and monitor illegal waste disposal. 7. Create village specific NTFP and fuelwood plantation by - Training villagers for sustainable use - Identifying species that are stress-tolerant coppicing hardwoods, readily available to farmers as seed or saplings, easy to establish, fast-growing with the early culmination and nitrogen-fixing ability to meet the fuelwood needs of local communities - Establishing nurseries for NTFP-related species.
3	Protection, restoration and rehabilitation interventions for mangroves, wetlands, and corals to ensure their continued survival.	1. Undertake scientific evaluation of carbon sequestration potential of wetlands and mangroves (carbon incentives scheme), and explore restorative technologies that could reduce the impact of climate change on mangroves, wetlands, and corals in tourist hotspots. 2. Design interventions and implementation of restoration of mangroves, wetlands, and corals by - Drafting guidelines for restricting the number of tourists engaged in water adventure sports in areas where coral reefs are found to preserve the coral reefs and prevent their degradation. - Preparing and implementing strict guidelines for solid waste and untreated water disposal in areas having coral reefs.

Geographic areas impacted	Implementing government departments	Financial implications (INR, crore) 2023–2030	Outcome
All districts	Nodal agency: Maharashtra State Biodiversity Board (MSBB) Implementing agency: Forest Department (all circles), Maharashtra State Biodiversity Board, Bombay Municipal Corporations, Urban Local Bodies, and Gram Panchayats.		
All districts	Nodal agency: Maharashtra State Biodiversity Board (MSBB) Implementing agency: Maharashtra Forest Department (all circles), Maharashtra State Biodiversity Board, Bombay Municipal Corporations, Urban Local Bodies, and Gram Panchayats.		
All districts	Nodal agency: Forest Department Implementing agency: Forest Department (all circles), Maharashtra State Biodiversity Board, Bombay Municipal Corporation, Rural Development Department, bilateral agencies, donor agencies, and government and private institutions.		
All districts	Nodal agency: Maharashtra Forest Department Implementing agency: Maharashtra Forest Department (all circles), Maharashtra State Biodiversity Board, Bombay Municipal Corporation, Gram Panchayats, bilateral agencies, donor agencies, and government and research institutions.		
Konkan	Mumbai Mangrove Conservation Unit, and agencies involved in managing solid waste.		
All districts	Nodal agency: Forest Department Implementing agency: Forest Department (all circles), Maharashtra State Biodiversity Board, Bombay Municipal Corporations, Gram Panchayats, NGOs, Rural Development Department, and Tribal Development Department.		
Mangroves: Wetlands in Mumbai city and suburban, Raigad, Ratnagiri, Sindhudurg, Palghar, and Thane districts, and all forest circles. Coral: Entire coast of Maharashtra.	Maharashtra Forest Department and Environmental and Climate Change Department, Forest Department-Mangrove Cell, Urban Local Bodies and State Wetland Authority. Integrate with National Mission on Green India.	204	
Mangroves: Wetlands in Mumbai city and suburban, Raigad, Ratnagiri, Sindhudurg, Palghar, and Thane districts and all forest circles. Coral: Entire coast of Maharashtra.	Maharashtra Forest Department, Environmental and Climate Change Department, Forest Department-Mangrove Cell, and State Wetland Authority.		

S. no.	Recommendations/Targets	Actions to be undertaken
		3. Build capacity and empower local coastal communities, and promote mangrove conservation committees at the village level to undertake • Mud crab farming • Bivalve farming (oyster and mussel) • Cage culture of Asian sea bass • Value addition in fisheries • System of rice intensification (SRI) • Ecotourism guide training 4. Restoration of wetlands and springs through • Identification of priority wetlands and springs important to the state and preparation of action plan. • Training of local communities and awareness generation.
4	Incorporation of participatory monitoring, evaluation, and learning.	1. Promote climate friendly ecotourism in the state through • Training workshops on ecotourism for youth volunteers to engage them in biodiversity conservation. 2. Incorporate training on monitoring protocols, field supervision, and data verification into the design of community-based monitoring. 3. Organise training workshops that integrate and address the needs of multiple stakeholders into the process, creating a network that brings a lasting restorative effort, and in particular, encourage the hospitality industry (hotels/guest houses/ B&B etc.) to adopt green measures such as water conservation, solid and liquid waste management, and e-mobility. 4. Collect and use gender-disaggregated data to examine gender-specific needs, rights, and roles in forest management at the local and regional level. 5. Prepare manuals and best practices kits addressing women's and men's needs and priorities around sustainable forest management. 6. Design activities to allow gender active participation in joint forest management and social forestry.
Total Budget		

Source: Authors' analysis

The total overall financial outlay needed for implementing the recommendations for the forest sector is INR 13181 crore.

Geographic areas impacted	Implementing government departments	Financial implications (INR, crore) 2023–2030	Outcome
200 villages in all coastal districts. The sustainable livelihood programme is to be scaled up so that by the end of 2023, about 200 villages may become a part of this scheme.	Maharashtra Forest Department and NGOs.		
Wetlands: all districts. Springs: hilly districts, especially Western Ghats.	E&CC dept, Forest Department, State Wetland Authority, Urban Local Bodies, Gram Panchayats, Urban Development Department, Department of Rural Development and Panchayati Raj, Tribal Development Department, and District Administrations.		
State level	Forest Development Corporation of Maharashtra, Maharashtra Forest Department, and Department of Tourism.	3.6	Strengthened role of the communities for sustainable forest conservation, effective biodiversity conservation, and inclusive social change.
State level	Department of Rural Development and Panchayati Raj, and Maharashtra Forest Department.		
State level	Maharashtra Forest Department.		
State level	Maharashtra Forest Department.		
State level	Maharashtra Forest Department.		
State level	Maharashtra Forest Department and Department of Rural Development and Panchayati Raj.		
		INR 5008780 lakh	

5.4 Climate change impacts on the health sector and adaptation strategies

5.4.1 Context

Climate change is expected to severely impact human health in the coming decades. Between 2030–2050, globally, an estimated 250,000 mortalities are projected to occur each year due to climate change induced extremes such as floods, cyclones etc, resulting in an economic loss ranging from USD 2 to USD 4 billion annually (World Health Organisation 2021). The climate crisis is putting at risk various factors that significantly influence good health outcomes, such as people's livelihoods, equality, access to healthcare, and support systems in their communities.

Rising temperatures, increased precipitation extremes, and habitat destruction are leading to the emergence and spread of infectious diseases. The changing climate is altering the ecology of disease-carrying vectors, causing infections to appear in areas where they were previously absent (Githeko et al. 2000). Heavy rainfall and flooding also contribute to outbreaks of waterborne diseases. India is experiencing more frequent and severe heat waves due to climate change. These heat waves can have various health impacts, from heat-related illnesses such as heat strokes to cardiovascular and respiratory issues. The rise in pollution from vehicles and industries is deteriorating air quality, leading to acute respiratory infections, cardiovascular diseases, and cancers. The changing climate also affects agriculture, leading to unpredictable rainfall, droughts, and flash floods. This directly impacts food production and threatens food security, especially in resource-constrained vulnerable parts, where malnutrition is already a challenge. Moreover, climate change can also have adverse effects on mental health. The increasing intensity of extreme weather events can trigger conditions such as post-traumatic stress disorder, major depressive disorder, anxiety, and depression. Climate change poses significant risks to human health, affecting various aspects of well-being,

from infectious diseases to mental health and food security (Hayes et al. 2018).

Owing to its size and geographical spread, Maharashtra is diverse in terms of topography and climatic regions. Traditionally, while the coastal Konkan region experiences intense and heavy rainfall, Vidarbha and Marathwada face frequent droughts and dry spells. The temperature is usually uniform in Konkan due to the influence of the sea, while the interior regions, especially Vidarbha, can experience extreme variations in temperature between the summer and winter months. As a consequence of climate change, the state experiences frequent droughts and floods in various regions. The frequency of droughts in Marathwada and Vidarbha is currently once in five and six years, respectively (Patil 2012). Meanwhile, western Maharashtra and Konkan have witnessed extreme rainfall over the last few years, resulting in frequent landslides and flooding (Sangomla 2021).

The changing climate patterns and extreme weather events can negatively affect health outcomes in the state. Despite the state's good performance on several health indicators, the effects of climate change could jeopardise these accomplishments. In recent years, Maharashtra has witnessed a rise in vector-borne diseases such as dengue and malaria; dengue cases increased from 7,829 in 2017 to 12,720 in 2021, and similarly, the number of malaria cases increased from 10,757 in 2018 to 19,303 in 2021 (Figure 5.4.2).

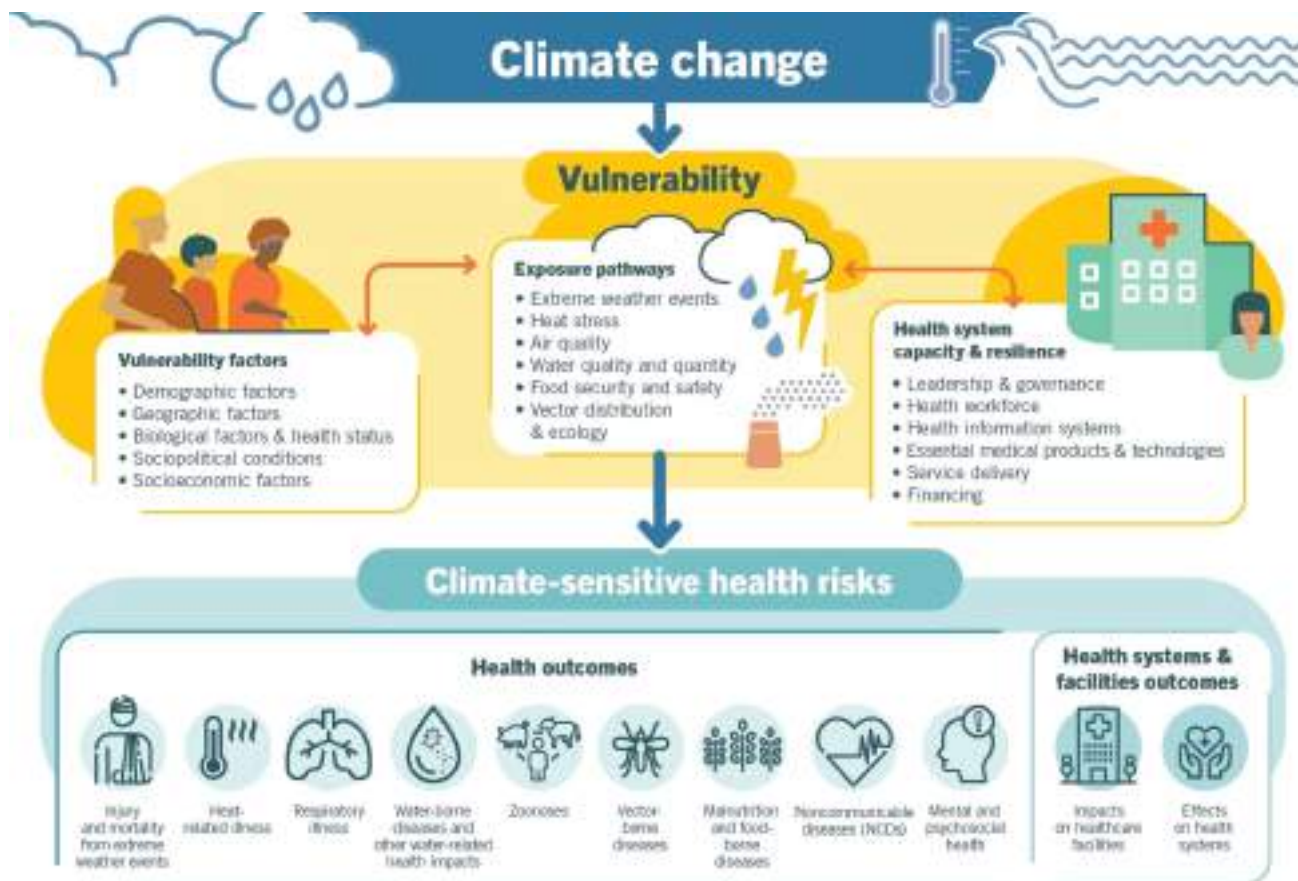
Vector-borne diseases are closely linked with three key factors — rainfall, humidity, and temperature — which dictate the spread and transmission of the infections. Therefore, an increase in temperature and rainfall directly correlates with the spurt in cases of malaria and dengue in Maharashtra. The reporting of dengue cases beyond the usually observed months is hypothesised to be the late withdrawal of monsoons from India (Deol 2022). The trends indicate that the Vidarbha and Konkan regions will experience more days conducive to malaria transmission in the coming years. Though the state has successfully controlled waterborne infections due to improvements in access to quality drinking water, there has been an increase in incidents of waterborne infections in various parts of the state following intense spells of rainfall (Devikar 2022).

Table 5.4.1 Impact of climate change and associated outcomes on the health sector

Climate change and associated outcome	Major impacts
Rise in temperatures and heatwaves	Heat-related illnesses, cardiovascular diseases, and skin cancer
Increase in precipitation and flooding	Waterborne and vector-borne diseases
Air pollution	Airborne diseases, acute respiratory infections, chronic obstructive pulmonary disorders, and respiratory allergies
Loss in agricultural productivity	Food insecurity and malnutrition
Disasters and displacement	Social and mental health stress

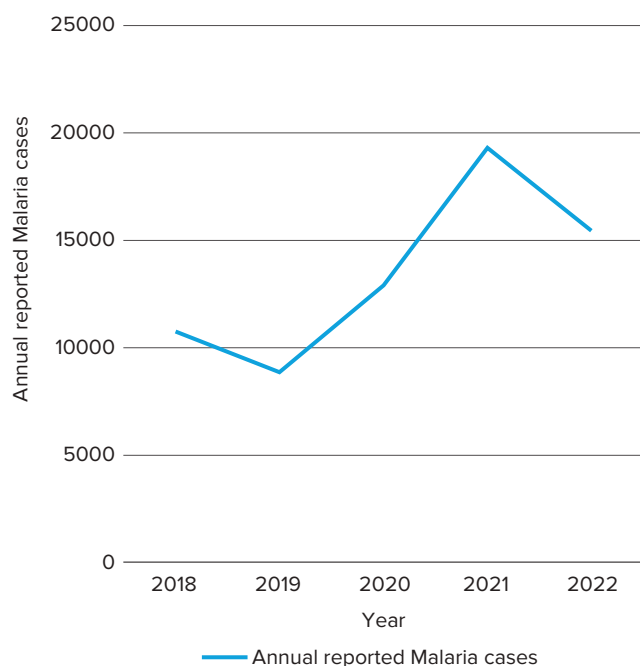
Source: Authors' compilation

Figure 5.4.1 Climate change affects health through climate-sensitive risks, exposure pathways, and vulnerability factors, which are influenced by environmental, social, and public health determinants



Source: World Health Organization

Figure 5.4.2 Annual reported Malaria cases in Maharashtra from 2018 to 2021



Source: Authors' analysis

Interior parts of the state are also witnessing an increase in the frequency of heat waves and rise in temperature, which can result in a rise in the prevalence of heat-related illnesses such as heat strokes and also have long-term implications by contributing to cardiovascular diseases and respiratory infections.

The drastic changes in weather patterns can negatively impact agricultural production, thereby contributing to food insecurity and malnutrition. The state already has a high burden of malnutrition, with nearly 34 per cent of children under six years of age stunted and more than 60 per cent of children in the same age category anaemic (National Family Health Survey 5 2021). This is bound to exacerbate if agricultural production is impacted due to extreme weather events and erratic climate.

5.4.2 Overview of the health system in Maharashtra

Maharashtra has a score of 61.76 (out of 100) on the NITI Aayog health index, which is a weighted composite score encompassing 24 variables covering important elements of health performance. According to earlier findings from the Common Review Mission, Maharashtra's health

facilities are adequate. The state has 92 operational sub-district hospitals and 23 district hospitals, in addition to 40 mobile medical units spread throughout 33 districts (National Health Mission n.d).

Additionally, Maharashtra has implemented several programmes to improve the health conditions of the population, which include the *National Reproductive Health and Child Health Programme*, the *National AIDS Control Programme*, the *National Programme for the Control of Blindness*, the *National Iodine Deficiency Disorder Control Programme*, *National Cancer Control Programme*, *National Mental Health Programme* etc. While the government manages some of these initiatives, others receive partial funding from the union government. The state has brought down the crude birth and death rate to 15.0 and 5.5 (2020) from 18 and 6.4 (in 2004), respectively. Further, the state has outperformed other states in terms of its reproductive and child health (RCH) indicators with special initiatives, including the establishment of first referral units, a 24-hour delivery scheme, appointment of consultants, conducting RCH camps, and establishment of neonatal care units. Despite advancements in traditional and summary indices of the population's health, Maharashtra is still susceptible to new infectious illnesses.

5.4.3 Health profile of the state

In Maharashtra, the average life expectancy at birth is about 72.5 years. The epidemiological transition ratio is 0.33, indicating a high burden of non-communicable diseases in the state. According to recent statistics, the top causes of health stress among children include diarrheal diseases, nutritional deficiencies, and lower respiratory infections, whereas, among older adults, it is cancer, cardiovascular diseases, and chronic respiratory diseases. Further, the *Integrated Disease Surveillance Programme* (IDSP) in Maharashtra reported 131 disease outbreaks, in addition to chikungunya and dengue as the most common outbreaks (Asian Development Bank 2022).

5.4.3.1 Disease burden in Maharashtra

Among children aged 0–14, the primary causes of mortality include lower respiratory infections, diarrheal illnesses, and nutritional deficiencies. Older adults (aged 40–69 and over 70 years old) are most affected by malignancies, cardiovascular issues, and chronic respiratory diseases.

The top 15 causes of premature mortality for both sexes include ischemic heart disease, stroke, chronic obstructive pulmonary disease, lower respiratory infections, diarrheal illnesses, complications from premature delivery, traffic accidents, tuberculosis, chronic renal disease, and more.

Furthermore, chronic diseases such as iron deficiency anaemia, loss of vision or hearing, low back or neck pain,

migraine, depressive disorders, skin diseases, chronic obstructive pulmonary disease, diabetes, oral disorders, complications of preterm birth, falls, osteoarthritis, and hemoglobinopathies contribute significantly to disabilities in Maharashtra. To address this growing burden and emerging public health challenges, stronger specialised services, improved hospital infrastructure, and enhanced epidemiological surveillance are required.

5.4.3.2 Status of the public health infrastructure in the state

The health department in Maharashtra primarily focuses on providing healthcare through primary and secondary health facilities. These include sub-centres (SCs), first referral units (FRUs), primary health centres (PHCs), and secondary-level hospitals. Tertiary-level facilities are mostly managed by the Directorate of Medical Education and Research (DMER), while urban local bodies handle public sector healthcare facilities in metropolitan cities such as Mumbai. The state has 23 district hospitals in the revenue district headquarters, along with eight general hospitals. The combined bed capacity of general and district hospitals is 9,593. Public health facilities are governed by population norms. For instance, in rural areas, one sub-centre is mandatory for every 3,000–5,000 people, one PHC for every 20,000–30,000 people, and one community health centre (CHC) for every 80,000–1,20,000 people. In urban areas, PHCs should serve 50,000 people in slum areas with high-density populations and 75,000 in slum areas with sparser populations.

Table 5.4.2 District-wise availability of public health facilities in Maharashtra

Facility	In position	Required	Shortfall (%)
SCs	10,673	14,255	3582 (25)
PHCs	1,853	2,323	470 (20)
CHCs	256	580	224 (39)
Urban PHCs	538	1,165	627 (53.8)
Sub-district hospitals	92	-	-
District hospitals	23	-	-

Source: Rural Health Statistics 2021–22

5.4.3.3 Status of health workforce in public health facilities

The Health Dossier Report (2021) for Maharashtra, prepared by the National Health Systems Resource Centre (NHSRC), shows a 26 per cent vacancy for medical officers, 26 per cent for nurses, and 14 per cent for auxiliary nurses and midwives (ANMs) in the state. Additionally, among the specialist cadre, of the 4126 sanctioned posts, only 2662 have been filled (with a reported vacancy of 1464).

Table 5.4.3 District-wise breakdown of healthcare facilities in Maharashtra

Name of district	Sub-centres	PHCs	CHCs	Sub-district hospitals	District hospitals
Ahmednagar	565	107	23	2	1
Akola	178	42	5	1	0
Amravati	334	75	9	4	1
Aurangabad	279	74	10	3	1
Beed	297	57	10	3	1
Bhandara	193	34	7	2	1
Buldhana	280	58	12	1	2
Chandrapur	339	67	10	3	0
Dhule	232	47	5	2	1
Gadchiroli	376	48	9	3	1
Gondia	258	41	10	1	0
Hingoli	132	27	3	2	1
Jalgaon	442	95	17	3	0
Jalna	218	44	9	1	1
Kolhapur	413	92	18	4	0
Latur	252	60	10	1	0
Mumbai	0	37	0	0	0
Mumbai Suburban	0	97	0	0	0
Nagpur	316	105	10	2	0
Nanded	379	79	13	4	1
Nandurbar	293	63	12	2	0
Nashik	589	155	24	6	1
Osmanabad	215	46	6	4	1
Palghar	306	69	10	3	0
Parbhani	214	38	6	2	1
Pune	546	192	40	5	1
Raigad	280	60	8	6	1
Ratnagiri	378	70	8	3	1
Sangli	328	75	15	2	0
Satara	402	76	15	2	1
Sindhudurg	248	38	7	3	1
Solapur	430	95	16	3	0
Thane	180	143	12	3	1
Wardha	181	32	9	2	1
Washim	150	27	6	1	1
Yavatmal	450	69	14	3	0
Total for all districts	10673	2539	398	92	23

Source: Rural Health Statistics 2021–22

5.4.4 Climate change and health vulnerability in Maharashtra

Analysing the disease profile at the district level is crucial to identify how the health system might be affected by climate-related environmental exposures or hazards. It serves as a valuable tool to prepare and plan for resilience against climate change impacts on health. Evaluating various health vulnerabilities arising from different diseases and illnesses can enhance the prioritisation of efforts, inclusive planning, communication,

and assessment of adaptation and interventions aimed at safeguarding communities from the effects of climate change.

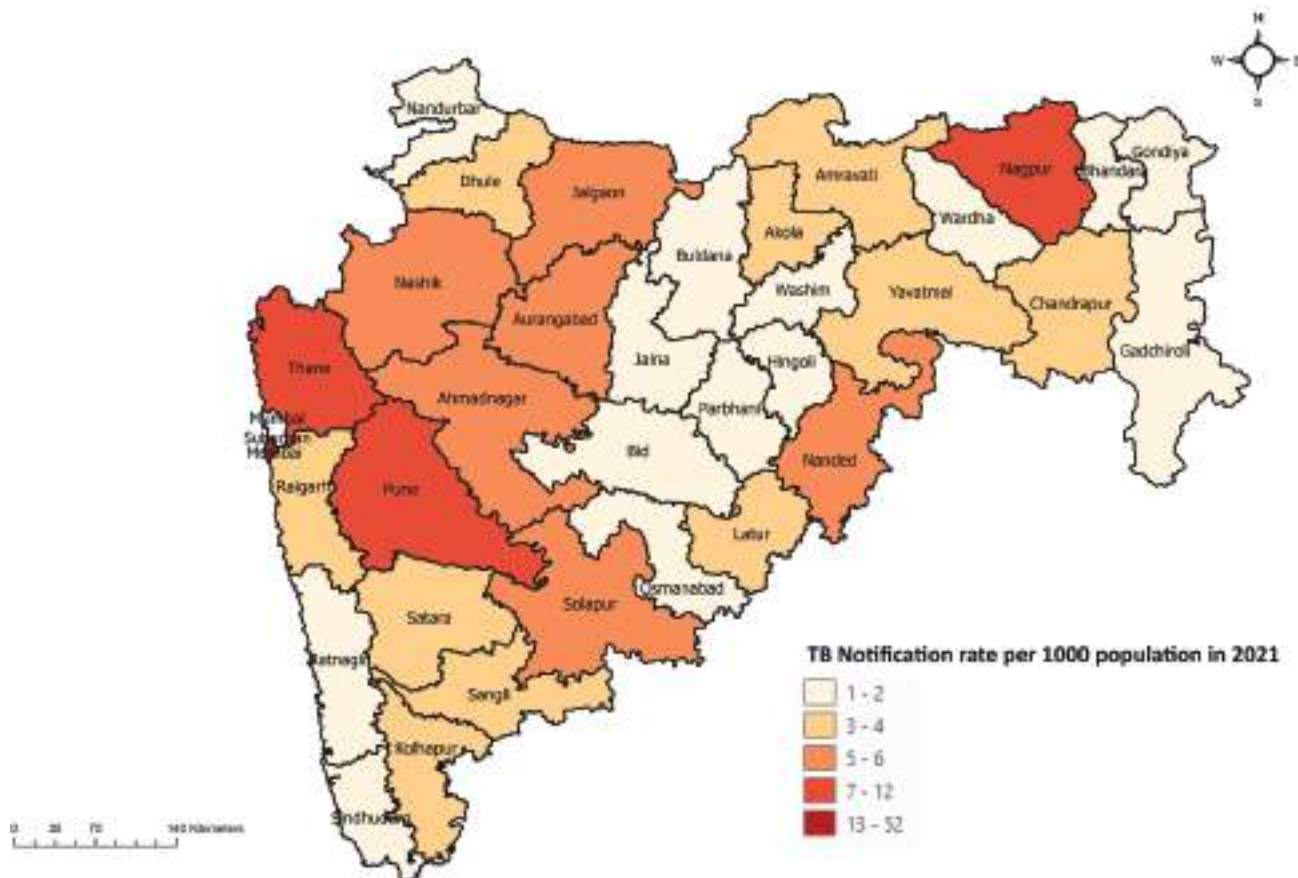
Based on sector-specific expert input and data accessibility, the maps in Figures 5.4.3a–3e show the profile of the state to different acute respiratory, vector-borne, waterborne, and nutrition diseases. The data sources include the Census 2011, the National Family Health Survey (NFHS-5), and the Directorate of Health Services (DHS), Maharashtra.

Table 5.4.4 Diseases and their relation to climate change

Diseases	Rationale	Source
TB notification rate	Communities residing in districts with high population density and existing high incidences of communicable diseases are more vulnerable to the impacts of future climate change.	National Tuberculosis Elimination Programme
Prevalence of symptoms of ARI NFHS-5	Climate change has the potential to heighten exposure to risk factors such as pollen, ozone, and particulate matter, which can worsen air quality and exacerbate respiratory diseases. Individuals residing in districts already facing poor air quality are more susceptible to these effects.	NFHS-5
Prevalence of diarrhoea in NFHS-5	Heavy rainfall and flooding can lead to an increase in waterborne diseases.	NFHS-5
Malaria prevalence	Climate change-induced alterations in temperature and rainfall patterns are expected to result in a rise in vector-borne diseases.	DHS, Maharashtra
Dengue prevalence		DHS, Maharashtra

Source: Authors' compilation

Figure 5.4.3a District-wise exposure to Tuberculosis



Source: : Authors' analysis

Figure 5.4.3b District-wise exposure to Acute Respiratory Infections (ARI)

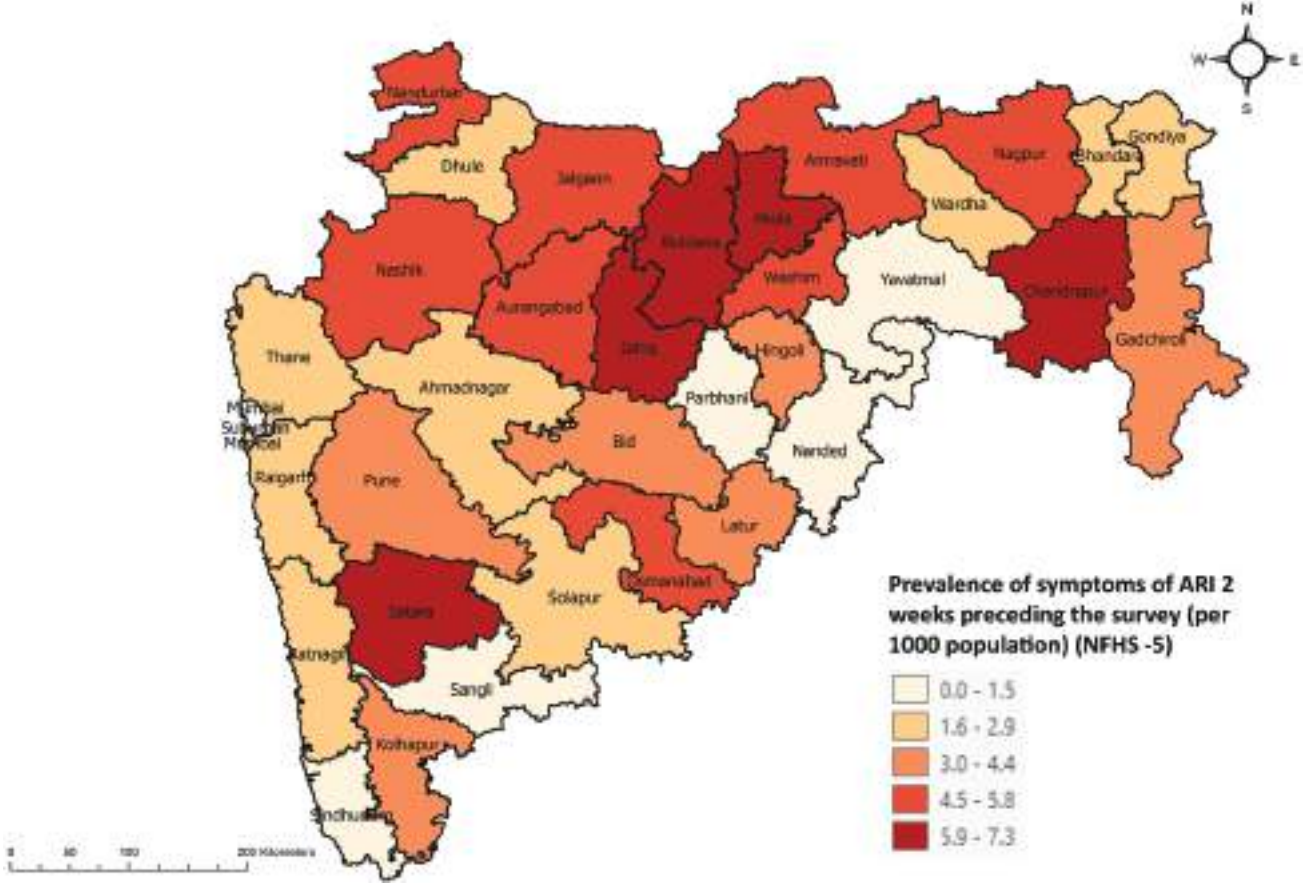


Figure 5.4.3c District-wise exposure to Diarrhoea

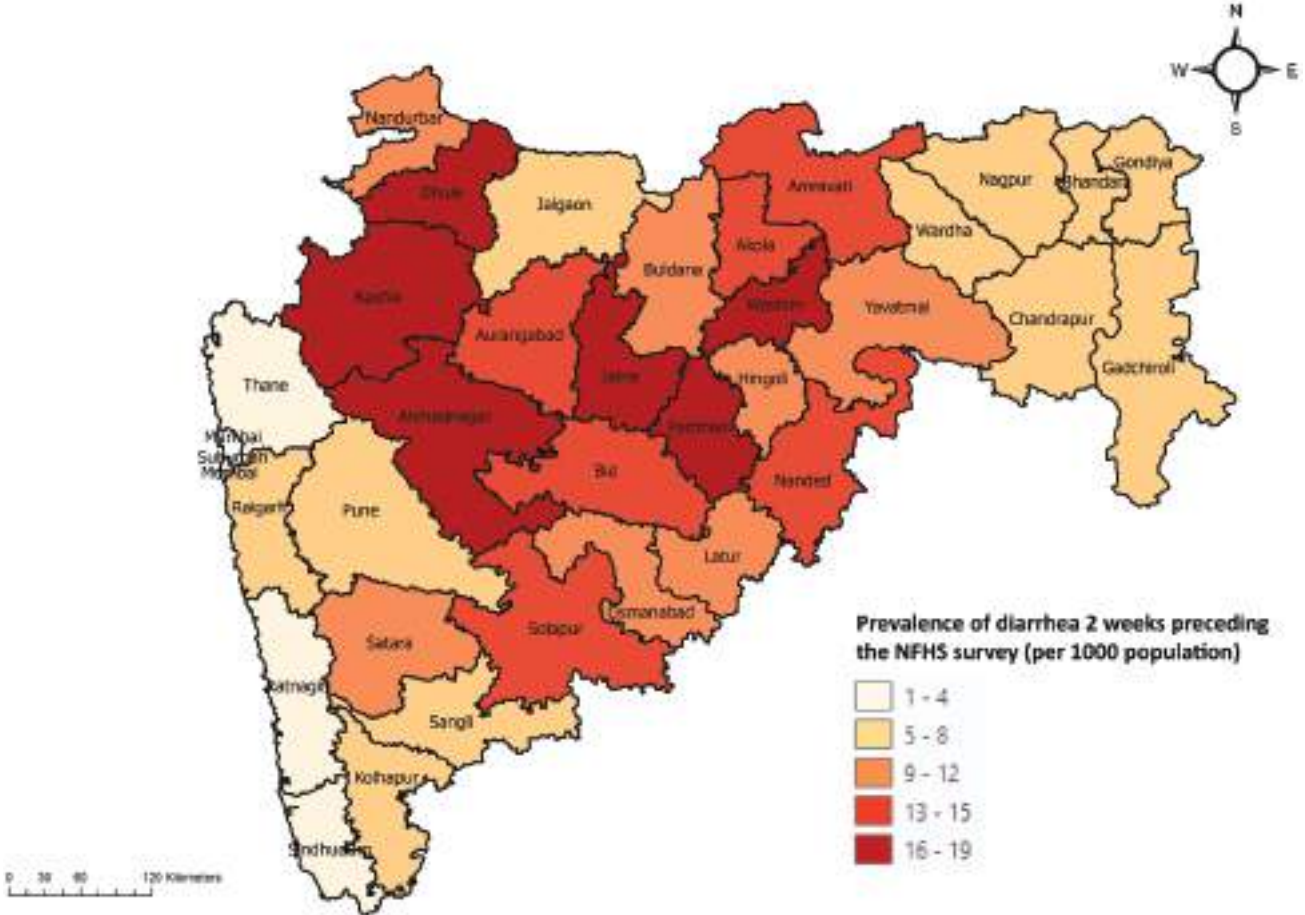
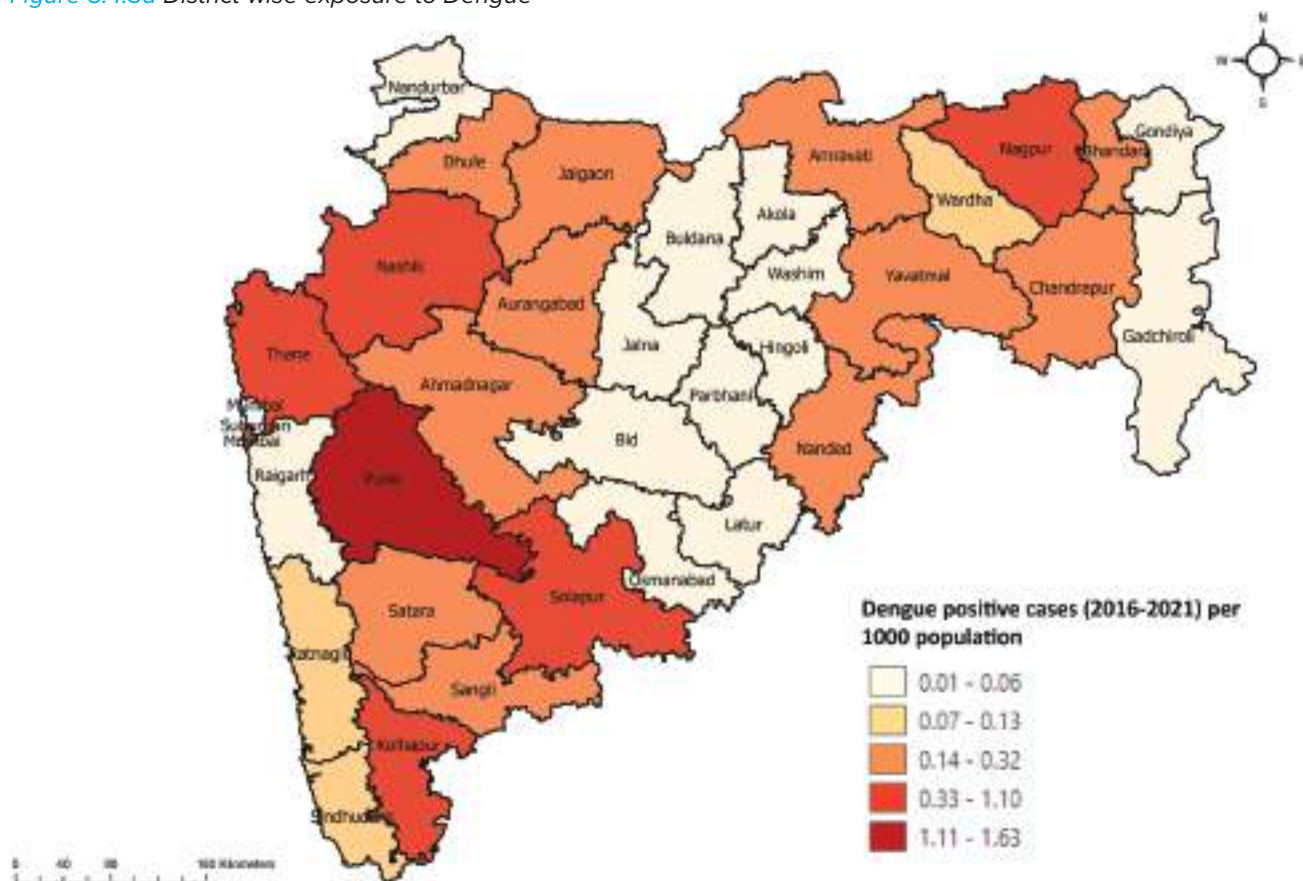
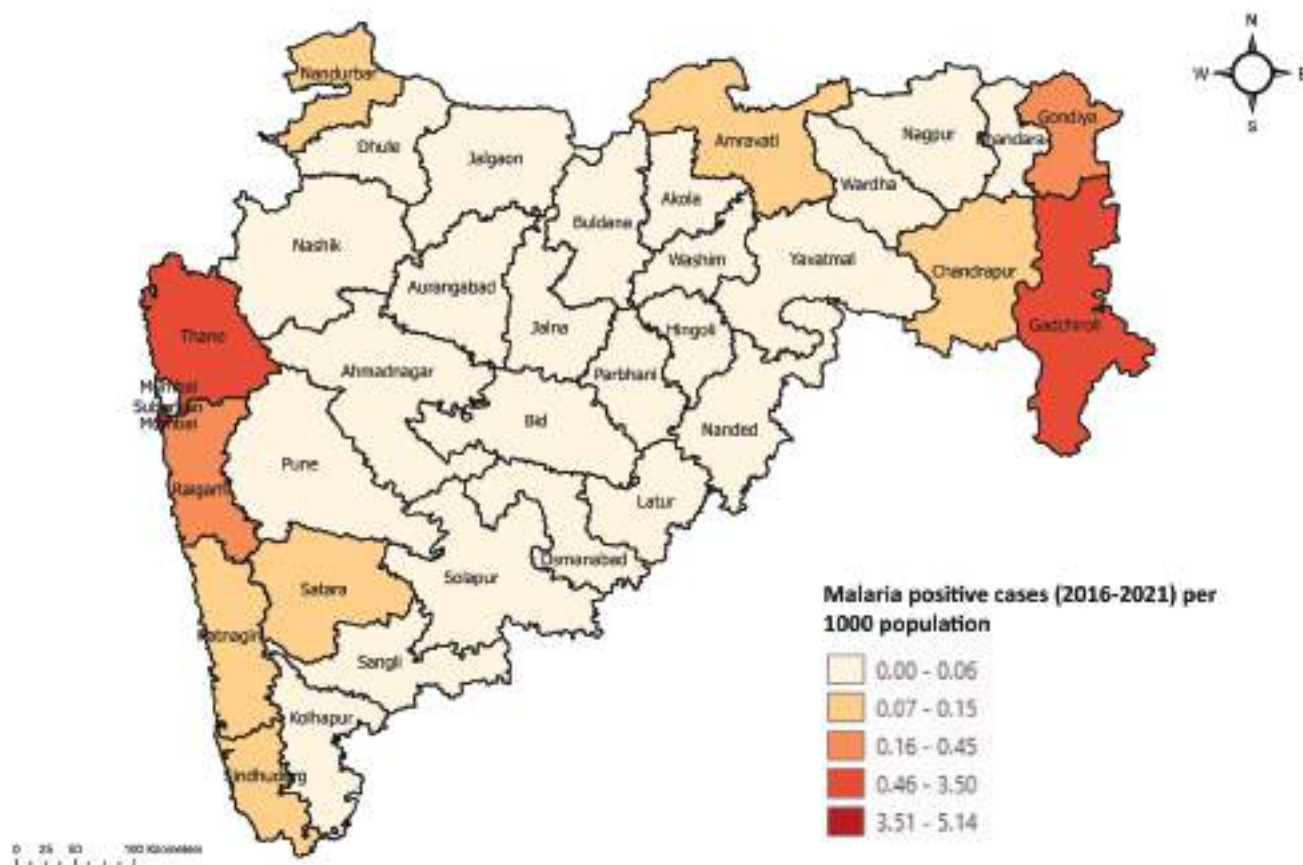


Figure 5.4.3d District-wise exposure to Dengue



Source: Authors' analysis

Figure 5.4.3e District-wise exposure to Malaria



Source: Authors' analysis

Table 5.4.5 Diseases and districts with the highest exposure

Disease	District with the highest exposure
TB notification rate in 2021 and achievement to date	Mumbai
Prevalence of ARI symptoms two weeks preceding the survey NFHS-5	Chandrapur
Prevalence of diarrhoea two weeks preceding the survey NFHS-5	Nashik
Dengue-positive cases (2016–2021)	Pune
Malaria Positive cases (2017, 2018, and 2019)	Mumbai

Source: Authors' analysis

For the purpose of assessing the health disease exposure due to climate change in Maharashtra, we have looked at five key illnesses/diseases that are highly sensitive to changing climate. The prevalence of these conditions is illustrated in Figures 5.4.3a–3e. From these, we can infer that some districts in regions, such as Vidarbha and Marathwada, are especially exposed to these climate-sensitive diseases. The Maharashtra State Action Plan on Climate Change (MH SAPCC) aligns with the directives of the Union Ministry of Health and Family Welfare, with the goal of reducing morbidity, mortality and health vulnerabilities addressing the climate-sensitive diseases through the integration of key national missions under NAPCC, including the National Health Mission. The National Programme on Climate Change and Human Health (NPCCHH) highlights the importance and implementation of the National Action Plan on Climate Change and Human Health (NAPCCHH) and the

State Action Plan on Climate Change and Human Health (SAPCCHH).

The NPCCHH aims to raise awareness among vulnerable communities, healthcare providers, and policymakers about the impacts of climate change on human health, while also strengthening the capacity of the healthcare system to address climate-related illnesses. Additionally, the program focuses on enhancing health preparedness and response through situational analyses at various levels, from national to sub-district. It promotes partnerships and synergies with other national missions to ensure that health is adequately represented in the national climate change agenda, and emphasises building research capacity to fill critical evidence gaps regarding the effects of climate change on human health. The recommendations that we have prescribed, therefore, are in alignment with these findings.

5.4.5 Adaptation strategies and recommendations for the health sector in Maharashtra

Table 5.4.6 Recommendations for building climate resilience of the health sector

S. no.	Recommendations/ Targets'	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications	Outcome
1	Mapping of vulnerable populations and strengthening of emergency response capabilities at all levels (block and district level) for all districts.	1. Map the proportion of vulnerable populations in each community within all districts and evaluate the gaps in services provided.	All districts.	Public Health Department. In convergence with National Mission on Strategic Knowledge on Climate Change.	Approximately INR 7–8 lakh. Mapping of the sensitive populations will be completed in the first two years. Follow-up activities are to be carried out every year for updating.	Improved understanding of the proportion of vulnerable populations in each district, which will help in the preparation of specific action plans for these groups in all the districts.
		2. Improve and strengthen emergency health services as per the need of the district for all the districts.	Washim, Parbhani, Nashik, Jalgaon, Nandurbar, Aurangabad, and Raigarh.	Public Health Department. In convergence with National Mission on Strategic Knowledge on Climate Change and National Health Mission.	Approximately INR 20 crore.	

S. no.	Recommendations/ Targets'	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications	Outcome
2	Improving the adaptive capacity of the vulnerable districts.	1. Ensure there is enough staff in the existing and newly established medical facilities in districts where there are gaps in services and a high level of vulnerability.	Washim, Parbhani, Nashik, Jalgaon, Nandurbar, Aurangabad, and Raigad.	Public Health Department. In convergence with National Health Mission and NPCCHH	This cost depends on the need identified during the assessment of vulnerability as per Recommendation.	Strengthened capacity of health systems in terms of adequate human resources and infrastructure to respond to climate-induced hazards and disasters.
		2. Upgradation and greening of public-health infrastructure, including provision of equipment and systems. Leverage strategic engagement of the private sector.	Washim, Parbhani, Nashik, Jalgaon, Nandurbar, Aurangabad, Raigarh, Nagpur, Akola, Nanded, Yavatmal, Gondia, Dhule, Gadchiroli, Bhandara, and Buldhana.	Public Health Department and Public Works Department. In convergence with NAPCCHH and SAPCCHH and National Health Mission.	Approximately INR 8000 crore would be required to Improve infrastructure and strengthening the facilities in Govt and Civil Hospitals of the entire state.	
3	Implementation of Climate Resilient and Sustainable Health Services.	1. Carry out health facility assessments, including energy audit. Prepare standard operating procedures (SOPs), job aids, and training modules on green, climate-resilient, and sustainable health facilities.	State level.	Public Health Department	INR 0.5 crore per year. Approximately INR 4 crore till 2030.	Provision of energy-efficient health services, thereby ensuring the decarbonisation of public health facilities. Strengthened capacity of healthcare infrastructure against extreme climate events.
		2. Build flood-resilient infrastructure for public health facilities in flood-prone districts.	Sindhudurg, Ratnagiri, Raigarh, Satara, Gadchiroli, Solapur, and Kolhapur.	Public Health Department and Public Works Department.	An approximate outlay of INR 50 crore.	
		3. Climate proof public healthcare facilities and implement adaptation strategies such as cool roofing to respond to heat waves.	Sindhudurg, Parbhani, Kolhapur, Hingoli, Chandrapur, Gadchiroli, Nagpur, and Nanded.	Public Health Department and Public Works Department. In convergence with National Health Mission	An approximate outlay of INR 50 crore.	

S. no.	Recommendations/ Targets'	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications	Outcome
4	Strengthening surveillance of climate-sensitive diseases and ensuring health system preparedness for these diseases.	1. Leverage digital and AI/ ML systems for real-time monitoring of data and enable forecasting. Strategic engagement with the private sector and research institutions in this area.	State level.	Public Health Department, MSDMA, IMD, and DoECC. In convergence with National Health Mission and NPCCHH.	An approximate outlay of INR 15 crore.	Establishment of Continuous Ambient Air Quality Monitoring Stations.
		2. Set up Continuous Ambient Air Quality Monitoring Stations in districts or cities where they are currently not in operation.	State level.	Public Health Department, and MPCB	An approximate outlay of INR 20 crore.	
5	Capacity building of health workers and community institutions on climate change–induced health risks	1. Increase awareness among the general public on climate-sensitive diseases through risk communication and community engagement strategy (RCCE).	State level.	Public Health Department, district administrations, PRIs, SHGs. Integrate with the National Mission on Strategic Knowledge on Climate Change and National Health Mission with NPCCHH.	An approximate outlay of INR 0.5 crore per year, a total of INR 4 crore till 2030.	Enhanced capacities of health workers and local community institutions towards climate-induced health hazards.

Source: Authors' analysis

Table 5.4.7 Recommendations for tribal communities

S. no.	Target	Rationale	Action Point
1	To bridge the current gaps in the health and nutritional status of the tribal communities in the state to help build a health and nutritional support system for the tribals for the upcoming climate change issues.	Health-related diseases are more prevalent in northern Maharashtra, Marathwada, and Vidarbha districts. Among these regions, northern Maharashtra and Vidarbha have a higher proportion of people belonging to scheduled tribes and scheduled castes. Additionally, these districts have a considerable number of children under age five who suffer from malnutrition (wasted) and experience high infant mortality rates. Moreover, more than half (54%) of tribal women in Maharashtra in the reproductive age group are affected by anaemia.	1. Train 1,000 local tribal youth volunteers, who can be called <i>Swasthya Mitra</i>, as dais and ASHA workers with the active participation of Gram Panchayats to promote kitchen garden schemes and enhance nutritional deficiency among tribals. 2. Design an integrated programme with the support of PHCs and health departments to provide quarterly services to the tribal children in schools, such as supplementary nutrition, immunisation, and health check-up by trained local tribal youth volunteers under <i>Navsanjeevani Yojana</i>. 3. Enhance community health surveillance and establish nursing homes, child welfare centres, and maternity centres in districts with a significant tribal population. This initiative is inspired by the successful <i>Tribal Action Plan</i> piloted in the Taloda and Akkalkuwa blocks of the Nandurbar district and aims to expand these services to other vulnerable districts as well. 4. Ensure health education and healthcare through school healthcare programmes in tribal areas, especially in Ashram Schools.

Source: Authors' analysis

The total overall financial outlay needed for implementing the recommendations for the health sector is INR 8249.56 crore.

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
State level with a special focus on Nandurbar, Nashik, Jalgaon, Gadchiroli, and Vidarbha regions.	Department of Public Health.	The cost of training 1,000 <i>Swasthya Mitra</i> includes awareness of climate change, nutritional deficiency, building capacities to conduct basic health check-ups and kitchen gardens.	Improved health and nutritional status of the tribal communities with well-established healthcare facilities available to them.
	Department of Public Health.	The total cost of training for 3 months and hand-holding for the following 9 months= INR 5 crore.	
	Department of Public Health.	Conducting quarterly health awareness programmes in 1,000 Ashram schools for 2 years= INR 5 crore.	
	Department of Public Health.		

5.5 Climate change impacts on habitats and adaptation strategies

5.5.1 Introduction

Climate change has been attributed to an increase in the number as well as the intensity of extreme events like floods, droughts, cyclones, landslides, and heat waves. With limited access to basic services, infrastructure, and healthcare, our habitats are vulnerable to these changing climate events. The *National Mission on Sustainable Habitats* (2022) defines sustainable habitat as an approach towards a balanced and sustainable development of the ecosystem of habitat, which offers adequate shelter with basic services, infrastructure, and livelihood opportunities along with environmental and socio-economic safety, including equality, inclusiveness, and disaster resilience.

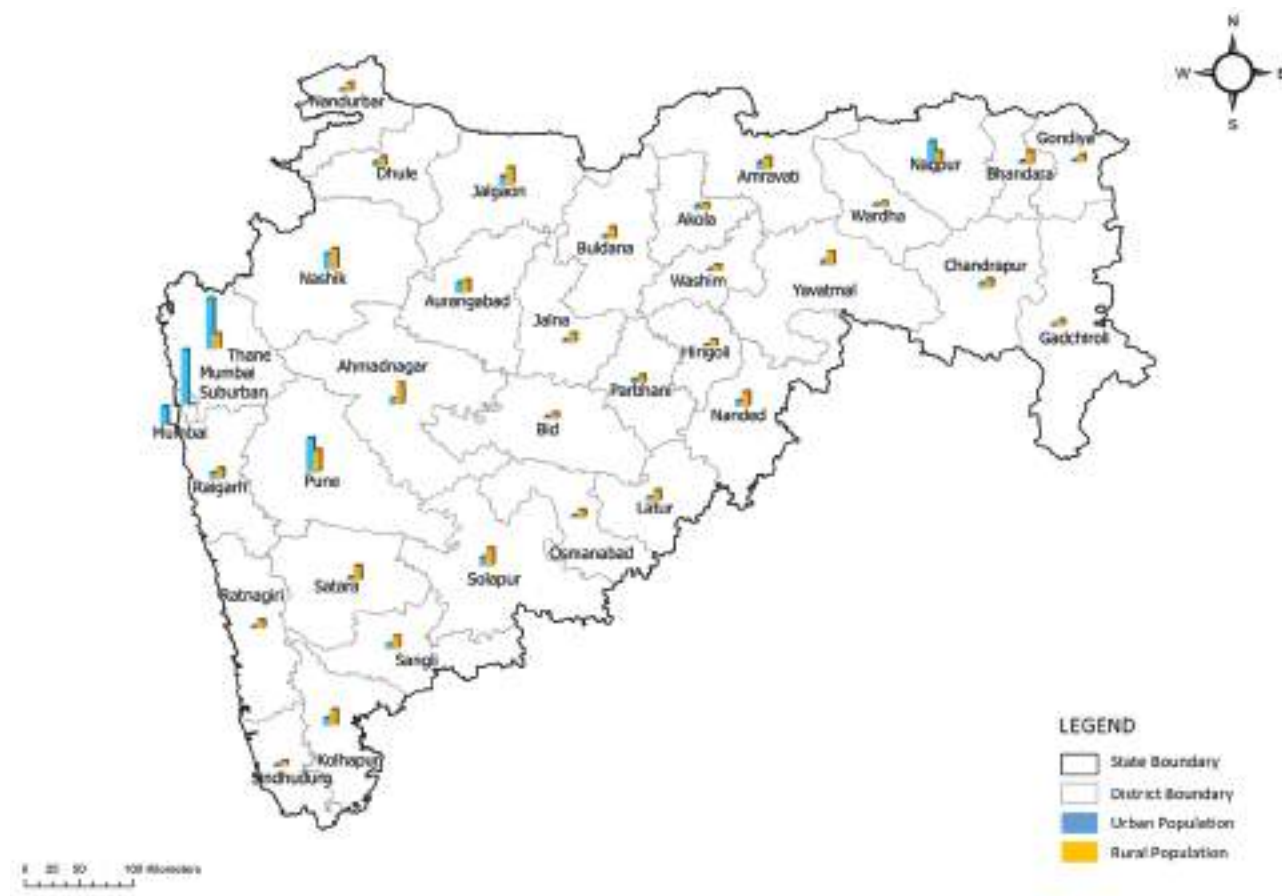
Maharashtra is India's second most populated state, with a population of 112.3 million (Ministry of Home Affairs 2011) and a geographical area of approximately 30.8 million ha. After Tamil Nadu and Kerala, Maharashtra is the third most urbanised state in the country. Approximately 45 per cent of the state's population lives in urban regions, compared

to 48 per cent in Tamil Nadu and Kerala, 43 per cent in Gujarat, and 31 per cent nationally. According to the National Sample Survey (NSS) 76th Round, slums are home to around every fourth household in urban Maharashtra (Ministry of Statistics and Program Implementation 2018).

Although highly urbanised, with nearly 51 million people living in urban areas, there is a considerable difference in levels of urbanisation across the state's six regions and 36 districts. Of the six revenue divisions, Konkan has the most urbanised population, mainly concentrated in Mumbai, Mumbai suburban, and Thane districts. Besides Konkan, Nagpur and Pune districts are also highly urban, with 2.4 and 5.05 million people living in the urban areas, respectively. Together, these five districts have a higher percentage of urban residents than the state's average of 45.2 per cent. A total of 26 Municipal Corporations, 230 Municipal Councils, 111 Nagar Panchayats, and 7 Cantonment Boards oversee the urban regions.

Maharashtra has experienced significant urbanisation due to people migrating from various parts of India, and it has one of the country's highest inter-state migration rates (Ministry of Home Affairs 2011). The reasons for migration skew towards employment opportunities (for men) and marriage (for women). The census also suggests that natural growth in the population contributes the maximum

Figure 5.5.1 Urban-rural demographic percentage distribution



Source: Authors' compilation based on Census 2011

(51%) to the rapid growth of the urban population, followed by net migration to urban areas (31%) and reclassification of rural areas to urban areas (18%).

Though urbanisation is generally seen as a positive change, unplanned and rapid developments without ensuring the delivery of basic facilities could decrease the quality of life, add pressure on the available natural resources of a region, and exacerbate the impact of natural disasters on the population (UNDRR 2015a). An estimated 11.8 million people, which is almost a quarter of the urban population in the state, live in slums that face several challenges, such as lack of access to basic services and vulnerability to extreme climate change events (Ministry of Home Affairs 2011). Most cities in the state are dealing with various difficulties, such as the need for water, sewage management, roads, transit, power, schools, and health care infrastructure that are outpacing population growth.

The total population in rural Maharashtra is about 61.5 million as per the 2011 census, with Pune, Ahmednagar, Nashik, Jalgaon, and Solapur districts having the highest rural populations. Even though a large portion of Maharashtra continues to reside in rural areas, the trend in population growth suggests a shift from rural to urban population. The rural population in the state increased by only 10 per cent compared to the 24 per cent increase in the urban population from 2001 to 2011. As more rural areas begin to convert, more development challenges will be experienced by the districts. There are 34 Zilla Parishads, 351 Panchayat Samitis, and 27,920 Gram Panchayats for local self-governance in rural areas.

Maharashtra is one of the few states in India where the urban and rural proportion of the population is similar. As of Census 2011, the urban-rural demographic dichotomy was 45–55 per cent, respectively. This section, therefore, aims to understand the impacts of climate change on both urban and rural habitat scales in Maharashtra. Taking into account the influence of multi-sectoral factors on the viability and efficiency of human settlements, the housing,

water supply, sanitation, healthcare, waste management, transport, and tourism sub-components have been studied at both urban and rural scales under the habitat sector. Further, understanding the risks and impacts of climate change on these subcomponents, strategies and actions for adapting to climate change have been proposed through 2030 for creating safe, inclusive, sustainable, resilient, and environmentally friendly communities in Maharashtra.

5.5.2 Current status of habitats in the state

Housing

Maharashtra faces a considerable shortage of housing. According to a 2012 analysis by the Planning Commission, the state is short by almost 5 million dwellings in total (2 million in urban and 3 million in rural). By 2022, 10 million more units should be built (5 million each in both urban and rural areas). This surge in housing demand is expected in cities due to rapid urbanisation, resulting in a quarter of the entire urban population living in slums.

There are approximately 23 million households in the state, of which 92.6 per cent of the houses are constructed with roofs built from materials such as concrete, GI sheets, tiles, or burnt bricks, and 6.7 per cent have bamboo, thatch, or plastic roof constructions (Ministry of Home Affairs 2011). The type of roof material plays a vital role in determining the quality of life. Urban centres in Maharashtra have more pucca houses, while at the district level, Ratnagiri has the maximum number of pucca houses, and Parbhani has the least (Ministry of Home Affairs 2011).

The Maharashtra government has established various entities to facilitate organised housing development in urban areas. The Maharashtra Housing and Area Development Authority (MHADA) and the City and Industrial Development Corporation Limited (CIDCO) are responsible for planned housing initiatives. Additionally, the Slum Rehabilitation Authority (SRA) was established to oversee the redevelopment of slums in urban regions. The state also instituted the Maharashtra Real Estate Regulatory Authority (MahaRERA) to regulate the real estate sector effectively.

Water supply and sanitation

Water supply is one of the basic services that is essential for maintaining a good quality of life. According to the National Multidimensional Poverty Index, 9.53 per cent of the population in Maharashtra does not have access to safe drinking water (Niti Aayog 2023). Tap water is the major source of water in the state, followed by wells, handpumps, and tube wells. Approximately, 67.9 per cent of Maharashtra had access to tap water connections (Ministry of Home Affairs 2011). There is a stark difference in the number of tap water connections between the urban and rural locations, with the former having nearly

Figure 5.5.2 Subcomponents of habitats



Source: Authors' compilation

90 per cent coverage, whereas the rural areas have 50 per cent coverage. Under the *Jal Jeevan Mission*, this figure has improved, and currently, 77.98 per cent of rural Maharashtra has access to tap water connections (Ministry of Jal Shakti 2023). Moreover, the mission has also focused on enhancing access to tap water in specific facilities such as *anganwadis*, schools, and CHCs. The latest data indicate that 94 per cent of *anganwadis*, 92 per cent of schools, and 75 per cent of CHCs in rural Maharashtra have tap water connections (Ministry of Health and Family Welfare 2021).

In the case of drainage, there is a notable difference between the rural and urban areas in the state. Overall 67.5 per cent of households in the state have access to drainage systems. However, access in urban areas is as high as 91.2 per cent, and in rural areas, it is 47.8 per cent (Ministry of Home Affairs 2011). Moreover, in a majority of the rural households which reported access to drainage (39.1%), the access is to open drainages, and only 8.7 per cent of households have access to closed drains.

Sanitation services have witnessed a significant improvement in the state. The state attained 100 per cent sanitation coverage in 27,668 Gram Panchayats and 351 Panchayat Samitis in 35 districts under Phase 1 of the *Swachh Bharat Mission (Rural) 1.0* as on March 2020. The state has reported no open defecation and complete access to sanitation facilities; certain problems, such as the capacity of the pit, faulty construction of sanitation facilities, and gender biases, were noted in several parts of the state (Ministry of Housing & Urban Affairs 2018). The lack of access to safe sanitation facilities is one of the primary reasons for the spreading of diseases. To address these concerns, *Swachh Bharat 2.0* aims to better manage sewage and water security in urban settlements.

Waste management

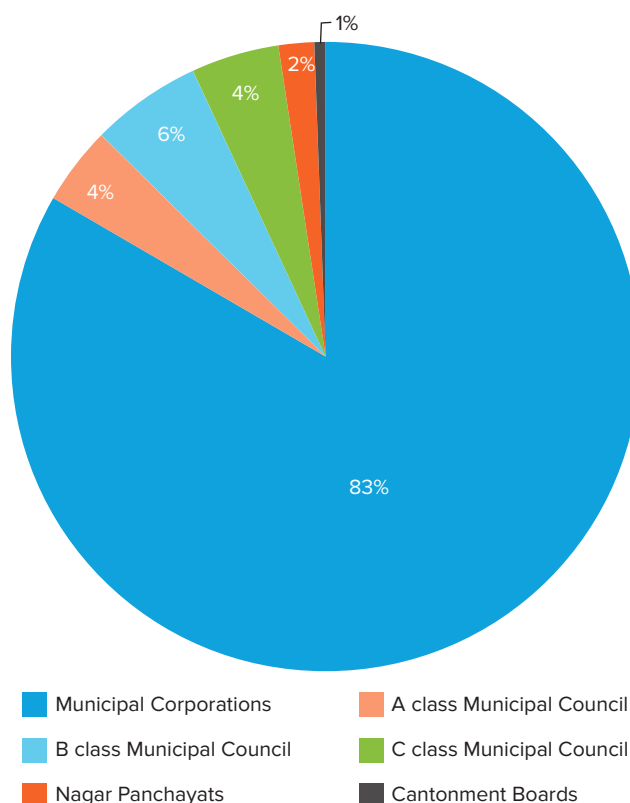
Solid waste includes various types of waste, such as household solid waste, construction and demolition debris, industrial solid waste, drainage residue, and waste generated from residential and commercial complexes. To manage this waste effectively, the state has established 56 common waste treatment facility centres, which are operated by Municipal Corporations, Municipal Councils, and Cantonment Boards. Impressively, 72.5 per cent of the total solid waste generated is treated on a daily basis (Ministry of Housing & Urban Affairs 2017).

For the purpose of solid waste processing, the state has initiated multiple projects across Urban Local Bodies (ULBs). These projects include 378 composting projects in 321 ULBs, 89 vermicompost projects in 79 ULBs, 47 biogas projects in 30 ULBs, 19 refuse-derived fuel (RDF) projects in 9 ULBs, and one Waste-to-Energy Plant with a capacity of 4MW.

Within solid waste generation, corporations contribute 19,882.08 MT/day, accounting for 83.38 per cent of the

total share. “A” class councils² generate 958.60 MT/day with a share of 4.02 per cent, “B” class councils generate 1353.08 MT/day with a share of 5.67 per cent, “C” class councils generate 1079.53 MT/day with a share of 4.53 per cent, Nagar Panchayats contribute 434.261 MT/day with a share of 1.82 per cent, and Cantonment Boards contribute 137 MT/day with a share of 0.57 per cent (Maharashtra pollution control board 2021).

Figure 5.5.3 Classification of waste generated in the state



Source: Maharashtra Pollution Control Board 2021

Transportation and mobility

Various departments are responsible for maintaining the infrastructure for road transportation in Maharashtra. The state’s major district roads and state highways are overseen by the Maharashtra Public Works Department (MPWD), while local governments, Zilla Parishad, and panchayat, control the roads in the rural areas. The central government manages the state’s national highways. Maharashtra has a total road length of over 2,67,000 km. The total length of its national highways is 4,176 km, and that of its state highways is 33,705 km. More than 80 per cent of passengers and 60 per cent

² Municipal councils are further sub classified as class A, B and C as per population. Population with more than 1,00,000 is Class A for small urban areas. Small urban areas with a population between 40,000 and 1,00,000 are classified as class ‘B’ and below 40,000 as class ‘C’ (Law And Judiciary Department, GoM 2016).

Figure 5.5.4 Maharashtra road network



Source: Open street map 2022

of freight traffic use roads as the dominant mode of transportation. Rural roads include ‘other district roads’ and ‘village roads’, making up 67 per cent of the state’s road network. The Road Development Plan aimed to construct 3,37,000 km of roads. Of this, 3,21,000 km was developed till the end of March 2021. There were 4,09,16,000 vehicles operational in the state as per the Economic Survey 2022. As of August, 2023, 3,05,006 battery-electric vehicles have been registered in the state (PIB, 2023).

Maharashtra’s well-developed railway system spans 5,983 km, connecting the state to the rest of the country. Mumbai serves as the headquarters for the Central and Western Railways. The intra-city and suburban railway carries 6.4 million passengers daily. The Western Railways link coastal Maharashtra to other states and ports. The Konkan Railway connects Mumbai to Mangalore. Metro rail projects in Mumbai, Navi Mumbai, Pune, and Nagpur provide rapid public transport within the cities.

Tourism

Maharashtra is one of the country’s most popular tourist destinations, with approximately 43.5 million domestic tourist arrivals. The state ranks second in the number of

Table 5.5.1 Districts receiving the highest contribution of tourism in the NDDP

S. no.	District	Tourism* (INR crores)	Total NDDP (INR crores)	Percentage contribution
1	Thane	40,104	232361	17.26
2	Nagpur	13,198	80008	16.50
3	Pune	30,273	186428	16.24
4	Aurangabad	6,737	43798	15.38
5	Mumbai	51,030	337549	15.12
6	Kolhapur	8,176	54672	14.95
7	Akola	2,712	18202	14.90
8	Nashik	11,538	78504	14.70
9	Nanded	4,224	28772	14.68
10	Dhule	2,838	19636	14.45

Source: Authors’ analysis

*Tourism here refers to the total addition to NDDP from trade, repair, hotels and restaurants; railways; and transport by means other than railways.

foreign tourist arrivals, with 0.18 million tourist visits in 2021 (Ministry of Tourism 2022). Raigad, Sindhudurg, Mumbai, Thane, and Kolhapur are the districts with the highest number of tourist attractions. share of tourism is significant in a few districts across the state. Tourism contributes 17 per cent to the Net District Domestic Product (NDDP) of Thane, which is the highest in the state. The contribution of tourism is also high in the districts of Nagpur, Pune, Aurangabad, and Mumbai.

5.5.3 Impacts of climate change on habitats

Maharashtra ranks third on CEEW's Climate Vulnerability Index (CVI) and is one of the most vulnerable states to extreme hydro-meteorological disasters in India.

Climate change poses a significant challenge for urban systems globally, with intensifying the effects expected in the coming decades. Increased rainfall intensity, storm surges, flooding, and urban heat island effects severely impact cities and their populations. Rising global temperatures lead to higher sea levels, more extreme weather events, and the spread of tropical illnesses. These effects strain essential services, housing, livelihoods, and health in urban areas. Cities are also major contributors to greenhouse gas emissions, responsible for 75 per cent of global CO₂ emissions (UNEP 2022).

The majority of the time, rural, and urban regions are contrasted, although this gap is reducing. Rural communities have specific features that make them more susceptible to the effects of climate change. For example, their greater reliance on agriculture and natural resources makes them particularly vulnerable to extreme climate events and climate change. Existing vulnerabilities brought on by poverty and lower literacy rate worsen the effects of climate change on the various components of the habitats in several ways.

Housing

As per the IPCC (2012) report, individuals living in informal settlements are typically at higher risk during climate events due to the absence of hazard resilient infrastructure, substandard housing, and limited coping capabilities. Communities are increasingly experiencing major hydro-meteorological disasters, which highlights the accelerated physical effects of a changing climate. The greatest immediate threats are associated with landslides and floods in coastal regions brought on by storm surges, sea-level rise, and increase in rainfall intensity. Building shelters in risky locations, such as floodplains along riverbanks or on hillsides where mudslides and erosion during heavy rains are a possibility, can have disastrous results. Increased climate variability, rising temperature, a shift in rainfall patterns, and increased humidity may also increase the rate of degradation and weathering of stone and metal structures (Grossi et al. 2007; Thornbush and Viles 2007;

Smith et al. 2008; Bonazza et al. 2009; Stewart et al. 2011).

Located in the most vulnerable areas of cities, slums house hundreds of millions of urban residents who face risks from direct and indirect impacts of climate change. These settlements lack crucial infrastructure and services to protect inhabitants during extreme weather events. Therefore, the ability of individuals, households, and communities to anticipate, cope with, and recover from disasters, including climate-related events, becomes especially critical where adequate housing, infrastructure, and services are lacking. As extreme climate events intensify in the state, districts such as Mumbai, Pune, Thane, Nagpur, Kolhapur, Nashik, and Aurangabad will be among those most affected, particularly concerning housing.

Water supply and sanitation

Urbanisation and climate change are together exacerbating water scarcity. The impact of climate change on water supplies interacts with increasing population, growing demand, and economic constraints, thus further amplifying water stress, declining water quality and quantity, along with other detrimental effects on other natural resources.

Flooding has a negative influence on water supply, and shifting rainfall patterns have a negative impact on water resources. Altered rainfall patterns lead to the oversaturation of urban drainage systems, resulting in flash floods. Heavy rains are made worse by poor drainage systems, which causes localised floods and weakens infrastructure. In addition to affecting sanitary facilities, heavy rains contaminate drinking water. A major concern is the lack of access to clean drinking water and sanitary facilities during floods, resulting in morbidity and mortality, especially among children (Bassma Taher Hassan 2022). Climate change has impacted water availability, causing stress from either an excess or a shortage of water supplies. Therefore, it is essential to comprehend the dangers of climate change and how it affects human health, drinking water, and sanitation services.

Sanitation issues include the potential of uncontrolled sewage as well as the destruction or loss of existing infrastructure. Procuring water becomes more challenging during a drought for several disadvantaged groups since they continue to collect water from neighbouring ponds and rivers. The most vulnerable people frequently have the lowest levels of resistance to the consequences of climate change. The problem of urban drainage is exacerbated by unplanned development and encroachment on existing natural drainage corridors and waterways. Environmental benefits from natural functionaries such as waterways and water bodies are largely overlooked and compromised in the pursuit of extreme development.

This factor, along with recent trends in climate change, is contributing to an increase in acute waterlogging, urban flooding, and other negative economic and health consequences. Storm flows, if not regulated or routed to a safe disposal point, may cause unprecedented degradation of urban infrastructure, resulting in severe damage to life and property, depending on the severity of the storm event.

Waste management

Solid waste infrastructure is most at risk from extreme floods (Mishra 2022). Inadequate water catchment systems surrounding a landfill can cause degradation, resulting in fractures in the containment structure that let debris and leachate escape from the waste and damage nearby resources (UNEP 2011). Extreme storm flooding may weaken landfill foundations, spilling leachate into groundwater, blocking collection routes, sweeping trash into rivers, and clogging other infrastructure with trash. Landfills close to the shore or low-lying areas are at risk from storm surges and rising sea levels. Overflowing landfill garbage may result from water seeping into the pit. The impermeable liner of sanitary landfill sites may degrade due to below-ground saltwater incursion (Laner 2009).

Transportation and mobility

Climate change poses numerous challenges to transportation systems. The frequent extreme weather events like long-lasting heatwaves, heavy floods, and landslides put road infrastructures at risk from the effects of climate change.

Transportation systems, sensitive to weather fluctuations, face risks from rising sea levels in coastal cities, causing flooding and damage. Extreme weather can disrupt critical public transit links, hindering access to work and increasing health risks for low-income urban residents (Love et al. 2010).

Effective disaster response relies heavily on transportation systems for timely evacuations and delivering essential services during emergencies. However, climate variability can impede daily transportation and impact public health systems in marginalised communities. The economic relevance of transportation systems, amplified by just-in-time delivery methods, increases their susceptibility to losses from extreme weather conditions. While the direct effects of extreme weather on transportation are assessable, indirect costs like delays, detours, and trip cancellations also play a significant role in climate change impacts.

Adapting to climate change requires careful consideration of location-specific hazards and the long-term effects of temperature and precipitation variations on road infrastructure, which is vital for emergency vehicle access and rapid evacuation.

Tourism

The tourism sector's vulnerability and contribution to climate change may be seen in its direct and indirect effects, which might include increasingly frequent and severe weather events, rising safety concerns, water shortages, the loss of biodiversity, and damage to tourist sites. Continued climatic deterioration and damage to cultural and natural assets have a detrimental impact on the tourism industry, lowering destination appeal and decreasing national and international economic potential.

According to the analysis done by CEEW, 7 of the 10 districts which depend on tourism are exposed to hydro-meteorological disasters.

Table 5.5.2 Exposure of the districts to hydro-meteorological disasters

S. no	District	Percentage contribution to NDDP	Exposure
1	Thane	17.26	High
2	Nagpur	16.50	High
3	Pune	16.24	High
4	Aurangabad	15.38	Not exposed
5	Mumbai	15.12	High
6	Kolhapur	14.95	Not exposed
7	Akola	14.90	High
8	Nashik	14.70	High
9	Nanded	14.68	High
10	Dhule	14.45	High

Source: Authors' analysis

In such a scenario, impacts due to climate change will damage lives and infrastructure and greatly affect the GDP of the district.

5.5.4 Adaptation strategies and key recommendations for the habitats sector

Mapping and analysis of the existing policies, acts, missions, and schemes

The government of Maharashtra has many policies, schemes, and missions related to urban and rural habitats. These address climate adaptation and mitigation towards climate change for resilience and sustainable development of the habitats.

Some specific policies and programmes related to habitats in the state were reviewed to determine their effectiveness during the climate extremes.

Table 5.5.3 Existing policies, schemes, and missions in the urban and rural habitats

S. no.	Title of the scheme/ policy	Nodal and implementing agency	Launch date/time period	Budget allocated	Relevance to SDGs
Sub-sector: Housing					
1	Pradhan Mantri Awas Yojana (Urban)	National level: Ministry of Housing and Urban Affairs. State level: Maharashtra Housing and Area Development Authority.	2015–2022	INR 27,672 crore central assistance	SDG 1 and 11
2	Pradhan Mantri Awas Yojana (Rural)	National level: Ministry of Rural Development. State level: Rural Development and Panchayat Raj Department.	2015–2022	INR 12,071.19 crore central funds	SDG 1, 6, and 11
3	Maharashtra State New Housing Policy and Action Plan, 2015	State level: Maharashtra Housing and Area Development Authority (MHADA).	2015	NA	SDG 3 and 11
Sub-sector: Water supply and sanitation					
5	Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0	National Level: Apex Committee (Headed by Ministry of Housing and Urban Affairs) State Level: State High Powered Steering Committee, Urban Development department	Launched in 2022	INR 9,500 crores allocated to Maharashtra	SDG 6 and 11
6	Swachh Bharat Mission (Urban) Phase 1 Phase 2	National level: National Advisory and Review Committee (headed by the Ministry of Housing and Urban Affairs). State level: State High Powered Committee (Multiple departments).	Phase 1: 2014–19 Phase 2: Launched in 2022	INR 1,41,600 crores – National outlay	SDG 11 and 13
7	Swachh Bharat Mission (Rural)	National level: Department of Drinking Water and Sanitation. State level: Water Supply and Sanitation Department.	Launched in 2014	The financial incentive provided by the centre: INR 3,936.50 crore	SDG 6
8	Jal Jeevan Mission	National level: Ministry of Jalshakti. State level: Water Supply and Sanitation Department.	Launched: 2019 Time period: Till 2024	INR 7,831.25 crores central fund allocated to MH for the financial year 2022–23	SDG 6
Sub-sector: Transport					
9	Maharashtra Electric Vehicle Policy	State level: Transport Department, Energy Department, Urban Development Department, Industries Department, Higher and Technical Education Department, Skill Development and Entrepreneurship Department.	Launched: 2021	NA	SDG 11
10	Smart Cities Mission	National level: Apex Committee (Headed by Ministry of Housing and Urban Affairs).	Launched: 2015	INR 100 crore per year for five years per city	SDG 3, 6, 7, 11, and 13
11	Pradhan Mantri Gram Sadak Yojana (PMGSY)	National level: Ministry of Rural Development. State level: Maharashtra Rural Road Development Association (MRRDA).	Phase III launched in 2019	INR 1,356.32 crore was allocated in 2018	SDG 1 and 11
Sub-sector: Waste management					
12	Solid Waste Management (Urban)	State level: State Pollution Control Board.	2016	NA	SDG 11
13	Swachh Bharat Mission Phase 2	National level: Ministry of Housing and Urban Affairs. State level: State High Powered Committee (multiple departments).	Phase 2 launched in 2022	The financial incentive of INR 3,936.50 crore	SDG 11 and 13
Sub-sector: Tourism					
14	The Tourism Policy	State level: Department of Tourism and Culture Affairs.	2016	INR 2,369 crores in 2021–22	SDG 8 and 11
15	Agro-Tourism Policy	State level: Department of Tourism and Culture Affairs	2020	NA	SDG 8

Source: Authors' compilation

Pradhan Mantri Awas Yojana (Urban)

Objective: The mission seeks to address the affordable housing requirement in urban areas through four verticals, which include:

1. In-situ slum rehabilitation of slum dwellers with the participation of private developers using land as a resource.
2. Promotion of affordable housing through credit-linked subsidy.
3. Affordable housing in partnership with public and private sectors.
4. Subsidy for beneficiary-led individual house construction/enhancement.

Performance of the policy: Maharashtra has the highest investment among states in PMAY(U), with INR 1,88,324.62 crore. According to the mission dashboard, the number of sanctioned houses until the end of the mission date surpasses the calculated demand for the houses.

Adaptation and mitigation components: As a part of the mission, the Global Housing Technology Challenge introduces lighthouse projects that encourage demonstrating innovative construction technologies that are cost-effective, green, and sustainable construction technologies.

Challenges of the policy: The dashboard also highlights the positive progress made in terms of funds sanctioned by the central government in comparison to the amount of funds released. Under the mission, the state government has sanctioned INR 27,672 crores for the state, and it has already released INR 13,908.

Maharashtra is actively addressing the demand for housing among the urban poor by aiming to build over 1.5 million houses. While the completion rate currently stands at less than 50 per cent, there is a significant ongoing effort to fulfil this demand (Ministry of Housing and Urban Affairs 2022). Furthermore, it's worth noting that Maharashtra has the highest percentage of houses to be constructed under the Affordable Housing in Partnership (AHP) and In-Situ Slum Redevelopment (ISSR) programs in the country, highlighting its commitment to providing affordable housing solutions.

Relevance to NDCs and SDGs: The mission supports SDG 1: No Poverty with a focus on SDG targets 1.3, 1.a, and 1.b. The mission also works towards SDG 11: Sustainable Cities and Communities with a focus on SDG targets 11.1 and 11.3.

Pradhan Mantri Awas Yojana (Rural)

Objective: The mission aims to provide a pucca house with basic amenities to all houseless households and households living in kutcha and dilapidated houses in rural areas by 2022.

Performance of the policy: The number of houses sanctioned under the scheme since its inception stands at 12,43,023. Almost 90 per cent of the sanctioned houses have been grounded, and almost 65 per cent have been completed under the scheme.

The government of Maharashtra also launched a 100-day campaign titled Maha Awaas Abhiyaan to accelerate the implementation of all rural housing programmes, including this mission.

Adaptation and mitigation components: The policy guidelines do not mention any specific adaptation or mitigation components.

Challenges of the policy: The 16th report of the Standing Committee on Rural Development and Panchayati Raj points out a few challenges in implementing the scheme. These include problems related to the identification of beneficiaries, inflationary pressures, and support for landless beneficiaries.

Relevance to NDCs and SDGs: The mission supports SDG 1: No Poverty with a focus on SDG targets 1.3, 1.a, and 1.b. The mission also works towards SDG 11: Sustainable Cities and Communities with a focus on SDG targets 11.1 and 11.3.

Atal Mission for Rejuvenation and Urban Transformation

Objective: Phase 1 of the mission aims at providing basic services (e.g. water supply, sewerage, green spaces, urban transport) to households and building amenities in cities, which will improve the quality of life for all, especially the poor and the disadvantaged. Phase 2 of the mission aims to make 4,700 towns and cities 'water secure' and provide functional water tap connections for all households. This will be done by providing 26.8 million urban household tap water connections, benefiting approximately 107 million people. It also aims to achieve 100 per cent coverage of sewage and septage in 500 AMRUT cities by providing 26.4 million sewer connections and septage connections, benefiting around 106 million people.

Adaptation and mitigation components: The policy guidelines do not mention any specific adaptation or mitigation components.

Challenges of the scheme: The new AMRUT policy must build upon the challenges faced during the implementation of AMRUT 1.0. For instance, the Standing Committee on Urban Development in 2020 noted that the implementation and performance of the mission have been below target. It also noted that a large number of ULBs have not been able to meet the expectations of the mission by contributing funds from their side. Hence, financial assistance was required at a large scale for such cases.

Relevance to NDCs and SDGs: The mission contributes to the implementation of SDG 6: Clean Water and Sanitation and SDG 11: Sustainable Cities and Communities.

Swachh Bharat Mission (Urban)

Objective: Phase 1 of the mission has the following objectives:

1. Elimination of open defecation.
2. Eradication of manual scavenging.
3. Modern and scientific municipal solid waste management.
4. To effect behavioural change regarding healthy sanitation practices.
5. Generate awareness about sanitation and its linkage with public health.
6. Capacity augmentation for ULBs to create an enabling environment for private sector participation in Capex (capital expenditure) and Opex (operation and maintenance).

Phase 2 of the mission attempts to achieve 'garbage-free' status in all cities through sustainable solid waste management, sustainable sanitation and treatment of used water, awareness creation, and the creation of institutional capacity.

Adaptation and mitigation components: The policy aims to build disaster-resilient infrastructure that can increase the population's adaptive capacity.

Challenges of the policy: The new SBM policy must address the challenges faced during the implementation of AMRUT 2.0. For instance, the Standing Committee on Urban Development (2021) noted that the progress in achieving 100 per cent waste management has not been adequate due to less effort on segregating waste at source. Moreover, several sources cited inflated achievements, poor construction of structures, and local malpractices during the implementation of the mission's first phase. Such challenges need to be addressed in SBM 2.0 to ensure that the objective of 'garbage-free' status is achieved.

Relevance to NDCs and SDGs: The mission supports the implementation of SDG 6: Clean Water and Sanitation and SDG 11: Sustainable Cities and Communities.

Swachh Bharat Mission (Rural)

Objective: The objectives of the mission are to ensure cleanliness in rural areas, to stop the practice of open defecation, construction and sustained use of sanitary latrines at the household level. The focus of the mission is to make toilet facilities available to every household and make India open defecation-free (ODF), garbage-free, and adopt efficient solid waste management practices.

Performance of the policy: The state has achieved 100 per cent sanitation coverage in 27,668 Gram Panchayats and 351 Panchayat Samitis in 34 districts. The state was declared as ODF on 18 April 2018.

Jal Jeevan Mission

Objective: The main objective of the *Jal Jeevan Mission* is to supply a minimum of 55 litres of quality water per capita per day in every rural household through functional household tap connection (FHTC). Under the mission, FHTC is to be provided to every household, school, Gram Panchayat building, health centre, community building, etc., in rural areas by 2024.

Performance of the policy: According to the *Jal Jeevan Mission* dashboard, 71.77 per cent of households have access to tap water connection, with Jalgaon being the first district in the state to have covered 100 per cent of households. Approximately 80 per cent of all schools, *anganwadis*, GPs, and CHCs have access to tap water connections, with 8 districts covering 100 per cent of schools. Despite the disruptions caused by COVID-19, the progress in achieving the targets under the mission has been steady.

Adaptation and mitigation components: The policy acknowledges climate change as an important cause of the lack of availability of drinking water and proposes the utilisation of funds to build water storage facilities to counter scarcity. The policy also recommends restoring natural disaster-affected sources and storages of water.

Challenges of the policy: In Maharashtra, there is an opportunity to enhance the utilisation of funds for the Jal Jeevan Mission, for efficient utilisation of the funds. Table 5.5.4 shows the total available funds after the share contributed by the state and the central government, along with the expenditure.

Table 5.5.4 Utilisation of the Jal Jeevan Mission funds

Financial Year	Total Assured Funds (INR crore)	Total Expenditure (INR crore)	Percentage of Expenditure
2019–20	2,166.64	736.18	34
2020–21	4,179.28	797.75	19
2021–22	14,634.33	855.96	5
2022–23*	18,559.04	1405.3	7

* in progress

Source: Authors' compilation from Ministry of Jal Shakti reports

Standing Committee of the parliament on Drinking Water and Sanitation (2020–21) identified various areas for improvement within the mission. These observations included suggestions for enhancing participatory approaches, allocating more financial resources, securing additional technical human resources, and improving the operation and maintenance of completed schemes (PIB 2021).

Relevance to NDCs and SDGs: The mission supports the implementation of SDG 6: Clean Water and Sanitation.

Smart Cities Mission

Objective: The objective of the mission is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment, and the application of 'smart' solutions. The focus is on sustainable and inclusive development, and the idea is to explore compact areas and create a replicable model that will act like a lighthouse to other aspiring cities.

Performance of the policy: The *Smart Cities Mission* selected 10 cities in Maharashtra among the 100 cities selected across India. These cities include Amravati, Solapur, Nagpur, Kalyan-Dombivli, Aurangabad, Nashik, Thane, Navi Mumbai, Mumbai, and Pune-Pimpri Chinchwad. Among these ten cities, Pune, Solapur, and Nashik have adopted the most number of projects within the mission.

The Government of India has released funds worth more than INR 2,000 crore, and approximately 90 per cent of these funds have been utilised. Several cities from Maharashtra were featured among the top-ranking cities in the country, with Pune being ranked second, just behind Bengaluru.

Adaptation and mitigation components: The policy proposes the construction of a 'built environment' that is sustainable in nature and resilient to the impacts of natural disasters.

Challenges of the policy: The *Smart City Mission* is divided into two components, which include area-based development and pan-city development. A majority of the funding within the mission is for the former. This leads to development-related activities being conducted in specific regions of the city. The budget of each city is merely a fraction of the budget allocated to regions within the city, which makes replication of the mission a difficult task. In addition, feedback from within the state has flagged challenges stemming from the segregation of responsibilities among the different missions and stakeholders.

Relevance to NDCs and SDGs: *Smart City Mission* has several components that support the implementation of SDG 3: Good Health and Well-Being, SDG 4: Quality Education, SDG 6: Clean Water and Sanitation, SDG 7: Affordable and Clean Energy, SDG 11: Sustainable Cities and Communities, SDG 13: Climate Action, and SDG 17: Partnership for the Goals

Box - 3 Ek Paed Maa ke Naam

The Harit Maharashtra campaign undertaken by the Government of Maharashtra aligns with the "Ek Paed Maa ke Naam" campaign launched by the Union Government to encourage citizens to promote green cover to attain objectives of Mission LIFE towards promoting sustainable lifestyle, and enhancing the green cover by 20 per cent on private lands as set out by the Ministry of Rural Development and Panchayati Raj, Government of India.

Source: Ek Paed Maa ke Naam campaign, Ministry of Rural Development and Panchayati Raj, Government of India

Box - 4 Waste to power

With 'Waste to Wealth' as its driving philosophy, Swachh Survekshan 2023 was curated to achieve circularity in waste management. The objective of the 'Waste to Energy' programme is to support the setting up of waste-to-energy projects for the generation of Biogas/bioCNG / Syngas / Power from urban, industrial, and agricultural wastes/residues.

These projects aim to produce power/energy from non-recyclable dry waste using various technologies- **biomethanation, anaerobic digestion, incineration, gasification** and **pyrolysis**. The significance of these projects lies in the effective disposal of waste, reduction in waste going to landfills/dump yards, less import of petroleum, and promoting a circular economy. There are 6 big BioCNG plants and more than 11,100 small biogas plants commissioned under the National Bioenergy Programme (PIB 2023). About 22097 tonnes of Compressed Biogas (CBG) were sold in the financial year 2023-24 (SATAT. 2024).

A vast majority of plants are based on the technology of biomethanation generating bio-CNG to harness the energy from waste. The state of Maharashtra is a home to 3 big Bio-CNG plants while Punjab Tamil Nadu and Uttar Pradesh have 1 each. The processing capacity of the plants ranges from ~2TPD to 20MTPD or more. In addition to this, there are other examples like the centralised 14 MW integrated waste-to-energy plant established in Moshi, Maharashtra that generates energy along with recovery of recyclable materials, and wet waste conversion into compost (Pune Pulse 2023). For more information of some of the operational waste treatment plants in Maharashtra, refer Annexure - Table A9.

Maharashtra, being the second most populous and the third most urbanised state in the country, faces a significant waste management challenge. As part of the waste-to-wealth mission and in order to address climate change concerns, it is imperative that Maharashtra expands the implementation of waste-to-energy projects, as shown in Annexure Table A9. These projects can convert organic waste into biogas or electricity, reducing the landfill burden and contributing to clean energy production. However, in order to successfully run these projects, the following conditions must be met. :

- Ensuring continuous availability of segregated waste.
- Availability of suitable land to establish the plant
- Optimising the transportation cost
- Market demand for the end product: Evaluate the demand for energy or other products generated from the WtE process. Consider local energy needs and potential buyers.

Source: Ministry of New and Renewable Energy, 2022.

Key recommendations and actions

Table 5.5.5 Recommendations for climate change adaptation for urban and rural habitats

S. no.	Recommendations/ Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications	Outcome
1	Mainstreaming the components of climate change into the planning, design, and construction of the road infrastructure process (Climate Proofing Infrastructure).	1. Undertake proposed amendments to construction standards, norms, and codes for Indian roads: The current standards, norms, and codes for road construction in India, such as the India Road Congress (IRC:34–2011) and India Building Congress for Road Infrastructure, require amendments. For instance, the suggested camber or slope for national and state highway bituminous or cement concrete roads typically ranges between 1.7-2% (1 in 60 to 1 in 50), taking into account whether the area experiences heavy or light rainfall. These standards need to be reviewed and updated to align with the latest guidelines. 2. Modify road elevation and slope based on hazard profiles: Considering the projected rainfall data, the Konkan region will experience a significant increase in rainfall days. Hence, it is essential to modify the elevation and slope of roads in this region to address the associated hazards effectively. This retrofitting approach will ensure better drainage and minimise the risks of flooding and waterlogging. 3. Adapt road construction techniques for high temperatures and heat waves: In anticipation of high temperatures and heat waves, several measures should be taken during road construction. These include using hard bitumen to withstand heat during summer and employing flexible and solvent-working bitumen in winter conditions. Additionally, soil moisture control and maintenance planning should be incorporated to ensure the longevity and durability of road infrastructure.	State level Phase 1: Districts in the Konkan region which receive the highest annual rainfall, with Ratnagiri, Sindhudurg, Mumbai suburban, Mumbai, Thane, and Raigarh districts as priority districts.	PWD and Urban Development Department. Integrate with the National Mission for Sustainable Habitat and CDRI.	The estimated cost of construction per km is INR 25 crore as per the National Infrastructure Pipeline. In line with the hazard profile of the priority district, 100 km of road stretch needs to be identified. The total cost would be approximately INR 2500 crore.	Strengthening the road infrastructure for extreme climate events.

S. no.	Recommendations/ Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications	Outcome
		4. Implement blue-green corridors along major roads and highways: To mitigate the urban heat island effect, establish blue-green corridors along major roads and highways. These corridors will feature continuous green spaces, such as trees, shrubs, and vegetation, which act as heat sinks. They absorb and dissipate heat, helping to neutralise the temperature rise associated with urbanisation.				
2	Stormwater drainage capacity to be increased by 20% by 2030.	1. Synchronise storm water drainage network with natural contours and land cover: To effectively manage stormwater, the carrying capacity of the drainage network should be synchronised with the natural contours and land cover of the area. This synchronisation should consider factors such as land use and built density. In districts prone to extreme rainfall, it is crucial to also separate the routes of sewerage and stormwater drainage pipes, extend their lines, and expand the overall system capacity. 2. Promote resilient materials and technologies in flood-prone areas: To address non-functional stormwater drainage systems, initiatives should be launched to upgrade, supplement, or replace them with the use of resilient materials and technologies. This approach should be implemented on a large scale, particularly in flood-prone areas. 3. Prioritise focus on flood-prone districts in Maharashtra: More than 30% of the districts in Maharashtra are prone to flooding. These districts should be treated as priority areas. Conducting comprehensive studies of flood hazards and creating infrastructure maps on a geographic information system (GIS) platform will aid in identifying elements at risk. Identifying pockets like parks for expanding permeable surfaces within cities will allow water absorption into the ground, reducing reliance on stormwater systems.	The districts in the Konkan region receive the highest annual rainfall, with Ratnagiri, Sindhudurg, Mumbai suburban, Mumbai, Thane, and Raigarh districts receiving more than 2,000 mm of average rainfall every year.	State Water Supply and Sanitation Department, PWD, and Urban Development Department. Integration with the National Mission for Sustainable Habitat.	Access funds under schemes such as AMRUT and the annual revenue budget of municipal corporations and councils.	Adaptation to flooding and efficient water management during heavy precipitation events. Improved effectiveness and resilience of stormwater management. Enhanced stormwater management capabilities that minimise flood risks in the state.

S. no.	Recommendations/ Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications	Outcome
3	100% segregation of waste at source to reduce waste disposal by 40% in landfills by 2030 and transition to cleaner energy sources in supply and treatment plants.	1. Implement household-level waste segregation and efficient waste management systems. Establish waste-to-energy plants utilising combustion technologies and highly efficient power plants that use municipal solid waste as fuel instead of coal, oil, or natural gas in all urban settlements with a population of one million or more. 2. Transition secondary and tertiary water supply and sewage treatment plants from thermal energy sources to renewable energy sources. 3. Improve landfill site management by extending the operational period to 50 years, including 20 years of active operations. Opt for landfill locations at higher elevations to minimise the risk of groundwater upwelling into the waste zone. Strategically install extraction wells at critical locations and depths to prevent or reduce groundwater infiltration. Implement earthen structures like vegetated berms, swales, or stormwater ponds at vulnerable points to prevent stormwater accumulation from reaching the landfill system at higher elevations.	State level In all million-plus urban settlements, a waste-to-energy plant is to be installed.	SBM(U), SBM(G), municipalities and other governing bodies, and <i>Maharashtra Jeevan Pradhikaran</i> (MJP). Integrate with the National Mission for Sustainable Habitat, and National Mission for Enhanced Energy Efficiency.	<i>Swachh Bharat Mission</i> (SBM) urban and rural, as well as the annual budgets of municipal corporations and councils. In 2017, the Maharashtra government allocated a budget of INR 100 crore for energy conservation in wastewater treatment plants (WWTPs) under the <i>Energy Conservation in Wastewater Treatment Plants</i> (ECWTP) scheme.	Sustainable waste management that emphasises on the reduction, reusing, and recycling of waste from the source to reduce the load on landfills. Waste-to-energy plants will promote a circular economy, which is a system that keeps materials, products, and services in circulation for as long as possible.
4	Implementation of risk-informed tourism planning.	1. Conduct a comprehensive risk assessment: Begin by conducting a thorough assessment of the landslide-prone zones to identify areas where agro-tourism development can be safely pursued. Conduct a comprehensive climate risk assessment for the tourism sector, specifically focusing on flood-prone areas, coastal erosion, and the potential impact of extreme weather events. Determine the vulnerability of popular tourist destinations to these risks by considering factors such as slope stability, geotechnical characteristics, and historical extreme events data to determine suitable locations.	Priority tourism hotspots as per the frequency of extreme events.	Directorate of Tourism	Hiring geotechnical engineers, climate scientists, and risk assessment specialists ranges from INR 50,000 to INR 2,00,000 per expert per month, depending on their qualifications and experience. The cost of field surveys, equipment, and laboratory testing can vary, but it could range from	Development of effective adaptation and resilience strategies and promotion of sustainable tourism practices and enhanced capacity to cope with the impacts of climate change.

S. no.	Recommendations/ Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications	Outcome
		2. Adopt a climate-resilient construction approach: Assess the resilience of tourism infrastructure and evaluate the potential impact on local communities' dependence on tourism-related activities. Develop and enforce guidelines for construction practices that prioritise climate resilience in tourism infrastructure like agro-tourism. This may involve using erosion control measures, reinforced structures, and appropriate slope stabilisation techniques to minimise the risk of climate extremes such as floods, cyclones, and landslides and protect visitors and local communities. Implementing these measures will protect these areas and preserve their ecological integrity. 3. Undertake carrying capacity assessment: Integrate the findings from the climate risk assessment into the carrying capacity assessment of tourist destinations. This will provide a more holistic understanding of the population that can be accommodated while considering climate risks. 4. Quantify economic losses: Quantify the potential displacement and loss of livelihoods that could occur in the event of climate-related disruptions. 5. Engage local communities: Engage key stakeholders, including tourism operators, local communities, NGOs, and academia, throughout the vulnerability and risk assessment process. Foster collaboration, gather diverse perspectives and incorporate local knowledge to understand climate risks and effective adaptation strategies comprehensively.			INR 1,00,000 to INR 10,00,000, depending on the size and complexity of the assessment. The cost of organising and conducting training programmes for construction professionals and local communities can range from INR 1,00,000 to INR 10,00,000, depending on the number of participants and the duration of the programmes. The cost of data collection, analysis, and modelling for carrying capacity assessments can vary depending on the complexity and scale of the assessments. It could range from INR 2,00,000 to INR 20,00,000.	

S. no.	Recommendations/ Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications	Outcome
5	Building capacities and training for sensitising climate adaptation at all levels.	1. Develop comprehensive strategies to disseminate accurate and region-specific knowledge about climate change risks to districts, which are tourist hotspots for effective management at a local level. 2. Train major stakeholders at a community level sensitising about climate change and its impacts. It will also enable them to take risk-informed decisions and actions for resilience. 3. Provide training and capacity-building programmes for local communities, farmers, and agro-tourism operators. Focus on skills development related to climate-resilient construction, sustainable agriculture, hospitality, and tourism management. Empower individuals and communities with the knowledge and tools to operate and maintain agro-tourism ventures.	Priority tourism hotspots as per the frequency of extreme events.	Directorate of Tourism. Integrate with the National Mission on Strategic Knowledge on Climate Change and CDRI.	1. The cost of developing training materials, including manuals, presentations, and multimedia resources, can range from INR 1,00,000 to INR 10,00,000. 2. Developing communication materials such as brochures, posters, and websites can range from INR 50,000 to INR 5,00,000.	Community participation and a strengthened role in improved sustainable tourism development.

Source: Authors' analysis

The total overall financial outlay needed for implementing the recommendations for the habitat sector is INR 190 crore, and for the tourism sector it is INR 32.2 crore.

5.6 Climate change impact on tribal development and adaptation strategies

5.6.1 Introduction

Due to their dependency on and intimate interaction with the environment and its resources, tribal communities are among the first to experience the direct effects of climate change. Climate change increases these populations' socio-economic and geo-political vulnerability and makes their adaptive capacity towards the extreme events caused by climate change more challenging. Access to traditional foods, such as fish, wildlife, and cultivated plants, is endangered by current and anticipated climate change effects. For decades, these resources have supplied nourishment in addition to cultural, economic, medical, and community health benefits.

Under Article 46 of the Constitution of India, the Directive Principles of State Policy urge the state governments

to promote the educational and economic interests of the weaker sections of the population, especially the Scheduled Castes (SCs) and Scheduled Tribes (STs) and protect them from social injustice and all forms of exploitation.

India is home to about 700 distinct tribes. According to the 2011 census, 8.6 per cent of India's population was tribal. In Maharashtra, there are 47 Scheduled Tribes, as per The Scheduled Castes and Scheduled Tribes Orders (Amendment) Act 1976 (Act No. 108 of 1976) and The Scheduled Castes and Scheduled Tribes Orders (Amendment) Act 2002 (Act No. 10 of 2003) (Tribal Research and Training Institute (TRTI) n.d).

1. Andh
2. Baiga
3. Barda
4. Bavacha, Bamcha
5. Bhaina

6. Bharia Bhumia, Bhuinhar Bhumia, Pando
7. Bhattra
8. Bhil, Bhil Garasia, Dholi Bhil, Dungri Bhil, Dungri Garasia, Mewasi Bhil, Rawal Bhil, Tadvi Bhil, Bhagalia, Bhilala, Pawra, Vasava, Vasave
9. Bhunjia
10. Binjhwar
11. Birhul, Birhor
12. Chodhara (excluding Akola Amravati, Bhandara, Buldhana, Chandrapur, Nagpur, Wardha, Yavatmal, Aurangabad, Bheed, Nanded, Osmanabad, and Parbhani districts)
13. Dhanka, Tadvi, Tetaria, Valvi
14. Dhanwar
15. Dhodia
16. Dubla, Talavia, Halpati
17. Gamit, Gamta, Gavit, Mavchi, Padvi
18. Gond, Rajgond, Arakh, Arrakh, Agaria, Asur, Badi Maria, Bada Maria, Bhatola, Bhimma, Bhuta, Koilabhuta, Koilabhuti, Bhar, Bisonhorn Maria, Chota Maria, Dandami Maria, Dhuru, Dhurwa, Dhoba, Dhulia, Dorla, Gaiki, Gatta, Gatti, Gaita, Gond Gowari, Hill Maria, Kandra, Kalanga, Khatola, Koitar, Koya, Khirwar, Khirwara, Kucha Maria, Kuchaki Maria, Madia, Maria, Mana, Mannewar, Moghya, Mogia, Monghya, Mudia, Muria, Nagarchi, Naikpod, Nagwanshi, Ojha, Raj, Sonjhari Jhareka, Thatia, Thotya, Wade Maria, Vade Maria.
19. Halba, Halbi
20. Kamar
21. Kathodi, Katkari, Dhor Kathodi, Dhor Kathkari, Son Kathodi, Son Katkari
22. Kavar, Kanwar, Kaur, Cherwa, Rathia, Tanwar, Chattri
23. Khairwar
24. Kharia
25. Kokna, Kokni, Kukna
26. Kol
27. Kolam, Mannervarlu
28. Koli Dhor, Tokre Koli, Kolcha, Kolgha
29. Koli Mahadev, Dongar Koli
30. Koli Malhar
31. Kondh, Khond, Kandh
32. Korku, Bopchi, Mouasi, Nihal, Nahul, Bondhi, Bondeya
33. Koya, Bhine Koya, Rajkoya
34. Nagesia, Nagasia
35. Naikda, Nayaka, Cholivala Nayaka, Kapadia Nayaka, Mota Nayaka, Nana Nayaka
36. Oraon, Dhangad
37. Pardhan, Pathari, Saroti
38. Pardhi, Advichincher, Phans Pardhi, Phanse Pardhi, Langoli Pardhi, Bahelia, Bahellia, Chita Pardhi, Shikari, Takankar, Takia
39. Parja
40. Patelia
41. Pomla
42. Rathawa
43. Sawar, Sawara
44. Thakur, Thakar, Ka Thakur, Ka Thakar, Ma Thakur, Ma Thakar
45. Thoti (in Aurangabad, Bhir, Nanded, Osmanabad, and Parbhani districts, and Rajura tehsil of Chandrapur district)
46. Varli
47. Vitolia, Kotwalia, Barodia

Three Scheduled Tribes have been identified and categorised as Particularly Vulnerable Tribal Groups (PVTGs) in Maharashtra. They are Madia, Katkari/Kathodi, and Kolam.

The overall geographical coverage of the tribal people in Maharashtra is 50,757 sq km, compared to the state's geographical area, which is 3,07,713 sq km. This represents around 16.5 per cent of the state's land area.

Most of Maharashtra's tribal people live in the western hilly districts of Dhule, Nandurbar, Jalgaon, Nashik, Thane, and Palghar (Sahyadri region) and the eastern forest districts of Chandrapur, Gadchiroli, Bhandara, Gondia, Nagpur, Amravati, and Yavatmal (Gondwana region).

5.6.2 Socio-cultural status of tribal population

5.6.2.1 Literacy

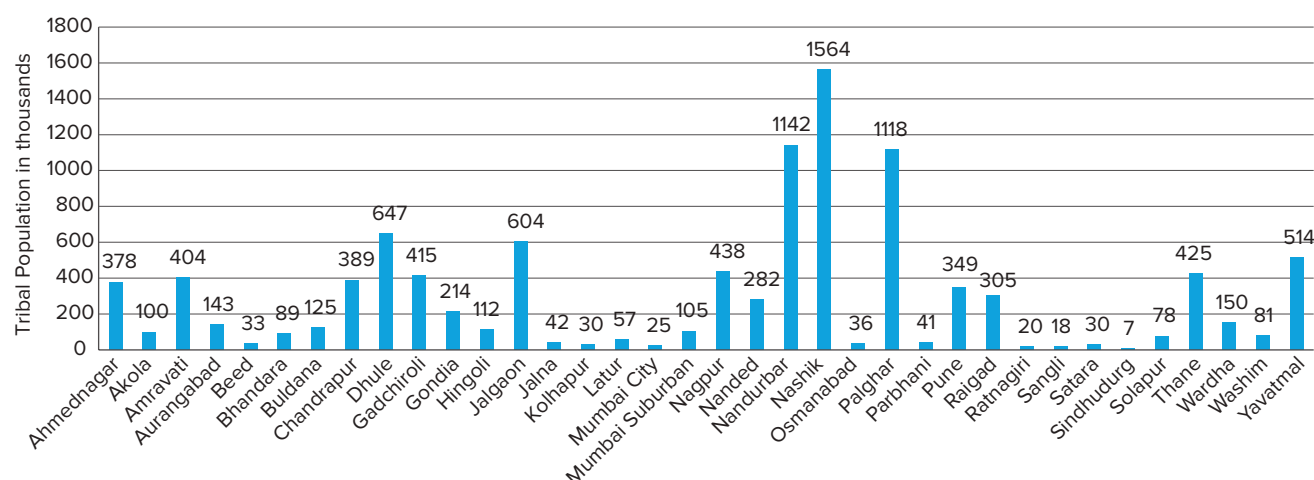
According to the 2011 census, 65.7 per cent of the tribal people in Maharashtra are literate. The literacy rate for men is 74.3 per cent, and for women, 57 per cent. Compared with the overall literacy of the state, there is a gap of 16.6 per cent in the literacy rate; there is a gap of 14.1 per cent in the tribal male literacy rate and an 18.9 per cent gap in the female literacy rate.

Table 5.6.1 District-wise tribal population in Maharashtra as per Census 2011

District	Tribal population (in '000)	Percentage of the tribal population to the total population	District	Tribal population (in '000)	Percentage of the tribal population to the total population
Ahmednagar	378	8.3	Nagpur	438	9.4
Akola	100	5.5	Nanded	282	8.3
Amravati	404	13.9	Nandurbar	1142	69.3
Aurangabad	143	3.8	Nashik	1564	25.6
Beed	33	1.3	Osmanabad	36	2.1
Bhandara	89	7.4	Palghar	1118	37.4
Buldhana	125	4.8	Parbhani	41	2.2
Chandrapur	389	17.6	Pune	349	3.7
Dhule	647	31.5	Raigad	305	11.2
Gadchiroli	415	38.6	Ratnagiri	20	1.2
Gondia	214	16.1	Sangli	18	0.6
Hingoli	112	9.5	Satara	30	1
Jalgaon	604	14.3	Sindhudurg	7	0.8
Jalna	42	2.1	Solapur	78	1.8
Kolhapur	30	0.7	Thane	425	5.2
Latur	57	2.3	Wardha	150	11.5
Mumbai City	25	0.81	Washim	81	6.7
Mumbai Suburban	105	1.12	Yavatmal	514	18.5

Source: Tribal Research and Training Institute, Government of Maharashtra

Figure 5.6.1 District-wise tribal population



Source: Tribal Research and Training Institute, Government of Maharashtra

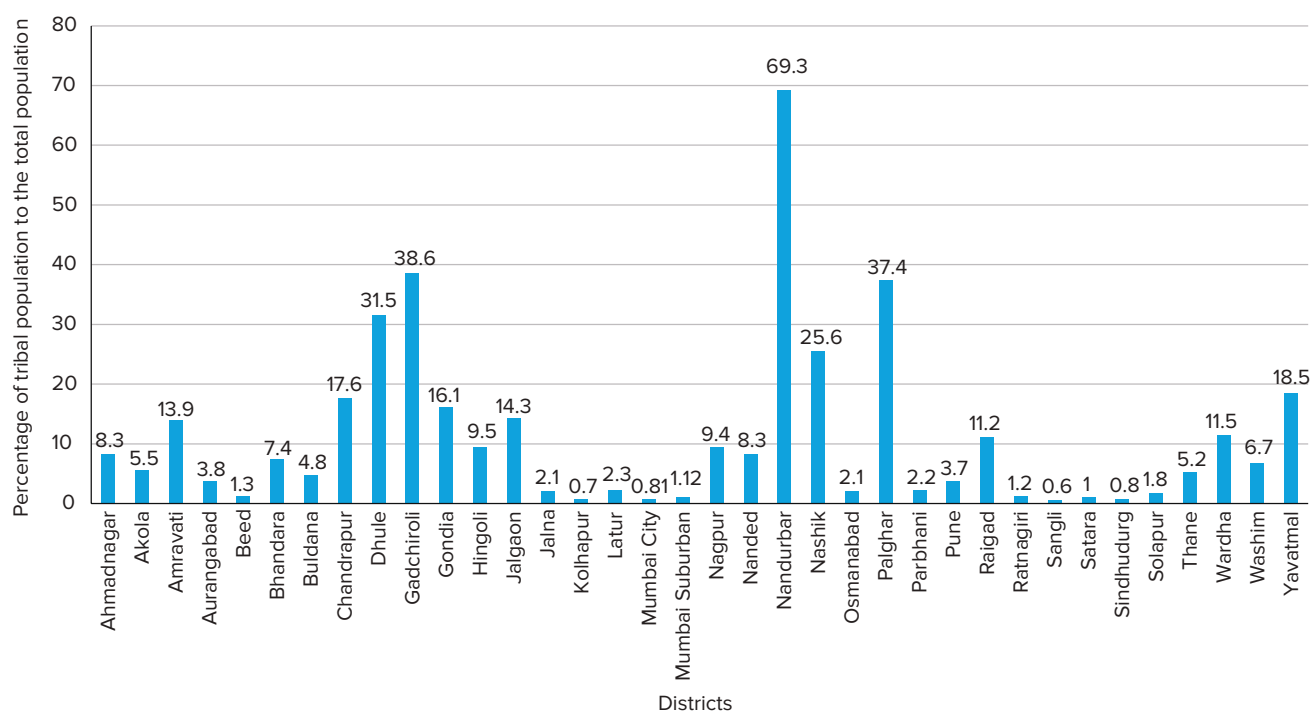
5.6.2.2 Sex ratio

The overall sex ratio among the tribal population is 977. The average child sex ratio among the tribes is 955. Among the tribal population, Kolhapur has the lowest child sex ratio (890), and Gadchiroli district has the highest child sex ratio (985).

5.6.3 Livelihood sources and activities followed by the tribal community

Tribal communities depend on natural resources in their surrounding for their livelihood. Forest plays a vital part in tribal life. They provide a source of livelihood for the community through direct employment, self-employment, and secondary employment. The tribal regions are diverse regarding available resources such as forests,

Figure 5.6.2 Percentage of tribal population to the total population in Maharashtra



Source: Tribal Research and Training Institute, Government of Maharashtra

water, and land. Hence, the livelihood sources of the tribal community are region and tribe-specific.

The tribal people are small cultivators, gatherers of non-timber forest produce (NTFPs) and minor forest produce (MFPs), occasional fishermen, daily-wage labourers, and

skilful artisans. They collect NTFPs and MFPs such as mahua flowers, tendu patta, tendu fruits, tamarind, honey, and lac from the forests. A few examples of livelihood sources for some of the tribes in Maharashtra are given in Table 5.6.2.

Table 5.6.2 List of livelihood sources for a few tribal communities in Maharashtra

Tribal community	Livelihood sources
Bhil	Most Bhil people are farmers and agricultural labourers. Bhil also has traditional medical specialists such as <i>Budwa</i> (Shaman), <i>Huvarki</i> (traditional birth attendant), <i>Vaidu</i> (herbalist), and <i>Had Vaidu</i> (Bone setter), with some communities also having male midwives. They are also skilled sculptors.
Bison Horn Maria	They practise shifting cultivation methods of agriculture and collect forest produce for existence.
Madia	They are primarily a hunting-gathering tribe. They are skilled in handling bamboo and take special care while cutting to avoid damaging the roots.
Koli Dhor	The Koli Dhor reside predominantly in the Sahyadri range of mountains forming part of the Western Ghats and are principally found in Thane, Nashik Dadra and Nagar Haveli. They are engaged in the tanning of cattle hide, and in recent times, are increasingly involved in agricultural activities. They also migrate to nearby cities and towns to work as daily labourers and return to their villages only in June to work as agricultural and daily-wage labourers.
Korku	The Korku are found in the adjoining Melghat region of Maharashtra. They are primarily cultivators. While they share the love for the forests with the Gonds, they are also skilled agriculturists and have pioneered the cultivation of potatoes and coffee.
Kokna	The Kokna are known for making masks, bamboo, wooden craft, and brass and copper motifs. Being skilful artists, they can craft ordinary wooden tobacco containers into appealing works of art.
Ka Thakar	The Ka Thakar are found in the Thane, Raigad, Pune, Ahmednagar, and Nashik districts of Maharashtra. Ka Thakars are small-scale cultivators, gatherers of minor forest produce, occasional fishermen, and daily wage labourers. They are also skilful bamboo artisans.
Warli	The Warli is spread across Maharashtra's Thane, Nashik, and Dhule districts. They are small-scale cultivators and cultivate rice, pulses, and vegetables. They also sell NTFPs such as toddy, mahua, and fuel wood within their community and neighbouring populations for a living.

Source: Ministry of Tribal Affairs, Government of India and United Nations Development Programme (UNDP)

5.6.4 Impact of climate change on tribal population

5.6.4.1 Economy and livelihood activities

Maharashtra has the second-largest tribal population in the country. Most of the tribal population resides around forest areas, particularly in Amravati, Chandrapur, Dhule, Gadchiroli, Jalgaon, Nandurbar, Nanded, Nashik, Pune Palghar, and Thane districts.

The economy in these communities primarily depends on agriculture and available forest resources such as NTFPs. Approximately 85 per cent of the tribal population is engaged in farming, out of which 40 per cent are farmers and 45 per cent are agricultural labourers (Devera 2016). However, they inhabit fringe forest settlements with agricultural lands in climatic risk-prone areas placing agricultural production systems at risk and unstable. These climatically challenged locations are increasingly witnessing erratic rainfall, heat waves, seawater intrusion, and other climatic risks. Fertile lands have been degraded, have low productivity, and are vulnerable to erosion. Climate-related crises have led to a loss of approximately 36 million ha of crops over the last 5 years in Maharashtra. The state has 24 per cent of the drought-prone area of the country, with 99 talukas being chronically drought-affected (NABARD 2021).

Climatic variability in the previous decade, especially due to erratic rainfall patterns and extreme rises in temperatures, induced an extreme reduction (30–40%) in the kharif onion crop yield in Nashik. Increases in temperature, erratic rainfall, and relative humidity also affected the post-storage quality giving rise to considerable losses (up to 40%) in storage (Chahal and Mishra 2021).

The urban and rural population of the state constitutes 54.78 per cent and 45.22 per cent, respectively. The high rural population in the state depends on the forests substantially for livelihood and basic needs (FSI 2019). Besides the decline in crop production, increase in the occurrence of crop diseases, and livestock mortality, climate change has severely impacted the production of NTFPs. The uncertainty in annual rainfall patterns and weather conditions impacts forest crops and hampers the ability of the locals to plan for their crucial off-season income when other work is unviable. These are severely impacting their livelihood sources. In her article, Mridula Chari reported that self-help group members and tribals from Maharashtra's Yavatmal district shared the alarming trends regarding the production of NTFPs, where every alternate year, mahua flowers and seeds appeared in far smaller quantities than they did earlier. Further, in the case of charoli, or chironji, the fruit flourished for a short duration but was then typically destroyed by unseasonal summer rains (Chari 2022).

For the millions of people from tribal communities who depend on agricultural and forest products, these

changes can impact a vital part of their annual earnings. Tribals have very few livelihood choices, and overlooking these communities' economic pressures impacts their socioeconomic status. There is an urgent requirement to develop a comprehensive tribal development initiative that addresses numerous issues of various tribal communities, such as livelihood security, food, and nutrition security.

5.6.4.2 Socio-cultural and traditional knowledge

Lack of livelihood opportunities due to the impacts of climate change has resulted in large-scale migration of tribal populations from rural to urban areas, either temporarily or permanently. This has caused disturbances in their traditional socio-psychological family bonding, the network of neighbourly relationships, and social relations. Heavy rainfall is common during the monsoon in Gadchiroli district, which is surrounded by forests. The major tribes that reside in the district are Gond, Madia, Pardhan, and Kolam. The erratic rainfall in the region led to the displacement of 700 families in the region in 2022.

Along with the respective roles of men and women, the nature of struggles with the state regarding land issues, particularly concerning the land in and around the forests, has also escalated. Loss of habitat during flooding or heavy rainfall is also a major cause of migration among the tribal community. Tribal communities turning towards modern livelihood opportunities is affecting the transfer of traditional knowledge from generation to generation. The skilful artisans from the tribe are no longer interested in continuing their artwork because either they are migrating for labour work or do not have sufficient time and interest. This is thus impacting the transfer of traditional knowledge to the future generation. Some tribes also switch their primitive livelihood activities due to legal restrictions on forests and their resources. The Katkari tribe is found in the hilly and forest areas of Raigad, Thane, Pune, Nashik, Ratnagiri, and Sindhudurg districts of Maharashtra. As a traditional occupation, they collected and prepared the secretion of *Acacia Catechu* plants (Black Catechu) for medicines and other products. However, with the increasing importance of forest conservation and high restrictions on the cutting of Khair trees from forested areas, most Katkari tribes have moved away from their traditional Kath procuring occupation over the years. They have now moved on to working on a daily wage basis in coal mines and other sites as contractors (TRTI 2022).

Incidents such as increased frequency of wildfires, higher temperatures, changes in the ecosystem processes, forest conversion, and land degradation threaten tribal access to the crucial resources that outline and identify their culture. Forests and land degradation directly affect culturally important fungi, plant, and animal species, thus affecting tribal sovereignty, culture, and economy. Most of their daily food items are procured from the forested areas or crops grown for subsistence. Therefore, a decrease

in agricultural and NTFPs production is cumulatively impacting the tribal household food consumption pattern and dietary diversity.

Climate change affects the quality and quantity of all the resources that the tribes depend on for the continuance of their cultures and traditional knowledge. However, with a wealth of traditional knowledge and practices, tribal communities have an influential role in achieving climate change mitigation goals. Without their purposeful participation, knowledge, and practices, effective climate action and sustainable development will not be achieved.

5.6.4.3 Women

Tribal women are equally dependent on nature and natural resources as men for their sources of livelihood and day-to-day activities. They depend on the forest for fuelwood, NTFPs, and local fruits and vegetables for daily consumption and are also engaged in agricultural activities. Climate change will impact both men and women; however, its impact on them is not the same. Women are seen as more at risk of the effects of climate change, primarily because they are proportionally more dependent on threatened natural resources. Tribal women face the following challenges due to climate change:

- Due to a shortage of resources and an increase in unemployment, men migrate to other resources for their work. This has increased the burden on women, who usually take charge of farming activities, household chores, managing livestock, and rearing children.
- Managing livestock and food has become exceptionally difficult due to water scarcity and lack of grazing pastures.
- In addition, food sources are becoming more uncertain and scarce, and thus, women face loss of income and harvests.
- During droughts and floods, women work more to secure their houses and livelihoods. This leaves limited time for women to gain training and education and develop skills or earn income.
- Reduction in the availability of fuelwood and forest resources makes it harder for them to collect resources for day-to-day activities.

The difference in the impact of climate change between men and women is also prevalent due to their differential roles, responsibilities, decision-making, and access to land and natural resources. Women have limited access to and control of natural resources and services; they have negligible involvement in decision-making and are not involved in distributing environment management benefits. Consequently, women are less resilient towards climate change.

5.6.4.4 Increase in human-animal conflicts in forested and buffer areas

Human-wildlife conflict is the direct interaction between humans and wildlife with adverse outcomes where both compete for the limited resources in the shared ecosystem. Human-animal conflict is rising, and climate change could be one of the reasons for escalating it. However, the dynamics of climate-ecology-society contributing to the conflict are yet to be researched further. An article mentioned that Maharashtra lost a total of 88 lives in human-animal conflict primarily because of leopard and animal attacks in 2020 (Pinjarkar 2021). There was also an increase in livestock killing of approximately 9,000 in 2020. Most of the attacks were observed in the regions of Chandrapur and Vidarbha districts.

Climate change leads to resource scarcity and that in turn leads to the tragedy of commons for humans and wildlife. Due to the degradation of soil quality and reduction in agricultural produce, along with the loss of NTFPs, people are encroaching on the forest land leading to the shrinking of wildlife habitat. Also, the lack of palatable food within the habitat for wildlife attracts them towards the cultivated agricultural field. These are the major causes of human-animal conflict. Wildlife not only attacks human life but is responsible for destroying agricultural crops and attacking livestock. Human-animal conflict leads to loss of lives and loss of income for the local communities.

5.6.5 Importance of Forest Rights Act (2006) in supporting tribal communities from forest areas

A large number of people belonging to the Scheduled Tribes have lived in and around forests for time immemorial and have developed a relationship with nature. However, considering the judicious use of forest resources has led to the creation of customary rules and regulations for use and extraction. Initially, in the earlier days, ethical beliefs and practices ensured that forests were not degraded to a large extent, supporting the safeguarding of forest land. Later, the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, was formulated to secure individual and community rights on the community land (FRA 2006).

Features of FRA

The act recognises the forest rights and occupation of forest lands in Forest Dwelling Scheduled Tribes (FDST) and Other Traditional Forest Dwellers (OTFD) residing in such forests for generations. It establishes the responsibilities and authority for sustainable use, biodiversity conservation, and maintenance of the ecological balance of FDST and OTFD. The act aims to strengthen the conservation process of the forests while ensuring the livelihood and food security of the forest dwellers.

The act identifies four types of rights:

1. Title rights: It gives FDST and OTFD the right to ownership of land farmed by tribals or forest dwellers subject to a maximum of 4 ha. Under this right, ownership is only for the land being cultivated by the concerned family, and no new land will be granted.
2. Use rights: The rights of the dwellers extend to extracting MFP, grazing areas, pastoralist routes, etc.
3. Relief and development rights: Right to rehabilitation (in case of illegal eviction or forced displacement) and basic amenities, subject to restrictions for forest protection.
4. Forest management rights: It includes the right to protect, regenerate or conserve, or manage any community forest resource which they have been traditionally protecting and conserving for sustainable use.

Impact groups for the FRA

1. Members of communities of the Scheduled Tribes who primarily reside in and depend on the forests or forest lands for bona fide livelihood needs.
2. It can also be claimed by any member or community who has, for at least three generations (75 years) before 13 December 2005, primarily resided in forest land for bona fide livelihood needs.
3. The Gram Sabha is the authority to initiate the process for determining the nature and extent of Individual Forest Rights (IFR), Community Forest Rights (CFR), or both that may be given to FDST and OTFD.

Status of FRA in Maharashtra

The then Maharashtra Governor issued a notification modifying the Forest Rights Act, 2006, entitling forest-dwelling Scheduled Tribes and other traditional forest-dwelling families to build their houses in the forest neighbourhood. The decision aimed to provide a major reassurance to Scheduled Tribes and other traditional forest-dwelling groups living in the scheduled areas of the state. It was hoped that it would prevent the migration of forest-dwelling families outside their native villages and provide them with housing areas by increasing the number

of village sites in forest land in their neighbourhood (Raj Bhavan Maharashtra 2020). As per the report by CFR Learning and Advocacy Group Maharashtra in 2017, a few positive trends observed due to the implementation of FRA in Maharashtra were: efforts were taken by Gram Sabhas towards local and sustainable governance, management, and conservation of forests through the CFR Management Committee. They also evolved formal and informal CFR management strategies and plans supported by government agencies towards filing claims and supporting drafting and implementation of CFR management plans. Along with, they exercised rights over NTFP, particularly bamboo and tendu to enhance local economies and livelihoods.

5.6.6 Adaptation strategies and key action points

5.6.6.1 Mapping the existing policies

Government Ashram School Group Scheme

The objective of the scheme is to increase education among Scheduled Tribes, including PVTGs. The scheme allows for the construction of Ashram Schools for the primary, middle, secondary, and senior secondary stages of education as well as the upgradation of existing Ashram Schools for Scheduled Tribe boys and girls, including PVTGs.

Pandit Deendayal Upadhyay Swayam Scheme

This scheme offers financial aid to ST students who have enrolled in higher education programmes after their 12th grade but were unsuccessful in getting a seat in a government hostel. Up to INR 60,000 in financial aid is given for food, housing, educational materials, and subsistence allowance. Under this scheme, approximately 16,000 students benefited in the year 2021–2022 (Directorate of Economics and Statistics, Planning Department, Government of Maharashtra 2023). There was an increase in the number of students who have enrolled under this scheme in comparison with the previous years.

This scheme is vital for its contribution to the SDGs, in particular, SDG 2: Zero Hunger, SDG 3: Good Quality Health and Well-Being, SDG 4: Quality Education, and SDG 10: Reduce Inequalities.

Table 5.6.3 List of existing schemes and policies for tribal development

S.No.	Title of the Scheme/Policy	Nodal/Implementing Agency	SDGs
1	Government Ashram School Group Scheme	Ministry of Tribal Affairs (MoTA)	1, 2, 4, and 10
2	Financing of voluntary organisations to run ashram schools	Ministry of Tribal Affairs (MoTA)	1, 2, 4, and 10
3	Development Scheme for Indigenous People	Ministry of Tribal Affairs (MoTA)	1, 10, and 11
4	Pandit Deendayal Upadhyay Swayam Yojana (Scheme)	Department of Social Justice and Welfare	2, 3, 4, and 10
5	Dr. A. P. J. Abdul Kalam Amrut Aahar Yojana	Ministry of Tribal Affairs (MoTA)	10

Source: Economic Survey of Maharashtra 2021

Dr. A. P. J. Abdul Kalam Amrut Aahar Yojana

The objective of this scheme is to provide a 'one full hot cooked nutritious food' to all pregnant women and lactating mothers through *Anganwadi* centres (AWC) in scheduled areas. *Amrut Ahar Yojana* is beneficial for pregnant and lactating mothers. A one-time square meal of *Amrut Ahar Yojana* is advantageous compared to the dry ration.

The Khwati Anudan Yojana

The *Khawti Anudan Yojana* was introduced in 2013–2014 in Maharashtra to help families that were economically weaker. To address the economic circumstances brought on by the COVID-19 pandemic, the *Khawti Anudan Yojana* was reinstated in 2020 and is now being executed in the form of a 100 per cent grant. A total of INR 486.00 crore was spent in 2020–21. The objective of the scheme is to provide food grains, essential items as well as financial assistance for eligible poor tribal families.

Nav Sanjeevan Yojana

This initiative aims at integrated and coordinated implementation and strengthening of various services, such as drinking water and health facilities, to the tribal community, which were previously being implemented by several agencies at several levels without ensuring proper coordination. The schemes included in the *Nav Sanjeevan Yojana* for coordinated implementation are the *Employment Programme*, *Employment Guarantee Scheme*, centrally sponsored *Sampurna Gramin Rojgar Scheme*, health services, providing primary health care services, providing pure and clean drinking water, *Nutrition Programme*, which includes *Integrated Child Development Scheme* and *School Feeding Programme*, supply of food grains, distribution of food grains through fair price shops, revamped public distribution system, door delivery system, *Consumption Loan Scheme*, and *Grain Bank Scheme*.

5.6.7 Key action points and strategies for better tribal development

Frequently, the tribal community collaborates proactively with a range of partners to combine traditional knowledge with technological instruments and varied study methodologies. Nearly 85 per cent of the tribal population in Maharashtra is agricultural. While 40 per cent of them are farmers, 45 per cent work as agricultural labourers. Tribal agriculture is characterised by limited input resources and poor technology, which results in low agricultural productivity of different crops. Additionally, there are very few irrigation facilities in the tribal regions. Sector-specific interventions are needed to ensure the quality and quantity of agriculture production among the tribal communities.

The majority of the state's tribal population lives close to or around forests, mainly in the districts of Thane, Palghar, Nashik, Dhule, Nandurbar, Jalgaon, Pune, Nanded, Amravati, Gadchiroli, and Chandrapur (Government of Maharashtra n.d). The state's entire forest area is 63,867 square kilometres, which is approximately 16.9 per cent of the state's overall land area. Nearly 49 per cent, or 31,277 sq km, of this forest area, is under the state's Tribal Sub Plan. Therefore, forestry activities are crucial to the tribal community's socio-economic growth. The majority of the forestry labour involves extracting both major and minor forest products, planting new trees, conserving wildlife and the environment, protecting forests, etc. Due to the employment opportunities provided by the Forest Department, Forest Laborers Cooperative Societies, Maharashtra State Cooperative Tribal Development Corporation, Forest Development Corporation, etc., the tribal economy is primarily supported by the products found in the forest. The tribal community might pay their bills by working on various forestry projects. The Forest Department's training programmes in logging, among other topics, help the indigenous people develop their skills and increase their earning potential.

Box - 5

How indigenous tribal practices are championing mission LiFE

The traditional and indigenous knowledge of the tribal communities in Maharashtra has long been embedded in sustainability and environmental stewardship. Their practices have been consistently in alignment with the ecosystem, reflecting a deep understanding of nature. The following table illustrates the activities of tribal communities that align with the themes of Mission LiFE, showcasing their role as environmental stewards and their contributions to a sustainable future.

Mission LiFE themes	Traditional practices by Tribal communities
Adopt healthy lifestyle	a. Tribes have extensive knowledge of local flora and use various plants and herbs for medicinal purposes. They prepare remedies for common ailments using these natural resources. For instance, Bhilla, Thakar, Warli and Kokna tribes in the northwestern region of Maharashtra use various wild plants to treat gastrointestinal disorders, such as <i>Andrographis paniculata</i>, <i>Cassia fistula</i>, and others (Pawar 2008). b. Tribal festivals often include traditional dances and physical activities that promote physical fitness and community bonding.
Reduce waste	Tribal farmers in Maharashtra, such as the Warli, Bhil, and Gond communities, use a variety of organic manures in their traditional mixed cropping and sustainable agriculture practices. They also use forest organic matter, such as leaf litter, as a natural fertiliser (Government of Maharashtra).
Save energy	a. Traditionally, the tribes used solar drying techniques to preserve fruits, vegetables, and fish. This method saves energy and ensures a longer shelf life for food products. b. The tribal communities in Maharashtra, such as the Warli and Bhil, have developed unique architectural styles incorporating natural materials and responding to the local climate.
Save water	Tribals often practice rainwater harvesting, collecting and storing rainwater for various uses. Tribal communities in Maharashtra employ several indigenous irrigation practices aimed at conserving water, especially crucial in regions with erratic rainfall.
Adopt sustainable dietary habits	The traditional diets of Maharashtra's tribes were highly nutritious, relying on diverse wild foods foraged from the forests. For instance, the staple food of the Warli tribe includes coconut or rice bhakri (flatbread), toor (pigeon pea) dal cooked with moringa and other nutritious vegetables and leaves, suran (yam) curry, and boiled toor pods.

Source: Author's compilation



Maharashtra hosts Western Ghats, which is one of the thirty six global biodiversity hotspots.

Table 5.6.4 Recommendations for climate change adaptation and resilience building for tribal development

S. no.	Recommendations/ Targets	Rationale	Actions to be undertaken
1	Provide hand-holding support and build capacities of the tribal communities to improve the agri-allied-based livelihood opportunities in the region to enhance their income and build their resilience in overcoming future challenges caused due to climate change.	Approximately 85% of the tribal population is engaged in farming, of which 40% are farmers and 45% are agricultural labourers. Climate-related crises have led to a loss of approximately 36 million ha of crops in the last 5 years in MH. Climatic variability in the last decade, especially erratic rainfall patterns and extreme spikes in temperatures, resulted in a drastic reduction in the kharif onion crop yield, i.e., 30–40% in Nashik. Increases in temperature, rainfall and relative humidity also adversely impacted the post-storage quality causing considerable losses in storage (up to 40%).	1. Provide support to commercially viable crops for the farmers. In Nandurbar (69% tribal population) and Nashik (25% tribal population), support commercial cultivation of onion and garlic to 1,000 farmers in Phase 1, followed by 2,000 farmers in Phase 2 via ICAR. 2. Provide 150 solar cold storages to farmers from Nashik, Vidarbha, and Marathwada divisions. 3. Provide 5000 pumps (1-2 HP), and 3000 pumps (3-5 HP) to tribal farmers from all districts under PM-KUSUM/ <i>Mukhyamantri Saur Krushi Pump Yojana</i> (>1,50,000 deployment potential of solar micro-pumps in the state). 4. Set up and strengthen 360 tribal cooperatives (in each Talukas) for marketing, grading, and packing centre products and sensitising agricultural cooperatives network on climate-proofing production and marketing via Tribal Cooperative Marketing Development Federation (TRIFED), KVKs.
2	Support and strengthen the livelihood activities of the tribal population residing near the forest fringe areas and support the tribal to uplift and diversify their livelihoods. Support the tribal forest communities to overcome climate change challenges and uplift their livelihoods and diversify them.	55% of the rural population resides in rural regions, of which a high percentage is dependent on forests for livelihoods (FSI, 2019). Value addition of NTFPs will support the improved income of the tribal communities and build resilient sources of income.	1. Launch Innovative livelihood initiatives to bring corporate houses and industries to initiate Social Business Enterprises to create livelihood opportunities for the poor through profitable, sustainable, and scalable ventures. 2. Set up or build existing 1,000 self-help groups (SHGs), producer companies, and co-operatives' capacities to provide market access to tribal women for processing and selling their NTFP commodities. <i>Shabri Adivasi scheme</i>, KVKs, and SRLM-UMEED could play a vital role in building capacities, training, and financing of SHGs and FPOs. 3. Promote deployment of 500 small horticulture processor units (50 L) to strengthen the collection and storage of NTFP for an initial phase of 5 years. 4. Provision of an affordable and sustainable solar drying device of 100 kg that adds value to the marketing and collection of NTFP. 300 units of dryers could be provided. 5. Provide 6,000 solar animal-repellent light and sound systems to 2,000 farmers from forested regions (set of 3 systems to 2,000 farmers as 1 acre of land requires 3 systems).

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
Entire state, with a special focus on Vidarbha, and Marathwada regions.	Department of Agriculture	Total support cost to farmers for onion and garlic crops includes training, capacity building, hand-holding support for the first crop, and cost of trainers for Phase 1 and Phase 2: INR 5 crore.	Improved agricultural production, which in turn improves the livelihoods of the local tribal community.
	Department of Agriculture and Maharashtra Energy Development Agency	Provision of 200 cold storages: ~INR 8–9 crore (at 30% capital subsidy).	
	Department of Agriculture and Maharashtra Energy Development Agency	Provision of 8,000 solar pumps for tribal farmers under PM KUSUM/ <i>Maharashtra Saur Krishi Pump Yojana</i> . Provision of 8,000 solar pumps will cost INR 45 crore (at 30% capital subsidy).	
	Department of Agriculture and Department of Tribal Development	Capacity building of tribal cooperatives includes training, knowledge dissemination, and technological interventions: INR 5 crore.	
All tribal districts with a special focus on Gadchiroli, Chandrapur, Gondiya, Yavatmal, and Nashik.	Department of Tribal Development	-	Improved livelihood opportunities for forest-dependent tribal communities and forest conservation activities leading to biodiversity restoration.
	Integration can be done with the existing scheme; National Mission on Green India.		
	Department of Tribal Development in collaboration with the Indian Council of Agricultural Research (ICAR), Department of Agriculture, SRLM- Umeed, and Ministry of Rural Development	For institutionalising 1,000 SHGs and co-operatives, the cost comprises awareness of new technologies, value addition, marketing, and entrepreneurial skills. Along with the cost of trainers, estimated total cost: INR 5 crore.	
	Department of Agriculture and Maharashtra Energy Development Agency	For the initial phase of 5 years, 500 multi-purpose food processors are to be provided. The cost of one unit (50 L) is INR 1.5 lakh. Total cost: INR 3 crore (at 30% capital subsidy).	
	Department of Agriculture and Maharashtra Energy Development Agency Integration can be done with the existing scheme; National Mission for Enhanced Energy Efficiency.	A solar drying device that adds value to NTFP costs ~INR 1,50,000 for 100 kg. In the Initial phase, 300 units could be provided. Total cost: INR 2 crore (at 30% capital subsidy).	
	Department of Agriculture and Maharashtra Energy Development Agency	~3 systems for 1 acre of land where 1 system costs ~INR 10,000–15,000. Total cost: INR 3 crore (at 30% capital subsidy).	

S. no.	Recommendations/ Targets	Rationale	Actions to be undertaken
3	To bridge the current gaps in the health and nutritional status of the tribal communities in the state to help build a health and nutritional support system for the tribals for the upcoming climate change issues.	Climate change-related health-diseases are high in districts of northern Maharashtra, Marathwada, and Vidarbha. Northern Maharashtra and Vidarbha have a higher proportion of ST and SC communities. Districts in these regions also have high infant mortality rates and a high proportion of children under 5 who are wasted (as per CEEW analysis). In addition, more than half of tribal women (54%) in Maharashtra are anaemic in the reproductive age group.	1. Train 1,000 local tribal youth volunteers, who can be called <i>Swasthya Mitra</i>, <i>daai</i>, and ASHA workers, with the active participation of Gram Panchayats to promote a kitchen garden scheme and enhance nutritional deficiency among tribals. 2. Design an integrated programme with the support of PHCs and health department to provide a quarterly package of services to the tribal children in schools, such as supplementary nutrition, immunisation, and health check-up by trained local tribal youth volunteers <i>under Navsanjeevani Yojana</i>. 3. Increase in community health surveillance and facilitation of nursing homes and child welfare and maternity centres each in districts with a high concentration of tribal populations (as piloted Tribal Action Plan in Taloda and Akkalkuwa blocks of Nandurbar district to cover all other vulnerable districts). 4. Ensure health education and healthcare through school healthcare programmes in tribal areas, especially in Ashram Schools.
4	Generate awareness among the tribal population on climate change adaptation strategies and increase engagement of tribals in the decision-making process to make them aware and resilient during forthcoming climate change impacts.	-	1. Build organisational capacity by allocating financial resources for the outreach staff trained to discuss climate change with the community. 2. Hold quarterly sessions and workshops on using traditional food and crafts with the support of local tribal leaders. Sessions on climate change and its impacts. 3. Enhance the involvement of local tribes to influence local- to landscape-scale management decisions when tribes effectively partner with other stakeholders in climate adaptation planning. 4. Encourage elders and harvesters to pass traditional knowledge to younger generations.
Total Budget			

Source: Authors' analysis

Note: A variation of 10% in the costs of the technology could be incurred based on the MRP on the date of purchase

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
Entire state with a special focus on Nandurbar, Nashik, Jalgaon, Gadchiroli, and Vidarbha regions	Department of Public Health	Cost of training 1,000 <i>Swasthya Mitra</i> includes awareness of climate change, nutritional deficiency, building capacities to conduct basic health check-ups and kitchen gardens. The total cost of training for 3 months and hand-holding for the following 9 months: 1 crore to 5 crore. Conducting quarterly health awareness programmes in 1,000 Ashram schools for 2 years: INR 5 crore.	Improved health and nutritional status of the tribal communities with well-established healthcare facilities available to them.
	Department of Public Health		
	Department of Public Health		
	Department of Public Health		
Entire state with a focus on forested regions such as Gadchiroli (68%), Nandurbar (20%), and Chandrapur (31%).	Department of Tribal Development	Financial resources for outreach staff within the organisation to build their capacities, including training cost: INR 8 crore. Cost implication comprises conducting quarterly sessions for two years in ~350 tehsils. Cost of workshop, refreshments, and trainers: INR 5 crore.	Improved awareness of the local tribal communities on different climate change adaptation programmes and schemes.
	Department of Tribal Development		
	Department of Tribal Development		
	Department of Tribal Development		
		~INR 100 crore	

5.7 Decentralised renewable energy (DRE) for enhancing livelihoods

5.7.1 Current status and need for DRE

Half of Maharashtra's total population resides in rural areas and is largely engaged in agriculture, but it contributes only 11.9 per cent to the state economy. Of the total 15.2 million farmers in the state, an overwhelming majority (79.5%) are small and marginal (Directorate of Economics and Statistics 2021).

Sub-par storage and logistic infrastructure result in wastage of up to 30 per cent of produce before it reaches the market (ADB 2021c). Increased frequency of excessive rains and drought-like conditions would leave crops such as soybean, cotton, and wheat with lower yields (Bhagawat and Nazareth 2021), pushing farmers further into poverty. These factors leave the rural population in Maharashtra, mostly farmers, prone to climate change and extreme events induced by climate change. Their livelihoods and incomes, dependent on unorganised forms of employment, do not usually provide a safety net.

Ensuring reliable access to electricity and providing technological solutions to rural livelihoods could help farmers realise better incomes and have a better quality of life. This could be sustainably achieved with decentralised renewable energy-powered and energy-efficient appliances for livelihoods to augment the clean energy transition and improve household incomes and productivity. It also provides a significant opportunity for the state to transition to clean energy while ensuring livelihoods and income generation at the rural level. Organisations such as the Maharashtra Energy Development Agency (MEDA) could collaborate with Maharashtra State Rural Livelihoods Mission and agriculture departments to successfully drive this transition.

5.7.2 Overview of DRE-based livelihood technologies

Poverty being multidimensional, compels users to have multiple sources of income. For this reason, livelihoods, especially of rural populations, usually cut across sectors and activities. The diverse nature of livelihoods practised by rural communities often requires tailored solutions

with varied energy needs. Centralised and grid-based electricity often does not plan to capture the capacity of productive loads and integrate with livelihood opportunities. Further, there are still some apprehensions around the accessibility of grid-based electricity for rural enterprises and some marginalised sections of society (IRENA and SELCO Foundation 2022).

Against this backdrop, DRE-powered livelihood solutions have the potential to provide reliable electricity access to livelihoods, eliminate the reliance of livelihoods on diesel and other conventional sources of energy, as well as improve productivity. There are successful pilots and business models, of DRE livelihood applications in agriculture, agro-processing, dairy, poultry, fisheries, tailoring, etc., which have been tested at the field level in India and other countries in Africa and Southeast Asia by various agencies and have shown the potential to be replicated in larger numbers.

5.7.3 Scope for DRE livelihood applications in Maharashtra

5.7.3.1 Market and impact potential

While the push for solar pumps for irrigation has been in the state with the deployment of almost 99,588 solar-powered pumps under the scheme of *Maharashtra Saur Krishi Pump Yojana* to increase produce and irrigated land area, the state holds significant potential for other DRE technologies as well. As per CEEW research, the state-level market potential for DRE technologies for livelihoods for each technology is provided in Table 5.7.1. While solar water pumps (>1 HP) have the highest deployment potential, solar vertical fodder grow units have the highest livelihood impact potential in Maharashtra.

5.7.3.2 Impacts from the deployment of DRE livelihood technologies

The deployment of the technologies would lead to more than 29 lakh livelihoods being created in the state, giving a source of income to the rural population. The integration of DRE livelihood technologies will also result in drudgery reduction, improvement in efficiency and overall productivity among its users. For end users, especially women, the adoption of technologies has been perceived to increase decision-making power, knowledge and skills to work on technologies and mobility.

What are DRE-based livelihood technologies?

Decentralised Renewable Energy (DRE) livelihood applications can be defined as applications powered by renewable energy — solar, wind, micro-hydro, and biomass and their combinations — that are used for earning livelihoods. The scope may also include grid-based energy efficient technologies and DRE applications operating in hybrid mode with the grid as long as the system is capable of running standalone in the off-grid mode. Livelihood applications powered by mini and micro-grids may also be considered, provided such livelihood appliances are energy-efficient and cost-effective. There are myriad technologies such as solar dryer, solar powered mills, solar or biomass powered cold storage and chiller, solar charkha and looms, solar refrigerators, and multi-purpose food processors.

Table 5.71 Deployment and livelihood impact potential of few DRE livelihood technologies in Maharashtra

Technology	Deployment potential* (no. of units)	Market potential	Livelihood potential	
		Unit cost (INR)	Livelihoods created per unit	Total impact (livelihoods)
Higher HP pumps	5,72,300	2,50,000	1	5,72,300
Solar vertical fodder unit	2,86,529	43,211	3.5	10,05,717
Solar dryer	2,21,119	1,10,250	2	4,42,238
Micro solar pump	1,76,938	45,000	1	1,76,938
Solar refrigerator	1,68,698	95,000	1	1,68,698
Solar grain milling	1,32,261	7,28,079	2	2,64,522
Solar charkha	26,372	43,599	1	26,372
Micro food processor	23,063	1,20,000	2	46,126
Solar cold storage	6,133	14,17,650	30	1,83,990
Bulk milk chiller	4,532	7,33,932	1	4,532
Solar loom	4,449	1,50,154	2	8,898
Silk reeling machine	278	25,672	1	278
Total	16,22,672			29,00,609

*Deployment potential for each technology is calculated considering the backward linkages present in the state and the number of users engaged in that particular activity from publicly available government data.

Source: Authors' analysis

The potential environmental impact from the deployment of clean energy-powered livelihood technologies such as micro solar pumps, solar refrigerators, solar vertical fodder grow units, and micro food processors, among others, is the mitigation of approximately 12,000 tCO₂e emissions from adding up to the atmosphere. Additionally, relatively higher capacity solutions such as solar cold storage, higher HP water pumps and bulk milk chillers come with even higher emission abatement potential. This number is typically arrived at by considering the power consumption of similar technologies operating on grid electricity and the average number of hours of usage reported.

5.7.4 Key action points for adoption and scaling up of DRE-powered livelihood technologies

5.7.4.1 Key action point 1: Undertake a holistic study to establish the district-wise deployment, livelihood and income-generating potential for at least five DRE livelihood technologies in Maharashtra

Description

It is important to establish the district-wise demand for DRE livelihood technologies so that the resource allocation on the remaining components (capital support, awareness, training, monitoring etc) of the ecosystem can be accordingly planned.

Demand mapping for the DRE livelihood technologies could be done following a two-step approach:

1. District-level demand mapping using secondary data.
2. Demand mapping at the user level through primary research in high-potential districts.

Further, demand for DRE livelihood technologies could be classified into two types of users:

1. *Sensible demand* among the end users would improve their current net income through the integration of DRE technologies into their livelihoods.
2. *Latent demand* among the end users who will start or add a new source of livelihood after adopting the DRE technology.

5.7.4.2 Key action point 2: Leverage SHGs and farmer collectives in Maharashtra to build awareness and capacities of at least 10,000 people on DRE technologies

Description

With the district-wise potential established, it would help to undertake active awareness and capacity-building programmes on DRE livelihood technologies for users and other stakeholders in the ecosystem. This would involve setting up of experience centres, deployment of demo units, organising hyperlocal events at cluster level for increasing awareness on DRE technologies for productive

use, and conferences and workshops or seminars for staff and other relevant ministries and departments. The capacity-building programme would also enable relevant stakeholders to increase their awareness of DRE livelihood technologies and help in evaluating potential projects according to government support as part of a dedicated project management unit.

5.7.4.3 Key action point 3: Develop a dedicated state-level policy (two phases) with an ecosystem approach for mainstreaming DRE livelihood technologies that would enable the creation of resilient and sustainable livelihoods by 2030 in Maharashtra

Objective

- To undertake an ecosystem approach to mainstream DRE-powered livelihood technologies.
- To leverage existing infrastructure, schemes, and stakeholder expertise to increase the penetration of these technologies.

The specifics of this proposed policy including the approach, implementation plan, approximate budget is elaborated in section 5.7.5.

5.7.5 A DRE livelihoods policy

The DRE for livelihoods policy is proposed to be implemented in two phases.

5.7.5.1 Pilot phase, 2023–26

It would be designed to create adequate infrastructure and enable the ecosystem at the state level to create 2500 livelihoods. In this phase, the focus would be to ensure gender-inclusive strategies such that there would be significant women users of the promoted DRE livelihood technologies. A detailed insight into high-gender impact technologies is placed in Annexure Table A8. Moreover, a special focus also has to be provided to tribal communities in Maharashtra by providing the technologies listed in Table 5.7.5 in the tribal-dominated districts.

Types of technologies: In the pilot phase, in addition to the technologies listed in Table 5.8.1, solutions such as solar home lighting system, solar dryers, biomass based technologies would be considered for demand estimation and subsequent deployment by leveraging existing schemes.

Table 5.7.2 Pilot phase of DRE for livelihoods policy

Recommendations/ Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications
Pilot phase: Focus on creating adequate infrastructure and enabling ecosystems at the state level and creating 2,500 DRE livelihood deployments in the first two years.	1. Undertake demand mapping for technologies at the district and block levels. A two-step approach can be adopted — using secondary data at the district level and primary research in high-potential districts for end-user mapping. 2. Build capacity and awareness at the state, institution, and end-user levels. Set up experience centres, deploy demo units, and organise hyperlocal events at the cluster level to increase awareness of DRE technologies for productive use. Organise conferences and workshops or seminars for staff and other relevant ministries and departments. 3. Incentivise the adoption of DRE technologies for productive use. Enhance affordability through subsidy, and enable credit access through interest subvention and credit guarantee.	Entire state. High potential districts after mapping exercise.	Maharashtra Energy Development Agency (MEDA). Integration can be done with the existing scheme; National Mission for Enhanced Energy Efficiency.	An estimated budget of INR 45 crore may be required to achieve the objective of creating 2500 deployments. Demand mapping: INR 1 crore. Capacity building and awareness: INR 2 crore. Technology adoption: INR 40.2 crore. Programme Management Unit: INR 1 crore. Administrative: INR 0.8 crore. Total: INR 45 crore.

Recommendations/ Targets	Actions to be undertaken	Geographic areas impacted	Implementing government departments	Financial implications
	4. Collaborate with ministries and departments for outreach, credit access, and policy integration. Forge partnerships with UMED, <i>Deen Dayal Upadhyaya Grameen Kaushalya Yojana</i> (DDU-GKY) for training and skill building of the end users. Explore opportunities with other relevant ministries and departments at the state and central levels. 5. Establish implementation arrangements. Create a Programme Management Unit within MEDA and form a Steering Committee at the state level led by the Chief Secretary or the Energy Secretaries with Secretaries from other departments as members. Launch an online portal for management information system (MIS) portal. Appoint a lead bank as a loan bank in consultation with NABARD.			

Source: Authors' analysis

5.7.5.2 Scale-up phase, 2026–30

Learnings from the pilot phase would be incorporated, and the programme would be scaled up to impact 2,00,000 livelihoods through technology deployments in the state by 2030.

Types of technologies: In the scale-up phase, based on the learnings from the pilot phase, only those technologies that showed significant impact and high potential for deployment would be focussed for deployments.

Target end users: The targeted end users for the dedicated policy shall largely be the rural population, including small and marginal farmers and farmer groups such as FPOs and SHGs.

Pilot Phase, 2023–2026

Objective: To support the ecosystem and infrastructure development of the DRE livelihoods ecosystem and enable the creation of 2,500 livelihoods through the deployment of DRE-powered livelihood technologies in the state of Maharashtra by 2026.

Table 5.7.3 Scale-up phase of DRE for livelihoods policy

Targets	Actions to be undertaken to achieve targets	Geographic areas impacted	Implementing government departments	Financial implications
Scale-up phase: To promote sustainable livelihoods through widespread deployment of DRE-powered technologies across the state of Maharashtra.	1. Undertake focussed mapping for shortlisted technologies post-pilot phase at district and block level. 2. Undertake targeted capacity building and awareness at the state, institution, and end-user levels. 3. Incentivise the adoption of select DRE technologies through support for the disbursement of loans.	State-level	MEDA Integration can be done with the existing scheme; National Mission for Enhanced Energy Efficiency.	An estimated budget of INR 432 crore may be required to promote 2,00,000 DRE-based livelihood technology deployments in Maharashtra. Demand mapping: INR 5 crore. Capacity building and awareness: INR 7 crore.

Targets	Actions to be undertaken to achieve targets	Geographic areas impacted	Implementing government departments	Financial implications
	4. Collaborate with relevant ministries and departments for outreach, credit access, and policy integration. 5. Establish implementation arrangements. Create a Programme Management Unit within MEDA and form a Steering Committee at the state level led by the Chief Secretary or the Energy Secretaries with Secretaries from other departments as members. Launch an online portal for management information system (MIS) portal. Appoint a lead bank as a loan bank in consultation with NABARD.			Technology adoption: INR 412 crore. Programme Management Unit: INR 5 crore. Administrative: INR 3 crore Total: INR 432 crore.

Source: Authors' analysis

Table 5.7.4 Implementation plan of the pilot phase

Activity	Action points
Demand mapping	Undertake demand mapping following a two-step approach: 1. District-level demand mapping using secondary data. 2. Demand mapping at the end user level through primary research in high-potential districts. Demand for DRE livelihoods could be classified into two types of end users: 1. <i>Sensible demand</i> among the end users who would improve their current net income through the integration of DRE technologies in their livelihoods. 2. <i>Latent demand</i> among the end users who will start or add a new source of livelihood after adopting the DRE technology. This could be done by a research organisation with expertise in the subject matter.
Capacity building and awareness	1. Establish a demo unit and experience centre. Map potential districts for the deployment of 50 demo units and setting up of at least 10 experience centres for potential end users at the district level. 2. Organise hyperlocal events at the district or cluster level to create awareness among end users. 3. Organise conferences, workshops and seminars for outreach, networking, building partnerships, and strengthening communities. Enhance DRE technical skills, showcase DRE-based livelihood generation models, and address specific knowledge and learning needs.
Technology adoption	1. Encourage end-user financing: MEDA can enable end-user financing through the integration of DRE livelihood applications and convergence with other schemes. 2. Offer subsidy: 30 % subsidy and an additional 10% to initial 100 adopters. 3. Facilitate interest subvention: For end users who avail of loans, interest subvention can be provided at 5% per annum. 4. Offer credit guarantee: Credit guarantee coverage will be available for eligible beneficiaries under the <i>Credit Guarantee Fund Trust for Micro and Small Enterprises</i> (CGTMSE) scheme for a loan up to INR 20 lakh. The fee for this coverage will be paid by the Government. 5. Provide incubation support to emerging start-ups and enterprises focusing on DRE livelihood technologies in the state: Provide incentives and financial support to start-ups and ideas emerging in DRE livelihood technologies for encouraging research and innovation.

Activity	Action points
Collaboration with other ministries	Coordinate and ensure policy coherence with other departments to enable integration of DRE technologies in existing schemes and policies, thereby leveraging existing infrastructure and practices. TRIFED - <i>Pradhan Mantri Van Dhan Yojana</i> (PMVDY). PMVDY is a component of the mechanism for marketing MFP through minimum support price (MSP) and the development of a value chain for MFP. The <i>Van Dhan</i> start-ups are a well-thought master plan for the socio-economic development of the tribal population of the country and can be leveraged for processing using the technologies.
Implementation arrangements	Programme Management Unit (PMU): Establish a PMU at the department level, which would provide overall coordination and support MEDA in policy implementation with necessary inputs. Executive Committee: At the state level, create an executive committee with personnel from various departments and ministries working for rural livelihoods. Online portal: The state-level scheme shall be monitored through an online portal to be established via an MIS platform for transparent and easy access to information. Lead bank: MEDA shall appoint a lead or nodal bank for the facilitation of loans to the end users.

Source: Authors' analysis

Table 5.7.5 Promotion of DRE technologies in tribal-dominated regions to support them in building climate-resilient livelihoods

S. no.	Recommendations/ Targets	Actions to be undertaken	Geographic Areas Impacted	Implementing Government Departments	Financial Implications
1	Provide hand-holding support and build capacities of the tribal communities to improve the agri-allied based livelihoods opportunities in the region to enhance their income and build their resilience in overcoming future challenges caused due to climate.	1. Provide 150 solar/biomass-based cold storages (5 MT capacity) to farmers from Nashik, Vidarbha, and Marathwada divisions 2. Provide 5,000 (1–2 HP pump), 3,000 (3–5 HP pump) to tribal farmers from all districts under PM-KUSUM/ <i>Mukhyamantri Saur Krushi Pump Yojana</i>.	Entire state with a special focus on Nashik, Vidharbha, and Marathwada regions.	Department of Agriculture and Maharashtra Energy Development Agency. Integration can be done with the existing scheme; National Mission on Sustainable Agriculture.	Provision of 150 Cold-storages: INR 8–9 crore (at 35% capital subsidy). Provision of 8,000 solar pumps for the tribal community in Nashik under PM KUSUM/ <i>Maharashtra Saur Krishi Pump Yojana</i>. Provision of 8,000 solar pumps will be INR 45 crore (at a 30% capital subsidy).
2	Support and strengthen the livelihood activities of the tribal population residing near the forest fringe areas and are dependent on NTFPs. Support the tribal forest communities to overcome climate change challenges and uplift their livelihoods and diversify them.	1. Promote deployment of 500 small horticulture processors (50 L) to strengthen the collection and storage of NTFPs for an initial phase of 5 years. 2. Provision of an affordable and sustainable solar drying device of 100 kg that adds value to the marketing and collection of NTFP. 300 units of dryers could be provided. 3. Provide solar animal-repellent light and sound systems to 2,000 farmers from forested regions.	All tribal districts with a special focus on Gadchiroli, Chandrapur, Gondia, Yavatmal, and Nashik.	Department of Agriculture and Maharashtra Energy Development Agency. Integration can be done with the existing scheme; National Mission on Green India.	For the initial phase of 5 years, 500 multi-purpose food processors are to be provided. The cost of one unit (50 L) is INR 1.5 lakh. Total cost: INR 3 crore (at 30% capital subsidy). A solar drying device that adds value to NTFP costs ~INR 1.5 lakh for 100 kg. In the initial phase, 300 units could be provided. Total cost: INR 2 crore (at 30% capital subsidy). At 3 systems per acre of land, where 1 system costs ~INR 10,000-15,000. Total cost: INR 3 crore (at 30% capital subsidy).

Note: A variation of 10% in the costs of the technology could be incurred based on the MRP on the date of purchase.

Source: Authors' analysis

Budget allocation for the pilot phase

An estimated budget of INR 45.0 crore can be put forth to achieve the objective of deploying 2500 livelihood technologies. The majority of the budget allocation would go towards enabling technology adoption through the provision of capital support to the users, credit guarantee and interest subvention, and incubation support to emerging start-ups in the DRE space at the state level.

Table 5.7.6 Budget allocation for the pilot phase

Activity	Cost (INR crore)
Demand Mapping	1.0
Capacity Building and Awareness	2.0
Technology adoption	40
Programme Management Unit	1.0
Administrative	0.8
Total (INR crore)	45.0

Source: Authors' analysis

Scale-up phase, 2026–2030

The scale-up phase shall focus on the learnings from the pilot phase and scale up to all remaining districts in the state. A detailed study shall be undertaken to assess the impact of the deployments made in the pilot phase. Benefits of these solutions to rural populations and women will be assessed to establish the impact potential for these solutions. It will also aim to disseminate success stories from the pilot phase in the form of films, testimonials, reports, and publications to build momentum in the sector.

For the scale-up phase, a dedicated portal for receiving and processing applications can be developed, enabling faster review of applications and grant of approval. Details of existing facilities both at the national level (PMFME, PMAY-U) and state level could be reviewed to help with the development of a similar handling portal. With solar pumps holding the highest deployment potential in Maharashtra, existing schemes and infrastructure can be leveraged to deploy maximum numbers followed by the remaining technologies, for which learnings from the pilot phase could help in finalising the numbers and strategy.

Table 5.7.7 Overall impact potential

	Budget	Livelihoods created
Pilot phase	INR 45 crore	2500
Scale-up phase	INR 432 crore	2,00,000

Source: Authors' analysis

5.7.5.3 Outcomes of the interventions

The objective of the DRE for livelihoods scheme is to create sustainable livelihood opportunities for rural

populations by encouraging the adoption of DRE livelihood technologies through an ecosystem approach. These technologies, in addition to contributing to the clean energy transition, also help create income-generating opportunities at the rural level. This state-level policy can ideally be designed along with relevant ministries and departments through collaboration. Gender-inclusive strategies are proposed to be a common feature across various activities of the dedicated policy.

Outcomes envisaged

- Demand estimation of DRE technologies for livelihoods
- Access to credit for end users of these technologies
- Capacity building and awareness among the end users and relevant stakeholders
- Convergence with other ministries for outreach, credit access, and policy integration
- Institutional set-up for DRE for livelihoods at the department level
- Incentivisation of DRE technology for productive use among women and marginalised groups
- Enable incubation and financial support to enterprises in the DRE space.

5.8 Disaster Management

As a result of the changing climate, extreme hydro-meteorological disasters such as floods, cyclones, and droughts are expected to occur more frequently and with greater intensity. These disasters have the potential to harm communities, which may result in fatalities and injuries significantly, cause displacements and lead to the destruction of infrastructures.

According to the United Nations Office on Disaster Risk Reduction (UNDRR), disaster risk reduction (DRR) involves systematic efforts to analyse and reduce the factors that contribute to disasters and disrupt their development pathways. The Sendai Framework for Disaster Risk Reduction 2015–2030 (UNDRR 2015), which succeeding the Hyogo Framework (2005–2015), unites 185 countries to address climate risks through DRR. A key priority of the Sendai Framework is to understand disaster risk through a multi-sectoral evaluation of risk intensity, vulnerability, and hazard characteristics.

Other priorities in DRR include strengthening disaster risk governance, financing DRR for increased resilience, improving disaster response, and promoting *Build Back Better* strategies for restoration, rehabilitation, and reconstruction. The Sendai Framework also introduces a methodology, built on the disaster risk management mechanisms from the Hyogo Framework, to estimate infrastructure damages based on the Warsaw International Mechanism (WIM) (UN Climate Change n.d).

The framework focuses on building resilience to disasters with a renewed sense of urgency within the context of sustainable development and poverty eradication and integrating both disaster risk reduction and strengthening response mechanisms, as appropriate, into policies, plans, programmes, and budgets at all levels. It states that although the member states (central governments) have the main responsibility for decreasing the risk of disasters, that responsibility should be shared with other stakeholders, such as local governments, the business sector, and other stakeholders. As far as the sustainability and urgent needs of impacts of climate change are considered, the Sendai Framework integrates the Paris Agreement on Climate Change, the Addis Ababa Action Agenda on Financing for Development, the New Urban Agenda, and the Sustainable Development Goals.

India is a party to various regional and international treaties related to disaster risk reduction (DRR). In 2019, India also became a signatory to the Delhi Declaration on Emergency Preparedness in the WHO Regional Committee for South-East Asia. While the national DRR framework, based on the Sendai Framework, emphasises precise risk management, there has been limited progress in integrating localised risk assessments to ensure climate-resilient developmental pathways. India's focus on disaster management (DM) policies and frameworks began after the Gujarat earthquake in 1999 when the Government recognised the urgency of disaster management as a national priority. To mainstream disaster management, a High-Powered Committee (HPC) and a National Committee were established, laying the foundation for disaster management plans in India (NDMA 2005).

The significance of disaster management was further emphasised in the 12th Five-Year Plan, which allocated fiscal provisions specifically for disaster management — the first time such a dedicated chapter was included (Ministry of Finance 2012). Subsequently, on 23 December 2005, the Government of India ratified the Disaster Management (DM) Act. The National Disaster Management Authority (NDMA) was established at the national level under the DM Act, with the Prime Minister as its head. Additionally, state disaster management authorities (SDMAs) were set up at the subnational level, headed by the chief ministers of each state. These governance arrangements were focused on enhancing resilience.

By reducing individual and community vulnerabilities, disaster risk reduction (DRR) is viewed as a proactive technique for reducing the consequences of disasters. DRR initiatives work to reduce the impacts of risks that could lead to a potential disaster by improving people's capacity to adapt to these extreme events. To be more precise, DRR includes steps taken to limit exposure to hazards, reduce vulnerability to damages, and make sure that communities have the capacity to deal with impacts when they do occur. To increase community and individual resilience to disasters, some initiatives and approaches for greater disaster risk reduction include:

1. Building disaster early warning systems that can provide timely and accurate warnings to the people before the onset of a disaster and help initiate early action.
2. Improving construction regulations and land-use planning to make structures more resilient to extreme weather and climate events.
3. Using the concept of community-based disaster risk reduction (CBDRR) to raise awareness and knowledge about disasters and the unique threats they pose at a grassroots level.

Disaster management cycle

The disaster management cycle is a sequence of actions used by individuals and organisations to prepare for, contain, and reduce the effects of unanticipated disasters. These may include natural disasters, unanticipated property damage, and other occurrences that jeopardise the lives of people. The disaster management cycle aids in mitigating the effects of unforeseen disasters and recovering as many resources as possible once the original crisis has passed. A disaster management cycle also aids persons affected by disasters by facilitating their reconstruction, rebuilding, and recovery.

Six components make up a typical disaster management cycle: prevention, mitigation, and preparedness in the pre-disaster phase; and response, rehabilitation, and recovery in the post-disaster phase. All these components are connected by a legal and institutional framework. Figure 5.8.1 shows the disaster management cycle.

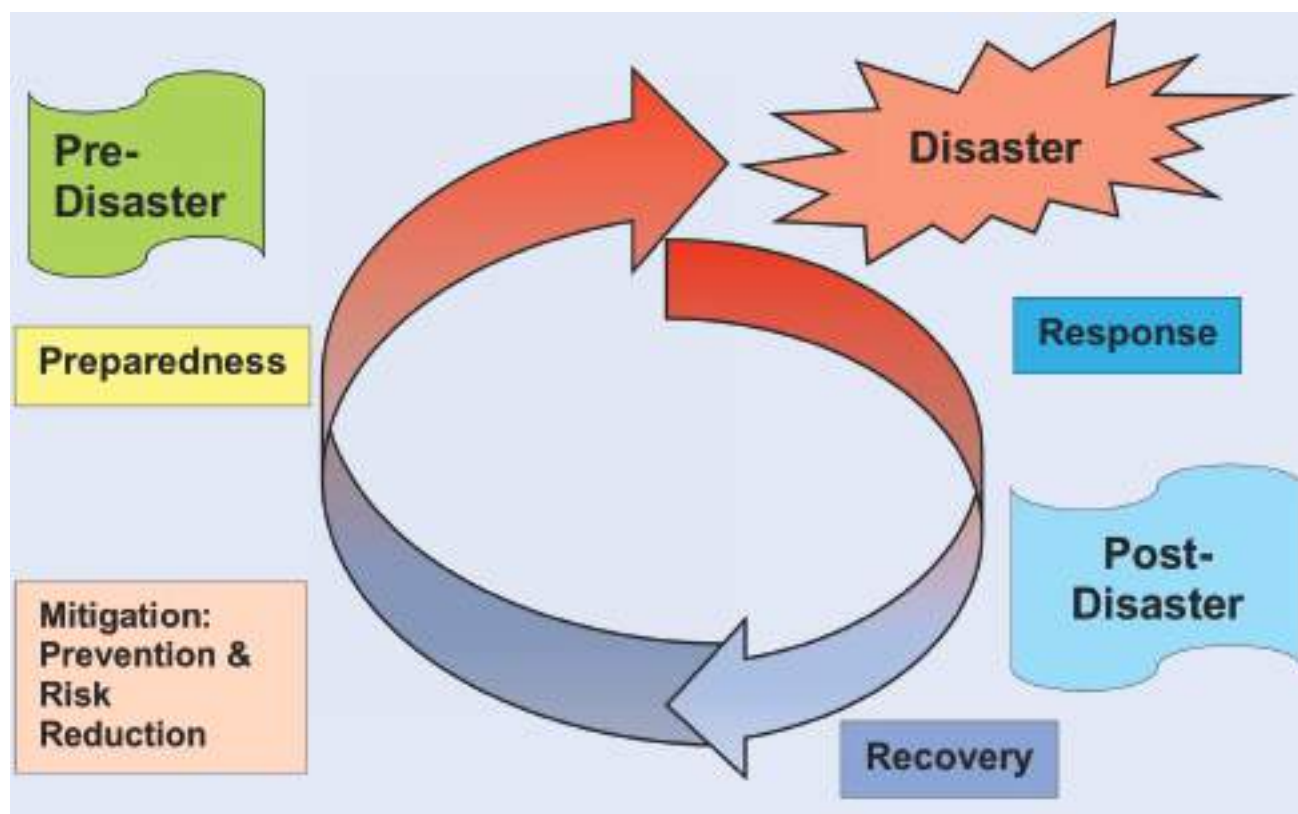
5.8.1 Disaster risks: Indian scenario

India is vulnerable to a wide range of natural and man-made disasters in varying degrees. Approximately 5,700 km of its 7,516 km coastline is vulnerable to cyclones and tsunamis. Around 58.6 per cent of the landmass is susceptible to earthquakes of moderate to very high intensity. Floods and river erosion threaten over 40 million ha (12%) of land, while 68 per cent of the cultivable area is vulnerable to drought. Hilly regions are at risk of landslides and avalanches. Moreover, there is a potential for CBRN (chemical, biological, radiological, and nuclear) catastrophes and crises. Factors such as population growth, urbanisation, industrialisation, expansion in high-risk areas, environmental degradation, and climate change contribute to increased vulnerabilities to disaster risks. The economically and socially marginalised segments of the population, including the elderly, women, children, and people with disabilities, are most severely impacted and vulnerable to disasters.

5.8.2 Disaster profile of Maharashtra

Due to a number of factors, including geography, climatological conditions, population, and anthropocentric

Figure 5.8.1 Disaster management cycle



Source: National Disaster Management Authority 2019

activities such as industrialisation and urbanisation, Maharashtra is particularly vulnerable to both natural and man-made hazards and disasters.

Recently Maharashtra witnessed severe extreme climate events causing huge infrastructural and sectoral losses and damages. The floods of 2019 caused serious disruption in all the developmental spheres across the state. The recent cyclones of Nisarga (2020) and Tauktae (2021) also caused severe damage on the western coast of the state. According to the district administration of Raigad, nearly 140,000 houses were damaged, and approximately 20,000 ha of agricultural land was destroyed due to cyclone Nisarga in June, 2020. About ten districts were impacted in the state due to cyclone Tauktae in 2021.

According to the Joint Rapid Needs Assessment Report, 11 districts of Maharashtra experienced significant localised devastation from the 2021 rains, which began on July 22 and devastated more than 1,035 villages and impacted nearly 1.2 million people, including 4,000 children. Further, in 2022, torrential rains caused floods, building collapses, and mudslides in a majority of Maharashtra's districts.

Apart from natural disasters, Maharashtra is susceptible to anthropogenic disasters, including road accidents, industrial accidents, fires, accidents in quarries and mines, drowning, and explosions. Industrial hazards

predominantly arise from accidents occurring during chemical processing, manufacturing, storage, transport, and disposal of toxic waste. The presence of numerous industries involved in the production, processing, or storage of hazardous goods increases the risk of fires and chemical explosions, especially when located in close proximity to residential and industrial areas.

The districts with a high concentration of major accident hazard units in Maharashtra include Thane, Mumbai, Nashik, Pune, Raigad, and Ratnagiri. Among these districts, Nashik, Mumbai, and Thane divisions experienced the highest number of accidents in industries involved in chemical manufacturing and processing.

Further, the Chembur-Trombay belt is in close proximity to the port activities of the Mumbai Port Trust (MPT), which handles hazardous cargo. MPT deals with 32 identified hazardous chemicals that require frequent handling and storage during loading and unloading operations. The convergence of hazardous industries and port operations increases the potential risks and underscores the need for comprehensive safety measures in the region.

Within Maharashtra, the oil and gas industry is a prominent contributor to industrial hazards. Several industries receive crude oil through underground pipelines. Unfortunately, incidents of underground leakages and fires have occurred in these facilities. Ensuring strict

adherence to safety protocols and proactive monitoring of pipeline integrity is crucial for preventing such incidents in the future (SDMA 2016).

Oil spills pose a significant threat to the marine environment, and Maharashtra, due to its extensive coastline and proximity to busy ports, is particularly vulnerable to such disasters. These spills can occur as a result of ship collisions at sea, loading and unloading operations in tankers at ports, vessel grounding and sinking, pipeline leaks, and blowouts from oil drilling platforms.

Maharashtra is the third-most vulnerable state to extreme hydro-meteorological disasters after Assam and Andhra Pradesh, according to the district-level Climate Vulnerability Index (CVI) published by CEEW in 2021. The CVI report states that more than 75 per cent of districts in Maharashtra are extreme hotspots for hydro-meteorological disasters, viz., cyclones, floods, and droughts. There was also a swapping trend noticed in the occurrence of these extreme events, i.e., the drought-prone areas are now becoming flood-prone areas and vice-versa. The CVI research also shows that since

Table 5.8.1 Major hazards and disasters in Maharashtra

Disaster or hazard	Vulnerability	Major occurrences
Natural disasters		
Earthquake	The west coast and the Western Ghats belt are very vulnerable to seismic movements based on previous earthquakes. Significant seismic activity has been seen in recent years at Ratnagiri along the western coast and in regions of the Palghar district, including Koyna, Nagar, Bhatsa, and Surya.	Koyna earthquake (1967). Latur (1993).
Flood	The majority of the districts, with the exception of a few in northern Maharashtra and Marathwada, are very vulnerable to flooding.	State-wide floods (2005 and 2006). Floods in Vidarbha (2013), Kolhapur/ Sangli regions (2019), Ratnagiri and Raigad districts (2021), and Vidarbha (2022).
Droughts	High-risk areas for drought include sections of Vidarbha, Northern and Western Maharashtra, and the Marathwada region.	Across various parts every year.
Cyclones	The state has been rated as having a moderate cyclone risk. However, over the last several years, Maharashtra has seen a rise in the frequency of cyclones. In the previous five years, the state has experienced four cyclones.	Cyclones Phyan (2009), Kyar (2019), Nisarga (2020) and Tauktae (2021).
Lightning	Lightning strikes in the state cause a lot of fatalities. The state now has declared lightning a State Declared Disaster as a result.	A total of 217 people were killed due to lightning in 2022 (Maharashtra PECOnet, Sphere India and RedR India 2021).
Anthropogenic disasters		
Fire accidents in the state	The State Secretariat (Mantralaya Main Building) blaze occurred on 21 June 2012, resulting in the destruction of three floors, numerous important files, and computers and causing the loss of 5 lives and 20 others injured. The Andheri Corporate Tower Fire took place on 18 July 2014 at the Lotus Business Park Building in Andheri (W), completely destroying the upper two floors. On May 9, 2015, the Kalbadevi fire resulted in the destruction of the five-story Gokul Niwas Bhawan and led to the loss of several firemen's lives (SDMA 2016). Blaze at Tarangan Building, Vartak Nagar, Thane, claimed six firemen while they were on duty on 18 October 2009.	
Health emergencies		
COVID-19	Total confirmed cases till June 2023: 81,69,258 Total deaths: 1,48,552 (Government of India, 2023)	

Source: Authors' compilation

2005, there has been an increase in severe weather occurrences, which are mostly caused by changes in the terrain and landscape. Districts along the western coast are vulnerable to severe weather conditions, such as extreme rainfall events or irregular rainfall patterns. These severe occurrences are becoming more intense due to a number of variables, including the urban heat island effect, land subsidence, and microclimate changes.

5.8.2.1 Disaster management in Maharashtra: Institutional framework

The Disaster Management Act of 2005 serves as the framework for disaster management at the national, state, and local levels in India. State governments play a major role in disaster management under national policy, while the central government establishes policies and guidelines and provides technical, financial, and logistical support. The state and district administrations collaborate with central and state-level agencies to carry out most disaster management activities.

State governments bear primary responsibility for disaster management within their regions. The institutional mechanisms at the central, state, and district levels support effective disaster management. The DM Act 2005 empowers governments to prepare state DM plans, integrate disaster prevention or mitigation measures into state development plans, allocate funds, establish early warning systems, and help the central government and other agencies with disaster management aspects.

State Disaster Management Authority (SDMA)

In 2006, the Maharashtra State Disaster Management Authority was established. The State Disaster Management Authority (SDMA), led by the Chief Minister, formulates disaster management policies and strategies at the state level. It coordinates the implementation of the State Plan, recommends funds for mitigation and preparedness measures, and ensures the integration of prevention, preparedness, and mitigation measures into the developmental plans of various state departments. During emergencies, the Chairperson of the SDMA is authorised to execute its functions, subject to ex post facto approval by the SDMA.

5.8.3 Adaptation strategies and recommendations for disaster management in the state

Climate change and disaster risk reduction do not have a one-size-fits-all answer. Strategies must be customised for the specific hazards and threats that each community faces. However, any robust strategy should have the following three core components:

1. Identifying and mapping the possible risks and related extreme events that affect the regional landscapes and communities.

2. Identifying hazard particular regional vulnerabilities through evaluation of the hazards, vulnerabilities, and risks associated with potential disasters.
3. Expanding the reach of community-based disaster risk reduction through awareness-raising initiatives.

5.8.3.1 Key action point 1: Improve flood hazard mitigation through a Real-Time Flood Decision Support System (RTDSS) for flood early warning and operational management of reservoirs and river basins through developing a real-time data acquisition system (2023–2026)

Description: Due to people residing in flood plains and engaging in economic activities such as building, agriculture, and tourism, accurate and early forecasting of floods is required to warn the affected population, limit flood damages, and preserve lives and property. Due to the requirement of disseminating warnings for operational reservoirs and emergency floodways, an accurate flood forecasting service for the river system has significant relevance. To improve the accuracy of flow forecasts, it is necessary to adopt modern methods and the latest technology.

The Ministry of Earth Sciences (MoES), Government of India, in collaboration with the Disaster Management Department, Municipal Corporation of Greater Mumbai (MCGM), Government of Maharashtra, has developed a state-of-the-art flood warning system for Mumbai called iFLOWS as an excellent example of a toolkit for ground to ground disaster resilience. The government has also taken initiatives for building saltwater embankments throughout the coastal area of the state for coastal flood mitigation.

Need for improved flood hazard mitigation through a Real-Time Flood Decision Support System (RTDSS):

Though iFLOWS is regarded as a state-of-the-art flood system to increase resilience, it is only confined to the Mumbai region. In the context of recent floods and also in the context of a rise in extreme rainfall events in India that are driven by warming temperatures and changes in the monsoon due to climate change, Maharashtra should be prepared for the anticipated risks of these extreme events. According to the comprehensive vulnerability assessment done by the CEEW, more than 19 per cent of Maharashtra's districts are vulnerable to severe floods and related events.

The population in western Maharashtra and the Konkan area are regularly impacted by Maharashtra's multihazard propensity as well as extreme climate events. The 2019 floods, which were followed by unseasonal rains in November 2019, cyclone Nisarg in 2020, cyclone Tauktae in 2021, and most recently, unprecedentedly heavy rains in July 2021, are evidence of this (Maharashtra PECOnet, Sphere India, and RedR India 2021). In light of these facts,

it is vital to have an enhanced flood mitigation system, which might be done by implementing a real-time flood decision support system similar to iFLOWS in all of Maharashtra's river basins. Priority might be given to the Godavari and upper Krishna river basins and reservoirs for the initial project implementation. The details and key activities of the proposed recommendation are given in Table 5.8.3.

5.8.3.2 Key action point 2: Empower risk-informed decision-making for disaster risk reduction

Description: Future disaster scenarios will not mirror those of the past or even those of the present. To develop long-term resilience, communities must comprehend their future risks and possess the means to adapt to their impacts. Currently, the majority of a community's disaster risk is determined by prior disaster activity. This historical data no longer represents future situations due to the changing climate. In this context, SDMA must increase the availability, accessibility, and comprehension of future condition data and numerical modelling. This can be achieved through:

- Risk-informed hazard-specific studies by engaging research organisations such as the Indian Institute of Tropical Meteorology (IITM) and the Indian Institute of Technology Bombay (IITM) with SDMA by offering internship programmes.
- Sub-district level risk assessment should also be carried out in order to establish data tools and public messaging to ensure that highly technical information is communicated in a palatable, understandable, and accessible manner. This will allow people and communities to comprehend technical information better in order to make more informed decisions. Moreover, the state should envision disaster response as a holistic, participatory, and comprehensive process.

5.8.3.3 Key action point 3: Incorporate amateur radio operators (Ham radio) into District Emergency Operations Centres (DEOCs)

Description: Ham radio, commonly known as amateur radio, is the use of the radio frequency spectrum for non-commercial communications, wireless experimentation, self-training, private recreation, radiosport, and emergency communications. The word 'amateur' refers to "a lawfully authorised individual engaged in a radioelectric activity for a purely personal purpose and without a financial motive".

Amateur radio stations serve as a second line of communication in the event that current public or government communication lines cease to function. For instance, during a post and telegraph strike in India in 1960, radio amateurs proved as lifesavers by providing crucial public service by transmitting vital communications.

During the flash floods at Morbi in September 1979, caused by the Machhu dam rupture in Gujarat, over a dozen amateur radio stations in western India operated emergency radio services. They assisted relief agencies, government officials, and disaster victims in Rajkot, Baroda, and Ahmedabad. Additionally, hams provided similar services during cyclonic storms in Saurashtra and multiple instances in Andhra Pradesh, a state prone to cyclonic storms due to meteorological disturbances over the Bay of Bengal. They played crucial roles in search and rescue operations and disaster response activities (Vigyan Prasar 2021). In 2018, ham radio operators rendered a highly remarkable service by establishing contacts and communication during rescue efforts throughout Kerala in the midst of devastating floods and landslides (PTI 2018). In this context, for better communication during emergencies at the grassroots level and to ensure last-mile connectivity, it is important to leverage the services of ham radio operators in the state.

Even though the State Disaster Management Plan of Maharashtra identifies the importance of ham radio operators and suggests leveraging their services, a key gap remains in their institutionalisation during emergencies. The following key actions can be undertaken by the SDMA to institutionalise ham radio operators:

- SDMA should identify and keep a list of ham radio operators and amateur radio clubs or societies in Maharashtra.
- SDMA must ensure that each DEOC has at least one amateur radio operator whose services may be used during emergencies.
- Radio operators should be provided with infrastructure arrangements inside emergency operation centres for smooth functioning during emergencies.
- The State Emergency Operations Centre (SEOC) should provide incentives to these operators during emergency circumstances.

5.8.3.4 Key action point 4: Mainstream NGOs into the DRR process

Description: In order to adopt a multi-disciplinary and multi-sectoral strategy, the shift from a relief-centric approach to a multi-dimensional endeavour including several scientific, engineering, financial, and social processes, mainstreaming the NGOs into the DRR process is inevitable, and the role of NGOs remains crucial in all phases of disaster management. The NGOs aid in sectors such as health, education, water supply and sanitation, housing, and infrastructure. They are also active in many phases of disaster response, such as search and rescue operations, provision of immediate relief, and first aid. The Disaster Management Act, 2005, sections 10 (2) (n), 22 (2) (f), 24 (j), 30 (2) (xiii), 30 (2) (xix), 30 (2) (xxvii), 34 (l), 35 (2) (a), and 38 (2) (a) highlight the importance of NGO collaboration in disaster risk reduction.

The state could take the initiative to formulate an Inter-Agency Group (IAG) at the state and district levels. The IAG would act as a consortium of all NGOs, civil society organisations, and other external stakeholders who are actively involved in disaster risk reduction processes. The participation of the private sector and NGOs in emergency management planning and coordination provides emergency operations centres (EOCs) with vital information regarding the issues faced by these organisations, such as operational timelines, facility locations, building access needs, transportation needs, relocation logistics, security concerns, and recovery priorities. Furthermore, an IAG member could be posted in the DEOCs during the time of emergencies for better coordination and response during emergencies.

The MahaPECONet is also a prominent initiative in Maharashtra, serving as a unified response platform for both disaster and peacetime preparedness. Under its latest version, MahaPECONet 3.0, the platform has adopted a thematic approach, focusing on risk-informed development for vulnerability reduction, disaster preparedness, and mitigation. Its primary goal is to enhance community resilience and facilitate social sector recovery, thereby enabling early restoration and a more robust *Build Back Better* strategy. By operating at both macro and micro levels, MahaPECONet aims to promote holistic development and build a more resilient and prepared Maharashtra and its presence across all districts (Mahapeconet 2021).

Taking all these things into consideration, the state IAG could be established as a Government-NGO (GO-NGO) coordination scheme, providing a platform for all NGOs to contribute to disaster response and community building. This scheme will promote collaboration, information sharing, and partnerships, maximising the impact of NGO interventions. By engaging NGOs in structured and coordinated efforts, the state can leverage their expertise, resources, and networks to address community needs and enhance disaster management capabilities. This will lead to safer and more resilient communities.

5.8.3.5 Key action point 5: Mainstream Civil Defence and Aapda Mitra volunteers into DEOCs

Description: Civil Defense is a volunteer-based emergency response organisation under the Government of Maharashtra. Civil Defense volunteers support frontline emergency services by providing first aid, firefighting, and search and rescue at both local and national emergencies. This will ultimately enhance the response system of SDMA, decrease response time, which is very crucial in the initial response stages, build trust within the community, build awareness, and create a first line of trained respondents. As per the policy of the central government, it has been decided to establish Civil Defence in 14 districts of Maharashtra. And according to the first stage of implementation of the

project, Civil Defence has been established in the districts of Mumbai, Thane, Raigad, Ratnagiri, and Sindhudarg.

The District Disaster Management Authorities (DDMAs) could take proper initiatives and implement specific guidelines to streamline the roles and responsibilities of Civil Defence volunteers in the state. The established body of volunteers under the direct supervision of the District Collector may hold general body meetings at least once every six months for proper monitoring and evaluation.

The NDMA has been implementing the *Aapda Mitra* central sector scheme since May 2016. The scheme focuses on training 6,000 community volunteers, with 200 volunteers per district, in disaster response across 30 most flood-prone districts in 25 states of India.

The primary objective of *Aapda Mitra* is to equip community volunteers with the skills necessary to respond to immediate needs in the aftermath of a disaster, particularly in flood, flash flood, and urban flooding situations. The scheme aims to provide training in lifesaving skills, coordination, assistance, essential equipment, and emergency responder kits to the volunteers.

The key objectives of the scheme include the development and standardisation of national-level training modules, the establishment of an information knowledge management system linked to states and union territories, and the empanelment of training institutions by respective states and union territories.

Thus far, a total of 5,186 community volunteers have been trained across 23 project states. These volunteers have played a vital role in rescuing stranded individuals during various floods and cyclones in Kerala, Kolhapur, Assam, Tripura, Sikkim, and cyclone Fani. They have also made significant contributions during the COVID-19 pandemic, assisting with tasks such as ration distribution, temperature monitoring, home delivery of essential items, logistical support for quarantine and isolation centres, and awareness campaigns.

Based on the positive feedback and recommendations from states and union territories, NDMA plans to expand the scheme nationwide. The goal is to train 100,000 volunteers in 350 highly vulnerable districts prone to floods, cyclones, landslides, and earthquakes. This initiative aims to strengthen community resilience and promote a culture of volunteerism in disaster risk reduction across India.

In Maharashtra, training has been provided to volunteers in 20 districts, with a total of 7,900 volunteers successfully completing the programme under the *Aapda Mitra* scheme. In light of these outcomes, the state could extend the training to cover all districts within the state. Moreover, it is crucial for the training programmes to be tailored to the specific hazard and vulnerability profiles of each district.

To ensure the ongoing effectiveness of the scheme, the state should prioritise the regular refreshing of training on a timely basis. This will help to reinforce the knowledge and skills acquired by the volunteers and keep them well-prepared for potential disaster scenarios. Additionally, there should be a concerted effort to increase the participation of women volunteers in the scheme. Their inclusion will contribute to a more diverse and inclusive response network and better address the specific needs and concerns of women during emergencies.

By implementing these recommendations, Maharashtra can enhance the reach and impact of the *Aapda Mitra* scheme, effectively equipping volunteers across all districts, tailoring training to local vulnerabilities, ensuring regular updates, and promoting gender equality in disaster response efforts.

5.8.3.6 Key action point 6: Undertake regular updation of the state disaster management plan (SDMP)

Description: According to section 23 (1) of the DM Act 2005, there shall be a State Disaster Management Plan (SDMP) for every state. Section 23 (5) also mandates that the SDMP should be reviewed and updated annually.

The current SDMP of Maharashtra was last updated in 2016, and there is an urgent need to review and update the current SDMP for better disaster management in the state. The updating of the SDMPs is always crucial to provide updated information regarding disaster risks and vulnerabilities and also helps in forming contingency planning.

Section 31(1) of the DM Act 2005 also states that every district in the state should have a District Disaster Management Plan (DDMP), which should be reviewed and updated annually.

According to our analysis, out of 36 districts, only 22 DDMPs are available on public platforms (Table 5.8.2), and only 22 of these DDMPs have been updated post-2017.

DDMPs act as the first line of response towards disasters by ensuring a detailed mechanism of disaster preparedness and response is in place. Since DDMPs are essential for the proper execution of disaster risk reduction and management activities, respective DDMPs must initiate the process of revamping their DDMPs according to the national guidelines.

Implementation of sub-district disaster management plans

In addition to the implementation of DDMPs in the district, the DDMPs, in collaboration with local self-governments (LSGs), can facilitate the implementation of Panchayat-level DM plans throughout the state. Given that most of the impacts of disasters are highly local, these localised DDMPs are really important to enable action on the ground and build resilience from the bottom up.

5.8.3.7 Key action point 7: Build capacity at Taluk and Block levels

Capacity building is an integral part of the disaster management process. It strengthens the current institutional mechanism and also enhances the effectiveness of the different stages of disaster management, viz., preparedness, response, relief and rehabilitation, and mitigation. Capacity building also helps to identify the gaps in the system and institutional mechanisms. Though the focus on capacity building has resurfaced with the new vision in disaster management, the efforts towards building capacities at the state, district, and sub-district levels have not been very systematic. Therefore, it is recommended that a systematic, comprehensive, and scientific approach be followed in building the capacity at Taluk and Block levels. The following key actions are suggested for building capacities at a taluk and block level:

1. The SDMA should take initiatives to build and strengthen the capacity of the government officials

Table 5.8.2 Districts with DDMPs on public platforms, which were updated post-2017

S. no.	District	S. no.	District
1	Akola	13	Nagpur
2	Aurangabad	14	Nandurbar
3	Beed	15	Osmanabad
4	Buldhana	16	Palghar
5	Chandrapur	17	Satara
6	Dhule	18	Sindhudurg
7	Gadchiroli	19	Wardha
8	Gondia	20	Washim
9	Hingoli	21	Yavatmal
10	Latur	22	Jalna
11	Mumbai City	23	Kolhapur
12	Mumbai Suburban		

Source: Authors' compilation

and representatives of the local self-governing departments (Panchayati Raj institutions) in the areas of disaster prevention, response, and recovery. This can be achieved through training and expert workshops conducted on a timely basis. The SDMA should ensure the continuity of these training programmes and workshops.

2. The SDMA could involve the support of local NGOs and other external stakeholders to ensure capacity building on various aspects of disaster prevention, response, and mitigation.
3. The SDMA could prioritise training programmes to reinforce the technical skills of government officials for better hazard, vulnerability, capacity and risk analysis (HVCRA). The training should be given to the authorised officials on new software and techniques for HVCRA.
4. The SDMA may take initiatives to equip the disaster management functionaries at taluk and block levels for immediate response to disasters. This could be done by giving more financial powers to Taluk and Block level officials to purchase relevant search and rescue machinery related to disaster response.

5.8.3.8 Key action point 8: Invest in infrastructure development of SDMA in the state

There should be a dedicated website for disaster management under SDMA in the state. The SEOC in Maharashtra should be modernised by adopting real-time monitoring mechanisms within the SEOC for better communication and adaptation strategies, and the SDMA should take initiatives for proper repair and maintenance of the existing infrastructure and equipment in a timely manner.

The SEOC must be equipped with adequate human resources, including subject experts in all the domains related to disaster risk reduction. There should be at least one of the following experts in the SEOC:

- From the field of social work
- Subject expert on coastal process and meteorology
- Urban planner
- Industrial safety expert
- Geologist/geophysicist

This list of experts is non-exhaustive in nature, and the DDMAAs are advised to include more subject experts based on their requirements.

5.8.3.9 Key action point 9: Developing heat action plans to build resilience against heatwaves

One of the direct impacts of climate change is the increase in the frequency, intensity, and duration of heatwaves. As outlined in Chapter 3, summertime temperatures

and heat extremes have been rising rapidly in the state of Maharashtra. Most districts are witnessing a rise in mean daytime temperatures, while districts in Konkan, Pune, Nashik, Jalgaon and Thane besides others are experiencing increases in both daytime and nighttime temperatures. Climate change projections suggest that both daytime and nighttime temperatures will continue to increase linearly across all regions of Maharashtra during the 2030s under both RCP 4.5 and RCP 8.5 scenarios. These projections further indicate a twofold increase in daytime extremes and a fivefold increase in nighttime extremes under both RCP 4.5 and RCP 8.5 scenarios.

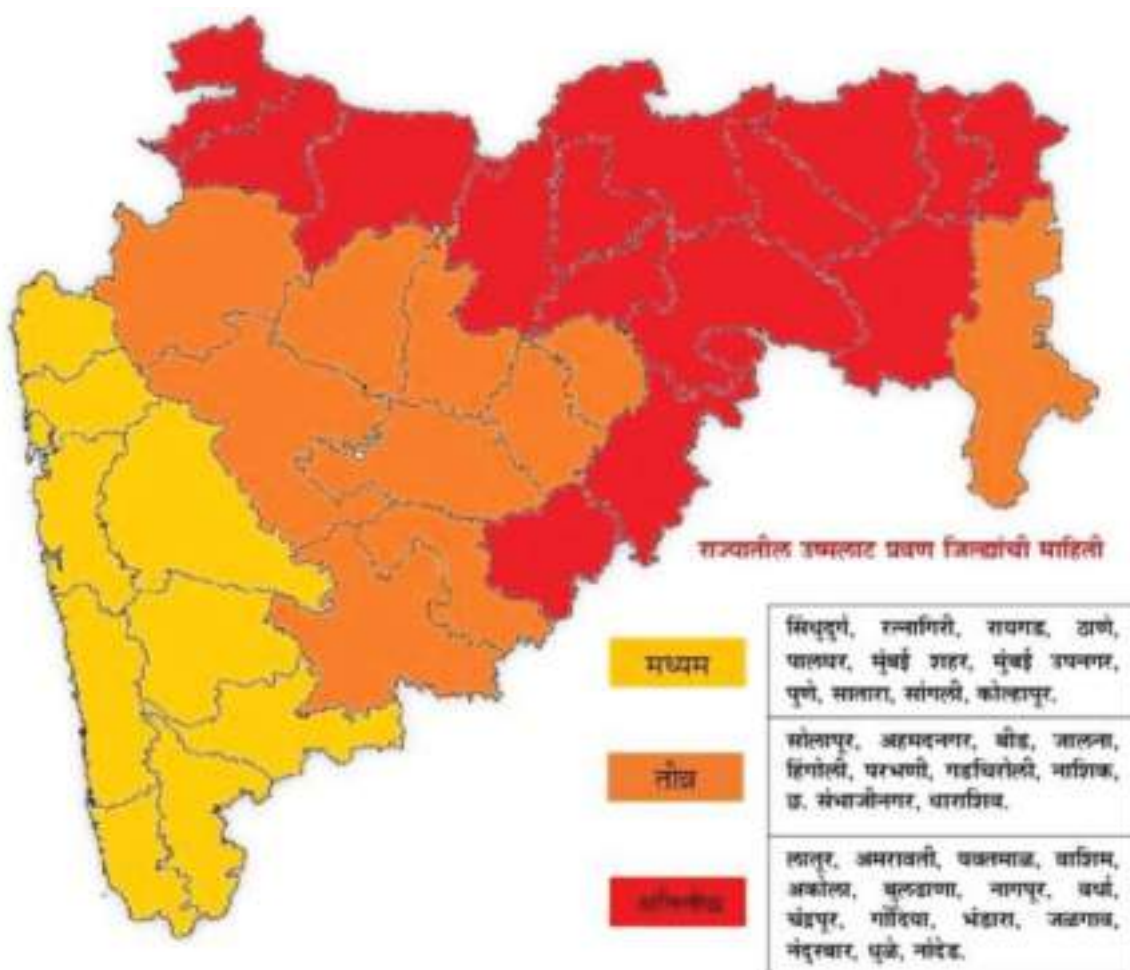
More than 100 crore Indians are exposed to heatwaves in the 23 heatwave-prone states and in just 2024, record breaking heatwaves have been witnessed after IMD had forecasted 20 heatwave days this summer, compared to the normal range of 4-8 heatwave days in the past. The cities of Maharashtra face compounded risks from urban heat islands effect due to rapid urbanisation. Additionally, coastal parts encounter the added challenge of increased humidity, which can raise the felt heat by up to 4-5 degrees Celsius (TMC and CEEW 2024).

To combat these heatwaves, NDMA has developed guidelines for development of heat action plans in 2019, 'National Guidelines for Preparation of Action Plan: Prevention and Management of Heat Wave'. The framework focuses on early warnings, vulnerability and risk mapping, disaster response and mitigation among others. The Maharashtra State Heat Action Plan has been prepared by the Maharashtra SDMA in 2023, based on the common NDMA framework.

As highlighted in the Maharashtra State Heat Action Plan 2023, heat waves are generally observed in 36 districts during March to June, with April and May witnessing severe heat waves. Initially, approximately seven districts in Vidarbha, Marathwada, and Khandesh were considered vulnerable to the influence of heat. However, in the last decade, 15 districts, including Akola, Amravati, Bhandara, Buldhana, Chandrapur, Dhule, Gadchiroli, Gondia, Jalgaon, Latur, Nagpur, Nanded, Yavatmal, Wardha, and Washim, have been identified as heat-prone based on temperature and humidity trends (State Disaster Management Authority, 2023). Recognising heat stress as a 'silent disaster' and classifying it as a disaster in a 'local context' as part of its disaster management plans, Maharashtra has developed twelve district HAPs and three city HAPs as of 2024. This includes the districts of Gondia, Wardha, Jalgaon, Washim, Akola, Nanded, Yawatmal, Nandurbar, Amravati, and Latur and the cities of Nagpur, Chandrapur and Thane.

It is crucial that all the vulnerable districts and cities of Maharashtra prepare their HAPs to combat heatwaves. The HAPs should build upon some of the recent HAP frameworks such as Nagpur and Thane, which focus on mapping heat risks and establishing inter-agency coordination mechanisms for dealing with heatwaves.

Figure 5.8.2 Heatwave-prone districts of Maharashtra



Source: Maharashtra State Heat Action Plan 2023

Adaptation and Mitigation strategies and recommendations for disaster management

Table 5.8.3: Recommendations for disaster management sector

S. no.	Recommendations/Targets	Actions to be undertaken
1	Improved flood hazard mitigation through a Real-Time Flood Decision Support System (RTDSS).	1. Enhance flood forecasting through satellite imagery review (e.g., from IMD, ECMWF, UKMET GeoSFM, GFS, Dartmouth Flood Observatory, TRMM/GPM, MODIS, Radar, and a variety of other products from NASA, NOAA, and ESA). 2. Conduct essential field surveys, pilot the RTDSS, and design a web-based spatial tool, as well as stimulate and maintain the hydraulic model for three years from the date of operation and training. 3. Prepare various reports assisting with procurements, optimising water releases from dams and reservoirs under the control of the Maharashtra Electricity Board and Irrigation Department and utilising them as flood buffers to reduce flood impacts, as well as providing a system to better predict and manage floods, thereby mitigating the effects of floods. 4. Develop a web-GIS-based interactive tool including real-time data updates, data processing, and modelling tools for real-time flow and flood forecasting and coordinated reservoir operation guidance along with a scenario management system, data input/output display system, information dissemination, and report generation tools.
2	Implementation of disaster risk reduction strategies at sub-district levels.	1. Conduct risk-informed hazard vulnerability analysis at the sub-district level. 2. Hire professionals for hazard-specific zonation and mapping.
3	Increased disaster response in the state by 2025.	1. SDMA should identify and keep a list of ham radio operators and amateur radio clubs or societies in Maharashtra. 2. SDMA must ensure that each DEOC has at least one amateur radio operator whose services may be used during emergencies. 3. Radio operators should be provided with infrastructure arrangements inside emergency operation centres for smooth functioning during emergency times. 4. The SEOC must provide incentives to these operators during emergency circumstances. 5. The SDMA should recruit: • One expert from the field of social work who has a postgraduate degree or equivalent in the field of social work. • Subject expert on coastal process and meteorology who has a postgraduate degree or higher qualification and also has proven research experience in coastal process and atmospheric science. • An urban planner, preferably an architect who has a postgraduate degree and experience in planning. • Geologist or geophysicist, preferably a person with good research expertise in geo-hazards.

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
All river basins. Priority should be given to the Godavari and upper Krishna river basins in view of the recent floods.	Department of Water Resources in collaboration with the Irrigation Department, SDMA, and other stakeholders. Integration can be done with the existing scheme; National Mission on Sustainable Habitat.	As a pilot project, setting up of RTDSS, including optimised reservoir operation guidelines, will involve 2 years for the development of the system live demonstration and 3 years for hand-holding support for real-time operation. 1. Data collection, a primary survey of all rivers, dams, and other hydraulic structures, and other required fieldwork: INR 2 crore. 2. Processing and development of high-resolution satellite imagery of 3 m accuracy and field verification, including creating DEMs (Digital Elevation Models)/DTMs (Digital Terrain Models) for the study area: INR 2 crore. 3. Man-month cost for external consultancy (international and national experts), if required, for 2 years for model development and 3 years of hand-holding period: INR 3 crore. 4. Stakeholders meeting and training for all the staff and officials for 5 years: INR 3 crore.	Improved flood hazard preparation and management.
All districts at Taluka level.	SDMA	Financial requirements include: 1. Recruitment of technical staff: INR 25 lakh per person for 2 years. 2. Field staff: INR 7 lakh per person for 2 years. 3. Capacity building and training programmes: INR 45 lakh estimated for 2 years.	Improved decision-making during emergencies.
The service of ham radio operators should be available in all DEOCs.	Department of Disaster Management, SDMA, and Rural Development Department. Integrate with National Mission for Sustainable Habitat and CDRI.	SDMA can provide monetary incentives to the operators during emergencies. The estimated cost will be INR 1000–1500 per day per volunteer during emergencies. For subject matter experts, INR 48 lakh/year is required, assuming a total of 8 subject matter experts at INR 50,000 per month/per expert as salary.	Effective disaster response in the state.

S. no.	Recommendations/Targets	Actions to be undertaken
4	Infrastructure development of the State Emergency Operation Centre (SEOC) and District Emergency Operation Centres (DEOCs).	The SDMA should take initiatives to improve basic infrastructure inside the SEOC in the state. 1. An exclusive website for the Department of Disaster Management should be set up in the state. 2. The SEOC and DEOCs should be modernised by adopting real-time monitoring mechanisms within the SEOC for better communication and adaptation strategies, and the SDMA should also take initiatives for proper repair and maintenance of the existing infrastructure and equipment in a timely manner.
5	Enhance Maharashtra's coastal management	1. Implementation of Coastal Zone Management Plans (CZMPs): Enforce CZMPs in line with the Coastal Regulation Zone (CRZ) Notification of 2019 to ensure sustainable development and conservation of coastal areas. 2. Conservation of Coastal and Marine Resources: Formulate strategies for the preservation and sustainable use of coastal and marine biodiversity, focusing on critical habitats and species. 3. Identification and Management of Ecologically Sensitive Areas (ESAs): Utilise frameworks developed by National Centre for Sustainable Coastal Management (NCSCM) to identify ESAs and implement conservation measures to protect these vulnerable regions. 4. Coastal Hazard Preparedness and Climate Change Adaptation: Develop guidelines for hazard preparedness and evolve climate change adaptation and mitigation strategies, particularly for vulnerable coastal communities. 5. Marine Litter Management: Implement comprehensive strategies to address marine litter, including public awareness campaigns, clean-up drives, and involvement of local businesses to maintain environmental quality along the coast.
6	Building institutional capacity	1. The SDMA should take initiatives to build and strengthen the capacity of the government officials, representatives of the local self-governing departments (Panchayati Raj institutions) in the areas of disaster prevention, response, and recovery. This can be achieved through training and expert workshops conducted on a timely basis. SDMA should ensure the continuity of these training programmes and workshops. 2. The SDMA should prioritise the training programmes to reinforce the technical skills of government officials for better hazard, vulnerability, and risk analysis (HVCRA). The training should be given to the authorised officials on new software and techniques for HVCRA. 3. The SDMA should take initiatives to equip the disaster management functionaries at Taluka levels for immediate response to disasters. This could be done by giving more financial powers to Taluk and Block level officials to purchase relevant search and rescue machinery related to disaster response.

Source: Authors' analysis

The total overall financial outlay needed for implementing the recommendations for the Disaster management is INR 78.4 crore.

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
SEOC and all DEOCs.	SDMA	For the website: INR 50,000–2,50,000 may be allocated as per standard costs.	Effective disaster response in the state.
In all the coastal districts of Maharashtra	DoECC, Mangrove Cell, Maharashtra Coastal Zone Management Authority (MCZMA), Maharashtra Maritime Board (MMB), Disaster Management Cell.	Utilise funds from the ongoing schemes and mandates of Union and State Governments.	Enhanced Coastal Resilience, Disaster Risk Reduction and protection of human and natural resources.
	SDMA Integration can be done with the existing scheme; National Mission on Strategic Knowledge on Climate Change and CDRI.	For software purchase and training, INR 5,00,000 could be allocated.	Mainstreaming disaster response into developmental plans.

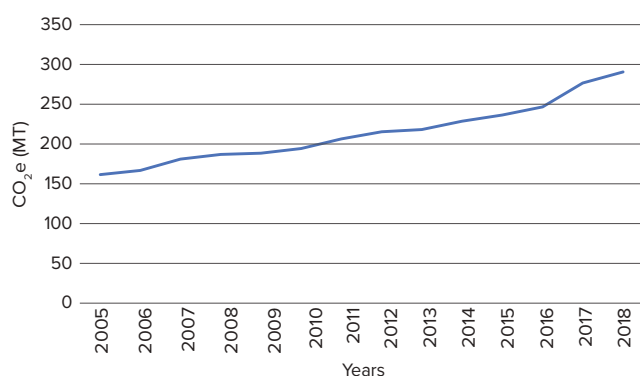
Mitigation

6.1 Introduction and emissions profile

Over the past decades, Maharashtra has witnessed an increasing trend in its urban population, rate of industrialisation, and consequently its per capita income levels. With these rising trends, the state's emissions recorded an 80 per cent increase, from 161 MtCO₂e (carbon dioxide equivalent) to 290 MtCO₂e over the last 15 years, while India's total emissions witnessed a 86 per cent rise and currently are at 2,953 MtCO₂e. Currently, Maharashtra accounts for 9.83 per cent of the country's total emissions (GHGPI, 2018).

Figure 6.1a shows the year-on-year rise in total CO₂ equivalent emissions in Maharashtra between 2005 and 2018. In 2018, per capita GHG emissions in Maharashtra were estimated to be around 2.6 tCO₂e, slightly higher than the national average of 2.4 tCO₂e.

Figure 6.1a Maharashtra's total CO₂ equivalent emissions



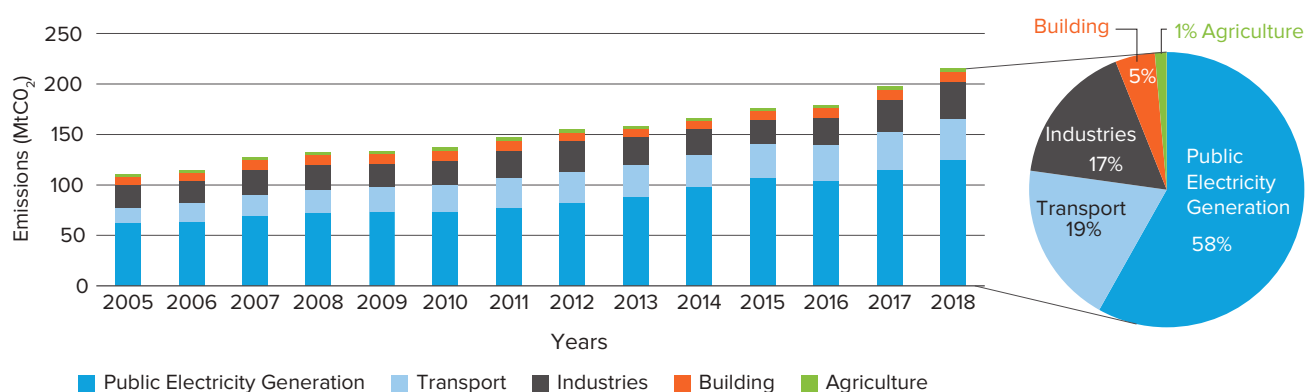
Source: GHGPI, 2018

Emissions from the energy sector account for the largest share (approximately 82.13%) in the state's total GHG emissions, followed by industrial processes and product use (IPPU) with a share of 7.66 per cent, agriculture, forestry, and other land use (AFOLU) with a share of 6.16 per cent, and lastly waste with a share of 4.05 per cent. Additionally, among the sectors, emissions from the IPPU sector witnessed a rapid jump, with a compound annual growth rate (CAGR) of 7.45 per cent between 2005 and 2018, followed by energy (4.46%), waste (1.98%), and AFOLU (1.66%) (GHGPI 2018).

Figure 6.1b depicts CO₂ emissions from various sub-sectors within the energy sector. A rising trend can be observed in emissions from all the sub-sectors due to continuous population growth and subsequent increases in consumer demand across sectors. Electricity generation from public utilities accounts for approximately 58 per cent of total energy emissions in the year 2018, followed by transport (19%), industries (17%), buildings (5%), and the agriculture sector (1%). Between 2005 and 2018, transport sector emissions witnessed the fastest growth rate at 7.16 per cent CAGR, followed by agriculture (5.61%), public electricity generation (5.01%), industries (3.67%), and buildings (0.25%).

While absolute emissions give a broad and general overview of the state's current situation, emissions intensity depicts a relatively more comprehensive view by explaining the level of efficiency in the economic operations of the state. Figure 6.1c depicts the percentage contribution of the top 12 states to the national gross value added (GVA) along with the emission intensity metric across these states in 2018. Maharashtra contributes approximately 15 per cent (highest among all states)

Figure 6.1b Sector-wise energy emissions



Source: GHGPI, 2018

to the national GVA and still has a comparatively lower emissions intensity. As shown in Figure 6.1c, for each unit of addition to the national GVA, the state is adding less to the country's overall emissions. However, given the higher level of absolute emissions and Maharashtra's commitment to its climate policy targets, the state needs to streamline its energy usage across sectors. In 2018, the emission intensity for manufacturing and industries in the state was 0.53 (CO₂ tonnes Eq per lakh INR), i.e., for every lakh added to the state's manufacturing GVA, 0.53 additional tonnes of carbon is emitted.

6.1.1 Power

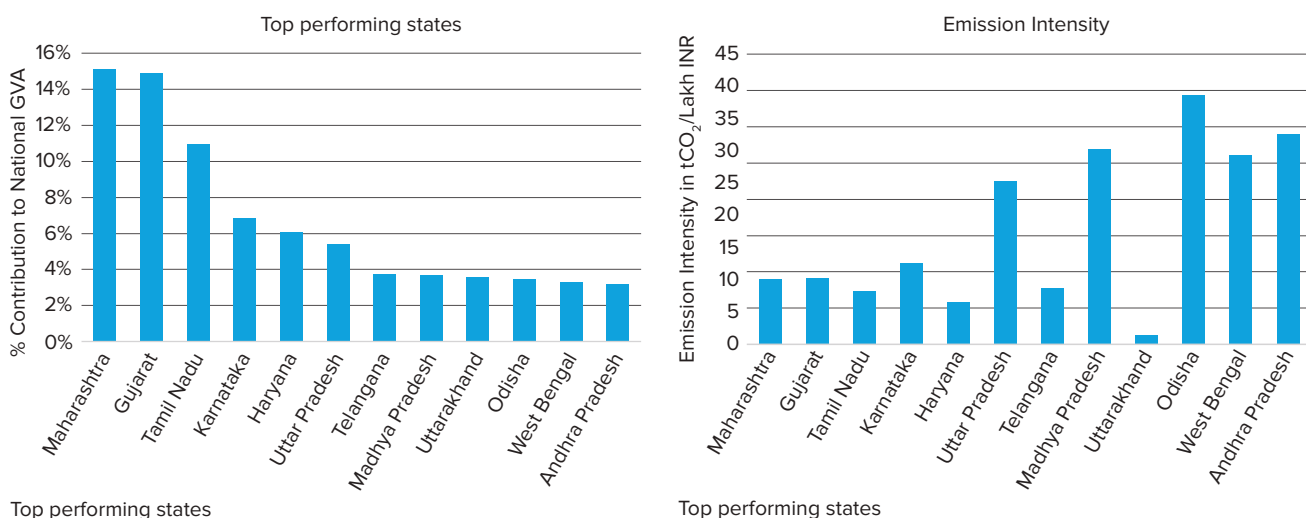
This sector is highly relevant from a mitigation perspective, as electricity generation holds the largest share (58%) in total energy emissions in 2018 (GHGPI 2018). As of November 2022, the installed capacity of electricity generation in Maharashtra was 44.32 GW, the second highest in the country (excluding unallocated capacity in the western grid) (Central Electrical Authority 2022). It is among the top 15 states in terms of energy

consumption, with a per capita electricity consumption of 1,588 kWh in 2021–22 as noted in Figure 6.2a, which is approximately 27 per cent higher than the India average of 1,255 kWh. Maharashtra has succeeded in meeting the rapidly increasing electricity demand over the years by strengthening its power supply position despite having the largest electricity consumer base among all states (Indian Energy Storage Alliance 2020).

While the share of renewable energy has increased considerably in the last few years, the state continues to rely on fossil fuels for its electricity needs. From Figure 6.2b we can see that coal accounts for the largest share – 57 per cent (25.25 GW) of total installed capacity – showing that the state is heavily reliant on fossil fuels to meet its electricity needs.

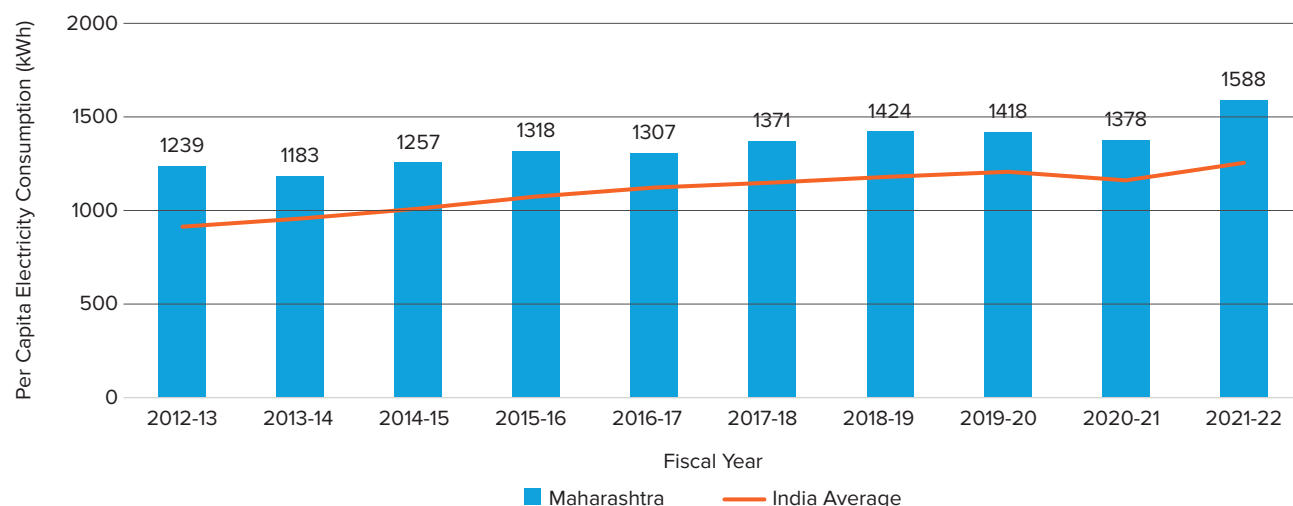
Over the past decade, Maharashtra has been implementing policies and plans to scale up its renewable energy sources, and it is the first state to set up a green energy fund to support the transmission of renewable energy projects. As of November 2022, the state has the fifth highest installed capacity of renewable energy in India, at 11.53 GW, which

Figure 6.1c Emissions intensity, by state



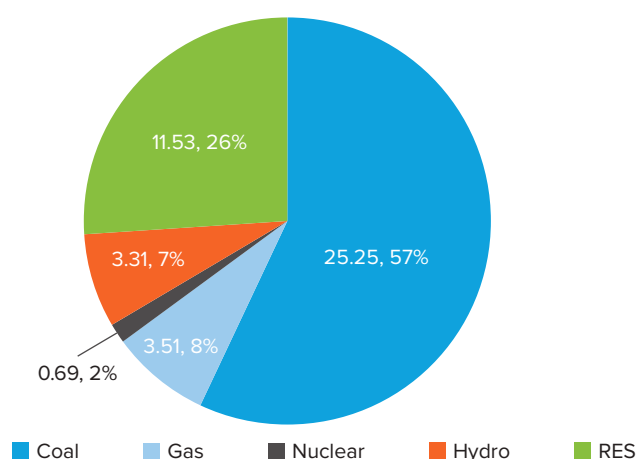
Source: Data on emissions from GHGPI and data on GVA from RBI (2022)

Figure 6.2a Per Capita Electricity Consumption



Source: Central Electricity Authority dashboard

Figure 6.2b Fuel-wise installed capacity (in GW)



Source: Central Electricity Authority, 2022a

includes wind power, solar power, biomass power, and small hydroelectric power (MNRE 2022). Maharashtra also ranks among the top states in terms of renewable purchase obligation (RPO) compliance, and according to MEDA, the state has met the majority of its RPO targets in the past decade (MEDA 2021).

6.1.2 Transportation

The transport sector accounts for 19 per cent of total energy emissions in Maharashtra (GHGPI 2018), with contributions from the road, rail, aviation, and shipping sectors. Maharashtra has the highest motor vehicle population (35.39 million, which is 12 per cent of the national aggregate) (MoRTH, 2018–19). In order to decarbonise its vehicle fleet, the state needs to aggressively shift towards cleaner fuels, including electricity and hydrogen, and it is already making steady progress in this direction.

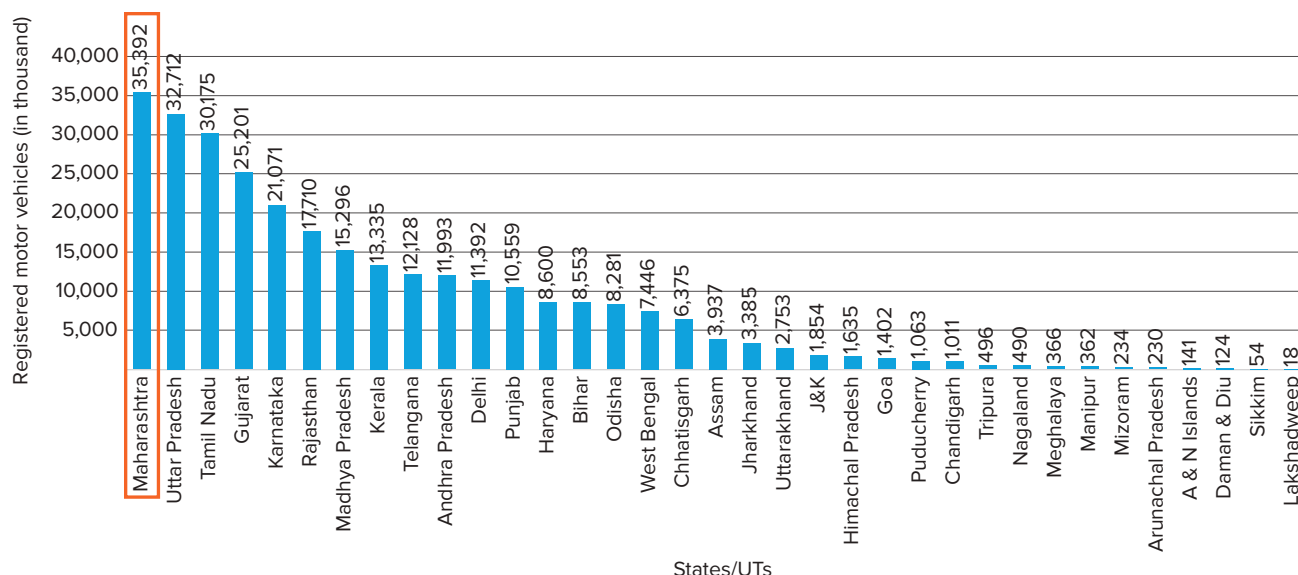
In 2022, Maharashtra sold a total of 1,36,036 electric vehicle EVs, accounting for 13.27 per cent of the total

EV sales in India. EV penetration in the state in the 2W (two wheelers) market increased from 3.75 per cent in January 2022 to 9.58 per cent in December 2022. During the same period, the electric 4W (four wheelers) market also witnessed a rise in EV penetration from 0.56 per cent to 1.55 per cent. However, the electric 3W passenger segment had the highest penetration of 17.88 per cent in December 2022 (compared to 9.24 per cent in January 2022) (MoRTH 2022). Further, in terms of energy demand, EVs are more efficient than standard internal combustion engine (ICE) vehicles. Therefore, while the demand for personal vehicles will rise in the future owing to the increase in income and population, the rise in energy demand will not be proportional, but lower, as EV penetration increases.

To sustain the increase in electric vehicles, Maharashtra will need to have a reliable and well-connected electric charging infrastructure. The total road length maintained by the Public Works Department (PWD) and *Zilla Parishad* (ZP) at the end of March 2021 was 0.3 million (3.21 lakh) km (excluding the road length maintained by other agencies). The state needs to ensure that the entire road network is well connected and has a reliable EV charging infrastructure in order to induce faster adoption of electric vehicles (Economic Survey of Maharashtra 2021–22).

The suburban railway is the major mode of public transport in Mumbai and carries more than 7.5 million passengers daily, making it the world's busiest suburban railway network. Two zonal railways – namely, the Western Railway (WR) and Central Railway (CR) – operate the Mumbai suburban railway system. During the year 2020–21, an everyday fleet of 228 local trains was utilised to run 3,037 train services, carrying an average of 14.2 lakh passengers (Economic Survey of Maharashtra 2021–22).

Figure 6.3a State/UT wise distribution of registered motor vehicles (in thousand) as on 31 March 2019



Source: MoRTH, Offices of State Transport Commissioners/UT Administrations.

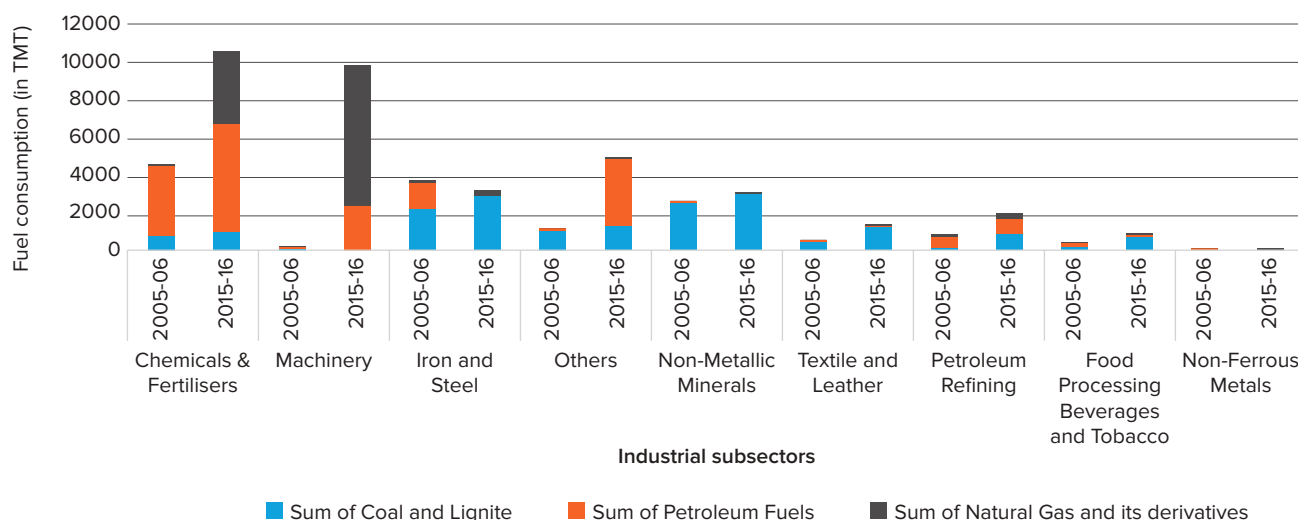
6.1.3 Industry

Maharashtra has maintained a leading position in India's industrial sphere. The state is a pioneer in small-scale industries and has the largest number of special export promotion zones. It also has the third-highest number of factories in the country, accounting for 10.39 per cent of the total number of factories in India, and the second-highest industrial GVA, that is, 14.53 per cent of the national industrial aggregate (Ministry of Statistics and Programme Implementation 2019–20). Well-developed infrastructure, abundant natural resources, connectivity to all major areas, skilled manpower, and quality education make Maharashtra an ideal destination for setting up new industries. The state has also focussed on the development of infrastructure and smart cities. While the ease-of-doing-business score of

the state has improved significantly from 49.43 in 2015 to 92.88 in 2017, its rank has fallen from 8 to 13 in the same period (Reserve Bank of India 2021). Maharashtra also possesses eight per cent of the total number of micro, small and medium enterprises (MSMEs) in the country – the fourth largest (47.78 lakh) among all the Indian states – and employed 90.77 lakh individuals in the period 2015–16 (Ministry of Micro, Small and Medium Enterprises 2021).

Figure 6.3b shows the fuel consumption by various industrial sectors in the state for the financial years ending 2006 and 2016. There is a rise in energy consumption for all other industries, except iron and steel. The largest rise in fuel consumption can be seen in the machinery industry, followed by other industries and chemical and fertiliser industries.

Figure 6.3b Fuel consumption by different industrial sub-sectors



Source: GHGPI, 2018

The industry sector accounts for 17 per cent of total energy emissions (GHGPI 2018). Figure 6.3c shows the CO₂ equivalent emissions across various sub-categories of industries in Maharashtra between 2004–05 and 2015–16. The top three contributors are iron and steel, non-metallic minerals, and petroleum refining. Devising mitigation strategies in these sectors is crucial for the state to meet its climate commitments.

6.1.4 Buildings

The building sector contributes five per cent to the state's energy emissions (GHGPI 2018). The only direct emissions from building are the cooking emissions. Most households in Maharashtra use clean fuel for cooking. Among the clean fuels, liquified petroleum gas (LPG)/natural gas is the preferred fuel in 78.4 per cent of households (NFHS-5 Maharashtra 2019–21). As per the India Residential Energy Survey (IRES) 2020, Maharashtra has one of the highest number of average LPG refills, amounting to slightly more than eight. The average annual rate across India is 6.7 refills per household (Mani et al. 2021).

Apart from direct emissions from the building sector, the design of the buildings plays a role in reducing energy demand (cooling and lighting demands) during the operation phase. Maharashtra has contributed significantly to the total number of green buildings registered with the Indian Green Building Council. With commitments from states, India's registered green building footprint reached 5.27 billion square feet in 2018, placing India in the top three countries worldwide in terms of the registered green building footprint (IGBC 2018).

6.1.5 Agriculture, forestry, and other land use (AFOLU)

There are two types of AFOLU emissions: CO₂ and non-CO₂. Emissions from the agriculture sector are methane and nitrous oxide, which come under the non-CO₂ emissions category, while the land use sector accounts for CO₂ emissions. The agriculture and land use emission profiles of Maharashtra are discussed below.

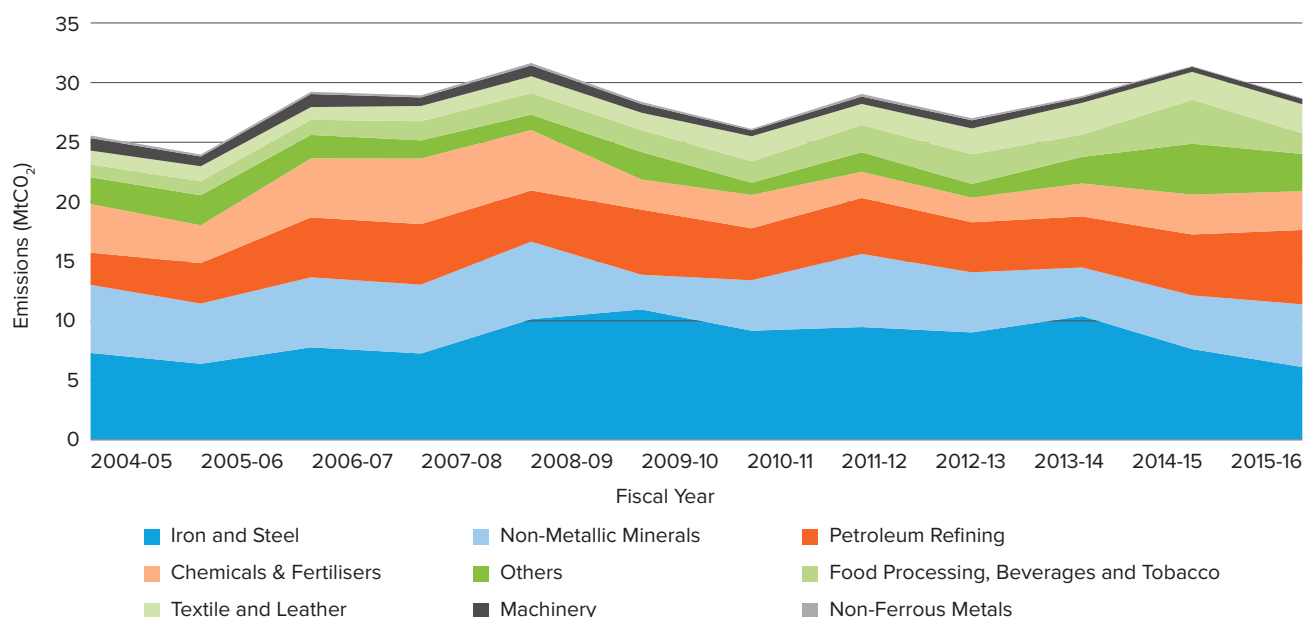
Maharashtra is the fifth largest AFOLU emitter and is the fourth largest agriculture emitter in the country (GHGPI 2018). As a result of certain agricultural practices, GHGs such as methane and nitrous oxide are released and trapped in the atmosphere. These gases have high global warming potentials of 28 and 310, respectively.

The major activities contributing to agricultural emissions are livestock rearing, rice cultivation, crop residue burning, and emissions from the application of fertilisers to the soil.

Livestock emissions come from enteric fermentation and manure management. Ruminant animals have methanogen bacteria in their digestive tract, which produce methane from enteric fermentation and nitrous oxide from manure management. In rice cultivation, agricultural land remains submerged under water for a prolonged period, where the methanogen bacteria act on the substrate/organic matter present in the soil in the anaerobic condition and produce methane gas.

Applying fertilisers to the soil causes direct and indirect nitrous oxide emissions: some of the emissions are released into the atmosphere through nitrification and

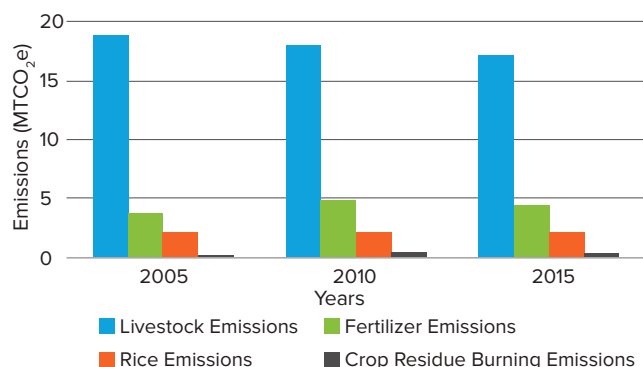
Figure 6.3c CO₂ equivalent emissions across different industries



Source: GHGPI, 2018

denitrification, whereas indirect emissions occur due to volatilisation of the applied fertiliser as it leeches into the soil or due to surface runoff. Crop residue burning also releases some amount of methane and nitrogen dioxide into the atmosphere.

Figure 6.4 Agriculture sector emissions in Maharashtra, 2015



Source: GHGPI, 2018

Agriculture sector emissions for Maharashtra accounted for 23.68 MtCO₂e (million tonnes of CO₂ equivalent) in 2015 (GHGPI 2018). The livestock sector is the major contributor, accounting for 70.4 per cent of the emissions. Livestock emissions have declined between 2010 and 2015 despite an increase in the total livestock population. This is due to the declining bovine population, which has the highest emission factor among all animals. Emissions from fertiliser usage account for approximately 19.8 per cent of the total emissions from the agriculture sector in Maharashtra. Additionally, rice cultivation contributed around 9.4 per cent of the total emissions in the agricultural sector in 2015, whereas crop residue burning accounted for only 1.8 per cent.

6.2 Existing policy analysis

In this section, we analyse the existing policies of the state as well as those of the central government that have a bearing on the state's emission mitigation capacity as noted in Table 6.1.

Table 6.1 SDG and NDC mapping of existing policies

S. no.	Sector	Title of the policy	Centre/State – implementing agency	Launch/ Time period	Nationally Determined Contribution (NDC)	Sustainable Development Goals (SDG)
1	Energy	Maharashtra Renewable Energy Generation Policy	State – Maharashtra State Electricity Distribution Company Limited, Maharashtra Energy Development Agency	2020–25	NDC 2, NDC 3, NDC 4, NDC 8	SDG 7, SDG 11, SDG 13
2	Energy	Mumbai Climate Action Plan	State – Maharashtra Ministry of Environment and Climate Change	2022	NDC 1, NDC 2, NDC 3, NDC 4, NDC 5, NDC 8	SDG 6, SDG 7, SDG 11, SDG 12, SDG 13
3	Energy	Save Energy Programme	State – Maharashtra Energy Development Agency	2011	NDC 1, NDC 2, NDC 3, NDC 4	SDG 7, SDG 11, SDG 12, SDG 13
4	Energy	National Solar Mission	Central – Government of India	2010–22	NDC 2, NDC 3, NDC 4, NDC 8	SDG 7, SDG 11, SDG 13
5	Industry	PAT Scheme	Central – Bureau of Energy Efficiency	2008	NDC 2, NDC 3,	SDG 12, SDG 13
6	Industry	Energy Conservation Policy	State – Maharashtra Energy Development Agency	FY2018 to FY2022	NDC 1, NDC 2, NDC 3, NDC 8,	SDG 7, SDG 12, SDG 13
7	Transport	Maharashtra Electric Vehicle Policy	State – Government of Maharashtra, Environment and Climate Change Department	2021–25	NDC 2, NDC 3, NDC 8,	SDG 11, SDG 13
8	Transport	Mumbai Urban Transport Mission	State – Mumbai Metropolitan Region Development Authority (MMRDA)	2002–24	NDC 2, NDC 3, NDC 7	SDG 11, SDG 13
9	Transport	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) Scheme	Central – Ministry of Heavy Industries and Public Enterprises	2015–24	NDC 2, NDC 3, NDC 8	SDG 9, SDG 11, SDG 13
10	Buildings	Energy Conservation Building Code (ECBC) Scheme	Central – Bureau of Energy Efficiency/Maharashtra Energy Development Agency	2007	NDC 1, NDC 8	SDG 12, SDG 13
11	Buildings	Pradhan Mantri Ujjwala Yojana	Central – Ministry of Petroleum and Natural Gas	2016	NDC 2, NDC 3	SDG 3, SDG 7, SDG 13
12	Buildings	Unnat Jyoti by Affordable LEDs for All (UJALA) Scheme	Central – Ministry of Power	2015	NDC 1, NDC 2, NDC 8	SDG 11, SDG 12, SDG 13

S. no.	Sector	Title of the policy	Centre/State – implementing agency	Launch/ Time period	Nationally Determined Contribution (NDC)	Sustainable Development Goals (SDG)
13	AFOLU	Majhi Vasundhara Abhiyan	State – Environment and Climate Change Department, GoM	2020	NDC 1, NDC 2, NDC 3, NDC 4, NDC 5,	SDG 7, SDG 11, SDG 12, SDG 13
14	AFOLU	Joint Compensation Scheme, Mangrove Cell and Mangrove Foundation	State – Mangrove Cell, Maharashtra Forest Department	2015	NDC 5,	SDG 13, SDG 14,
15	AFOLU	PM KUSUM	Central – Ministry of New and Renewable Energy	2019–26	NDC 2, NDC 4	SDG 12, SDG 13

Source: Authors' compilation

6.2.1 Energy

This section details recent policies introduced by the state government with a broad aim of decarbonising its energy sector and scaling up its renewable energy capacity.

1. Maharashtra Renewable Energy Generation Policy, 2020

The Maharashtra government announced the Renewable Energy Generation Policy in 2020 with the objective of increasing the share of renewable energy in total energy generation. It aims to deploy 17.76 GW of power-generating projects, synthesising renewable energy sources by 2025. Apart from initiating new projects, the policy encourages all existing non-conventional energy projects to enhance their generating capacity. This can be accomplished by installing new capacity in the same source, boosting efficiency, and hybridising with other renewable energy sources.

The overall power generation target of 17.76 GW covers multiple renewable sources – namely, 12,930 MW of solar power projects (including 10 GW of stand-alone projects, 2 GW of grid-connected rooftop solar projects, 530 MW of solar-based water supply projects, and 250 MW of transmission-connected solar generation projects for farmers and others), 2,500 MW of wind energy projects, 1,350 MW of co-generation projects from by-products available from sugar factories and agro-industries, 380 MW of small hydroelectric power projects, and 200 MW of urban solid waste-based projects.

Several decentralised renewable energy undertakings have been outlined to increase the renewable energy share. These include 1,00,000 agricultural solar pumps, 52,000 kW of rooftop solar systems, 2,000 solar water pumps, the electrification of 10,000 rural homes, micro-grid projects for 20 villages, 55,000 square feet of solar hot water plants/cooking systems, and 800 solar cold storages. There are numerous places in Maharashtra that are not linked to the traditional grid system, and for these, decentralisation might be a game changer.

2. Mumbai Climate Action Plan (MCAP), 2022

The MCAP launched by the state government intends to achieve a climate resilient Mumbai by focussing on various mitigation and adaptation strategies. The action plan has established short-, medium-, and long-term climate targets with an overarching net-zero target by 2050. The provisions of the MCAP comprise the following, among others:

- Energy and buildings** aims to decarbonise the electricity grid, induce the transition to comparatively cleaner fuels without compromising on resource efficiency, encourage passive design strategies, and promote low-carbon buildings.
- Sustainable mobility** aims to expand EV penetration by incentivising key players in the mobility market, expanding metro networks, and improving last-mile connectivity. The target for Mumbai is ambitious: the aim is that the city will transition towards 100 per cent zero emission vehicles by 2050.
- Air quality** improvement is proposed to be achieved by reducing the pollution levels by 20 per cent to 30 per cent by 2030 through improved monitoring and forecasting.
- Urban flooding and water resource management** includes optimal use of natural rainwater and freshwater sources while reducing the risk of floods.
- Urban greening and biodiversity** includes planting more trees to increase the vegetation cover by 30 per cent to 40 per cent in 2030 and providing more green spaces to residents while reducing the heat island effect, in turn reducing energy demand for cooling in buildings.
- Sustainable waste management** aspires to reduce waste disposal at landfills by 40 per cent by 2030 and establish a decentralised waste management system.

3. Save Energy Program, 2011

The Maharashtra Energy Development Agency (MEDA) launched the Save Energy Program in order to effectively tackle the problem of excess demand given the supply shortages. The policy mandates energy audits to identify avenues for energy conservation. The scheme includes an energy audit programme, a state EC award programme, and a public awareness programme. It outlines conservation options in different sectors: up to 30 per cent for both agricultural and commercial sectors, 25 per cent in the industrial sector, and 20 per cent in the domestic sector. The primary goal of this initiative is to give qualifying organisations financial support to conduct detailed energy audits at their facilities. The financial assistance provided by MEDA is up to 50 per cent of the cost of the energy audit study, ranging from INR 15,000 to INR 40,000, depending on the sector and category (determined by the annual electrical bill) of the firm (MEDA 2011). A total of 1,851 energy audits were conducted in industries by March 2023 (MEDA).

4. National Solar Mission, 2010

The ambitious National Solar Mission (NSM) initiated by the Government of India in 2010 resulted in an exponential increase in solar installations in India from 25 MW in 2010–11 to about 67.07 GW in April 2023. Maharashtra currently accounts for 4,722 MW of the total solar installed capacity (Ministry of New and Renewable Energy (MNRE) 2023). Various policy measures, including declaration of Renewable Purchase Obligation (RPOs), provision for rooftop solar, guidelines for tariff-based competitive bidding process for solar power and development of green energy corridors, have been undertaken for scaling up the deployment, which has resulted in grid parity for solar tariffs in India (MNRE 2022).

6.2.2 Industry

The following section highlights major policy interventions supported by the state government of Maharashtra in order to systematically enhance the energy efficiency of industries.

1. Perform, Achieve and Trade (PAT) Scheme, 2008

The PAT scheme is the Bureau of Energy Efficiency's (BEE's) flagship initiative within the National Mission for Enhanced Energy Efficiency (NMEEE). NMEEE is one of eight national missions established by the Government of India as part of the National Action Plan on Climate Change (NAPCC) in 2008.

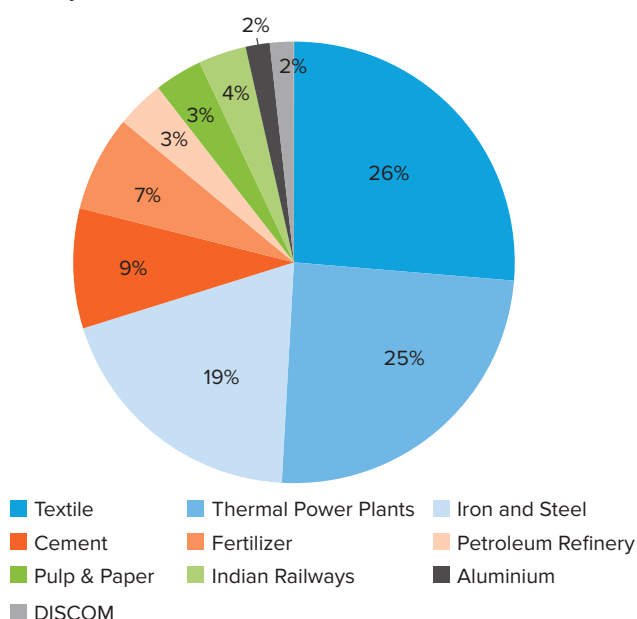
The PAT scheme is undertaken in three-year cycles, with designated consumers (DCs), who are selected on the basis of threshold energy consumption, allocated specific energy consumption (SEC) reduction targets. Industries that surpass their predetermined targets are awarded energy-saving certificates (ESCerts), which can be exchanged on energy exchanges such as the Indian Energy Exchange or the Power Exchange India. The BEE looks after the issuance of ESCerts

following evaluation by third-party verifying agencies on the performance of firms in the assessment year.

The BEE launched six PAT cycles till financial year 2020, with a total of 1,073 DCs across 13 industries. The total energy savings expected by March 2023 is around 26 MTOE (million tonnes of oil equivalent), which corresponds to avoiding emissions of approximately 110 million tonnes of CO₂ (BEE 2021).

In PAT cycle II, a total of 57 DCs participated from Maharashtra. The pie chart in Figure 6.5 shows that the majority of DCs in PAT cycle II from Maharashtra belonged to the textile industry (15), followed by thermal power plants (14) (BEE 2020).

Figure 6.5 Sectoral break-up of DCs from Maharashtra in PAT cycle II



Source: Bureau of Energy Efficiency, 2020

The total energy savings achieved by Maharashtra in PAT cycle II was 1.84 MTOE, the highest among all the states (Bureau of Energy Efficiency 2018–19). Maharashtra (96) has the second highest number of DCs registered till date with PATNET after Gujarat (96) (BEE PATNET).

PAT cycle VII was notified in 2021 to be launched for a period of three years beginning 2022–23, wherein 509 DCs have been notified, with a potential energy savings target of 6.627 MTOE (Ministry of Power 2022).

2. Energy Conservation Policy, 2017

This policy was launched by the Government of Maharashtra for a period of five years till financial year (FY) 2021–22, with a target to achieve energy savings of 1,000 MW in various sectors in the state. It promotes large-scale implementation of energy-saving innovative technologies in commercial, residential, and industrial spheres through obligatory energy audits (Industries, Energy and Labor Department, Government of Maharashtra 2017).

Separate guidelines and measures are specified for different sectors such as commercial and government buildings, municipal corporations, the agricultural sector, electricity distribution, generation and transmission companies, and industries. For the industrial sector, industries exceeding threshold energy demand are required to get an energy audit done and implement the suggestions in the audit report within two years. Financial assistance for the same and special training sessions for technicians will be provided by MEDA. Energy conservation awards are given by MEDA to promote firms who have imbibed practices for efficient utilisation, management, and conservation of energy. The total energy savings through the units participating in the EC award was reported to be 270 MW in FY 2014–15 (MEDA).

6.2.3 Transport

The following section addresses major policy measures supported in the state for efficiently decarbonising its vehicle fleet and incentivising adoption of low-emission intensive modes of mobility.

1. Maharashtra's Electric Vehicle Policy, 2021

The Electric Vehicle policy is a flagship scheme of the Maharashtra government, launched in 2021, with the objective of accelerating the adoption of clean mobility in the state. The policy aims at a 10 per cent share of EVs in the new vehicle registration in the state by 2025. In six metropolis cities, the policy aims to achieve 25 per cent electrification of public transport and freight carriers. It also intends to make Maharashtra the top producer of battery electric vehicles (BEVs) in the country. In order to achieve the above-mentioned targets, the policy offers various incentives.

On the demand side, the policy provides monetary incentives for the earliest EV buyers in the state. Early bird incentives over and above the basic incentives will also be provided, with subsidies and other benefits ranging up to INR 1,00,000. In addition to this, the electric vehicles will also be eligible for extended warranty, buy back, and scrappage incentives. Moreover, there will be no motor vehicle tax for the electric vehicles sold and registered in the state. The government will also encourage financial institutions and banks to provide preferential interest rates to EV customers (Government of Maharashtra 2021).

On the supply side, the government seeks to attract investments in order to foster a strong EV manufacturing and research and development (R&D) ecosystem in the state. Under this policy, all the industries engaged in the manufacture of EVs will be eligible for all the benefits under 'D+' categories (least developed areas) of mega projects. In 2021, the Government of India authorised the production-linked incentive (PLI) plan for advanced chemistry cell (ACC) battery manufacture. Maharashtra aims to set up at least one gigafactory for the manufacture of ACCs by 2023. The state also intends to develop an ecosystem for environmentally friendly car scrapping (including electric vehicles) and plans to prepare a 'State Scrapping Policy'.

As regards the development of charging infrastructure, urban local bodies are entrusted with preparing a charging infrastructure plan for their cities to meet the target demand by 2025. According to this policy, financial incentives will be provided towards the cost of installation of public and semi-public charging stations (PCSs and SPCSs). Urban local authorities will be encouraged to offer property tax breaks to residents who install private charging infrastructure in their premises. New residential buildings will be required to ensure that at least 20 per cent of the total number of parking spaces are EV ready.

2. Mumbai Urban Transport Mission, 2002

Mumbai is the capital of Maharashtra and the financial centre of India. The problem of efficient urban transport infrastructure in the city is a long-standing one. The Mumbai Urban Transport Mission was introduced in 2002 by the Mumbai Metropolitan Region Development Authority (MMRDA), in collaboration with Indian Railways and with financial assistance from the World Bank. It comprised three phases, phase 1, phase 2, and phase 3 launched in 2019 (Mumbai Urban Transport Project 3, AIIB Official document).

The project aims to offer adequate transportation capacity, eliminate transportation bottlenecks between major urban areas, and reduce carbon emissions by facilitating the transition to lower-carbon modes of transportation. It also prioritises investments in urban mobility, paving the way for a more sustainable and resilient city. Finally, it aims to support transport sector initiatives that improve carbon and energy efficiency.

The targets for this project include quadrupling the railway route, allowing for a modal shift from road to suburban rail, leading to a reduction in emissions. Railways use a less carbon-intensive mix of fuels as compared to road transport, which depends on fossil fuels. The net GHG emissions reductions over the project's life are estimated to be an aggregate 1.66 million tonnes of CO₂. The policy also targets the use of solar panels on station buildings and roofs to reduce the stations' reliance on grid-generated electricity for operation and maintenance. A better station roof design that allows rainwater harvesting has also been proposed.

3. Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) Scheme, 2015

As part of the National Electric Mobility Mission Plan (NEMMP) 2020, the Ministry of Heavy Industries introduced phase I of the FAME scheme in 2015 to encourage the manufacturing of electric and hybrid vehicles and ensure faster adoption of the relevant technology. The first phase (2015–19) concentrated on four major domains – namely, demand creation, technology platform, pilot project, and charging infrastructure. The second phase (2019–24) focusses on public transport electrification and shared transportation (Ministry of Heavy Industries & Public Enterprises 2022). The overarching objective of the policy is to minimise automotive emissions and air pollution levels throughout the country.

Under FAME II, 317 charging stations have been sanctioned in Maharashtra, with eight operational in Nagpur (seven) and Navi Mumbai (one) as on 26 July 2022 (Ministry of Heavy Industries 2022).

6.2.4 Buildings

The following section aims to assess policies and programmes that have been introduced in the buildings sector with the objective of streamlining energy usage by commercial and residential establishments in the state.

1. Energy Conservation Building Code (ECBC), 2007

Introduced as a voluntary policy measure in 2007 and notified in 2018, the ECBC was set up with the aim of making the building sector in India more energy efficient. It establishes minimum energy performance criteria for commercial buildings with a connected load of 100 kW or contract demand of 120 kVA, whichever is higher. Buildings consume a sizable percentage of energy resources, and the ECBC is a critical regulatory instrument that aims to reduce their energy footprint (BEE 2017).

2. Pradhan Mantri Ujjwala Yojana (PMUY), 2016

Introduced in 2016, the PMUY offers LPG connections to 8 crore below-poverty-line (BPL) families. The scheme has been launched to promote clean fuel usage and reduce the consumption of traditional biomass in order to decrease indoor pollution, which primarily affects women and children.

In Maharashtra, the percentage share of households with LPG/piped natural gas (PNG) as the primary fuel for cooking has increased from around 60 per cent in 2015 to more than 90 per cent in 2020 (Mani et al. 2021). Further, the per capita consumption of PMUY beneficiaries in Maharashtra has increased from 3.17 refills in 2019–20 to 4.19 refills till February 2022 (Ministry of Petroleum and Natural Gas 2022).

3. Unnat Jyoti by Affordable LEDs for All (UJALA) Scheme, 2015

To encourage energy efficiency in all households, the Indian government launched the UJALA initiative in 2015. Under the scheme, conventional electrical appliances such as fans and lights are replaced with energy-efficient counterparts. The scheme is implemented by Energy Efficiency Services Limited (EESL), which is a joint venture of four public sector units under the aegis of the Ministry of Power. The success of the scheme can be witnessed through the drop in prices of LED bulbs from INR 325 per bulb to INR 75 per bulb (Ministry of Power 2022).

As of 26 December 2022, Maharashtra has installed about 2.2 crore LED bulbs, leading to energy savings of 28,55,330 MWh per year and 23,12,817 tCO₂ reduction per year (Ministry of Power 2022b).

Due to such measures, Maharashtra's performance in the State Energy Efficiency Index (SEEI) has been remarkable.

SEEI employs a comprehensive indicator framework to analyse states' energy efficiency performance. With one of the highest scores, Maharashtra is a top-performing state in energy efficiency initiatives (Ministry of Power 2020).

6.2.5 Agriculture, forestry, and other land use (AFOLU)

This section addresses the schemes and policies introduced by the government of Maharashtra that aim to promote sustainable management of the state's resources along with benefits accruing to the state from certain national policies such as *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan* (PM KUSUM).

1. Majhi Vasundhara Abhiyan, 2020

Majhi Vasundhara Abhiyan is a comprehensive, citizen-centric state-wide initiative led by the Environment and Climate Change Department, Government of Maharashtra. This campaign aims to protect and restore natural ecosystems, raise climate change awareness among urban and rural local self-governing bodies as well as citizens, and encourage individual climate action. It emphasises the "Panchamahabhutas," the five elements of nature: Bhumi (Earth), Vayu (Air), Jal (Water), Agni (Energy), and Akash (Enhancement). The philosophy of the Abhiyan is that climate change is the result of the imbalance that has set in the five elements of nature which must be restored. The campaign aligns directly with SDGs 11 (Sustainable Cities and Communities), 13 (Climate Action) and 15 (Life on Land), and indirectly supports SDGs 6 (Clean Water and Sanitation), 7 (affordable and Clean Energy), and 12 (Responsible Consumption and Production) through various initiatives. The three core pillars of the Majhi Vasundhara Mission are

1. Reducing greenhouse gas emissions,
2. Carbon sequestration through enhancement of carbon sinks, and
3. Promoting the 5 Rs of a sustainable lifestyle: Reduce, Refuse, Reuse, Recycle, and Recover (which aligns with the Government of India's Mission LIFE).

The initiative, which began on Gandhi Jayanti in 2020, is designed as a competitive activity wherein local self-governing bodies participate by implementing various environmental initiatives, which are evaluated at the end of the year. This approach incentivises exceptional performers and grassroots leaders with suitable awards, creating a multiplier effect for broader impact. The initiative encourages active participation from all individuals, regardless of gender or social group. In its inaugural year, the initiative saw participation from 683 local bodies with a combined population of 61.18 million, encompassing 88% rural and 11% urban populations. By the third year, the initiative had expanded to over 16,000 local bodies, and in the fourth year, it extended to more than 22,500 local bodies. Both urban and rural local bodies are assessed based on customised indicators suited to their

local context, ensuring equity and uniformity throughout the campaign. The work done by local self-governments in each thematic area is evaluated through a two-phase third-party assessment process, desktop assessment followed by field assessment.

Based on this evaluation, awards are given in five categories: AMRUT cities, Nagar Parishads, Nagar Panchayats, Gram Panchayats (with populations over 10,000), and Gram Panchayats (with populations under 10,000). Additionally, awards are presented to the Best Divisional Commissioner, Best Collector, and Best Chief Executive Officer of Zilla Parishad, based on the overall performance of their respective Revenue Divisions and Districts. Furthermore, local bodies are also recognised for their outstanding performance in the Bhumi thematic area, which has the highest potential for carbon sequestration.

The four cycles of Majhi Vasundhara Abhiyan have resulted in an increase in:

- Green cover across the state through planting trees of native species and the creation of green spaces,
- Water conservation potential through rejuvenation of water bodies and creation of rainwater harvesting structures
- Registration of EVs, both in private as well as public transport
- Installed capacity of solar energy by means of rooftop solar harvesting
- Funding leveraged through collaboration and alternative channels

The competitive spirit of the campaign has sparked enthusiasm among local self-governing bodies, government officials and citizens, encouraging active participation in grass root climate and environmental action, leading to beautifying their towns and cities, making eco-friendly decisions, and enhancing sanitation and quality of life for the communities. The Abiyan is fast turning in to peoples' movement towards combating climate change.

2. Joint compensation Scheme, Mangrove Cell, and Mangrove Foundation, 2015

This scheme is a joint effort by the Mangrove Cell and the fisheries department of the state. The mangrove ecosystem plays an instrumental role in carbon sequestration. Mangrove forests play a crucial role in creating a carbon sink due to their high sequestration potential, and the government of Maharashtra has made considerable progress in the conservation of mangrove forests over the past decade (Mangrove Foundation, 2020–21).

3. Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM KUSUM) Scheme, 2019

The scheme aims to install 30,800 MW of solar capacity by 2022, with a total central financial support of INR 34,422

crore (Ministry of New and Renewable Energy 2022). The scheme involves setting up 10,000 MW of small solar power plants, installing 20 lakh solar water pumps, and replacing 15 lakh diesel pumps with electric and solar pumps.

The Maharashtra Electricity Regulatory Commission (MERC) has authorised the Maharashtra State Electricity Distribution Company Limited's (MSEDCL's) purchase of 12.5 MW of solar electricity under the KUSUM programme (Mercom India 2022). Since the launch of PM-KUSUM up to 31 October 2022, it is estimated that a total of 21,499 farmers in Maharashtra have benefitted from the scheme.

6.3 Modelling scenario

The scenario analysis undertaken in the following segment allows us to understand the business-as-usual (BAU) projections for energy demand and subsequent emissions in the end-use demand segments for building, industry, and transport as well as the supply sector that looks after the power generation in the state. The growing stature of the state is bound to have implications on the sustainability goals, and charting out low-carbon development pathways is the need of the hour. In the following sections, we display the BAU projections on the basis of current policy trends and the economic growth trajectory.

6.3.1 Modelling framework – Global Change Analysis Model (GCAM)

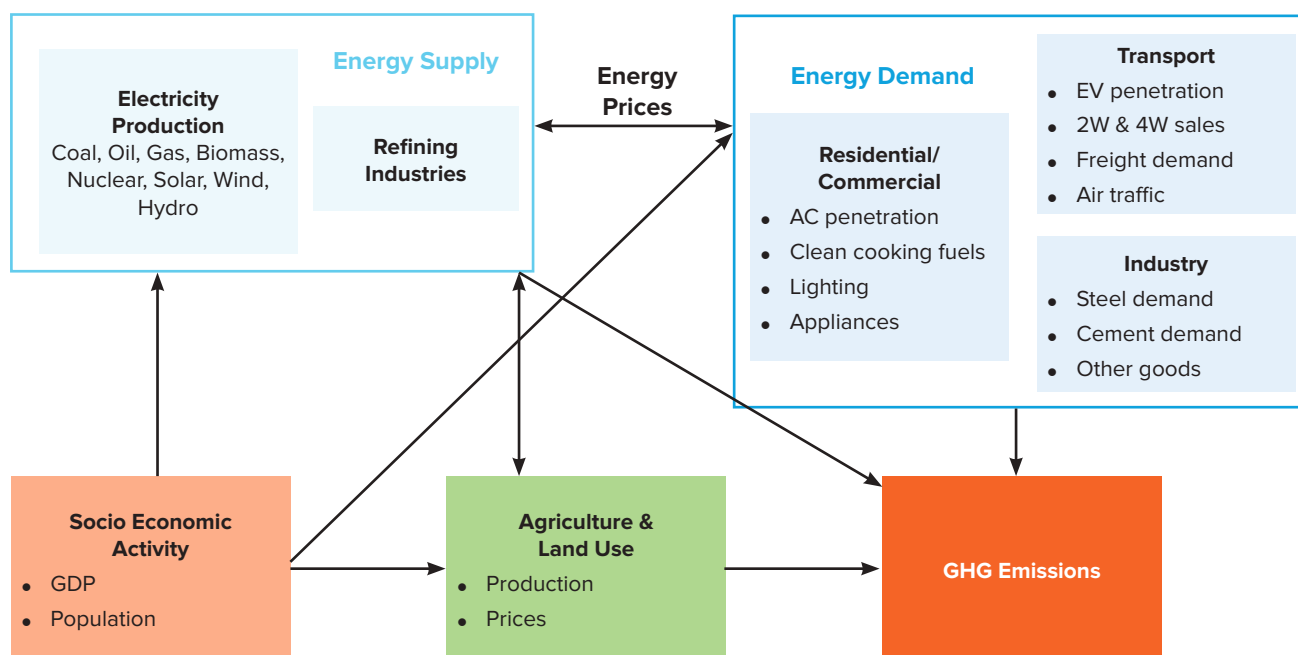
For this analysis, we use the GCAM, which is an energy sector-focussed model used extensively for energy and climate policy analysis. The GCAM represents the behaviour of and interactions between energy systems, water, agriculture and land use, the economy, and the climate. The GCAM is housed at the Joint Global Change Research Institute (JGCRI), USA, and models 32 regions of the world, with India as a separate region. The GCAM-IIM version was set up at IIM Ahmedabad during 2007–09 and since then has been used extensively for India-specific analyses.

GCAM-India is an updated version of GCAM-IIM. It has a detailed representation of the building and transportation sectors and an aggregate representation of the industrial sector for demand sectors; it also has a detailed representation of the electricity supply and refining sectors on the supply side. GCAM-India has been developed in collaboration with the Centre for Global Sustainability (CGS), University of Maryland (UMD), USA. The model has a detailed representation of the energy system of all the Indian states and union territories (UTs). For each state, the energy demand has been modelled for the following:

- Household/Buildings sector (urban and rural)
- Transport sector (passenger and freight)
- Industrial sector (aggregate)
- Agricultural sector

Energy demand from these sectors is serviced by the energy supply sector, which includes the power generation

Figure 6.6 Schematic representation of the Global Change Analysis Model (GCAM)



Source: Authors' adaption from Joint Global Change Research Institute (JCRI)

sector that is modelled in detail within the GCAM. Figure 6.6 depicts the interaction between energy demand and supply and how it is modelled within the GCAM.

The key drivers of future sectoral energy demands are economic and population growth, urbanisation rate, consumer behaviour, technology costs and energy prices, and government policies. The model can explore various scenarios like the implications of high or low economic growth and urbanisation rates, high or low solar/wind electricity generation cost trajectories, high or low adoption rates of electric vehicles, and high or low rates of efficiency improvements, among others. The model can explore alternative deep decarbonisation policies and availability of breakthrough technologies such as hydrogen and carbon capture and storage (CCS).

For this analysis, we present the modelling results from the BAU scenario. It is important to note that this scenario includes an inherently defined improvement in energy efficiencies and reduction in costs of technologies, while the policy scenario includes policy recommendations and their implications for energy demand and emissions. Data for current energy consumption across sectors are based on government sources. For assumptions regarding future consumption, we make use of the market trends.

Some of the characteristics of the GCAM are listed below:

- GCAM does not try to predict the future. It tries to simulate how the energy system could evolve under a set of assumptions on emissions limits, available technologies, efficiency growth, and energy costs.
- GCAM seeks pathways that minimise economic costs.

To sum up, modelling exercises are not intended to predict the future. However, they can offer insights into key factors and potential policy directions that could enable positive outcomes and mitigate risks.

6.3.2 Data sources

Sources for historical data and future projections across socio-economic, energy-producing, and consuming sectors are given below.

6.3.2a Socio-economic data

1. Population and urbanisation projections for states are based on Census of India projections until 2036. Beyond that, we have assumed similar growth trajectories, so that the national numbers are aligned with United Nations (UN) population projections (Ministry of Home Affairs 2011).
2. The projection for the gross domestic product (GDP) is based on the theory of conditional economic convergence, meaning that less-developed states will grow faster than the more-developed ones and converge at similar levels of income. National GDP projections are aligned with NITI Aayog projections.

6.3.2b Energy data

The first step to estimating emissions is to gather the historical sectoral fuel consumption data for all fossil fuels, including coal, oil products and gas, in the particular state/region for a given year.

1. **Coal:** Data could be obtained from the Coal Directory, Ministry of Coal, Government of India.

2. **Refined liquids:** These include petrol, diesel, kerosene, LPG, aviation turbine fuel (ATF), light diesel oil (LDO), and furnace oil. Data for consumption of refined liquids were obtained from the Ministry of Petroleum and Natural Gas (MoPNG), Government of India.
3. **Gas:** Includes PNG and compressed natural gas (CNG). Data on gas consumption were obtained from GHGPI.
4. **Electricity:** Generation data was taken from the Economic Survey of Maharashtra. Consumption data for all demand sectors were from the Economic Survey of Maharashtra and CEA Dashboard.

6.3.2c Other technological data

1. **Building sector:** Ownership of appliances from India Human Development Survey (IHDS) and National Survey Sample Office (NSSO) for estimation of service-wise demand in urban, rural, and commercial buildings.
2. **Transport sector:** Zone-wise route kilometres from Ministry of Railways, vehicle registration data from MoRTH, fuel consumption data from the GHGPI.
3. **Industry sector:** Annual Survey of Industries (ASI) data.
4. **Costs for the future:** Vehicles and technology costs in the building sector from market surveys.
5. **Technology efficiency in the future:** For building appliances, vehicles, and so on from literature and market surveys.

6.3.3 Key assumptions for future projections

The population for historic years and projections till 2035 are based on census data. Beyond 2035, state-level projections are based on estimations that are aligned with population projections by the UN at the national level. For Maharashtra, the population between 2020 and 2030 will grow 1.07 times and by an aggregate 1.20 times between 2020 and 2070. Maharashtra will be the third most populated state in 2070. Figure 6.7 shows the projected population across major states between 2010 and 2070.

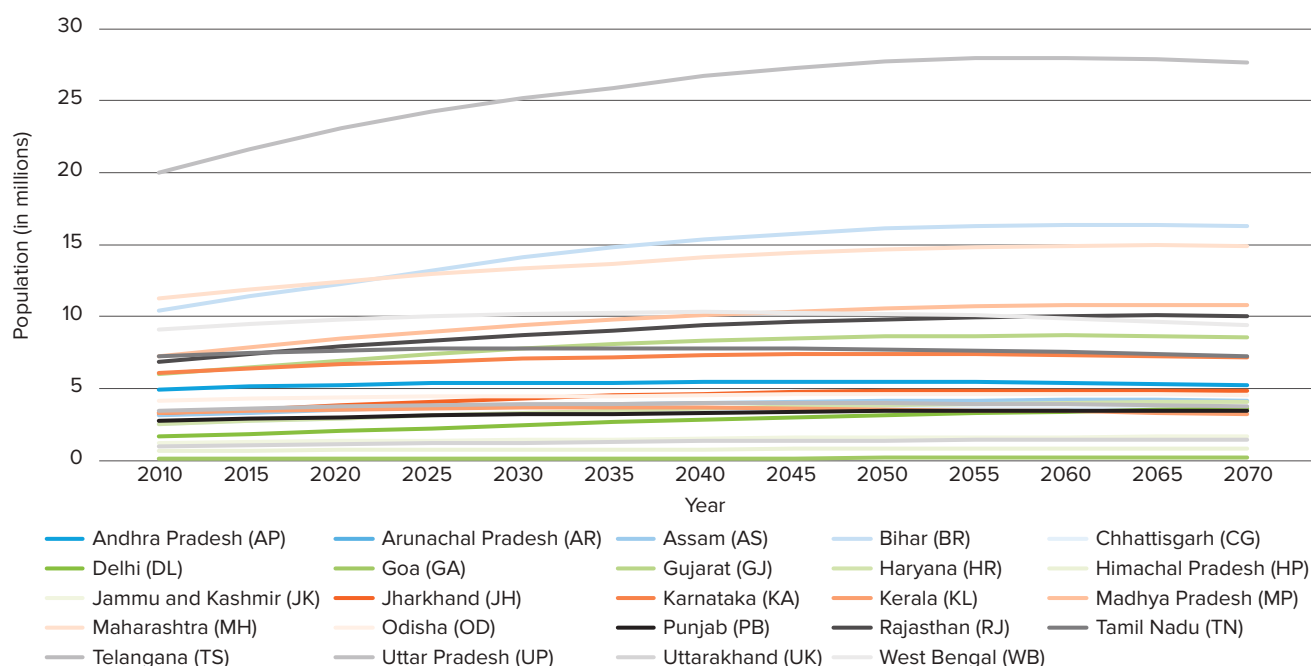
Table 6.2 shows the GDP growth in five-year time stamps for Maharashtra and India. The GDP for historical years is from the Ministry of Statistics and Programme Implementation (MOSPI), and future GDP projections are aligned with NITI Aayog's projected growth rates for the overall Indian GDP, further based on the principle of conditional economic convergence. Maharashtra has one of the highest growth rates in the Indian economy and makes a sizable contribution to the country's GDP. As we can see, the fact that it is developed makes it lag behind India's CAGR till 2030–35. Nonetheless, in the long run, Maharashtra's CAGR will coincide with India's CAGR.

Table 6.2 GDP projections for Maharashtra and India

	2015–20	2020–25	2025–30	2030–35	2035–40
Maharashtra	2.7%	8.0%	7.5%	6.8%	6.5%
India	2.8%	8.1%	7.6%	7.0%	6.5%

Source: Authors' compilation

Figure 6.7 Population projections based on Census and United Nations (UN) projections



Source: Authors' analysis

Maharashtra has one of the highest urbanisation rates in the country, ranking third after Tamil Nadu and Kerala currently. The urbanisation rate, as per the 2011 census, is 45.2 per cent and is estimated to rise to 50.7 per cent in 2030 and 74.0 per cent in 2070. This rate is indicative of high incomes in an economy, and the high GDP growth corroborates the rising urbanisation rate.

6.3.4 Sector-wise long-term energy modelling results: BAU

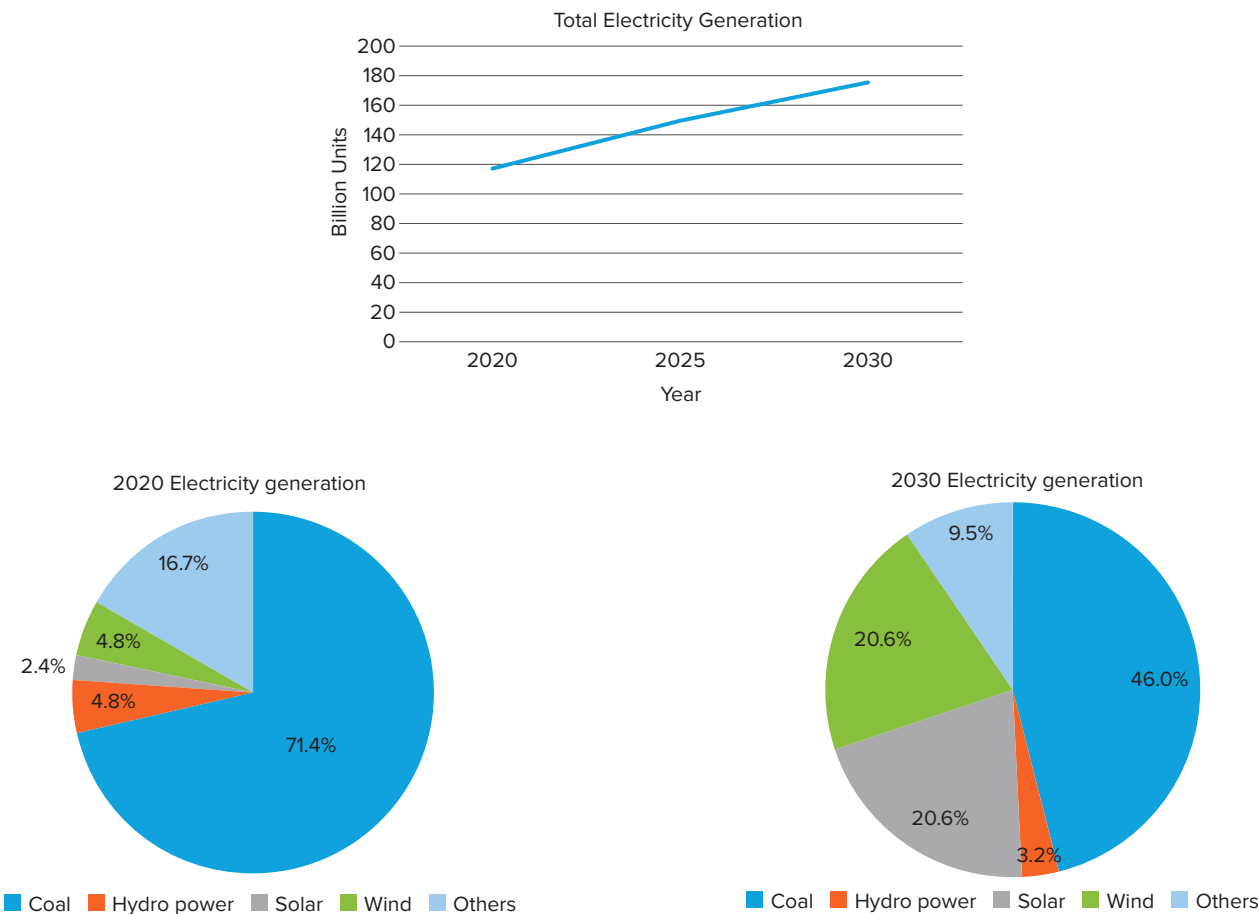
This section showcases key results from the long-term energy modelling exercise for the BAU scenario. At the outset, we would like to clarify that as specified by the Intergovernmental Panel on Climate Change (IPCC), emissions can be categorised into four broad areas – namely, energy, waste, IPPU, and AFOLU. As mentioned in Section 6.1, waste (4.09%) and IPPU (7.66%) constitute a minor share in the overall emissions profile of the state. Therefore, our analysis focuses on energy and AFOLU emissions only.

6.3.4a Power

Electricity generation in Maharashtra will grow by 1.49 times by the end of this decade. Figure 6.8a shows the growth of electricity generation till 2030. The current electricity generation mix in the power sector is dominated by fossil fuels, especially coal, which accounts for almost 74 per cent of the total. Renewable energy, that is solar, hydroelectric power, and wind, accounts for 11 per cent of the total share. With the current growth rate and decreasing costs of solar, the share of coal generation is expected to reduce to 54 per cent in 2030, with the share of renewable energy rising to 35 per cent.

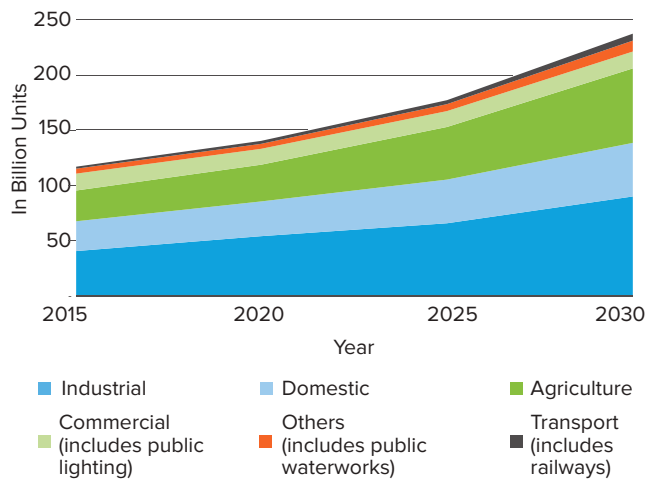
Figure 6.8b shows the total electricity consumption across different demand sectors – namely, buildings in the domestic and commercial sectors, agriculture, industry, transport, and other sectors. At 38.34 per cent, the industry sector accounts for the largest share in 2020, followed by buildings (32.08%). The total electricity consumption will rise by almost 70 per cent by 2030.

Figure 6.8a Total electricity generation and generation mix: 2020 vs 2030



Source: Authors' analysis

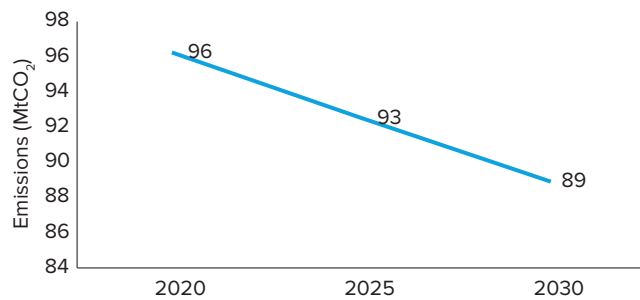
Figure 6.8b Electricity consumption, by sector



Source: Authors' analysis

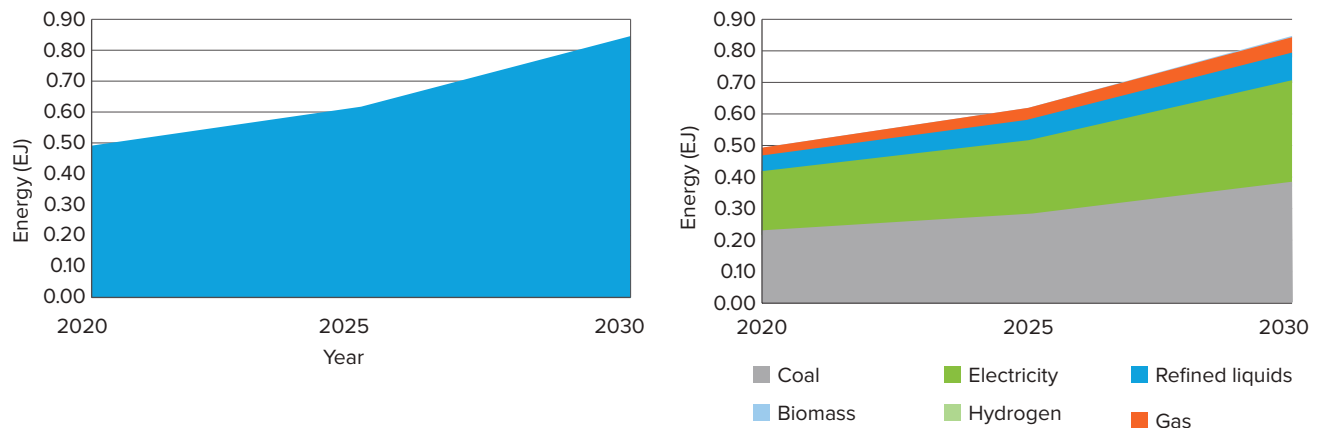
Power generation emissions are primarily attributed to thermal plants (coal). Our results indicate that the power generation emissions will fall due to the increasing share of solar and wind power in the electricity sector and also because no new thermal power plants are set to come up in the near future in the state.

Figure 6.8c Power generation emissions



Source: Authors' analysis

Figure 6.8d Cumulative energy demand and energy demand by fuel



Source: Authors' analysis

Demand-side sub-sectors

This section assesses the long-term trends in energy demand across key end-use sectors, namely, transport, industry, buildings, and agriculture under the BAU scenario. With rising population and urbanisation, energy demand continues to rise across all the sectors.

6.3.4b Industry

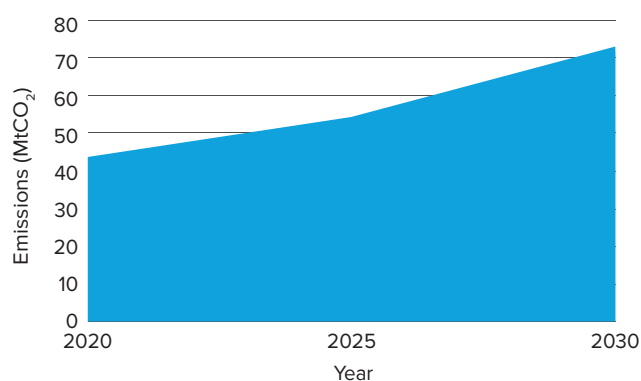
The leading industries within Maharashtra in terms of energy demand are iron and steel, with a 36 per cent share in total energy demand, followed by other industries (26 per cent) and cement (22 per cent). These hard-to-abate sectors have high emissions intensities. The energy demand by the industry sector is expected to rise by 1.7 times between 2020 and 2030.

Regarding the share of different fuels in the total energy demand in 2020, coal (46%) and electricity (38%) have the highest shares, followed by other fuels. Biomass and hydrogen have negligible shares. Total emissions will also rise by 1.7 times between 2020 and 2030, from about 43.66 million tonnes CO₂ (MtCO₂) to 72.96 MtCO₂ in 2030.

6.3.4c Buildings

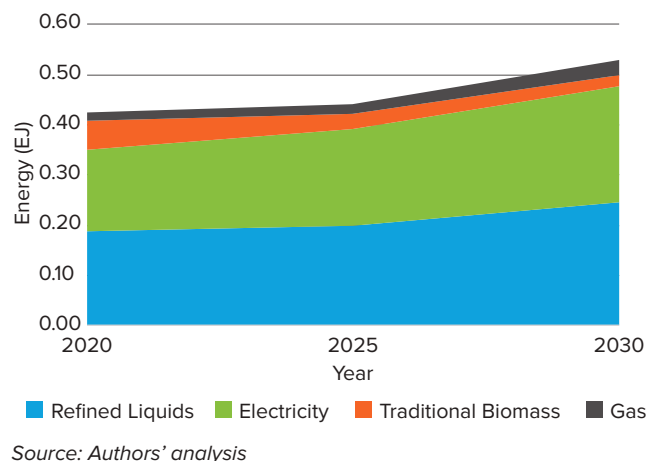
The total service demand in the building sector will grow by 1.61 times by the end of this decade. Demand in this sector is driven by the residential and commercial sectors. The total service demand in the commercial and residential sectors will grow by 1.82 and 1.12 times, respectively, by the end of this decade. Figure 6.8f shows that the energy consumption in the building sector will rise by 1.37 times, from 0.42 EJ in 2020 to 0.53 EJ in 2030. Refined liquids and electricity jointly account for over 80 per cent of the total energy consumption. This is because of the heavy reliance on LPG for cooking and on electricity for other services such as cooling, lighting, and operating other appliances.

Figure 6.8e Industry emissions by fuel



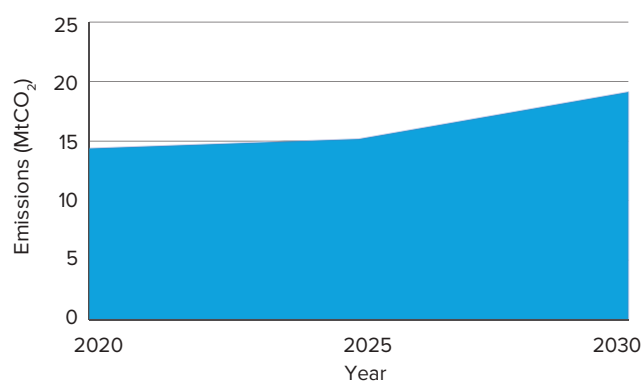
Source: Authors' analysis

Figure 6.8f Energy consumption in the building sector



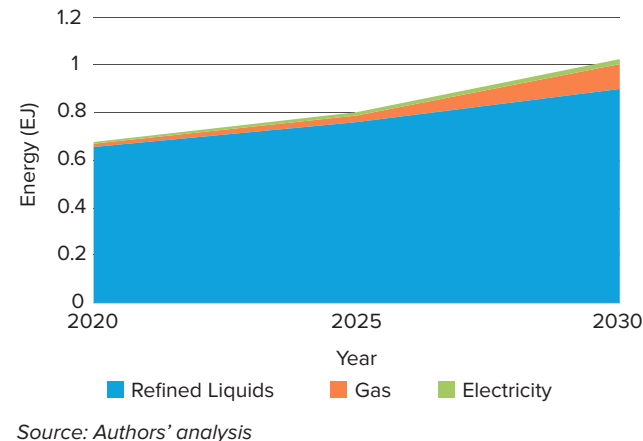
Source: Authors' analysis

Figure 6.8g Emissions, by building sector



Source: Authors' analysis

Figure 6.8h Energy demand, by fuel



Source: Authors' analysis

The total emissions from the building sector were 14.38 MtCO₂ in 2020 and will rise by 1.3 times between 2020 and 2030. Direct emissions in the building sector are dominated by the cooking sector, which is dominated by LPG (refined liquid) and PNG (gas).

6.3.4d Transport

In GCAM, the transport segment is divided into passenger and freight segments. The passenger segment comprises two-wheelers, four-wheelers, three-wheelers, buses, passenger railways, aviation, and non-motorised transport (NMT – i.e., cycling and walking). Currently, 2W and railways constitute the majority share in the passenger segment. As incomes and urbanisation rates rise, the service demand of 4W will rise by 1.84 times between 2020 and 2030, and four-wheelers account for the highest share in this segment. This is because as urbanisation and per capita income rises, people shift to personal, faster, and more convenient means of transport. Therefore, people move from NMT or bus to 2W and then to 4W. This trend is observed around the world and is expected to play out in India and Maharashtra too if Maharashtra

does not actively push for a public transport system and support NMT infrastructure.

Maharashtra has an extensive freight segment comprising freight railways, shipping, and trucks. Within the freight segment, trucks fulfil about 68 per cent of service demand, followed by freight railways (22%) and shipping (10%).

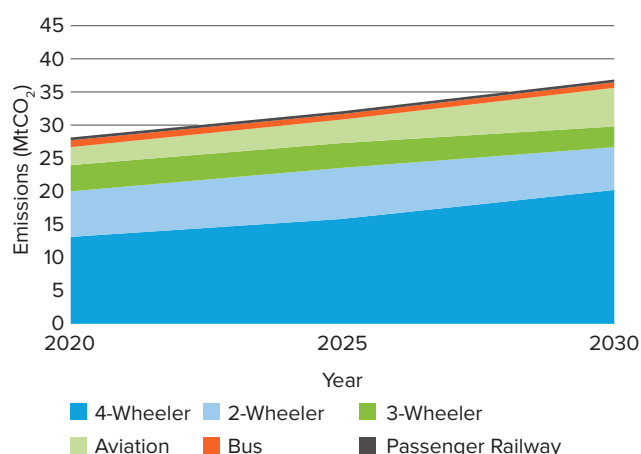
The total energy demand will grow by almost 1.5 times between 2020 and 2030.

The total emissions from the transport sector will rise by almost 1.31 times from 28 MtCO₂ in 2020 to 37 MtCO₂ in 2030, dominated by four-wheelers and two-wheelers. This underscores the importance of pushing for public transportation and decarbonising the personal transport segment through electrification.

Overall energy emissions

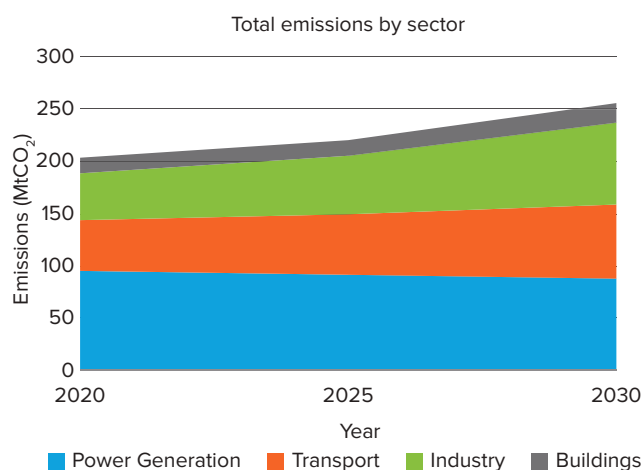
In 2020, power generation accounted for about 47 per cent of the total power emissions, followed by transport (23 per cent) and industry (22 per cent). The total CO₂ emissions was 203 MtCO₂ in 2020, which will rise to 256 MtCO₂ in 2030 – that is, by 1.26 times.

Figure 6.8i Total emissions, by mode



Source: Authors' analysis

Figure 6.8j Overall emissions – energy



Source: Authors' analysis

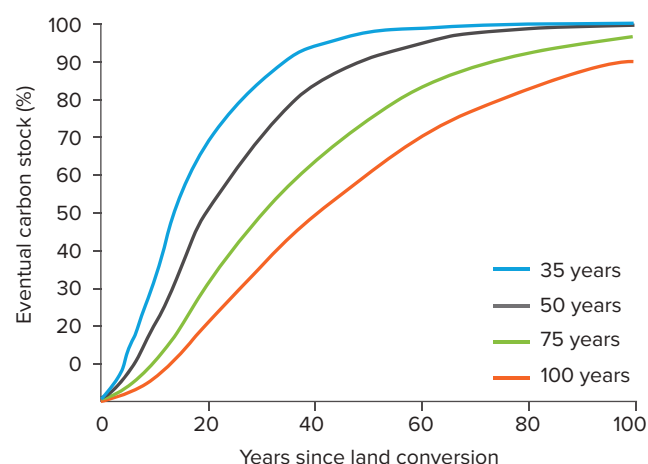
6.3.5 Sector-wise long-term AFOLU modelling results: BAU

6.3.5a Forest emissions

GHG emissions or GHG removal in forests is the result of changing vegetation carbon (i.e., above-ground biomass, below-ground biomass, deadwood, and litter) and soil organic carbon (SOC) due to the conversion of forest land to other land categories and vice versa. Maharashtra, which is the third largest state in India, had a total of $62.92 \times 10^3 \text{ km}^2$ (20.45 per cent) of forest and tree cover (16.51 per cent forest and 3.94 per cent tree cover) in 2021 and has great potential to increase its forest cover because of the locational and climatic factors. In order to estimate the CO_2 emissions and CO_2 sequestration in the forest sector, data regarding the area under forest and tree cover, vegetation carbon density, and SOC density were collected from the published Forest Survey of India (FSI) reports. Then, the carbon stock change method was used to obtain the differences

in carbon stocks which were allocated differently over time for vegetation and soil carbon. It is noteworthy that carbon sequestration in the forest depends upon the maturity (age) of the forest; the newly grown forest sequesters more vegetative carbon as compared to the mature forest following a sigmoid curve (Figure 6.9a). However, the emissions/sequestration in the soil follow an exponential curve. Therefore, to quantify the carbon sequestration in the above-ground vegetation, we applied a sigmoidal function, and if there was any decrease in forest area, we assumed that all emissions were released in that particular year. Most of Maharashtra (87.25 per cent) is covered by mature, tropical dry and moist deciduous forests (FSI 2009) whose age is 35 years (Houghton 1999). So, for simplicity, we assume that the whole Maharashtra forest region has a maturity value of 35 years while quantifying the carbon emissions/sequestration. More information about the methods used here can be found in Kyle et al. (2011).

Figure 6.9a Carbon uptake in different forests, by maturity



Source: Joint Global Change Research Institute

It is truly remarkable to observe the positive transformation occurring in the state of Maharashtra. Over the period from 2005 to 2021, Maharashtra has witnessed a significant increase in its forest and tree cover area, expanding from $56.45 \times 10^3 \text{ km}^2$ (18.35 per cent) to $62.91 \times 10^3 \text{ km}^2$ (20.45 per cent). Furthermore, if Maharashtra continues to diligently pursue its ambitious goal of increasing the forest and tree cover area by 33 per cent as outlined in the Maharashtra Forest Policy 2008, the state's landscape will be further enriched. If this objective is achieved, the forest and tree cover area is projected to reach an impressive $101.55 \times 10^3 \text{ km}^2$.

In the first scenario, we have selected a short-term target for the state government, aiming to achieve a significant increase in the forest area. The government's objective is to expand the forest by an additional 5,000 sq km, with a yearly target of 50 sq km. While this initiative will undoubtedly contribute to carbon sequestration, it is important to note that the overall forest area may experience a reduction in

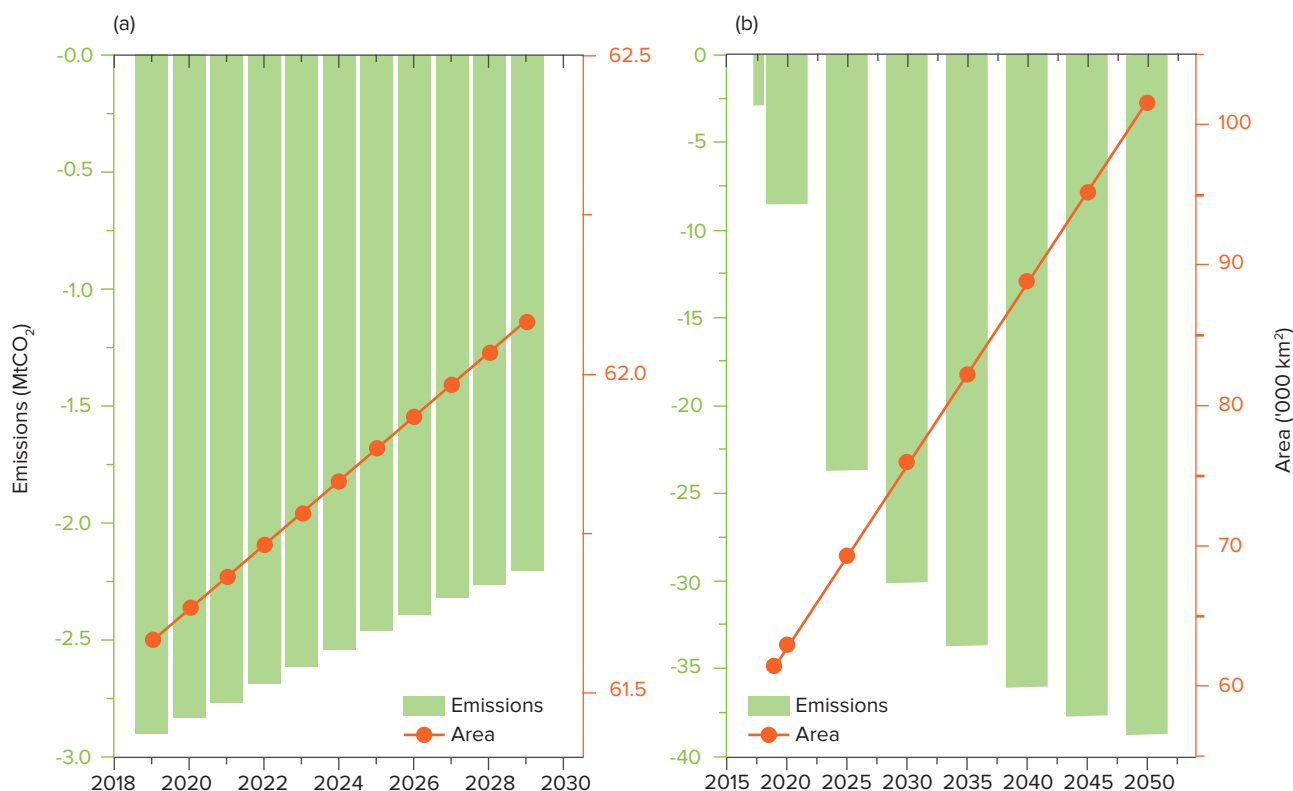
carbon sequestration. This is primarily due to the gradual expansion of the forest area each year, which is relatively small in comparison to the decreasing rate of carbon sequestration in the existing mature forest. The mature forest, having reached its peak capacity, naturally exhibits a higher decline in carbon sequestration than the newly added forest area can compensate for. Consequently, it is estimated that the overall carbon sequestration will decline to -0.7 MtCO_2 by 2029 (Figure 6.9b). However, despite this decline in sequestration, it is worth noting that the carbon stock in the forests will still increase from 1.97 Billion tonnes carbon dioxide (BtCO_2) in 2019 to 1.99 BtCO_2 in 2029. Although the change in carbon stock during this period is a modest 0.02 BtCO_2 , it demonstrates that the short-term target set may not yield significant benefits in terms of carbon sequestration. It is important to note that this finding does not undermine the importance of tree planting and increasing forest cover. Tree planting yields various ecological benefits, such as biodiversity conservation, soil protection, and local climate regulation. While the immediate climate change mitigation impact may be limited, these efforts can provide a foundation for long-term sustainability and environmental conservation.

It is crucial for us to recognise the limitations of such short-term goals and consider alternative strategies that prioritise long-term sustainability and effective carbon

sequestration. Therefore, the second scenario has been carefully considered, which aims to achieve a 33 per cent forest and tree cover by the year 2050. This ambitious target holds significant promise, as it is projected to result in a remarkable reduction in emissions, amounting to -38.66 MtCO_2 in 2050. Moreover, this expansion of forest areas will lead to a substantial increase in the carbon stock, from 1.97 BtCO_2 in 2019 to 2.93 BtCO_2 in 2050. Throughout this period, a noteworthy change of 0.96 BtCO_2 is anticipated, underscoring the long-lasting benefits that can be derived from sustained efforts in expanding forest cover. To effectively accomplish these goals, it is essential to consider the annual growth rate required to achieve the desired outcomes. In this scenario, the forested area would need to increase by an annual increment of $1.29 \times 10^3 \text{ sq km}$. By carefully planning and implementing strategies to achieve this growth rate, we can ensure significant progress in mitigating emissions and enhancing carbon sequestration.

The second scenario's comprehensive approach, which is focussed on long-term objectives, exemplifies the importance of prioritising sustainable forest management practices. By emphasising the expansion of forest and tree cover over a substantial period, we can achieve enduring benefits for the environment and effectively combat climate change.

Figure 6.9b The reduction in CO_2 emissions following (a) short-term (from 2019 to 2029) and (b) long-term (from 2019 to 2050) forestry targets



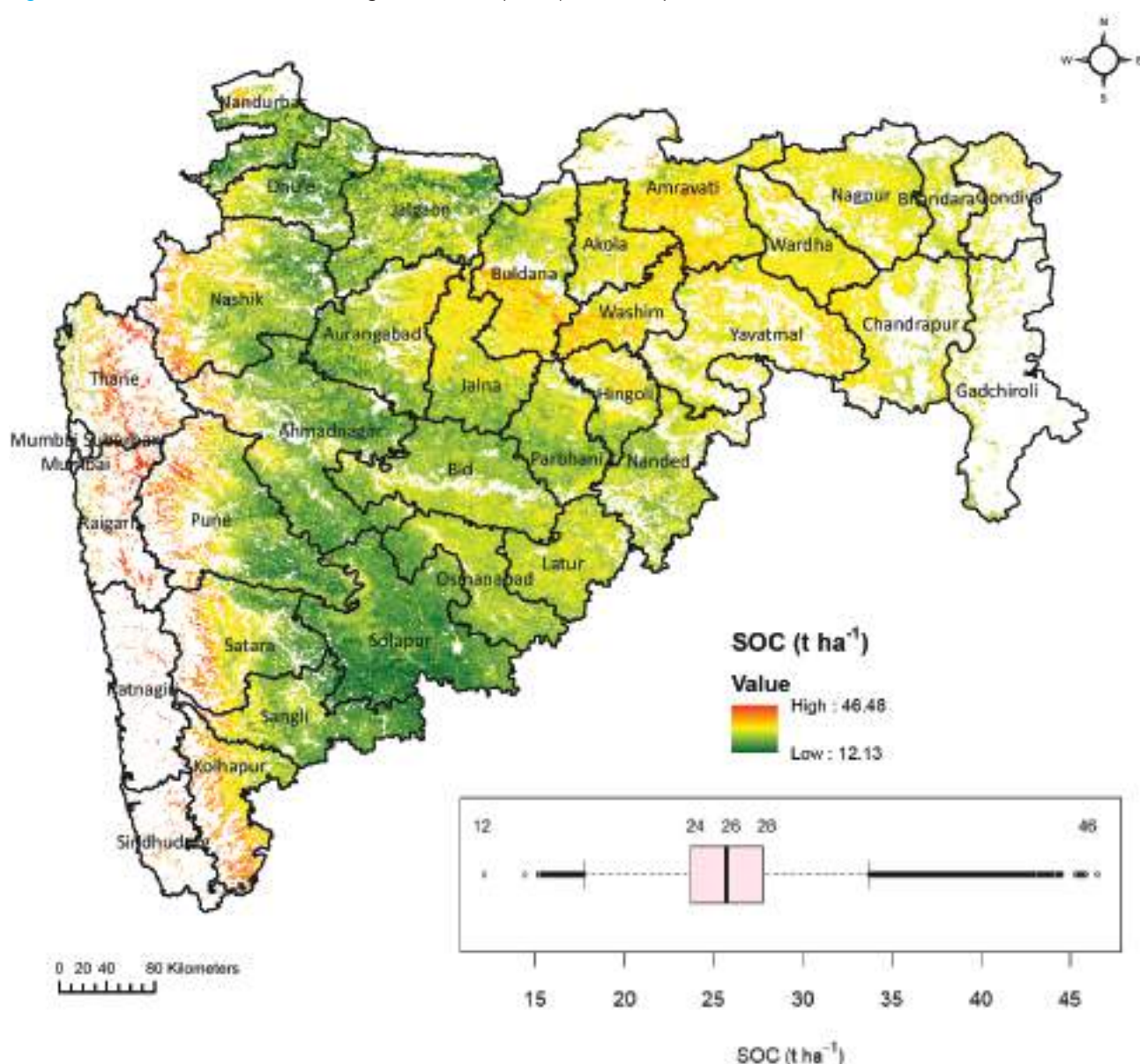
Source: Authors' analysis

6.3.5b Cropland emissions

Cropland is used for the cultivation of various crops and has a different vegetation structure compared to the other land use categories. The CO₂ emissions in cropland are mainly associated with soil and root respiration and the decomposition of organic matter. Again, the stock change method has been adopted to quantify cropland CO₂ emissions. However, it should be noted here that, unlike forest maturity, cropland has a maturity age of only one year, which means that all the vegetative carbon will be stored/emitted in a single year and will not be distributed over a longer time period. Nevertheless, the soil will still follow the exponential approach, which indicates that during the initial years of land conversion, the soil will sequester/emit CO₂ at a very rapid rate, and gradually, the process will slow down. To estimate future emissions

using the stock change method, we require the steady-state carbon value both for vegetation and soil. The rate of change of vegetative carbon (i.e., 0.05 tC/ha/year is taken from the Biennial Update Report (BUR3), India. For SOC, the global SOC map of the Food and Agricultural Organisation (FAO 2023) has been used. The map is prepared by using 1,75,993 soil samples from different parts of India and interpolated using the Support Vector Machine algorithm. The SOC map was masked using the cropland category of Environmental Systems Research Institute (ESRI) Land Use Land Cover (LULC) data for Maharashtra state. SOC in the cropland area ranges from 12.13 tC/ha to 46.48 tC/ha with a mean value of 25.8 tC/ha (Figure 6.9c). It is common to consider the third quartile (q3) of all available grid cells for SOC as the steady-state value; hence, an SOC of ~28 tC/ha has been considered here (q3 value).

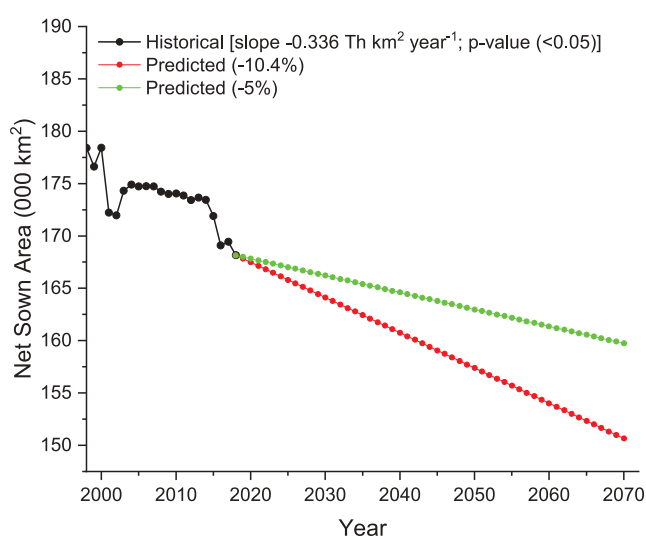
Figure 6.9c The distribution of soil organic carbon (tC/ha) in the cropland area, Maharashtra



Source: Authors' analysis

The emission is usually quantified in the harvested cropland area. Therefore, data on the area under cropland (i.e., net sown area) for Maharashtra were collected from the Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, website (<https://eands.dacnet.nic.in/>). From the historical data, it is observed that the area under cropland has decreased at a rate of -0.336×10^3 sq km/year (p value <0.05) from 1984 to 2018 (Figure 6.9d). If this trend continues, the cropland area will decrease by 10.4 per cent – that is, from 168.15×10^3 sq km to 150.66×10^3 sq km between 2018 and 2070. However, we have made one more assumption of decreasing net sown area by five per cent (159.74×10^3 sq km) in 2070. Here, we have quantified the CO₂ emissions for three different scenarios: decreasing cropland area, with cropland (i) converted to agricultural fallow, (ii) converted to range land, and (iii) converted to forest land. The vegetation carbon for range land area is taken as 7 tC/ha, following Houghton (1999), and the q3 value of SOC has been taken from the global SOC map (FAO 2019) after masking out the range land area using the ESRI 2019 LULC map (Figure 6.9e). For forest areas, the vegetation and soil carbon values have been taken from the FSI report 2019 (FSI 2019).

Figure 6.9d The historical cropland area and future change in cropland (net sown) area in Maharashtra



Source: Authors' analysis

In the first scenario, a linear decrease in sequestration from the vegetative carbon will be seen in the cropland since the land area is declining at a constant rate till 2070. Even though the area decreases at a constant rate, during the initial years of land conversion, the available cropland area will sequester a certain amount of soil carbon, which will help to reduce the emissions (i.e., -2.02 MtCO₂ in 2020). However, gradually, this sequestration will reduce as the soil reaches the saturation level, which will in turn increase emission rates from 2030 onwards.

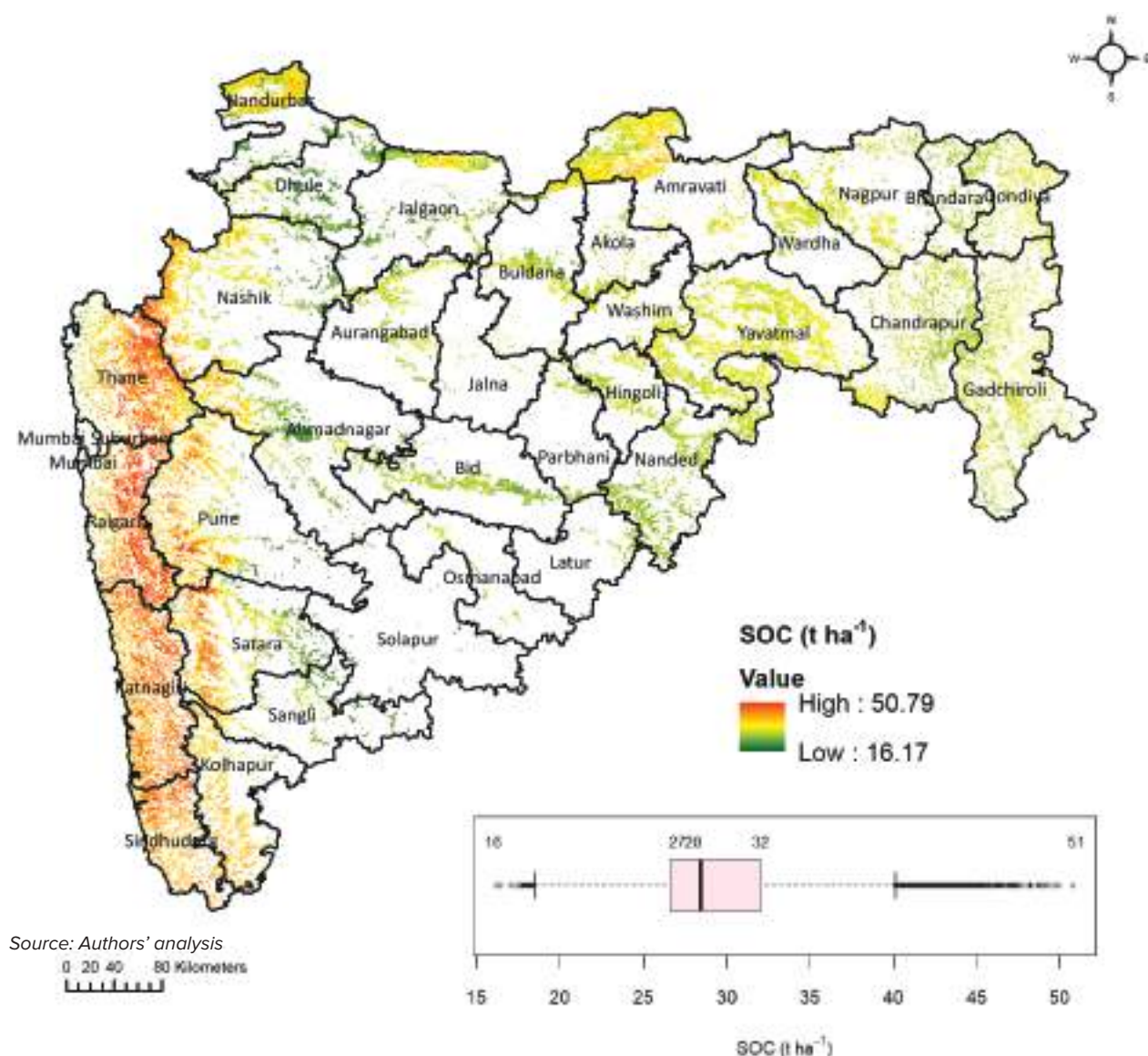
This decrease in cropland area will lead to emissions of 0.26 MtCO₂ in 2030, which will increase to 0.65 MtCO₂ in 2070 – this is a 150 per cent increase within four decades (Figure 6.9f). In the second scenario, if the cropland area is converted to a range land (open areas mostly covered with small plants/grasses/bushes/shrubs), the carbon emissions will decrease to -4.87 MtCO₂ in 2030 and -4.81 MtCO₂ in 2070. In the last scenario, if the cropland area is converted to forest land, the carbon sequestration will increase from 10.63 MtCO₂ in 2030 to 10.67 MtCO₂ in 2070, which is ~121 per cent higher than that in the second scenario for 2070.

In the alternative case, if the cropland area decreases to five per cent in 2070, the emissions/sequestration will follow the same trend in all scenarios, but the rates will be different (Figure 6.9g). In the last scenario, during the initial years of land conversion, the existing forest land together with the new areas will sequester more carbon from the atmosphere (i.e., 7.97 MtCO₂). However, with time, this sequestration will decrease (7.97 MtCO₂ in 2020 to 5.18 MtCO₂ in 2070) even if the additional area (0.16×10^3 km²/year) comes from agricultural land. This is because, every year, the land area added is very small and is 0.26 per cent of the available forest area (as per 2019). As a result, the carbon sequestration in newly added forest areas is very low and does not offset the declining rate of sequestration in existing mature forest areas.

It has been found that the decline in cropland areas can have a significant impact on carbon sequestration. Incorporating this shrinking land area into the agroforestry system, which combines trees and crops, can play a crucial role in enhancing carbon sequestration. In the agroforestry system, absorption by trees and biomass accumulation help to store carbon, while also improving soil health and reducing erosion. Its diversification and resilience contribute to sustained carbon sequestration and reduced GHG emissions. Moreover, agro-forestry offers a sustainable approach to food production while aiding in the mitigation of climate change. The duration of rotational periods in agroforestry plays a key role in carbon sequestration through tree growth and carbon accumulation. Longer rotations allow trees to reach maturity and store more carbon, while shorter rotations enable rapid biomass production. Optimal rotational periods are determined based on adaptation to changing conditions and market demands.

A study by Panwar et al. (2022) identified the various agroforestry systems practised in Maharashtra, such as agri-silviculture, agri-horticulture, and block plantation, and we attempted to quantify the carbon sequestration potential of these agroforestry systems. The vegetative carbon data for agri-silviculture and block plantation were obtained from the same literature source (Table 6.3), while the soil carbon value remained the same as that of the cropland area used before. We considered two rotation periods: a short rotation of 10 years and a long rotation

Figure 6.9e Distribution of soil organic carbon (tC/ha) in the range land area, Maharashtra



Source: Authors' analysis

Table 6.3 The carbon density values and rotational period

Agroforestry systems	TBC (tC/ha)	SOC (tC/ha)	Rotational period
Agri-silviculture	1.5–42.9 (10.24)	28	Short (10 years); long (30 years)
Block plantation	0.05–353.2 (38.12)	28	

Note: TBC, Tree + Crop biomass carbon; SOC, soil organic carbon. The mean value is given in parentheses

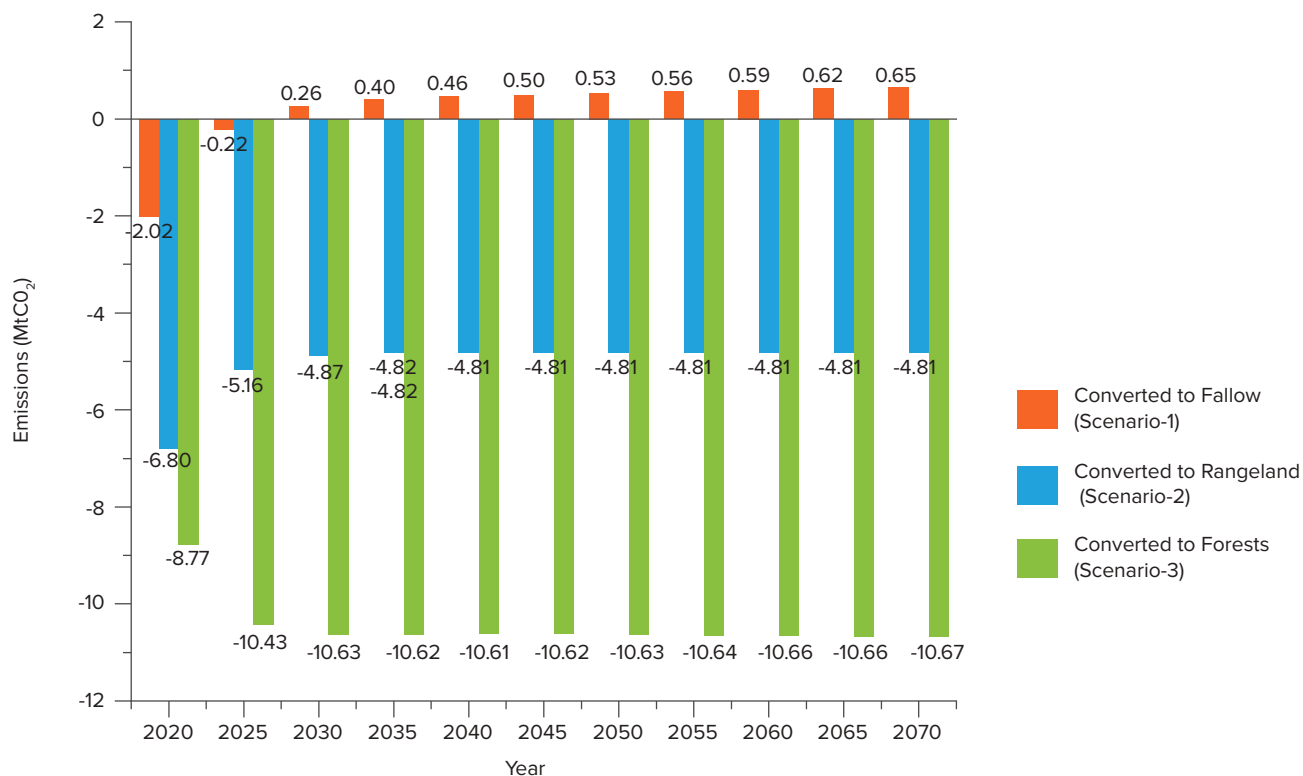
Source: Table collected from Panwar et al. (2022)

of 30 years. For the short rotation, we took the mean Tree + Crop biomass carbon (TBC) values, while for the long rotation, we considered the maximum TBC values. This choice was made because trees have sufficient time to mature and store maximum biomass within the long rotation period.

Our observations indicate that the first scenario (i.e., 10.4 per cent decrease in cropland area), with both agri-silviculture and block plantation (equally distributed area),

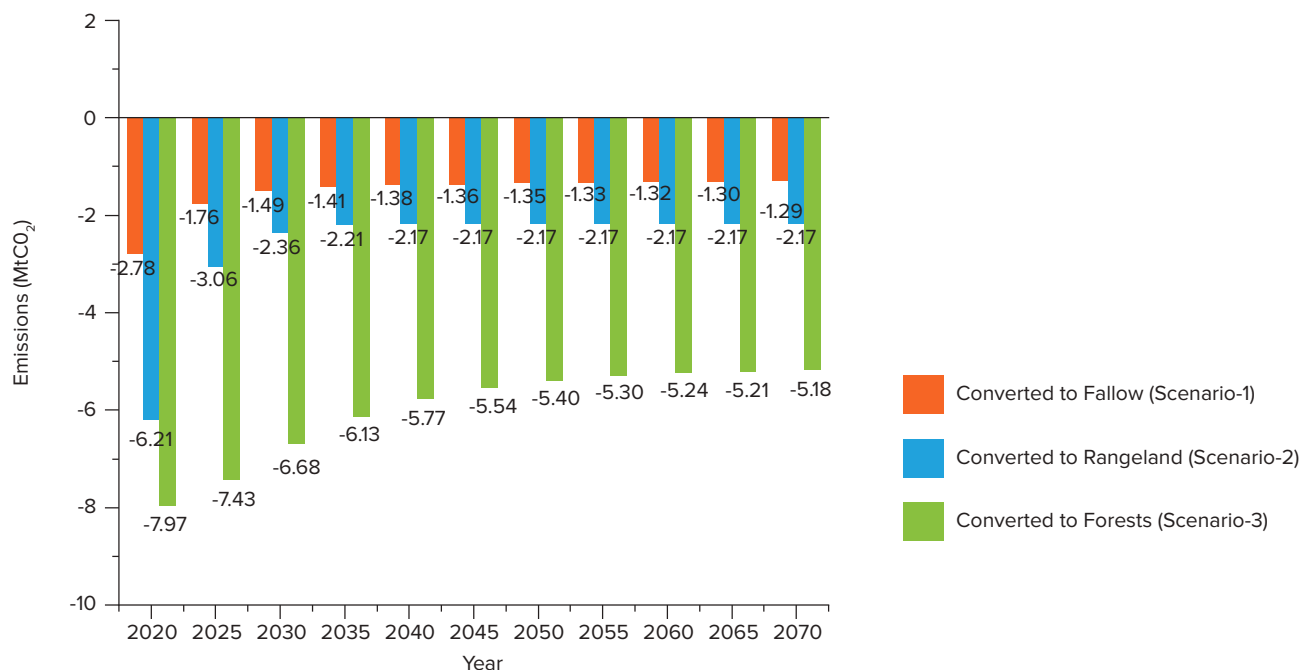
can sequester only 17.13 MtCO₂ in 2070 under a short rotation period (Figure 6.9h). However, the long rotation period yields a significantly higher sequestration rate – approximately 158 per cent higher, amounting to 44.36 MtCO₂ in 2070. In an alternative scenario where a five per cent decrease in cropland area is added to agro-forestry, the carbon sequestration ranges from 8.24 MtCO₂ to 21.32 MtCO₂ for the short and long rotational periods, respectively.

Figure 6.9f The emissions (MtCO₂) in three different scenarios with a 10.4% decrease in cropland area by 2070



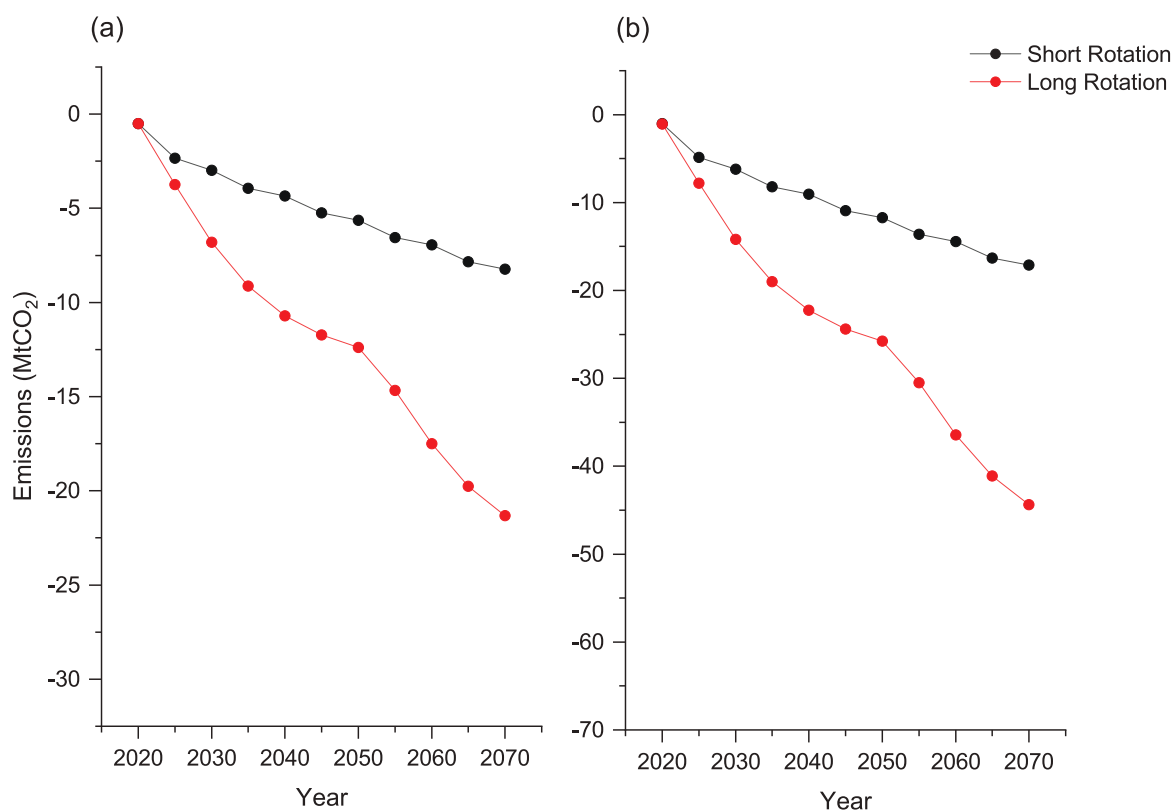
Source: Authors' analysis

Figure 6.9g The emissions (MtCO₂) in three different scenarios with a 5% decrease in cropland area by 2070



Source: Authors' analysis

Figure 6.9h The CO₂ emissions under (a) 5% cropland and (b) 10.4% cropland area added to the agroforestry system. The short and long rotational periods include both agri-silviculture and block plantations where the equal area was distributed every year



Source: Authors' analysis

6.3.5c Non-CO₂ AFOLU emissions

Key Assumptions for future trends

The major assumptions used while estimating future trends and the emissions trajectory in the AFOLU sector include the following:

- Livestock population:** The trend in the past 15 years showed that the livestock population increased from 2003 to 2007 but declined from 2007 to 2012 and from 2012 to 2019. A linear extrapolation of different growth trends was done considering that the goat and sheep population is expected to increase in the future, whereas indigenous dairy cattle may not decline by more than two per cent.
- Rice area under cultivation:** A declining trend has been observed for areas under rice cultivation during the past 15 years, and this is expected to continue in the future as some districts are expected to reduce paddy cultivation and move to crop diversification (1.39 tCO₂e/ha).
- Crop production:** The trend in the past 15 years was studied, and linear interpolation for crop yield was done. To calculate production levels, the yield

was multiplied by the current area for every year till 2050, and the total production for major crops was obtained using the above-mentioned method: Production = Area × Yield.

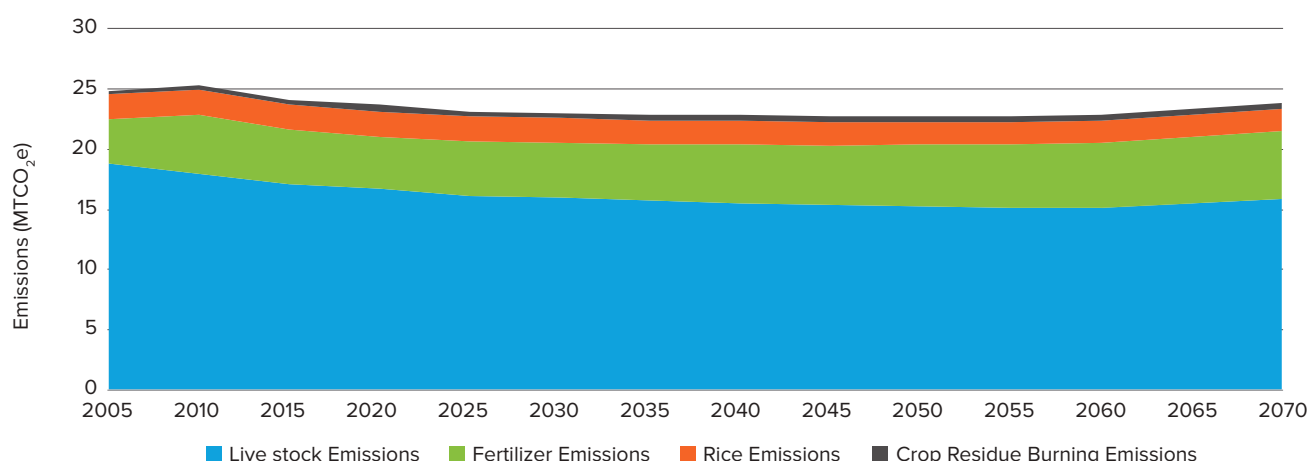
- Fertiliser consumption:** The correlation between the average increase in crop yield and fertiliser consumption was studied. A positive correlation was observed, and hence, fertiliser consumption in the state is also expected to increase as agricultural productivity increases.

Methodology

The IPCC 2006 guidelines were used to calculate emissions from the AFOLU sector. To estimate livestock emissions for the bovine population, country-specific emission factors were used, while for other animals, default IPCC emission factors were used. For state-specific livestock populations, data from the Government of India livestock census from the years 2003, 2007, 2012, and 2019 were used.

To calculate emissions from rice farming, the area under cultivation data were taken from the Agriculture Statistics report by the Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Government of India, for the years 2011 and 2020

Figure 6.9i Agriculture sector emissions projection



Source: Authors' analysis

(Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers welfare, Government of India 2020).

In order to estimate fertiliser emissions, urea consumption data were obtained from the *Indian Fertiliser Scenario* (Department of Fertilisers (DOF), Ministry of Chemicals and Fertilisers 2018). Nitrogen consumption data were obtained from the Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. India-specific emission factors were used (DOF, Ministry of Chemicals and Fertilisers 2018) (Fertiliser India 2021).

To calculate crop residue burning, crop production data were obtained from the agriculture statistics for the period 2005–21.

If the current trends continue, emissions from the state of Maharashtra will amount to 20.6 MtCO₂e by 2050. The

overall emissions from the agriculture sector may decline as livestock population is decreasing, which will lead to a corresponding decrease in emissions from enteric fermentation and manure management. However, given the need to support a growing population, there will be an increase in crop production and crop residue burning. Additionally, if crop production needs to be supported in the same cropland, the amount of fertiliser required will keep increasing. Therefore, there will be an increase in emissions from fertiliser consumption and crop residue burning.

6.4 Sector-wise recommendations and mitigation strategies

This section discusses the various recommendations based on the gaps and challenges identified during the existing policy analysis conducted in the previous section and the consultations held with the relevant departments.

Table 6.4.1 Energy

S. no.	Recommendations/Targets	Actions to be undertaken
1	100% energy audit compliance for large industries, government buildings, and large residential complexes by 2030	Under the existing Save Energy Programme, the Maharashtra Energy Development Agency (MEDA) has done remarkable work in the state with a total of 1,851 energy audits conducted till date. This scheme has an energy savings potential of 77.09 MUs per year. The Save Energy Programme should be revised to introduce mandatory compliance by large industrial firms, all government/semi-government/local self-government buildings, and large residential complexes. Industrial firms with an annual energy bill greater than INR 20 lakh may be categorised as large, and residential complexes with a minimum transformer rating of 200 kVA may be categorised as large. Unlike the existing programme, there shall be no financial assistance from the department. The implementing agency should define a proper plan for Monitoring, Reporting, and Verification (MRV) avenues and administer strict penalties to tackle non-compliance

Box - 6

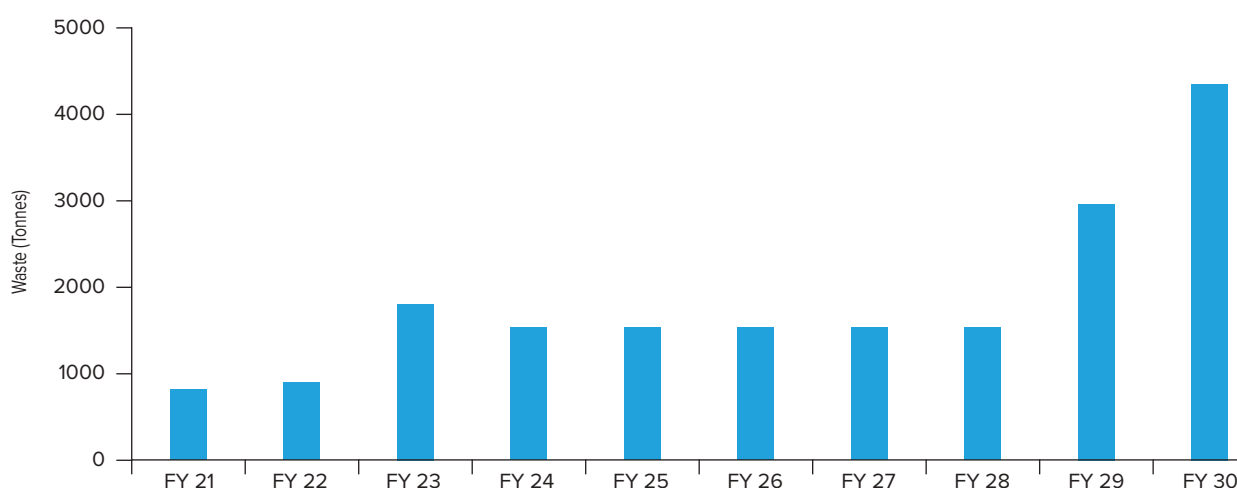
Quantum of solar waste generated annually due to solar PV installations until FY23.

The cumulative waste contains, as shown, around 2223 tonnes of aluminium, 741 tonnes of silicon, 556 tonnes of copper and around 10 tonnes of silver (IEA. 2022).

Suggestions:

1. Solar module producers (manufacturers, developers and importers) should
 - a) start building waste management infrastructure,
 - b) set up reverse logistics mechanisms to collect waste and conduct recycling pilots with technology providers,
2. There should be incentivisation of full recovery of materials from solar waste by introducing Extended Producer Responsibility (EPR) targets, including material-specific recovery targets,
3. Technology providers should expedite research on innovative module recycling technologies able to recover high-purity materials at high recovery rates,
4. Other circular approaches such as the reuse of modules for a second life and design for disassembly, design for repair and design for recycling should be considered.

Figure 6.9j Projected annual solar waste in Maharashtra



Source: Author's compilation

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
Entire state	The key implementing institution for this policy will be the MEDA	The department will have no financial implication in terms of costs, as the required firms will be solely paying for the energy audit. However, the department would have to spend on MRV to ensure the necessary compliance. For the MRV process, a task force of 15 trained officials may be set up, which includes two senior officials leading the team, five mid-level position officers, and eight junior officers. Special training sessions may be conducted with these officers to train them in the MRV process. Estimated salaries for this task force will be INR 1.12 crore per annum, amounting to 7.8 crore till 2030. The unit should verify if the energy conservation measures suggested in the energy audit are implemented in the facility within two years of the date at which the energy audit is conducted	Achieve energy efficiency leading to reduction in overall energy consumption and resulting power sector emissions

S. no.	Recommendations/Targets	Actions to be undertaken								
2	Establish installed capacity target of 44 GW of renewable energy (RE): <i>Table 6.4.1a RE target for installed capacity</i> <table><tr><th>Renewable energy</th><th>Target by 2030</th></tr><tr><td>Solar (ground mounted – 16 GW, rooftop solar, 4 GW and off-grid solar, 2 GW)</td><td>23 GW</td></tr><tr><td>Wind</td><td>17 GW</td></tr><tr><td>Other RE (pumped storage hydroelectric power, biomass)</td><td>4 GW</td></tr></table> The state has also set up a target for solar and wind storage, translating into a capacity addition requirement of 12,443 MWh	Renewable energy	Target by 2030	Solar (ground mounted – 16 GW, rooftop solar, 4 GW and off-grid solar, 2 GW)	23 GW	Wind	17 GW	Other RE (pumped storage hydroelectric power, biomass)	4 GW	The Central government has Announced that it will incorporate 50 GW of installed capacity of RE (including 10 GW of wind energy) annually to achieve an aggregate target of 500 GW by 2030 as per India's COP26 commitments. These targets have been specified based on the current solar and wind generation in Maharashtra, RE targets for 2025, RPO targets announced by the state for 2030, and the overall solar and wind potential of Maharashtra. These targets are also in line with the Energy Security study carried out by Prayas Energy Group. This study evaluated whether it is feasible to meet Maharashtra's energy demand with RE addition and no new coal capacity. Therefore, these RE targets are worked out taking into consideration the energy security of the state. Further, our projection of energy generation by RE is in line with the mandates of the State Commission station for 20% energy from RE in 2020, 25% energy from RE by 2025, and Ministry of Power's target of 45% energy from RE by 2030. To achieve these targets, we recommend the following to be strengthened and implemented: A. Continue with the existing policy framework as outlined in the Maharashtra Renewable Energy Generation Policy, 2020, and extend the policy beyond 2025 to incorporate the 2030 targets B. Develop ultra-mega-power parks for solar and wind C. Establish green energy corridors in the state dedicated for evacuation and integration of RE through a dedicated Green Energy Fund D. Introduce a 10% RE generation obligation (i.e., blending target) implying that the RE capacity addition should be 10% of any new fossil-based power generation capacity established in the state beyond the predetermined date E. Policy of low interest rate or interest subsidy for RE projects/storage/pump storage/green hydrogen F. Reduced GST or waive off of state GST and other local taxes for RE projects/storage/pump storage/green hydrogen G. Adopt Green Open Access Rules 2022 in the state to incentivise the access to green energy by reduction of the transaction limit from 1 MW to 100 kW and other appropriate provisions for cross-subsidy surcharge and additional surcharge, among others H. Mandate RE-based storage project including pumped storage project Based on internal analysis and department consultation, the top five districts with the highest solar potential in Maharashtra are Solapur, Satara, Nagpur, Latur, and Nanded
Renewable energy	Target by 2030									
Solar (ground mounted – 16 GW, rooftop solar, 4 GW and off-grid solar, 2 GW)	23 GW									
Wind	17 GW									
Other RE (pumped storage hydroelectric power, biomass)	4 GW									
3	Reduce aggregate technical and commercial (AT&C) losses from 26.55% to 15% by 2030	The above target is in line with the Revamped Distribution Sector Scheme (RDSS) launched by the central government, which aims to reduce the AT&C losses at pan-India levels to 12% to 15%. To achieve this target, the DISCOMs may install advanced metering infrastructure (AMI) with a robust accounting mechanism to allow accurate capture and tracking of data for energy flows and losses. Empowered with this thorough understanding of the energy systems, the AMI data can be used by DISCOMs to provide reliable energy supply, implement targeted solutions to reduce billing losses, and digitise the billing and energy accounting systems								

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
Entire state	The key implementing institutions for this policy will be the Department of Industry, Energy and Labor, and MEDA Integration can be done with the existing scheme; National Mission for Enhanced Energy Efficiency and National Solar Mission.	Majority of the recommendations for this section are non-fiscal in nature	Fossil fuel-based electricity generation contributes significantly to GHG emissions. RE-based generation has a lower carbon footprint and will lead to lower emissions, thus contributing to the cause of a sustainable future
Entire state	The key implementing institutions for this policy will be the Maharashtra State Electricity Distribution Company Limited (MSEDCL), Maharashtra State Electricity Board, Maharashtra State Power Generation Company Limited, and Maharashtra State Electricity Transmission Company Limited	The state has planned an outlay of INR 39,602 crore for installing smart metres and distribution transformers and for capacity enhancement and modernisation of existing power distribution systems	As per the Report on Performance of Power Utilities, AT&C losses in Maharashtra were estimated at 26.55% in 2020–21. This loss will need to be reduced to improve the operational efficiency of the DISCOMS and will enable them to become financially healthy and competitive
	Total budget =	INR 7.8 crore	

Table 6.4.2 Mitigation recommendations for industry sector

S. no.	Recommendations/ Targets	Actions to be undertaken
1	Establish a green hydrogen hub to set-up 0.5 GW electrolyser capacity every year by 2030 to achieve the green hydrogen installed capacity of 0.5 MTPA by 2030	Recently, the central government has launched the National Green Hydrogen Mission, which aims to develop the green hydrogen capacity of at least 5 MMT (million metric tonne) per annum by 2030, leading to a reduction of 50 MMT of annual GHG emissions (MNRE 2023). In order to achieve the national vision, a few states with an illustrious industrial base, have been identified, where green hydrogen manufacturing zones will be set up. To achieve these targets, the relevant department should introduce the following demand-side incentives: 1. Introduce a 30% blending target, such that 30% of the fossil fuel energy consumed by industries should be substituted with green hydrogen 2. In the refining sector, the process of desulphurisation uses grey hydrogen, which should be replaced with green hydrogen 3. In the fertiliser sector, 30% of the fossil fuel energy consumed by industries should be substituted with green hydrogen The state has recently launched its Green Hydrogen Policy, which includes various supply-side incentives for setting up hydrogen plants such as concession on transmission and wheeling charges and exemption in power tariffs, local body taxes, and registration fees. The policy also includes earmarking of funds for training of human resources
2	Install 15 GW of solar modules manufacturing capacity by 2030	In order to pillar the solar power installed capacity, India has announced a target of 90 GW of solar modules by 2026, increasing from 15 GW in 2022. Setting up a domestic solar equipment manufacturing capacity in Maharashtra will not only lead to job creation in the state economy, but also pave the way for a just transition of the workers in the fossil fuel industry. The central government has announced a slew of production-linked incentive (PLI) schemes costing the central treasury INR 19,500 crore. Therefore, in order to pave the way for achieving the 15-GW target by 2030, the relevant department may extend the following incentives: 1. Provide additional tax incentives to module producers such as capital subsidy, interest rate subsidy, or lower rate of interest and electricity duty exemption, 2. Sanction access to land through a simplified process, 3. Provide subsidy in special economic zones (SEZs), and 4. Facilitate easy access to finance. It should be noted that the central government will withdraw its subsidy post-2026. Therefore, based on the emerging landscape of solar module manufacturing in the country, the state government may revisit this scheme and offer incentives as needed
3	Enable preferential plot allotment to green industries	An industry can be categorised as green if it fulfils the following benchmarks: 1. Achieve 30% RE in energy mix. 2. Incorporate energy efficiency measures as outlined in the energy audit within one year of recommendation. 3. Industries in priority sectors such as RE, green hydrogen, and electric vehicles. 4. Attached effluent treatment plants (ETPs)
4	Encourage application of Best Available Techniques (BATs) in different industrial subsectors	BATs provide a sound reference point for industries to improve their production processes in accordance with established standards. Industry consortiums (CSI 2013, JISF 2022), and regulatory agencies (BEE 2023) provide a comprehensive list of recommended technologies for energy-saving, environmental protection, and recycling for emissions-intensive sectors such as cement and iron and steel. This list is exhaustive as it covers different stages of production across technological processes. Other industrial sectors should also carry out a detailed analysis of their sectors. The implementing department should encourage application of BATs in each industrial sector
5	Encourage plantations/ green belts around industrial units	Green belts around industries play a crucial role in promoting environmental sustainability, mitigating pollution, and fostering a healthier ecosystem. They also act as a noise barrier and hold CO₂ sequestration potential

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
Entire state	The key implementing institutions for this policy will be the Department of Industry, Energy and Labor Integration can be done with the existing scheme; National Green Hydrogen Mission.	In order to achieve the 0.5 MTPA installed capacity of green hydrogen by 2030, we need an electrolyser capacity of 4 GW. Based on a CEEW analysis, we estimate the CAPEX of the electrolyser to be US\$ 750 kW. Therefore, the total private investment required for 4 GW of electrolyser capacity will be around INR 24,600 crore. The state has already sanctioned INR 5,562 crore in its Green Hydrogen Policy	Green hydrogen is not only an important asset in India's decarbonisation journey, but also holds the potential for India, and consequently Maharashtra, to become the leading manufacturer and exporter to the world
Entire state	The key implementing institutions for this policy will be the Department of Industry, Energy and Labor Integration can be done with the existing scheme; National Mission for Enhanced Energy Efficiency.	A financial cost of INR 250 crore every year, amounting to INR 1,750 crore for 2 GW installed capacity per year may be incurred in the form of additional PLIs to attract private producers to set up base in Maharashtra	While active efforts are being made to escalate deployment of solar energy through various schemes and policies at the central as well as state levels, India lacks a robust supply chain, which is essential for the availability and cost-effectiveness of solar components and, instead, relies heavily on imports. Maharashtra can become the pioneer in module manufacturing, not just for domestic consumption but for national consumption as well as international export
Entire state	The key implementing institution for this policy will be Maharashtra Industrial Development Corporation (MIDC)	Not applicable	Promote RE generation and increase energy efficiency in the industrial sector
Entire state	The key implementing institutions for this policy will be the Department of Industry and MIDC	Not applicable	Promote BATs for energy-saving, environmental protection, and recycling and achieve international standards in production
Entire state	The key implementing institutions for this policy will be the Maharashtra Pollution Control Board (MPCB) and MIDC	Not applicable	Promote green spaces around industrial areas

S. no.	Recommendations/Targets	Actions to be undertaken
6	Aim 30% renewable energy mix in ETPs/STPs by 2030	The currently operational ETPs and sewage treatment plants (STPs) should be encouraged to blend 30% RE in their overall energy mix. This will contribute towards the RE targets of the state and reduce the emissions potential of ETPs/STPs. This may be achieved in a phase-wise manner

Table 6.4.3 Mitigation recommendations for transport sector

S. no.	Recommendations/Targets	Actions to be undertaken												
1	Based on the modelling results and taking into consideration the medium-term targets outlined by the state in the recently launched EV Policy, 2021, the state should plan for the following share of EVs in new registrations by 2030: <i>Table 6.4.3a EV target by 2030</i> <table> <tr> <th>S. no.</th><th>Vehicle mode</th><th>Policy target</th></tr> <tr> <td>1.</td><td>2W</td><td>At least 30%</td></tr> <tr> <td>2.</td><td>3W</td><td>At least 40%</td></tr> <tr> <td>3.</td><td>4W</td><td>At least 15%</td></tr> </table>	S. no.	Vehicle mode	Policy target	1.	2W	At least 30%	2.	3W	At least 40%	3.	4W	At least 15%	In order to achieve these targets, the transport department should extend the current EV policy, 2021, up to the medium-term till 2030. Besides the existing incentives as outlined in the current EV policy, the Department of Transport may implement the following steps: 1. Offer Manufacturing incentives beyond the industrial policy: investment subsidy, exemption of electricity duty, land tax, concessional land allotment, and interest rate subsidy. 2. Levy green taxes on sale of ICE vehicles and utilise the funds generated towards EV-related demand-side incentives. 3. Ramp up the target for charging stations beyond the five cities as specified in EV Policy 2021. 4. Introduce purchase subsidy for hybrid vehicles. 5. Promote green shipping and decarbonise waterways by introducing electric and hydrogen-fuelled vessels for fishermen at a subsidised rate
S. no.	Vehicle mode	Policy target												
1.	2W	At least 30%												
2.	3W	At least 40%												
3.	4W	At least 15%												
2	Develop the Mass Rapid Transit System (MRTS) in tier 1 and tier 2 cities	The MRTS should be developed in tier 1 and tier 2 cities (with a population of over 1 million). Based on our consultations with the department, we gather that it plans to set up supporting infrastructure in Atal Mission for Rejuvenation and Urban Transformation (AMRUT) cities first by way of launching pilot projects. Successful models may be implemented across the state later. International cities like Kuala Lumpur, which has an efficient public transport system providing last-mile connectivity, are referred to by the department for case study learning purposes. To achieve this target, the department should incorporate the following demand and supply measures: 1. Ramp up the connectivity of buses, particularly electric buses across the entire length and breadth of the state. 2. Increase last-mile connectivity in cities so that metro infrastructure is effectively utilised, such as an operational metro station within 500 m radius of all citizens. 3. Improve the public perception associated with travelling in public transport through relevant promotional campaigns; install required safety measures such as CCTVs and sound alarm systems. 4. Levy high parking charges and toll tax for personal vehicles. 5. Design residential areas in the vicinity of IT hubs and parks to reduce travel time												
3	Incorporate extended producer responsibility (EPR) on all EV battery sales in the state by 2030	To overcome this challenge, our foremost recommendation is to formulate an e-waste policy with a special focus on EV batteries and incorporate it into the ambit of the EV policy. EPR should be incorporated within the e-waste policy: i.e., battery producers may be entrusted to facilitate a buy back at the end of the life cycle of the battery and ensure proper recycling												

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
Entire state	The key implementing institution for this policy will be the MIDC	Not applicable	Promote RE in the overall energy mix and reduce emissions potential of ETPs/STPs
	Total budget =	INR 7,312 crore	

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
Entire state	The key implementing institution for this policy will be the Department of Transport and Department of Industries Integration can be done with the existing scheme; National Mission for Enhanced Energy Efficiency.	The EV policy 2021 has a budget of INR 930 crore for four years (2021–25). Given that Maharashtra's GDP will grow by 7.5% per annum CAGR, we can extrapolate a budget of INR 1,400 crore for the next five years – i.e., for the time frame 2025–30	Transport sector emissions in Maharashtra are expected to rise significantly by 2030. These are emissions mainly from the passenger and freight transport segments, due to the heavy consumption of refined liquids, i.e., petrol and diesel. Therefore, electric vehicles, because of their lower emissions potential, will lead to a reduction in emissions
Entire state	The key implementing institution for this policy will be the Department of Transport and Department of Industries, and Department of Urban Development Integration can be done with the existing scheme; National Mission on Sustainable Habitat.	Average cost of the Metro project (Mumbai, Bangalore, Jaipur, Lucknow): INR 420 crore/km. Maharashtra's chief minister announced INR 40,000 crore for Metro projects across the state in March 2023. In the union budget for FY 2023–24, INR 19,518 crore has been allotted for metro projects	With rising incomes and urbanisation, the share of personal vehicles is expected to increase significantly. MRTS are energy efficient sources of transport, with additional benefits of comfortable, accessible, affordable, and safe travel. They have high electrification potential whilst reducing congestion on roads. An efficient MRTS will provide an alternative to private cars, thus reducing overall transport emissions. For the Mumbai Metro line 1 (11.4 km long), a study estimated that emissions savings would increase from 40 tons/day (in 2022) to 90 tons/day (in 2025)
Entire state	The key implementing institutions for this policy will be the Department of Transport and Maharashtra Pollution Control Board (MPCB)	Not applicable	Based on our consultation with the Department of Transport, we infer that proper disposal of EV batteries is likely to become a significant environmental concern in the coming years. Therefore, this recommendation will ensure proper recycling of EV batteries in the state
	Total budget =	INR 1,400 crore	

Table 6.4.4 Mitigation recommendations for AFOLU sector

S. no.	Recommendations/Targets	Actions to be undertaken	Geographic areas impacted
1	1. Increase the tree cover area by 50,000 ha, with an annual increment of 5,000 ha. Along with this the government should include 1,571 km² area in an afforestation plan to restore dense forests with a canopy cover of over 40% that have been converted to open forests. 2. Increase the forest and tree cover area by 33% in 2050	To achieve the 33% forest and tree cover area by 2050, the state has to increase the area, with an annual increment of 1.29×10^3 sq km; the rest of the actions to be taken are discussed in the Forestry and Biodiversity chapter 5.3 and section 5.3.4.	All the districts of Maharashtra will be impacted.
2	Reducing the fallow land and promoting agroforestry.	1. The area under agroforestry needs to increase by 161.68 km²/year and 336.35 km²/year, respectively, under the 5% and 10% decreasing cropland (net sown) area scenarios. 2. The carbon sequestration has been calculated using overall Maharashtra agro-forestry carbon density values from the previous literature. However, it is important to note that the sequestration potential may vary based on the selection of tree species and climate types. Therefore, we highly recommend the implementation of pilot-based studies to accurately evaluate the carbon sequestration potential of agroforestry, considering the diversity of tree species involved. This will enable a more precise assessment of the benefits offered by agro-forestry in sequestering carbon. 3. It is recommended that <i>ain</i> (<i>Terminalia tomentosa</i>), <i>kinjal</i> (<i>Terminalia paniculata</i>), teak (<i>Tectona grandis</i>), cashew nut (<i>Anacardium occidentale</i>), mango (<i>Mangifera indica</i>), and bamboo (<i>Bambusa arundinacea</i>) for agroforestry systems because of the financial implications and their acceptance among the farmers.	This will impact all the districts of Maharashtra.
3	Reduce livestock emissions by 10% by 2030.	1. The state shall focus on the central government's <i>Ration Balancing Scheme</i>, which helps reduce emission intensity per litre of milk. 2. The state shall invest in research and development for the feasibility and availability of feed additives that help in reducing enteric fermentation emissions from livestock. The state shall collaborate with ICAR, which has developed a special feed additive 'Harit Dhara' that can reduce emissions without compromising the milk yield. Other additives such as tamarind husk, tannins, and saponins have also been used to reduce emissions. 3. For the first phase (till 2030), the state shall target at least 50% livestock population to be covered under this target. 4. Manure management strategies such as timely removal of the manure and feeding it in an anaerobic digester can help in reducing both methane and nitrous oxide emissions.	All districts.

Implementing government departments	Financial implications	Outcome
The key implementing institution for this policy will be the Maharashtra Forest Department. (National Mission on Green India)	1. The combined cost of implementing the short-term target and forest regeneration efforts would amount to approximately INR 771 crore (INR 150 crore + INR 621 crore). 2. The estimated annual cost of expanding the forest and tree cover would amount to INR 387 crore, with an average cost of INR 30,000 per ha. By 2030, the total cost would reach INR 3,096 crore. The cost between 2019 and 2022 would be approximately INR 1,548 crore and should be taken into consideration.	1. It would contribute to an increase in carbon stock from 1.97 BtCO₂ to 1.99 BtCO₂. 2. By 2050, expanded forest areas are projected to contribute to a significant reduction of -38.66 MtCO₂. 3. The increase in forest coverage is expected to lead to substantial growth in carbon stock, from 1.97 BtCO₂ in 2019 to 2.93 BtCO₂ in 2050. 4. The estimated change in carbon stock over this period is 0.96 BtCO₂, highlighting the enduring benefits that can be achieved through sustained efforts in expanding forest coverage.
The key implementing institutions for this policy will be the Department of Agriculture, Government of Maharashtra, and Maharashtra Forest Department. (National Mission on Green India)	1. The cost of establishing <i>ain</i> and <i>kinjal</i> plantations in Maharashtra is approximately INR 35,000 per ha, which includes land preparation, planting, weeding, and fertilisers for the first year. Teak plantations in agroforestry cost around INR 1,00,000 per ha, including land, saplings, fertilisers and labour. The cost of cashew plantations ranges from INR 70,000 to INR 80,000 per ha, while establishing a mango plantation can cost between INR 1,45,000 to INR 1,72,000 per ha. Finally, the cost of establishing a bamboo plantation can range from INR 25,000 to INR 35,000 per ha. 2. The average cost of plantation per ha is taken to be INR 83,143, devoted equally to both short (10 years) and long (30 years) rotational periods, which would incur a total cost of INR ~9,409 crore for increasing by 16,168.3 ha per year and INR ~19,575 crore for increasing by 33,635.3 ha per year. This could be implemented through public–private partnerships. If 50% public–private partnership is expected, the total cost for increasing by 16,168.3 ha per year would be approximately INR 4,704 crore, while the cost for increasing by 33,635.3 ha per year would be around INR 9,787 crore.	1. In all cases, agro-forestry has a sequestration potential ranging from 8.24 to 17.13 MtCO₂ in 2070 under a short rotation period and from 21.32 to 44.36 MtCO₂ in 2070 for a long-rotation period. 2. Planting <i>ain</i> can result in a net income of INR 1,60,000 per ha per year after the fifth year, while planting <i>kinjal</i> can result in a net income of about INR 68,323 per ha per year. Teak wood can fetch a high price, with incomes ranging from INR 5,00,000 to INR 10,00,000 per ha after 15 to 20 years of plantation. Cashew yields can range from 600 to 800 kg per ha per year, with income ranging from INR 4,20,000 to INR 9,60,000 per ha per year. Mango yield can range from 10 to 20 tonnes per ha per year, with income ranging from INR 3,00,000 to INR 12,00,000 per ha per year. Finally, income from bamboo farming can range from INR 75,000 to INR 2,25,000 per ha per year depending on the species, diameter, and market demand.
The key implementing institution for this policy will be the Department of Animal Husbandry and Dairy.	As the feed might be available in the market at INR 6 per kg, the state might require a total of INR 9–10 crore to implement the intervention (for 50% of the livestock population). Also, subsidies could be provided to farmers to adopt these effective solutions on a wider scale. Manure management strategy: The cost of constructing a biogas plant is around INR 10,000–15,000. Maharashtra has 41,000 villages and 378 urban centres. So a total investment of INR 41–62 crore may be required for the intervention. The investment can also be looked at from a circular economy perspective, where the gas produced can be used by households as a renewable energy source and the composted manure can be used in organic farming.	As per ICAR, Hari Dhara can reduce methane emission by 17-20%. Similarly, tamarind seed husk also has the potential to reduce methane emissions by 18%. Feeding a balanced ratio to the livestock can reduce the emissions by 13.7% per litre of milk. Manure management practices can reduce methane emissions by 87% and nitrous oxide emissions by 16%.

S. no.	Recommendations/Targets	Actions to be undertaken	Geographic areas impacted
4	Reduce rice emissions by 10%	Rice emissions can be reduced by using different rice cultivation strategies, such as direct seeded rice (DSR) and system of rice intensification (SRI). To reduce the emissions from rice cultivation, 11%–43% of the area under rice cultivation should adopt alternate cultivation strategies	All districts (majorly Konkan, Western Maharashtra, Marathwada, and Vidarbha)
5	Reduce fertiliser emissions by 15%	Currently, 1.3% (2.24 lakh ha) of the net sown area (167.22 lakh ha) is under natural farming. Fertiliser emissions can be reduced by adopting organic farming or natural farming techniques. To reduce the fertiliser emissions by 15%, the state should convert 25 lakh ha to organic farming by 2030. The state should also conduct field experiments on the emission reduction potential of nano fertilisers and biofertilisers	All districts
6	Reduce crop residue burning by 80%	To reduce crop residue burning, effective management techniques can be used, such as mulching or using the residue as fodder or for biochar production and industrial use (gasification). The state might produce 34.88 million tonnes of sugarcane residue by 2030, which will be targeted under the national policy for crop management residue. Infrastructure and markets should be developed along with an awareness campaign to encourage farmers to use the residue on the farm or sell it across the market	All districts

The total overall financial outlay needed for implementing the recommendations for the entire Mitigation sector is INR 59377.4 crore.

Box - 7 Maharashtra's Climate Vision

As one of India's most industrialised, urbanised and developed states, it is imperative that Maharashtra leads the country's climate action. Being an engine of India's economic growth, Maharashtra aspires to be a trillion-dollar economy soon. However, this must be done in a sustainable way. While Maharashtra's partakes India's vision of realising net zero by 2070, as a progressive state, it also aims at striving towards realising the same by 2050. Globally cities are at the centre of climate change. It is remarkable that Maharashtra's 43 AMRUT cities participated in the UNFCCC supported 'Cities' Race to Zero Campaign' and are thereby already committed to realise net zero by 2050.

Source: Department of Environment and Climate Change, Government of Maharashtra

Implementing government departments	Financial implications	Outcome
The key implementing institutions for this policy will be the Department of Agriculture and Farmers Welfare, Environment and Climate Change department, and Maharashtra Pollution Control Board	The annual cost to develop one cultivar is estimated at INR 1.12 crore, which takes 5–6 years (ICAR 2023). Developing at least two cultivars may cost INR 2.24 crore. For demonstration projects for alternate cultivation strategies, Krishi Vikas Kendra may have one additional activity. The average operational cost incurred by one KVK in Maharashtra is estimated at INR 1.96 crore, under which they are mandated to perform 10 activities. We recommend one additional activity. For six irrigated rice districts, six KVKs may require INR 1.17 crore (irrigated districts include Nasik, Nagar, Pune, Satara, Sangli, and Kolhapur). Total INR 3.5 crore	Based on a few studies done in other states of India, alternate cultivation methods such as DSR have the potential of reducing emissions by 50%–62%, and SRI has the potential of reducing emissions by 45%–50% (followed by aerobic irrigation). Hence the state should invest in experimental field studies to understand the district- and state-level mitigation reduction potential and feasibility of DSR and SRI
The key implementing institution for this policy will be the Department of Agriculture	As per the Ministry of Agriculture and Farmers Welfare, the total financial assistance available for 20 ha will be INR 10 lakh for farmer members and INR 4.95 lakh for the mobilisation and participatory guarantee system (PGS). Hence, to mobilise 25 lakh ha, the government may require INR 18.68 thousand crore for the period 2023–30, with an annual figure of approximately INR 2,500 crore	Organic farming enhances the nutrient composition of the soil and improves the yield while reducing the usage of chemical fertilisers like urea, hence reducing fertiliser emissions by 15%. In some experimental research, nano fertilisers and biofertilisers have shown a 50% emission reduction when compared to conventional fertilisers
The key implementing institutions for this policy will be the Department of Agriculture and Farmers Welfare, Environment and Climate Change department, and Maharashtra Pollution Control Board	The budget required for training community resource persons has already been covered under agriculture adaptation. The monetary requirement for market linkage and creating market demand for crop residue is difficult as the idea of crop residue to BioCNG or biogas is at the nascent stage in India. Hence, it is difficult to estimate the budget. Based on the ICAR report, the per-state, per-year figure is INR 143.5 crore. The calculation has been finalised based on this annual figure	Crop residue emissions can be reduced by 80%–100% by 2030
Total budget =	Agriculture: INR 19,745.6 crore Forestry: INR 11,335 crore	

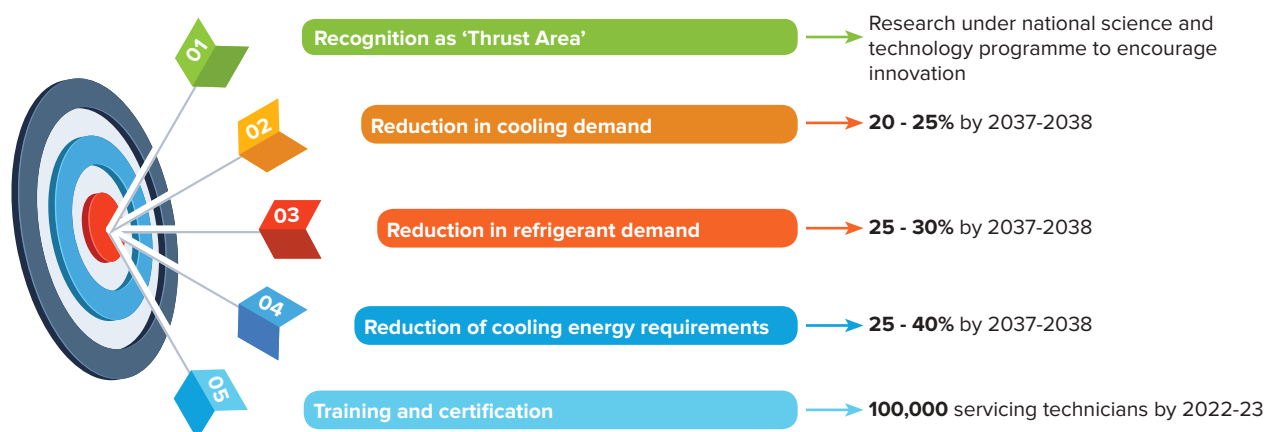
Chapter 7: Integrated cooling strategy for Maharashtra

7.1 Introduction

Despite global commitments under the Paris Accord to limit the rise in temperature to less than 1.5°C by 2100, the world is on track to face at least 2.5°C of warming (UNEP 2022). In 2022, India faced its warmest March since 1901 and its highest rainfall deficit since 1909, with Maharashtra reporting a 66 per cent rainfall deficit in the pre-monsoon months that year (IMD 2022). The IPCC estimates that, globally, hot-temperature extremes are likely to increase in intensity and frequency, a trend that can be ascribed to climate change (IPCC 2021). In preparing for rising temperatures, it is important for governments not just to manage heat through disaster-response mechanisms, but through long-term cooling strategies that build sustained resilience against heat.

Recognising this urgency, India became the first country to develop an integrated national cooling strategy by way of the India Cooling Action Plan (ICAP) in 2019. This was a first-of-its-kind initiative globally and projected an eight-time increase in the country's cooling demand between 2017–18 and 2037–38, going on to provide targets and sectoral recommendations to meet this demand equitably and sustainably. There is a need to translate this country-level plan into actionable state-specific strategies that lead to concrete action. This chapter seeks to highlight the importance of cooling as an adaptation and mitigation strategy against climate change for Maharashtra and the various policy recommendations that can be implemented to leverage the potential of this sector. It attempts to prioritise actions that can increase the adoption of energy-efficient and non-conventional energy-based technologies

Figure 7.1 Goals under the India Cooling Action Plan 2019



Source: Authors' compilation based on ICAP objectives

for space cooling and cold chain, in addition to ecosystem-based solutions to reduce ambient temperatures.

Sub-section 7.1 presents CEEW's modelling analysis and highlights the impact of rising temperatures on the cooling-energy demand in the state and the associated indirect emissions. This subsection also discusses cooling as a mitigation and adaptation strategy separately to lay out the different services provided by the sector that help increase the state's resilience against climate change. Given the state's socio-economic context and climatic vulnerabilities, it identifies space cooling and refrigeration as the two key sub-sectors that will require focused policy interventions due to their substantial impact on the thermal comfort and productivity of people, agriculture and allied sectors, and industry.

Sub-section 7.2 deals with space cooling in buildings; it begins by providing regional insights into the factors and districts in Maharashtra that are likely to drive the cooling demand in buildings. The section then proceeds to discuss the current policy gaps and respective recommendations that can mitigate energy consumption and indirect emissions from the rising demand for space cooling while increasing access to thermal comfort. It also discusses the existing policies that can be leveraged to accelerate the suggested recommendations.

Sub-section 7.3 discusses the importance of cold chain and refrigeration to increase the resilience of agricultural, marine, dairy, and pharmaceutical products to rising temperatures. It goes on to deeply analyse the diversity, geographical spread, and temperature sensitivities of agricultural produce in Maharashtra that depend on cooling while examining the weak links that must be bridged to create a well-connected and resilient cold chain for the state. The sub-section then identifies the gaps in the sector and proposes recommendations that can create the requisite capacity to install and operate cold storage. It also maps the policy levers and institutions that can implement the said recommendations.

7.1.1 Climate change and the need for cooling in Maharashtra

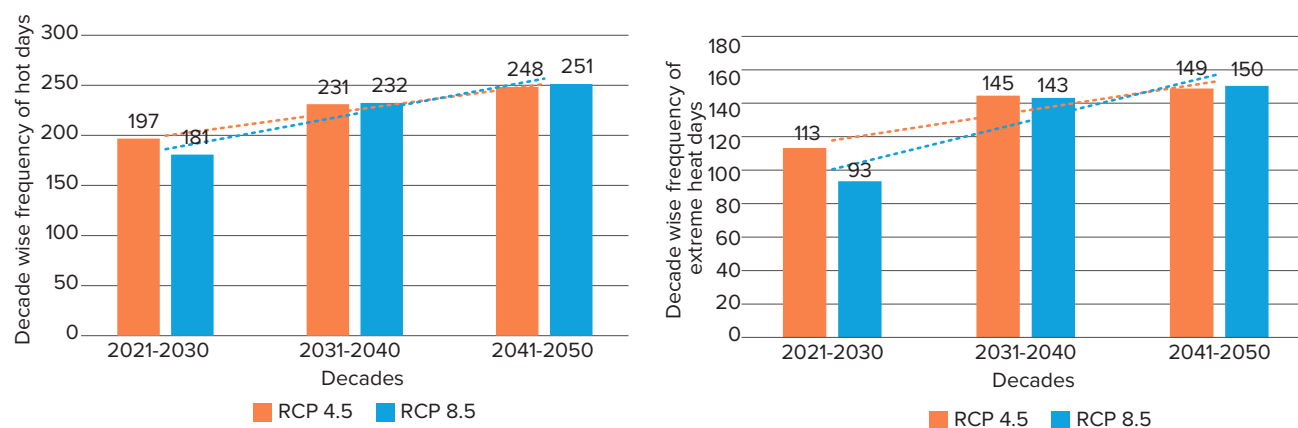
This sub-section discusses the historical trends and projections of rising temperatures in Maharashtra and the socio-economic context of the state, which necessitates cooling to build resilience against heat stress.

In 2022, Maharashtra was buffeted by prolonged heat waves, with the Marathwada and Vidarbha regions reporting among the highest temperatures in the country. CEEW's climatological assessment shows that there has been a near two-fold increase in the frequency of hot and extreme heat days in the past five decades, particularly from 2001–20. The graph in Figure 7.2 shows that while annual hot days have increased from 85–167 days between 1971–80 and 2011–20, the extreme heat days have increased from 21–50 days in the same period and the increase is likely to continue in the 2030s. Similarly, the decade-wise increase in the frequency of hot days is projected to increase from 197–248 days annually between 2021–30 and 2041–50 (RCP 4.5), while extreme heat days are likely to increase from 113–149 days in the same period.

The map in Figure 7.3 shows that in the past 5 decades, 30 districts of the state have shown a statistically significant trend of increase in the frequency of hot days, except Nandurbar and a few districts in Eastern Maharashtra. However, contrary to this historical trend, CEEW's analysis of the district-level projected trends shows that in terms of the maximum temperature, the highest increase is expected in eastern Maharashtra.

CEEW's climatological assessment shows that towards 2050 as well, annual average maximum and minimum temperatures across Maharashtra show a rising temperature trend across both low-emissions (RCP 4.5) and high-emissions (RCP 8.5) scenarios. This trend is consistent across the districts of Konkan, Amravati, Aurangabad, Nashik, Nagpur, and Pune, which stretch

Figure 7.2 Projected decadal total frequency of hot and extreme heat days in Maharashtra during the 2030s



Source: Authors' analysis

across all the four climatic zones of the state. As per CEEW's analysis, the five warmest districts are likely to be Chandrapur, Gadchiroli, Nandurbar, Yavatmal, and Gondia. These districts show the highest projected magnitude of increase in maximum temperatures, a trend consistent with current temperature forecasts for east Maharashtra. The highest annual magnitude of increase in the frequency of extreme heat days is witnessed in Sindhudurg (0.44 days increase per year), followed closely by Ratnagiri, Kolhapur, Pune, Raigad, and Mumbai.

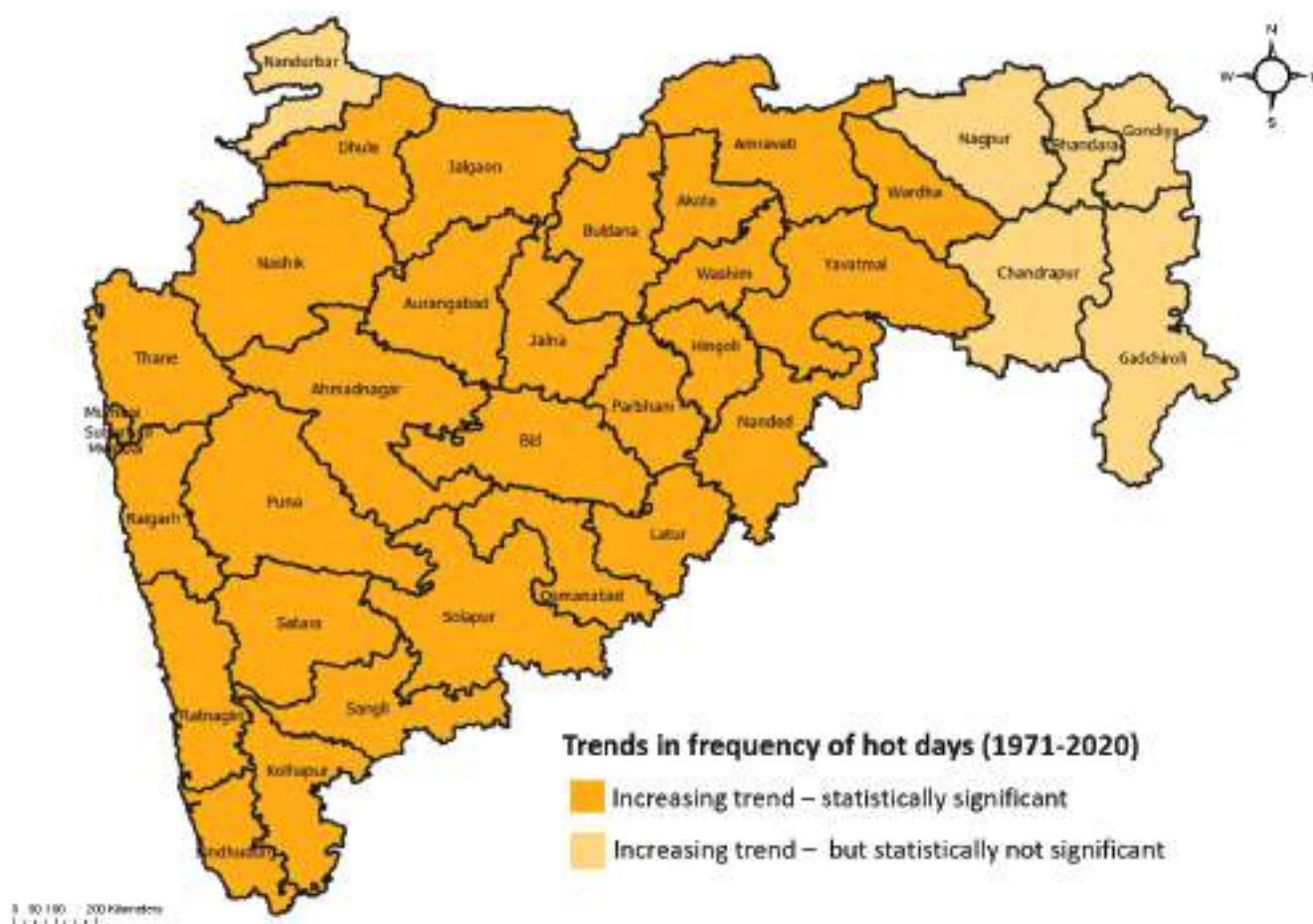
The state is also experiencing more warm nights, which is associated/associates with hotter days to create cumulative physiological stress on the human body and is known to exacerbate the top causes of death globally (WHO 2018). Warmer nights impact sleep and impair the recovery of the body from heat stress experienced during the day, which can impact productivity and health (Mizuno et al 2012). The phenomenon has been associated with the urban heat island effect in cities and therefore directly impacts the demand for air conditioning (Raj, Sarath et al 2020). CEEW's district-level analysis shows that more than 40 per cent of the districts are witnessing an increase in the frequency of warm nights, particularly in Konkan, Pune, and parts of Aurangabad, with a significant trend

also shown in urban areas such as Mumbai, Thane, Pune, and Nashik.

The first Maharashtra SAAPCC acknowledges that given the rising temperature projections, the demand for cooling and related energy requirements in the state is likely to increase. This is especially true for towns and cities with increasing population densities and urban infrastructure (GoM 2014).

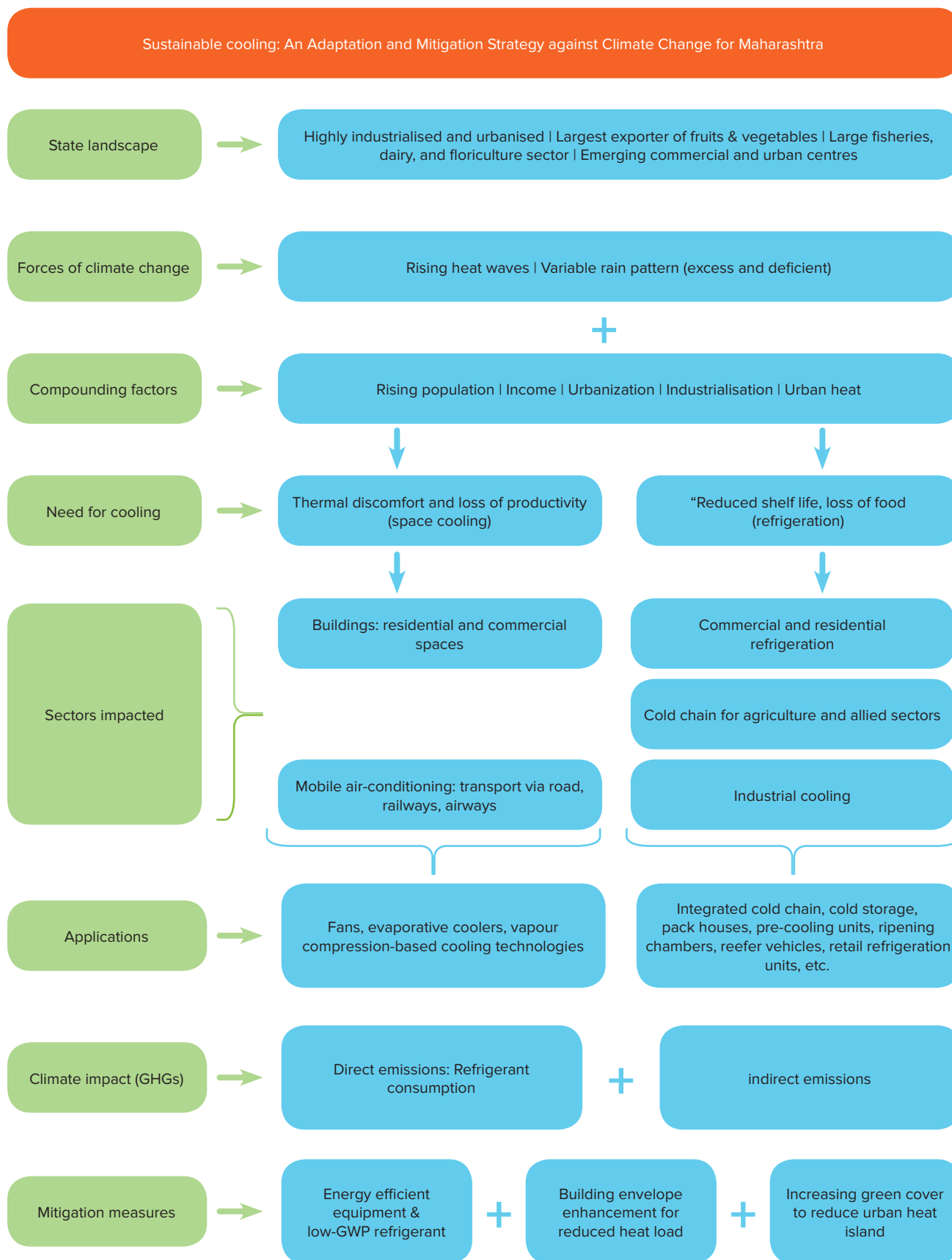
Maharashtra has the country's second-highest population, third-highest urbanisation levels, third-largest surface area, and high levels of industrialisation. The percentage share of the urban population in Maharashtra is increasing every decade, from 28.2 per cent in 1961 to 45.2 per cent in 2011, which is well above the national average of 31.1 per cent in 2011. This was characterised by an increase in the number of towns from 266–534, respectively, and an incremental increase in the per capita built-up floor space discussed in Figure 7.6. The rapid increase in building stock will create a significant demand for cooling the indoor building area, also known as space cooling. Maharashtra is also a leading producer and exporter of various fruits and vegetables, including mangoes, mandarins, onions, bananas, grapes, strawberries, and

Figure 7.3 District-wise trends in frequency of hot days during the historical period (1971–2020)



Source: Authors' analysis

Figure 7.4 Sustainable cooling as an adaptation and mitigation strategy against climate change in Maharashtra



Source: Authors' analysis

even flowers like roses, marigolds, carnations, etc. Nearly half of the state's population is dependent on agriculture and allied activities for their livelihood, with the sector contributing nearly 12 per cent to the state's GDP (GoM 2021). With the state's aspiration to become a trillion-dollar economy by 2025, the forces of industrialisation will also play a very important role in driving the demand for industrial cooling and the emergence of new urban clusters and residential complexes. Therefore, cooling is required not just for thermal comfort in the rapidly urbanising state, but also for preserving agricultural produce, fisheries, dairy, pharmaceuticals, and other industrial applications. Figure 7.4 captures the direct linkage between climate change and its impact on key sectors in Maharashtra wherein sustainable cooling will be an adaptation and mitigation strategy.

7.1.2 Sustainable cooling as a mitigation strategy

It is estimated that the energy demand from cooling (in BAU) across India will grow around 2.2 times the 2017 levels in 2027, while the cooling demand (in TR) is forecasted to grow by 3.1 times in the same period (BEE 2018). In 2027, space cooling in buildings will continue to occupy the largest share of energy consumption (57.31 per cent) and carbon emissions (60.51 per cent), followed by refrigeration and cold-chain applications (with energy consumption being 26.91 per cent and carbon emissions being 24.52 per cent respectively) (BEE 2018). Considering the nature of the service, in addition to the large share of energy consumption and carbon emissions, space cooling and refrigeration have been dealt with separately in this chapter to provide specific recommendations and regional insights for the state of Maharashtra.

Most cooling technologies consume refrigerants that have a high global warming potential (GWP). Containing the leakage or uncontrolled release of such refrigerants into the atmosphere will be important to mitigate global warming. In view of the scale, diversity, and ubiquity of cooling as an essential service across sectors, there is a need to mitigate its energy and emissions footprint.

7.1.2.1 Reducing energy consumption and emissions intensity

CEEW's modelling results project an increase in Maharashtra's per capita built-up area between 2020–30 to be from 1151.32–1778.92 million sq m. In view of the rising temperature trends discussed prior, this implies a consequent increase in demand for air-conditioned built-up spaces that will further lead to greater energy consumption for space cooling and secondary emissions from the energy consumed. These emissions are from the sources of electricity generation used in power-cooling applications, of which coal still occupies nearly

55 per cent of all fuels. On account of the large potential and increasing focus on solar energy in the state, this proportion will continue decreasing.

Therefore, this projected increase in cooling energy requirements must be absorbed by technologies and measures that optimise energy efficiency and reduce the demand for cooling.

7.1.2.2 Reducing refrigerant consumption

Another important aspect of the mitigation potential of the cooling sector is refrigerants. Apart from a few not-in-kind (NIK) technologies, the majority of air-conditioning units continue to operate on vapour-compression systems which employ refrigerants called hydrofluorocarbons (HFCs). These gases have a high GWP and are far more potent than carbon dioxide.

Due to various factors such as corrosion in the refrigerant pipe, improper installation, lack of regular preventive servicing, the use of improper tools for servicing, etc., damage may occur, which leads to leakage of the refrigerant. Some refrigerants have up to 4,000 times the potential to warm the atmosphere over carbon dioxide, and their leakage can therefore be detrimental.

Due to the demographic and socio-economic context discussed prior, a state like Maharashtra will play a key role in reducing the demand for refrigerants. Table 7.1 provides a snapshot of the refrigerants available in the market in various cooling applications and their corresponding GWPs.¹

As can be seen in Table 7.1, different variants of HFCs are used across different cooling applications and have varying GWPs. While the displayed share represents the stock of appliances in the market, there is a pre-existing installed stock of residential air-conditioners that are using R-22, a potent hydrocarbon with up to 1,780 GWP.

It is important to mention here that India is party to the Montreal Protocol for the Protection of the Ozone Layer, and has recently agreed to ratify the Kigali Amendment to the Protocol. This will imply that India must phase down the production and consumption of HFCs by 85 per cent by 2047. In view of the large levels of urbanisation and heat stress in the state, Maharashtra will have a significant cooling demand that can be absorbed by low GWP or natural refrigerant-based energy-efficient appliances. This will require timely policy interventions, targeted R&D, and strategic deployment, with schemes that will facilitate and incentivise efficient cooling technologies.

¹ While these are nation-wide figures, there is not much variation between states. This is because the products manufactured by the OEMs are designed to serve pan-India customers, and Maharashtra does not have a different mix of refrigerants in cooling appliances. These numbers are based on previous official estimates and subject to change.

Table 7.1 Cooling applications and the global warming potential (GWP) of refrigerants used

Cooling sub-sector	Cooling application	Refrigerant	GWP	Market share in 2017 (%)	BAU market share in 2027 (%)
Space cooling	Room air-conditioning	R-32	677	77	50
		R-410A	1,924	9	20
		R-22	1,760	14	20
		R-290	3	<1	10
	Packaged DX	R-32	677		15
		R-410a	1,924		85
	Scroll chillers	R-410A	1,924	95	100
		R-407C	1,624	5	-
	Screw chillers	R-134A	1,300	100	70
		R-513A	573	-	30
	Centrifugal chillers	R-134A	1,300	90	60
		R-123	1	10	-
		R-513A	573	-	10
		R-514A	2	-	10
		R-1233zd	1	-	20
	VRF systems	R 410a	1,924		100
Refrigeration and cold chain	Domestic refrigerators	R-134A	1,300	70	50
		R-600A	~20	30	50
	Deep freezers	R-404A	3,943	20	10
		R-134a	1,300	65	50
		R-744	1	5	10
		R-407A/410A	~1,924	10	30
	Cold storage	R-22	1,760	10	-
		R-134A	1,300		5
		R-717	<1	75	85
		R-404a	3,943		10
	Pack houses	R-134A	1,300	35	70
		R-22	1,760	30	5
		R-404A	3,943	35	25
	Reefer vehicles	R-134A	1,300	35	50
		R-407A/410A	~1,924	5	15
		R-404A	3,943	40	30
		R-22	1,760	20	5
	Ripening chamber	R-134A	1,300		35
		R-404A	3,943		35
		R-22	1,760		30

Source: Bureau of Energy Efficiency 2018, Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5) 2014

7.1.3 Cooling as an adaptation strategy

Climate change is expected to increase the heatwave duration (HWD) in India by 4–7 days per decade (NCDC 2022). This in turn will increase the incidence of heat-related illnesses (HRI) and heat-related deaths. As per statistical estimates, the extreme heat days in 21 out of the 36 districts in Maharashtra have been on the rise between 1971–2020.

Do you know? Estimates suggest that in the absence of adequate measures to provide space cooling for thermal comfort, India could lose up to 34 million jobs or USD 450 billion in revenue by 2030 due to fall in productivity levels.

Table 7.2 Sectoral applications of cooling to increase adaptive capacity

Cooling sectors	Sub-sectors	Applications
Space cooling	Buildings	Space cooling in residential and commercial buildings for maintaining the thermal comfort and productivity of occupants.
	Transport	Comfort cooling for passengers (trains, planes, cars, etc.).
Cold chain and refrigeration	Commercial and residential refrigeration	Refrigeration or cooling of perishable edibles like dairy products, bread, cooked food, packaged food, medicines, water, etc.
	Cold chain	Refrigeration of post-harvest produce (fruits, vegetables, flowers, etc.) sensitive to temperature and relative humidity.
	Industry	Air-conditioning or refrigeration needs in food processing, dairy, pharmaceuticals, breweries, etc.

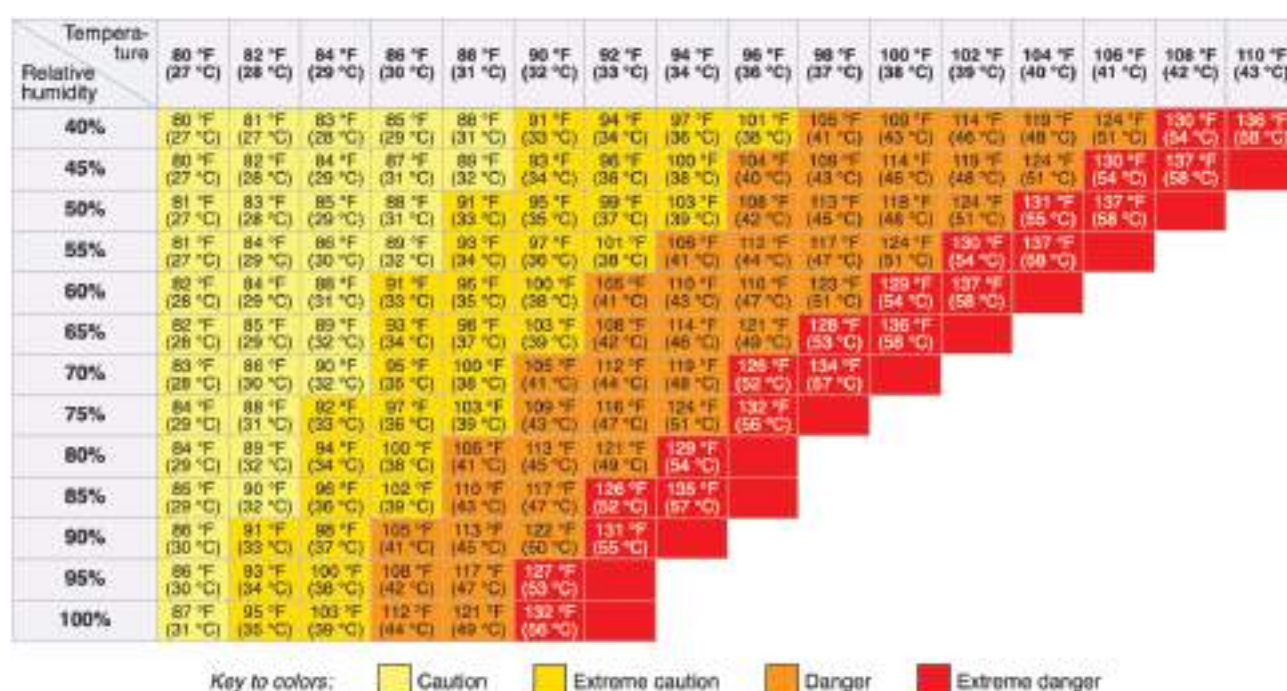
Source: Authors' analysis; Bureau of Energy Efficiency 2018

Thermal comfort is essential for maintaining the health and productivity levels of the population. In Maharashtra, the months from March–June remain extremely hot, with relative humidity worsening conditions upon the onset of monsoon. The heat index temperature matrix prepared for Maharashtra in the first SAPCC integrates relative humidity (RH) and temperatures to indicate human comfort levels and documents the high vulnerability of its populations at different combinations of temperature and RH ranges experienced in the state (TERI 2014). As per the matrix, temperatures over 40°C could actually feel like 57°C when experienced with higher humidity levels. In April 2022, 15 districts out of the 27 places in Maharashtra where IMD records day temperatures recorded temperatures of over 40°C (ToI 2022). In the absence of appropriate interventions, these conditions of heat stress will be exacerbated due to the urban heat island effect in an increasingly urbanised state. To increase the adaptive capacity of people towards heat, various passive and active cooling strategies will be necessary and have

been discussed later in this chapter. In view of the rising temperatures in the state, cooling will increase resilience across its various applications in buildings, transport, refrigeration, cold chain, industry, etc.

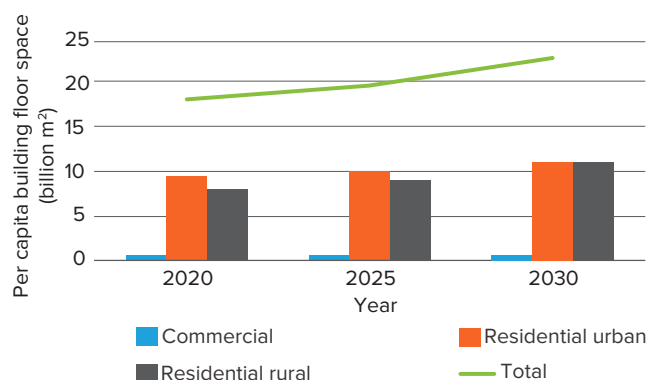
In the agriculture sector, the Asian Development Bank estimates that as much as 30 per cent of fruits and vegetables are lost in Maharashtra due to a lack of adequate post-harvest infrastructure, a range higher than the national average of 4.6–15.9 per cent (ADB 2020). In view of the existing losses and the potential impact of rising temperatures on the shelf life of produce, robust cold-chain infrastructure will be a key adaptation strategy for the state's agri-economy. With over 50 per cent of the state's population dependent on agriculture and its allied sectors (GoM 2022), strengthening post-harvest cold-chain infrastructure will also help in 'doubling farmers' income' by strengthening backward and forward linkages. Table 7.2 provides a snapshot of the various sectors that depend on cooling and describes how cooling improves

Figure 7.5 Heat index



Source: National Oceanic and Atmospheric Administration 2020

Figure 7.6 Maharashtra's per capita building floor space (2020–30)



Source: Authors' analysis

adaptive capacity by providing thermal comfort or reducing loss to fresh produce or processed products.

With this foundation of the inter-sectoral mitigation and adaptation potential of sustainable cooling, the following sections dive into the policy recommendations that can provide sustainable cooling for all people and sectors in Maharashtra.

7.2 Space cooling for thermal comfort and productivity

In terms of national projections, the space-cooling sector is expected to grow 11 times (tonnage of refrigeration) by 2037–38 vis-a-vis the overall national cooling demand that is set to increase by 8 times (ICAP 2019). It is estimated

that 50 per cent of the building stock that is to come up by 2030 is yet to be constructed (BEE 2022).

Even though the penetration of air conditioners in India is estimated at 8 per cent, this number is gradually increasing with rising incomes, aspirations, and temperatures, and is expected to be 15 per cent in this decade in a high-growth scenario (ICAP 2019). Among refrigerant-based cooling technologies, room air conditioners will continue to be the dominant appliance throughout this decade, while fans and air coolers will continue to enjoy higher penetration in both rural and urban areas (ICAP 2019).

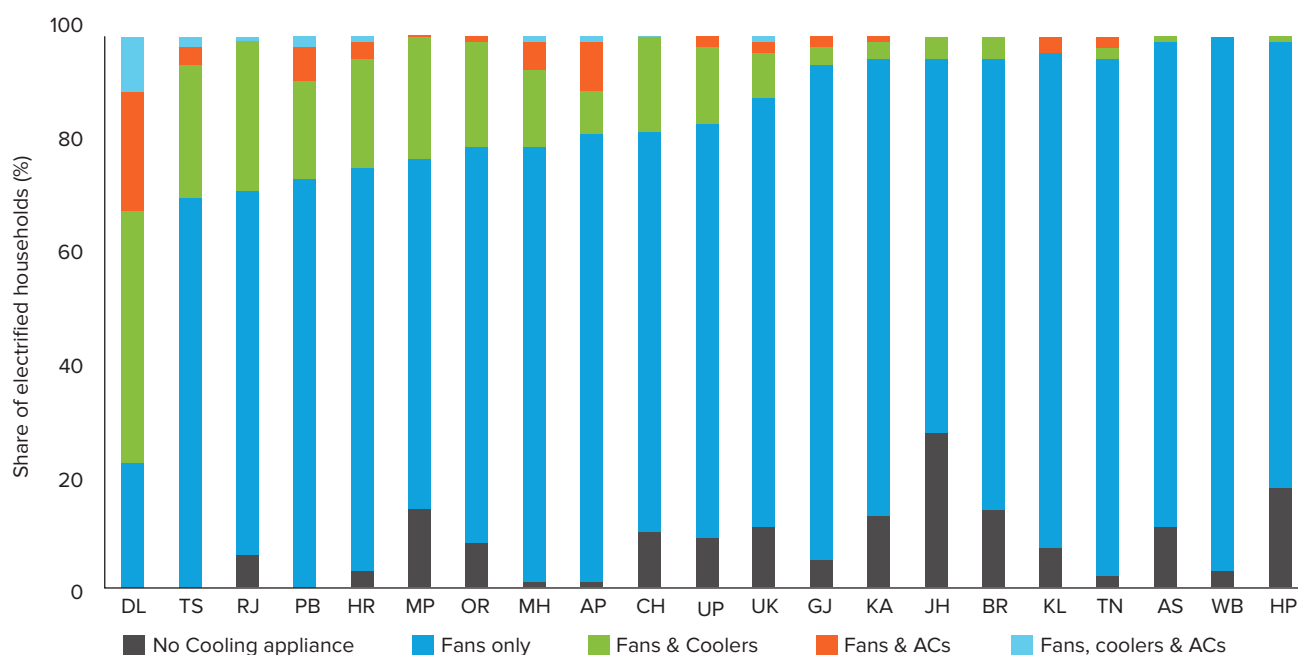
7.2.1 Regional insights

Maharashtra is divided into four climatic zones, namely, Konkan, Madhya Maharashtra, Marathwada, and Vidarbha. Eastern Maharashtra, specifically Vidarbha, has reported the highest temperatures, while Marathwada has been the most drought-hit across the state. While the penetration of cooling appliances is set to rise, it will be useful to focus on areas that have rising projections of hot weather extremes and warm nights, in addition to levels of high population density and urbanisation.

The percentage share of the urban population in Maharashtra is set to grow from 45.8 per cent in 2011–15 to 51.3 per cent in 2031–35 while reporting the highest urban population in the country by 2026 (MoHFW 2020). Unlike most other states, rapid urbanisation in Maharashtra is not confined to a few cities, which implies the emergence of multiple urban centres outside Mumbai and Pune.

The rise in urban populations will boost real-estate demand, accompanied by a rise in demand for cooling, especially in hot urban clusters where the heat is exacerbated by

Figure 7.7 Penetration of fans, coolers, and ACs in India's electrified households



Source: India Residential Energy Survey, CEEW, 2020

the urban heat island effect. The heat is compounded by overcrowding in slums and squatter settlements, especially in municipal corporation areas. Therefore, there will be greater demand for cooling in urban areas in Maharashtra and this demand must be met sustainably. Space-cooling applications in the commercial sector are more energy intensive due to longer operational hours.

As per the India Residential Energy Survey (IRES) conducted by the CEEW, it was found that the state has a high penetration of fans (CEEW 2020). Due to the state's largely humid climate, the penetration of air coolers is comparatively less. Figure 7.7 shows the penetration of different cooling appliances in Maharashtra's electrified households vis-a-vis other states, and highlights that the focus on energy-efficient fans must be a key pillar of the state's cooling strategy.

Mumbai, Thane, Pune, and Nagpur have the highest urbanisation levels across the state. Per the 2011 population census, the districts of Mumbai City and Mumbai Suburban have the highest population density of 19,652 and 20,981 persons per sq km respectively (refer to Table 7.3). The city's share in the country's real-estate absorption rate is nearly 32 per cent, making it one of the largest property markets. By virtue of being the commercial capital of India, the city is also a driver for employment, which in turn boosts demand for property. Therefore, up to 60 per cent of the summer peak load in cities like Mumbai is due to room air conditioners (ACs) (Daikin 2022). Mumbai will therefore be a priority area of intervention for replacement schemes that can replace inefficient cooling systems and retrofit inefficient building stock to increase energy efficiency and reduce thermal transmittance.

The million-plus cities with high urbanisation levels like Mumbai, Pune, Thane, Nashik, Nagpur, and Aurangabad must have aggressive interventions to increase penetration of energy-efficient cooling systems in addition to other passive cooling measures. At the same time, there is a need to also take timely measures in districts reporting a significant decadal increase in urbanisation, such as Amravati, Chandrapur, Raigad, Kolhapur, Solapur, Jalgaon, and Akola. This is important to avoid lock-in of inefficient cooling appliances for another decade going forward. Appended in Table 7.3 is a snapshot of districts with urbanisation levels nearly equal to or higher than the state average, as well as emerging districts with rising levels of urban growth.

CEEW's climatological analysis identified districts and certain parts thereof with dry climates, which is conducive to the use of evaporative coolers over ACs. These areas include the semi-arid portions of Jalgaon, Nashik, Aurangabad, Pune, Beed, Satara, Osmanabad, and Kolhapur, and almost the whole of the Dhule, Nandurbar, Ahmednagar, Solapur, and Sangli districts. These technologies may not be very effective in the highly humid Konkan belt, which is also highly urbanised with greater penetration of ACs. The hot-dry and composite areas of Maharashtra provide the ideal conditions for evaporative coolers.

The advantage of using evaporative coolers is that they can be up to 80–85 per cent cheaper than ACs and use 80–90 per cent less energy while also using water as a natural refrigerant as compared to artificial refrigerants with GWP (AEEE 2021). Among the various types of air coolers, indirect evaporative coolers (IECs) will be the

Table 7.3 Districts with high levels of urbanisation

S. no.	District	Urbanisation levels (in per cent)		Population density	Decadal Growth (in per cent)
		2001	2011		
1	Mumbai Suburban	100.00	100.00	20,980	8.29
2	Mumbai City	100.00	100.00	19,652	–7.57
3	Thane	72.58	76.98	1,157	36.01
4	Nagpur	64.25	68.31	470	14.40
5	Pune	58.08	60.99	603	30.37
6	Aurangabad	37.52	43.77	366	27.76
7	Nashik	38.79	42.52	393	22.30
8	Akola	38.49	39.67	320	11.27
9	Raigad	24.22	36.83	368	19.31
10	Amravati	34.51	35.91	237	10.79
11	Chandrapur	32.11	35.17	193	6.43
12	Solapur	31.82	32.41	290	12.16
13	Kolhapur	28.81	31.73	504	10.01
14	Jalgaon	28.58	31.74	360	14.86

Source: Census 2011

most effective in the districts mentioned. This is because IECs do not add humidity to the supply air while still managing a reduction in enthalpy and dry- and wet-bulb temperatures. As for commercial and industrial sectors in the aforementioned parts of the state, direct–indirect evaporative coolers (IDECs) will be the best option as the most energy-efficient variant of coolers.

Aurangabad has been identified as one of the fastest-growing cities in the world in terms of investment and growth potential, with Mumbai–Aurangabad recognised as the centre of the most suitable production units for information and computer technology (ICT), textile, pharmaceutical and mechanical (News NCR 2022). Other state-level developments that will trigger the emergence of new urban and commercial centres and the subsequent demand for cooling include the upcoming D. B. Patil International Airport at Navi Mumbai, the Mumbai Trans Harbour Link

(MTHL), *Samruddhi Mahamarg*, and rapid growth in municipalities including Vasai Virar, Kalyan-Dombivali, Mira-bhayandar, Ulhasnagar, Panvel, etc. Maharashtra also has a rapidly expanding tourism sector, with the state having the highest number of foreign tourists and the fifth-highest number of domestic tourists in the country in 2021 (GoI 2022). This associated demand for air-conditioned residential and commercial buildings must also attract targeted interventions. These emerging developments will be the low-hanging fruits where following the below listed recommendations of sustainable cooling can be prioritised.

7.2.2 Recommendations

Appropriate interventions in both active and passive space cooling will be key to helping Maharashtra deliver its sustainable cooling transition as a strategy against rising temperatures.

Table 7.4 Gaps and recommendations for sustainable space cooling in Maharashtra

S. no.	Target	Reduce state-level energy consumption from cooling by 15%
1	Actions recommended	Replacement or retrofitting of inefficient cooling equipment.
	Existing gap	It was found that only 48% of households in Maharashtra are aware of the BEE's star labelling scheme (CEEW 2020). Old ACs running beyond the prescribed life of 10 years, or inefficient fans, continue to operate in many public and private buildings in Maharashtra. This increases energy consumption and indirect emissions. Consultations revealed that replacement or retrofitting programmes with a focus on cooling are yet to gain momentum in the state.
	Focus districts	Districts with high urbanisation rates and population density: Mumbai, Thane, Nagpur, Pune, Aurangabad, Nashik.
	Implementing agencies	Nodal agency: Maharashtra Energy Development Agency (MEDA), Maharashtra State Electricity Distribution Co. Ltd. (MSEDCL), Energy Efficiency Services Ltd. (EESL), Refrigeration and Air-Conditioning Manufacturer's Association (RAMA).
	Financial implications	The total estimated cost of replacement in Phase 1 (FY 24–25) of the replacement cycle will be c. INR 32,25,37,737 for replacing 30,466 units. The total estimated cost of replacement in Phase 2 (FY 26–27) of the replacement cycle will be c. INR 35,55,97,855 for replacing another 30,466 units. ² The Maharashtra green cess fund may be utilised for this purpose.
	Outcome	MEDA has piloted demonstration projects on the replacement of inefficient appliances in 18 buildings with an estimated energy-saving potential of 7,83,240 kWh per year. More such projects will reduce the cooling load in new buildings.
2	Actions recommended	Mandate public procurement of only 5-star rated or super-efficient cooling appliances.
	Existing gap	The current mandate is to procure only star-rated appliances, as opposed to 5-star-rated or super energy efficient appliances.
	Focus districts	State-wide new government buildings.
	Implementing agencies	MEDA, Department of Urban Development (UD), Public Works Department (PWD), Maharashtra Housing and Area Development Authority (MHADA), Energy Efficiency Services Ltd. (EESL).
	Financial implications	The cost of installing 10,000 super-efficient BLDC fans installed in upcoming government infrastructure in the state is estimated at INR 2,06,31,400/- on current market prices. Similarly, the cost of installing 1,000 new super-efficient 1.5 TR split ACs is estimated at INR 3,55,18,000/-. ³
	Outcome	Bulk purchase of super-efficient cooling appliances will help reduce costs for manufacturers and decrease energy consumption from cooling.

² Here, it is assumed that there is a 5 per cent penetration of room ACs (CEEW 2020) in Maharashtra's total electrified households as of 2021–22, with 16.36 per cent of installed stock between 10–14 years of age. The cost of a 30 per cent discount offered per unit of the new 1.5 TR split 5-star AC has been computed along with installation charges of INR 1,200 per unit. 14 per cent GST has been reduced and the compounding rate of inflation has been used to assess costs for Phase 2.

³ Cost estimates are sourced from the EESL online mart and 14 per cent GST has been deducted (EESL 2022).

S. no.	Target	Reduce state-level energy consumption from cooling by 15%
3	Actions recommended	Create a 'Comprehensive Capacity Building and Training Strategy for Energy Efficiency and Thermal Comfort' and train 5,000 service technicians by 2027.
	Existing gap	Consumers: There is a greater need for informing consumers about the environmental and economic savings from energy-efficient cooling appliances. This can be done at the point of purchase through improved retailer training and via social media. Consumers also need to be informed about good-use practices, such as operating fans while running the AC, running the AC at 24°C or above, and servicing the unit at least twice a year. <i>Mahaurja</i> uploaded a film on energy conservation earlier this year 2020 on its YouTube channel, which has only managed to garner a little over 200 views (GoM 2023). This shows the need for a social media outreach strategy that informs the department's digital strategy to nudge consumer behaviour. Technicians: For maintaining optimal levels of energy efficiency, proper installation, operationalising, servicing and repair of ACs, and use of good servicing practices (GSPs). Building professionals: Architects, home-loan executives, consultants, builders, contractors, etc., must be trained about 'net-zero' or 'net-positive' energy buildings, ECBC compliances, as well as various HVAC installations and sustainable building materials and practices.
	Focus districts	State-wide, with a greater focus on districts with urbanisation rates near or above the state average, with a specific focus on million-plus cities: Mumbai, Thane, Nagpur, Pune, Aurangabad, Nashik, Akola, Raigarh, Amravati, etc.
	Implementing agencies	MEDA, electricity distribution companies, Department of Education, Resident Welfare Associations, Confederation of Real Estate Developers' Associations of India (CREDAI), Employment, Entrepreneurship, & Innovation, Maharashtra State Skill Development Society (MSSDS), District Skill Development Committees, Regional Directorate of Skill Development and Entrepreneurship, Electronic Sector Skill Council of India (ESSCI), Refrigeration and Air-conditioning Trades Association (RATA). Integrate with the National Mission for Enhanced Energy Efficiency.
	Financial implications	Phase I of training 5,000 service technicians (FY24–25): Total cost of training kits to be used during the training is INR 18,00,000 and the total cost of training 5,000 service technicians is estimated at INR 1,32,00,000; this brings the total one-time training cost to INR 1,50,00,000. If the same programme must be conducted in Phase II (FY 25–26) as a refresher course with updated market and technology developments, the cost is estimated at INR 1,65,37,500. ⁴
	Outcome	Training building professionals will be crucial to ensure the early integration of energy-efficiency principles in the planning, design, construction, operation, and maintenance stages of even those building complexes that do not fall within the ambit of the ECBC and ENS. Technician training will improve installations, reduce refrigerant leakage, and help maintain optimal efficiency levels, while strategic and continuous consumer education will help nudge behaviour towards the adoption of efficient cooling units.
4	Actions recommended	Conduct studies: (1) Impact assessment study of the Buildings Energy Efficiency Programme (BEEP); (2) Feasibility study for district cooling systems and support pilots to demonstrate viability.
	Existing gap	There is currently no district cooling project in Maharashtra despite an understanding of its immense mitigation and adaptation potential. District cooling technologies can reduce primary energy consumption by up to 25% (EESL 2021) and reduce peak power demand; they are highly versatile in terms of integrating renewable energy due to thermal storage technologies. An impact assessment study of the BEEP carried out in Maharashtra is required to analyse the wins and the challenges in retrofitting energy-efficient air-conditioners in government buildings across the state and for replicating the blueprint for Phase II of the programme, which is likely to start post-2023.
	Focus districts	The scope of the study will be state-wide.
	Implementing agencies	Study 1: Maharashtra Energy Development Agency (MEDA), Greentech Knowledge Solutions Pvt. Ltd., State ECBC Cell, etc. Study 2: Maharashtra Energy Development Agency (MEDA), Refrigeration and Air-conditioning Manufacturers Association (RAMA), Indian Society for Heating, Refrigeration, and Air-conditioning Engineers (ISHRAE).
	Financial implications	To be assessed at the time of drawing out the scope of the study; tentative budget of INR 50 lakh.
	Outcome	Improved understanding of feasibility and locations for installation of district cooling systems will prevent lock-in of less-efficient cooling technologies and reduce indirect emissions.

⁴ This assumes the cost of training one person per training to be INR 2,500, in addition to a one-time training kit per district at INR 50,000. This does not include the cost of training the assistant accompanying the technician.

S. no.	Target	Reduce state-level energy consumption from cooling by 15%
5	Actions recommended	Timely notification of amended ECBC in unified municipal bylaws and creating ECBC cells/ appointing officers at the district level.
	Existing gap	In line with the model ECBC 2017, the Government of Maharashtra vide notification dated 22.08.2019 has submitted the draft Maharashtra <i>Energy Conservation Building Rules 2019</i> for inputs from stakeholders. The amended and updated rules are yet to be notified in the state, which will be necessary to increase the adoption of energy-efficient and thermally comfortable buildings. The revised technical committee has been formed in March 23 under the chairmanship of the principal secretary (UDD) to review the draft and accelerate the process. Creating capacity at ULB levels will be key for effectively implementing and operationalising the code once it is finalised.
	Focus districts	State-wide implementation.
	Implementing agencies	Department of Energy, MEDA, State ECBC Implementation Committee, State ECBC Cell, Department of UD, municipal corporations, ULBs, Rural Development and Panchayati Raj, Confederation of Real Estate Developers' Associations of India (CREDAI), Department of Industries, green building rating agencies.
	Financial implications	To be determined based on the pay scale applicable and the number of officers to be deputed.
	Outcome	The district-wise ECBC cell/officers will help monitor and enforce compliance with the codes and discharge functions of data collection, empanelment and capacity building of energy auditors, etc. This will ensure that all government departments commissioning, constructing, operating, maintaining, or regulating any building or building complexes prioritise the principle of 'energy-efficiency as first-fuel', facilitate inter-departmental coherence, and influence the purchases, investments, incentives, capacity building, and budgetary decisions made at all levels of government.
6	Actions recommended	Integrate thermal comfort and energy efficiency in affordable group housing schemes and incentivise uptake in buildings beyond the ECBC threshold.
	Existing gap	The existing projects under the <i>Pradhan Mantri Awas Yojana</i> in the state do not integrate energy-efficient and thermally comfortable building envelopes in affordable housing schemes to reduce the cooling load of the built environment. Many redevelopment projects in the state such as slum rehabilitation, chawl redevelopment, and group housing for LIG and EWS have significant potential that must be tapped to avoid lock-in of inefficient building stock for another 40–50 years.
	Focus districts	State-wide applicability.
	Implementing agencies	Department of Urban Development, Department of Rural Development, and Panchayati Raj, Maharashtra Housing and Area Development Authority (MHADA), City and Industrial Development Corporation (CIDCO), Slum Rehabilitation Authority (SRA).
	Financial implications	To be determined based on the choice of building materials used as per the PWD schedule of rates.
	Outcome	Provide thermal comfort by reducing the cooling load of buildings, especially for EWS and LIG.
7	Actions recommended	Greater integration of cooling solutions and passive solutions like cool roofing in town planning to reduce the urban heat island effect.
	Existing gap	Given the state's high level of urbanisation, stakeholders shared that natural methods that reduce surface temperatures will play an important role to reduce the urban heat island effect. The state is developing 'Nagar Van' as urban forests in two cities of Warje (Pune) and Korari Road (Nagpur), and there is scope for wider implementation. There is also a need for a more focused approach towards cool roofing solutions that can reduce indoor air temperatures by 2.1–4.3°C at low upfront costs and maintenance, with a reduction in energy costs of up to 20%.
	Focus districts	State-wide, with a greater focus on emerging heat-stressed regions and urbanising clusters like Mumbai, Pune, Aurangabad, Thane, Nashik, Akola, Raigarh, Amravati, Chandrapur, Nagpur, etc.
	Implementing agencies	Department of UD, Rural Development and Panchayati Raj, Forest Department, Horticulture Department, ULBs, PWD. Integration with National Mission on Sustainable Habitat.
	Financial implications	To be determined based on the type of intervention.
	Outcome	Reducing urban heat island effect, which reduces surface temperature.
	Total budget outlay	INR 77,08,22,492 + budget for recommendations no. 5, 6, and 7 are to be determined as per project details.

Source: Authors' analysis

7.2.3 Policy enablers

7.2.3.1 Save Energy Programme

MEDA has implemented energy conservation programmes in different sectors, reporting an energy savings potential of 77.09 Million Units (MU) per year. During FY 2021–22 around 231 proposals have been received by MEDA divisional offices under this programme, which includes the following components:

(i) State Energy Audit Programme

Up to March 2022, a total of 1,851 energy audits have been carried out in various sectors, which have helped facilitate substantial energy savings in the audited industries. Similar audits in buildings falling under the ECBC threshold will be crucial for continued operational savings.

(ii) State Energy Conservation Awards

To promote energy conservation and energy efficiency in all potential sectors (including cooling) in the state, MEDA conducts the annual state-level Energy Conservation and Management Awards and invites applications for participation in the award from around 20 different sectors. The evaluation criteria assess the energy conservation measures implemented and savings accrued, as well as the investments made in energy conservation measures.

(iii) Public awareness programmes

Under the BEE programme, awareness amongst school children by way of establishing energy clubs, organising debates, quiz programmes, etc. is being carried out. MEDA has established a total of 533 energy clubs to date. Through these established energy clubs, various energy conservation-based programmes are organised. To pave the way for ECBC implementation, MEDA has conducted 33 webinars/workshops for different stakeholders in the state including govt officers from all ULBs, town planning departments, PWD departments, architects, engineers, environment consultants, manufacturers, students, etc. All this data has been obtained from the department. The MEDA has implemented energy-efficient activities in 301 schools, with an estimated energy savings potential of 3,79,582 kWh/year and a CO₂ reduction potential of 916 tonnes per year.

(iv) Strengthening state-designated agencies

Under the umbrella scheme 'Promoting Energy Efficiency activities in different sectors of the Indian Economy', an important component is the 'strengthening of SDAs to promote efficient use of energy and its conservation at state level'. This scheme has been approved by the Ministry of Power with the objective to enhance the institutional, technical, and financial capacity of the SDAs for undertaking energy-efficiency activities.

(V) Initiatives for the replacement of inefficient cooling appliances

- Model village initiative: The objective of this component is to make villages more energy efficient by replacing existing old inefficient equipment, including cooling equipment like fans, with energy-efficient BEE star-labelled equipment/appliances in Panchayat Bhawans, community centres, schools, hospitals, etc. This is a simple upgrade which can be leveraged to increase penetration of high star-rated BLDC fans and ACs as required. Covering about 13 villages across different appliances, including cooling appliances, the collective annual mitigation potential is about 6,06,429 kWh/year in addition to 466 tonnes of CO₂.
- Government schools: To date, MEDA has implemented energy-efficient activities in a total of 301 schools. The estimated energy saving potential will be 3,79,582 kWh/year and a CO₂ reduction of 916 tonnes per year.
- Replacement in hospitals: Implementation of energy-efficient demonstration projects in government hospitals comes under the *National Mission for Enhanced Energy Efficiency* (NMEEE) of the BEE scheme. Based on the detailed energy audit of 31 government hospitals, the demonstration project of the replacement of existing inefficient appliances with energy-efficient appliances has been completed in 31 government hospitals. The estimated energy savings potential will be 33,223 kWh per year and the CO₂ reduction will be 27.45 tonnes per year.

7.2.3.2 Infrastructure development projects

The following projects will be straightforward opportunities to integrate energy-efficient cooling systems like district cooling, promote increased penetration of energy-efficient cooling appliances, and ensure that the building stock under construction is compliant with the highest standards of thermal comfort and energy efficiency.

(i) Demonstration projects for energy conservation in buildings of government/semi-government/urban local bodies:

MEDA is trying to promote energy-efficient building designs by piloting them through energy-conservation demonstration projects, i.e., buildings constructed for government, semi-government, and urban local bodies. Under this programme, financial assistance is being provided of up to INR 25 lakh per building and has already been extended to a total of 113 buildings up till March 2022. The programme has reported an energy savings potential of up to 12.96 MUs per year and a CO₂ reduction potential of up to 10,627.2 tonnes per year.

Based on the detailed energy audits of six government and semi-government buildings, the demonstration project of

the replacement of existing inefficient appliances with energy-efficient appliances is completed in five buildings and work is under process at one building. The estimated energy saving potential will be 1,56,478 kWh per year and CO₂ reduction will be 128.311 tonnes per year. Details are shown in Table 7.5.

The PWD has also worked with the EESL to replace over 3,000 and 1,47,000 old and inefficient ACs and fans, respectively, in non-residential buildings with energy-efficient units. Hybrid solar ACs have been integrated into some projects, while others are deploying energy-efficient BLDC fans and green building standards. All new projects of the department are being fitted with energy-efficient cooling installations. This demonstrates that the principle of energy efficiency is a priority across the department's projects in the state.

(ii) Pradhan Mantri Awas-Yojana – Urban and rural

Being a central scheme, re-alignment will be required to position this not just as an affordable housing scheme, but an 'energy efficient affordable housing scheme'. Integration of pre-fitted super energy-efficient cooling appliances like BLDC fans or ACs (as appropriate) in affordable housing schemes combined with innovative financing models like on-bill financing could have a high impact. Ensuring compliance of this large building stock with the highest standards of thermal efficiency can ensure large parts of the new building stock to be resilient to heat while reducing cooling demand. A re-imagination of the scheme in the second edition of the PMAY will be crucial.

This is specifically true for Maharashtra, as it has the highest investment of any state in PMAY(U) at INR 1,88,324.62 crore (GOI 2022). Moreover, the percentage of houses which need to be constructed under AHP (Affordable Housing in Partnership) and ISSR (In-situ Slum Redevelopment) is the highest in Maharashtra in the country. The GoM also launched a 100-day campaign titled *Maha Awaas Abhiyaan* to accelerate the implementation of all rural housing programmes, including this mission.

(iii) Atal Mission for Rejuvenation and Urban Transformation (AMRUT)

In 2021, the GoM launched AMRUT 2.0. across all cities till FY 2025–26. This scheme will be crucial in increasing green spaces in urban areas and reducing the UHI, as developing green areas in cities, rejuvenating water sources, planting more trees, as well as undertaking afforestation in peri-urban areas are actions envisaged under it. Its coverage spans all cities across Maharashtra, and it, therefore, has a high potential to mainstream ecosystem-based solutions for reducing the impact of heat extremes in urban environments.

(iv) Shyama Prasad Mukherji National Rurban Mission

Launched in 2016, the Shyama Prasad Mukherji Rurban Mission (SPMRM) is a centrally sponsored scheme to develop nearly 300 village clusters provide urban infrastructure/facilities to create 'rurban' villages. As of December 2021, 291 Integrated Cluster Action Plans (ICAPs) and 282 detailed project reports (DPRs) have been developed by states/UTs with a proposed investment of INR 27,788.44 crore. These 'rurban' clusters provide yet another opportunity to integrate energy-efficient infrastructure and urban forestry in their development.

(v) Smart Cities Mission

The mission aims to strengthen the social, economic, physical, and institutional arms of the city, with a focus on sustainable and inclusive development, economic growth, and enhanced quality of living. The *Smart Cities Mission* selected ten cities in Maharashtra, including Greater Mumbai, Navi Mumbai, Aurangabad, Thane, Kalyan-Dombivali, Nagpur, Nashik, Solapur, Amravati and Pune-Pimpri Chinchwad.

(vi) Hon. Balasaheb Thackeray Smruti Matoshri Grampanchayat Bandhani Yojana

Under this *yojana*, Gram Panchayat buildings in 477 villages have been approved for construction. The state government will provide up to 12 lakh to villages with a

Table 7.5 Expected energy savings from demonstration projects by MEDA

Name of government building	Expected energy saving potential (kWh) units/year	Status of project
Mhaswad Nagarparishad, Tal. Maan, Dist. Satara	6,432	Completed
Ambarnath Nagarparishad, Tal. Ambarnath, Dist. Thane	36,168	Completed
Marathwada Mahsool Prashikshan Prabhodhini, Aurangabad, Dist. Aurangabad	38,907	Completed
Latur Municipal Corporation, Dist. Latur	33,803	Completed
Dr. Panjabrao Deshmukh Krushi Vidyapith, Vidyapith Library, Akola, Tal. Akola, Dist. Akola	36,239	Completed
Khapa Nagarparishad, Tal. Saoner, Dist. Nagpur	4,929	Work in progress
Total	1,56,478	

Source: Government of Maharashtra, 2022

population of less than 1,000, those with a population in between 1,000–2,000 will get 18 lakh, whereas more than 2,000 will deploy the public–private partnership model for constructing the Gram Panchayat buildings. These public buildings could pilot efficient cooling technologies.

(vii) Cluster development projects

Various industrial and residential clusters are being developed across Maharashtra and can be leveraged to integrate energy efficiency through pre-fitted appliances and thermal comfortable construction practices.

- *BDD Chawl Redevelopment Programme*: Old constructions from the British era, *chawls* are a prominent feature in Maharashtra and typically comprise one-room or two-room units that have a long corridor and shared toilets. The Bombay Development Directorate (BDD) seeks to redevelop the chawls of the area, which will entail the reconstruction of buildings housing over 16,000 flats, making it one of Asia's largest cluster redevelopment projects. This project has an enormous potential to reduce cooling loads, and its development must be carried out to reduce the urban heat island effect and emerge as a modern and sustainable housing cluster.
- *Aurangabad Industrial City (AURIC)*: It is recognised as one of the most well-developed industrial smart cities in the world, with dedicated residential spaces and investment of over INR 7,000 crore. The area will also include a textile park, a mega food park, an international convention centre, etc. Early interventions for sustainable cooling (like district cooling) and early integration of energy-efficient and thermally comfortable building practices will help mitigate the large power demand from cooling while making people more resilient to the projected increase in temperature.
- *Navi Mumbai Airport Influence Notified Area (NAINA)*: Development of the Navi Mumbai Airport Influence Notified Area (NAINA) in the Thane and Raigad districts (Konkan Division) of Maharashtra is another easy target that can be leveraged for maximising the penetration of sustainable cooling interventions. It extends over 600 sq km around the Navi Mumbai International Airport and will help the city plug its demand–supply gap for housing.
- *Manufacturing clusters and software parks*: The Ministry of Electronics and Information Technology (MeitY), Government of India recently announced that an electronics manufacturing cluster (EMC) will be set up in Ranjangaon Phase-III, Maharashtra, at the cost of INR 492.85 crore. These clusters will be crucial to promote collaborative R&D; the need for more integrated manufacturing clusters is underscored. Such clusters, in addition to software technology parks such as those in Mumbai, Nashik,

Nagpur, Kolhapur, Aurangabad, etc., are simple targets where energy efficiency interventions can be made at scale.

Energy Conservation Policy 2022

Energy efficiency target: Under the Energy Conservation Policy 2017 for Maharashtra, a target has been enshrined for achieving 1,000 MW of energy savings by FY 2021–22. The policy specifically mentions certain levers to maximise progress, which include the promotion of large-scale energy-efficient projects in commercial/residential buildings on the ESCO model, as well as the promotion of energy-efficient technologies. There is clearly scope and the requirement to implement these suggestions at a greater scale and specific focus to tap the mitigation potential of the cooling sector. The Energy Conservation Policy 2022–2027 must lay down the pathway for deeper intervention in the next cycle.

HVAC clusters for collaborative manufacturing and R&D: Another objective enshrined in the policy and delegated to MEDA includes the task of implementing the 'cluster development programme' for the 5 lakh+ micro, small, and medium enterprises (MSME) in Maharashtra, in collaboration with the Department of Industry. There is a need for greater HVAC industrial clusters in Maharashtra, and this scheme can be leveraged to conceptualise and execute these clusters. Pune could be an appropriate place to start with. The development of such HVAC manufacturing clusters also creates a conducive ecosystem for R&D by facilitating knowledge exchange among manufacturers.

The CEEW developed an HVAC Innovation Dashboard that mapped the various R&D efforts taking place across India in the HVAC sector. Within Maharashtra, Pune and Mumbai emerged as two centres where key engineering universities and private HVAC manufacturers were concentrated. This proximity can be leveraged for creating innovative solutions in HVAC, for energy efficiency, materials, as well as refrigerants.

A greater alignment of R&D priorities between industry and academia can, therefore, help strengthen India's innovation and manufacturing base for the HVAC sector. During the data-collection exercise for the HVAC dashboard, enhancing energy efficiency and emissions reduction emerged as the key drivers for innovation, in addition to the need to compete with changing global technology by undertaking manufacturing and process enhancements. This, therefore, emerges as a common purpose or objective upon which industry and academia must align their efforts; such clusters can facilitate this alignment.

Maharashtra Industrial Policy (2019–24)

The policy envisions Maharashtra to emerge as a global investment, manufacturing, and technology hub, while promoting sustainable development and emerging as the first USD 1 trillion economy in the country (GoM 2019).

There needs to be a specific focus on the HVAC industry as a sunrise sector in order to leverage this opportunity under the policy to promote the manufacturing of energy-efficient equipment, NiK cooling technologies, and targeted R&D of refrigerants. The development of HVAC-manufacturing clusters, knowledge-exchange ecosystems for collaborative R&D, and incentives for MSMEs in the HVAC sector to scale up operations and undertake technological upgradation are some of the transformations that this scheme can deliver.

7.3 Sustainable cold chain and refrigeration for agricultural and industrial resilience against climate change

Cold-chain logistics is a thrust area for development nationally and is considered part of the second green revolution. Since 2000, Maharashtra has emerged as one of India's largest producers and exporters of fruits, vegetables, pulses, cotton, and other high-value crops. More than 50 per cent of Maharashtra's population is engaged in agriculture and its allied sectors, which contributes nearly 11.9 per cent to the state's GSDP (GOM 2022). The sector, including animal husbandry, dairy, and fisheries (ADF) has been identified as the backbone of the state and integral to its self-sufficiency.

Besides impacting productivity, rising temperatures will also reduce the shelf life of post-harvest fruits and vegetables. To maintain an efficient and lucrative post-harvest value chain that reduces losses and increases returns, a robust cold-chain infrastructure will be essential.

7.3.1 Sectoral landscape

India is the fruit and vegetable basket of the world. Maharashtra, as the third-largest state with nine agro-climatic zones, boasts of a variety of agro-products that are used for both exports and domestic consumption. The state produces about 117.28 lakh MT of fruits and 123.06 lakh MT of vegetables, nearly all of which rely on cooling infrastructure at some point in the value chain.

The shelf life of agricultural produce is adversely impacted by fluctuations in temperature and humidity, both being factors impacted by variations in temperatures and rainfall patterns due to climate change. The CEEW's CVI accounts for variable rainfall patterns and changes in annual minimum temperature while assessing the sensitivity of districts to extreme weather events. The increasing trends in the state's mean annual minimum and maximum temperatures would imply an increase in the respiration rates of post-harvest agricultural produce. In the absence of robust cold-chain infrastructure, this will further increase post-harvest losses, adversely impacting farmers' revenue as well as the state's revenue and food security. Gross per capita GDP has been considered an

indicator of adaptive capacity in the CVI while assessing the vulnerability of the state's agricultural sector.

As per the CVI, agriculture in Ahmednagar, Solapur, Beed, Nandurbar, and Jalgaon is the most vulnerable in the state on account of varying rainfall patterns, floods, droughts, and extreme temperatures that heavily affect crop productivity. Regions like Marathwada experienced a maximum number of extreme rainfall events in the past years in terms of both rainfall deficit years and flash-flood episodes. Higher rainfall variability may also have resulted in a higher frequency of drought. Cold-chain systems at the farm gate can enable farmers to stock and sell their produce during non-harvest times or crop failures.

Most horticulture produce, especially high-value crops used for exports, is particularly dependent on robust, integrated cold-chain systems. However, it is estimated that up to 30 per cent of fruits and vegetables are lost in Maharashtra due to a lack of adequate post-harvest infrastructure (MOFPI 2014).⁵ In addition to post-harvest losses, not all farmers are able to fetch remunerative prices for their produce due to the lack of pack houses for grading, storage, and packaging of produce. Adequate facilities at the farm gate are important for increasing the shelf life and maintaining the quality of produce, thereby increasing the ability of the farmer to make appropriate market decisions and fetch better prices. Moreover, during non-harvesting periods or in times of crop failure due to extreme weather events, cold storages can continue to help farmers generate revenue and also help the state meet its food requirements. There is clear consensus among stakeholders on the need for cold-storage facilities as a primary requirement for climate-proofing farm products and to ensure farmers can fetch good prices without having to resort to distress sales (GOM 2014).

Do you know? Fruits and vegetables once plucked continue to breathe and require oxygen, emit CO₂, and release heat and moisture. This rate of metabolic activities varies among fruits and vegetables and therefore, differentially impact their shelf life. In the absence of cold chain infrastructure, the produce would perish and decompose into methane emissions. In developing countries, 20–25 per cent of perishable foods are lost due to want of adequate post-harvest infrastructure. It is further estimated that lost or wasted food releases up to 3.3 GtCO₂e worth of emissions.

Despite this acknowledgement, there continues to be substantial post-harvest loss in quality (Kshirsagar et al 2019). The previous MSAAPCC observed that the lack of integrated cooling infrastructure is an important issue

⁵ An updated gap analysis of the country's existing cold-chain infrastructure is being carried out by the NCCD. The previous estimate by the National Horticulture Board that categorised states based on high, medium, and low cold-storage gaps had positioned Maharashtra as having a high cold-storage gap of over 10 lakh MT

Ministry of Food Processing Industries. 2014. Fruits and Vegetables Availability Map of India. <https://www.mofpi.gov.in/sites/default/files/mapfileversion.pdf>

for the horticulture and food-processing sector since Maharashtra is the largest fruit producer and has a large industrial base for agro-processing activities. In view thereof, the plan suggested increasing storage capacities through energy-efficient cold-storage systems as an adaptive response to climate change and reduce losses, which continue to persist to date in the horticulture and allied sectors (ADB 2020).

It is therefore certain that Maharashtra will prioritise investment in expanding its cold-storage infrastructure. By the very nature of its operation and application, the cold storages will run round the clock, throughout the year (especially multi-commodity integrated cold storages) and will require large amounts of energy. It is, therefore, essential to create a cold-chain stock that is more energy efficient and green.

7.3.1.1 Sustainable cold chain for agriculture

Maharashtra has the largest seaport in India (JNPT), which is a strategic link for agricultural exports to the world, including the UAE, Bahrain, Netherlands, the USA, etc. It is the largest producer of grapes in India and accounts for nearly 90 per cent of the grapes exports from the country (GoI 2021). In fact, the last MSAAPCC stated that nearly 70 per cent of the cold stores in Maharashtra were used for grapes. The state is the largest exporter of Thompson seedless grapes and Alphonso mangoes, and the leading producer of mandarin oranges, grapes, pomegranates, sapotas, etc. The major vegetables produced in Maharashtra are onions, brinjal, beans, cabbage, cauliflower, okra, peas, tomato, etc., most of which are also exported. The state has identified floriculture as a sunrise industry and accorded it 100 per cent export status.

These export-focused crops occupy a significant portion of revenue share and require large amounts of cold-chain infrastructure. The ecosystem around these low-hanging fruits, quite literally, will have the necessary resources and capacity to invest in energy-efficient and high-quality

thermally insulated cold-storage systems. A snapshot of the revenue share (2018–19) of some of these fruits and vegetables for Maharashtra is excerpted in Table 7.6.

The scale of production and revenue warrants robust and integrated cold-chain systems that can preserve produce from anywhere between a few days to up to seven weeks or more, and be adjusted based on the differing temperature, air circulation, carbon dioxide levels, ventilation requirements, lighting conditions, etc. of different agricultural produce.

The temperature control in such facilities must be strictly administered with sound technology that must be adjusted to suit the sensitivity of the produce. For e.g., mangoes are susceptible to chilling injury if over-cooled and could lose shelf life if under-cooled. Therefore, each fruit and vegetable has varying storage requirements for temperature and relative humidity. Figure 7.8 gives an idea of the varying cold-chain requirements of some export-oriented produce that are required to be fulfilled throughout the year in Maharashtra, owing to the diversity of produce.

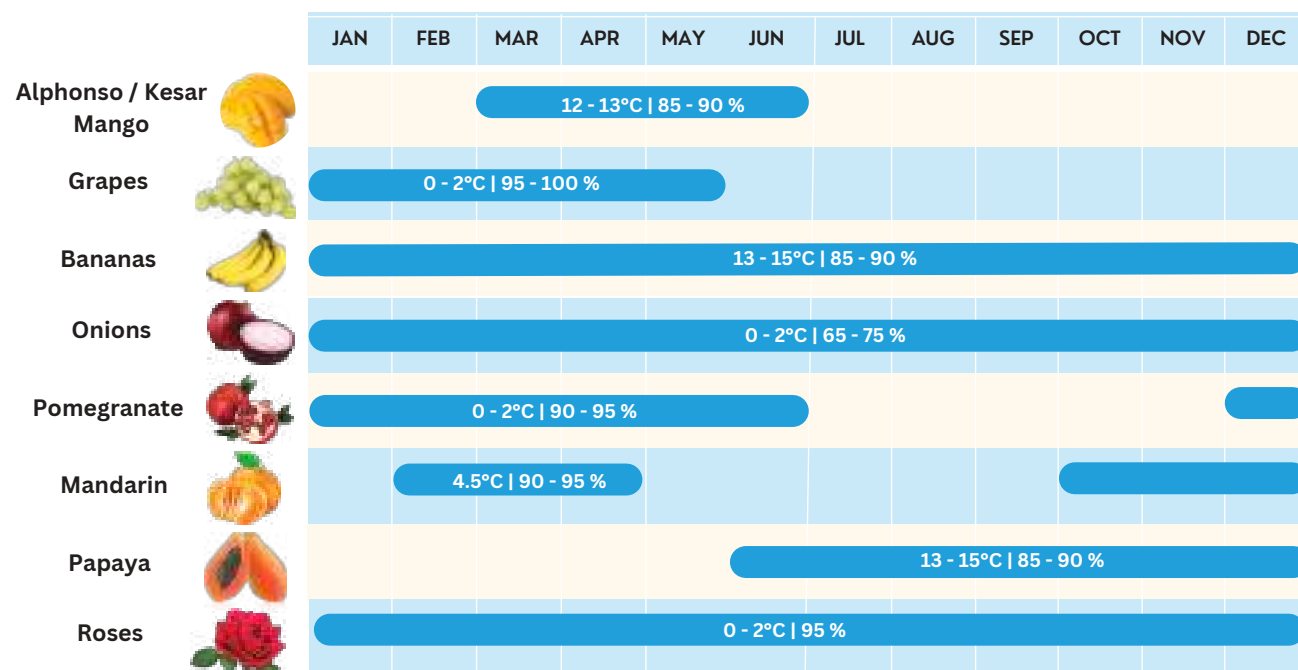
The various stages of the cold chain play different roles, ranging from pack houses to pre-cooling rooms, cold storages, and ripening chambers. Some fruits and vegetables require rapid cooling or pre-cooling within 4–24 hours post-harvest in order to preserve their freshness and quality. This process removes field heat after harvest to reduce the respiration and ripening rate, thereby increasing shelf life. This process has utility for preserving high-quality export produce (NHB 2010). Cold storages, on the other hand, are static infrastructure designed with insulated and refrigerated chambers for long-term or transient storage of whole fresh, ready-to-retail, or processed forms of perishable products. Reefer vehicles help maintain temperature and humidity levels as the produce is transported from pack houses to distribution centres, and from distribution centres to retail or export facilities.

Table 7.6 Production, revenue, and export share of fruits and vegetables in Maharashtra in 2018–19

Fruit/Vegetable crop	Production belt	Quantity (in MT) produced in Maharashtra	Revenue (in cr)	% share in quantity exported nationally	Major country
Grape	Western Kolhapur, Sangli	2,46,122	2,336	98	Netherlands
Mango	Konkan, Marathwada	46,510	406	48	UAE
Pomegranate	Solapur, Pune, Nashik, Sangli	67,891	688	85	UAE
Banana	Jalgaon, Pune, Nashik, Nanded	1,34,503	412	58	UAE
Orange	Nagpur, Akola, Amravati, Wardha	43,098	248	48	Bangladesh
Other fresh fruits	Buldhana, Amravati, Wardha,	2,72,213	1,834	49	UAE
Onion	Nashik, Ahmednagar, Pune, Dhule and Sholapur	13,23,481	1,941	57	-
Okra	Thane	2,115	20.9	71	-

Source: Government of Maharashtra, 2020

Figure 7.8 Temperature and humidity requirements of agricultural produce in Maharashtra



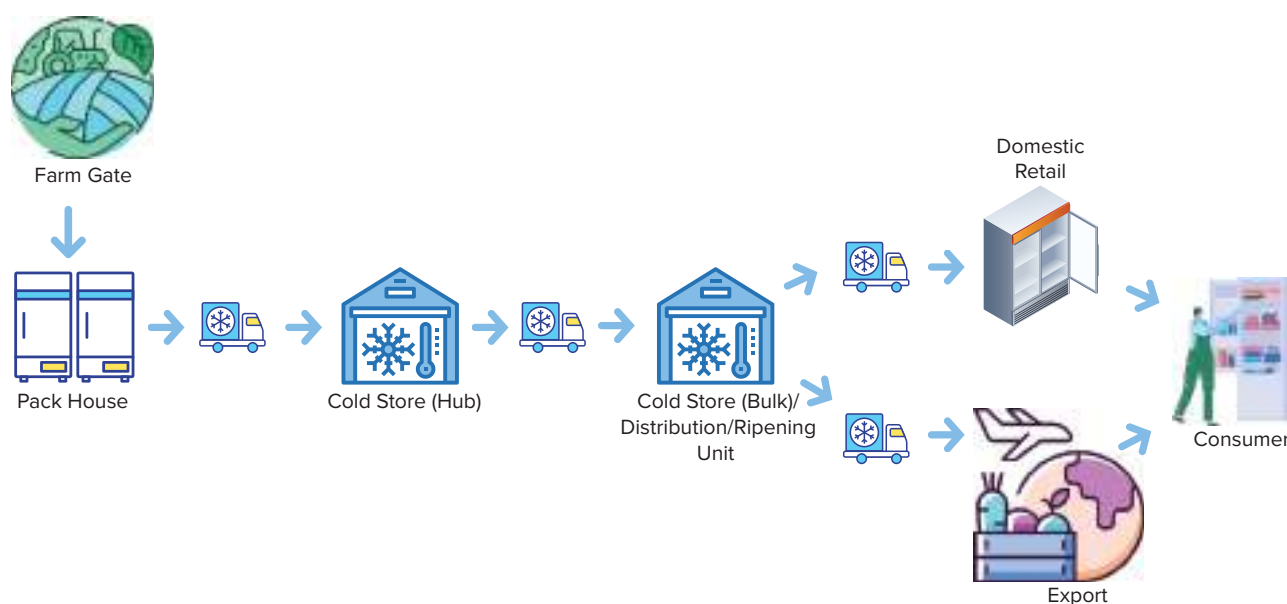
Source: Authors' compilation based on data from National Horticulture Board

In the state's vision document for 2030, a shift is envisaged from merely core agricultural work to allied activities for greater post-harvest value addition. Value addition in Maharashtra's food-processing sector, which employs approximately 2,40,000 workers and about 15 per cent of formal-sector employment, is continuing to increase. The state also has a large industrial base for supporting an agro-processing industry, and sustainable cooling infrastructure will be key in preserving and transporting processed food, both domestically and globally. It must also be kept in mind that cold-chain logistics and

refrigeration technology are complementary and mutually promoting. The development of cold chain promotes the development of refrigeration technology, and the application of new refrigeration technology ensures energy saving and consumption reduction of cold-chain logistics and the safety of cold-chain food.

Maharashtra also requires a cold chain for preserving agricultural imports, including perishables like apples, kiwis, grapes, etc. that are marketed from the USA, China, Thailand, Afghanistan, New Zealand, etc.

Figure 7.9 Cold chain for agricultural produce



Source: Authors' compilation

7.3.1.2 Cold chain for vaccine management

Transporting medical vaccines as per the World Health Organisation's prescribed temperature range is crucial to maintain efficacy between the points of production and consumption. The vaccines are highly temperature sensitive, and a well-managed cold chain is key to preserving vaccine potency and facilitating efficient immunisation.

The vaccine cold-chain system includes a walk-in cooler/freezer, deep freezers, refrigerated and insulated vaccine vans, cold boxes, vaccine carriers, etc. (ICAP 2019). Research has ascribed a drop in seroconversion rates and outbreaks of certain preventable diseases to a loss of vaccine potency either during transportation or storage (Chaudhari et al 2018).

Covid-19 highlighted the importance of a reliable vaccine supply chain, as initially, certain vaccines could not be used in India due to the requirement of extremely low-temperature storages. Vaccines were transported to makeshift Covid-vaccination centres such as schools, community halls, clinics, Gram Panchayats, municipality offices, etc., which did not have the prerequisite cold-storage infrastructure.

To bolster Maharashtra's vaccine distribution and management immediately after the first wave of Covid-19, there was an immediate requirement for ice-lined refrigerators, deep freezers, walk-in freezers, and walk-in coolers. With the central government's objective to achieve universal immunisation, a functional end-to-end immunisation supply chain for vaccines from the manufacturer to the beneficiary will be an essential public health service to guard against preventable diseases.

To reach the national goal of achieving 90 per cent immunisation, a resilient cold-chain infrastructure for vaccines will be key to ensuring the uninterrupted availability of vaccines at all levels.

7.3.1.3 Cold chain for dairy and fisheries

India is the largest producer and consumer of milk, with a 20 per cent share in global milk production. India is also one of the leading producers of fish and meat, with the third-largest fish-producing industry. Despite this unique position, our share in the global trade of these commodities remains relatively low due to high levels of loss across the value chain of key perishables, which require a controlled requirement to retard the pace of microbial, chemical, or enzymatic processes. For e.g., bacterial activity in milk begins after milking is complete; to avoid quality reduction, it must be preserved under 4°C in leak-proof refrigerated chillers. In its absence, milk can spoil due to improper conditions at the point of milking and during transport. This becomes even more relevant

considering the rising temperatures forecasted for the state.

Maharashtra remains a major milk producer along with Uttar Pradesh, Gujarat, Punjab, Haryana, etc. Per data from the Department of Agriculture, Animal Husbandry, and Dairy Development, the state's annual milk production has increased from 10,402.15 MT in 2016–17 to 13,703.32 MT in 2021–22 (GoI 2022). Ahmednagar continues to be the leading producer of milk, followed by Pune, Solapur, Kolhapur, Sangli, and Satara (GoI 2022). Most milk-chilling centres are located in remote villages, which facilitates effective collection from local areas. The carriage of fresh milk from the collection site to cooling centres and processing units requires insulated milk tankers for timely collection, and the milk should be chilled within three to four hours of collection to prevent spoilage (ICAP 2019).

Maharashtra has a 720 km long coastline, reporting a marine fish landing of 2,98,593 tonnes in 2018, and 3,81,142 tonnes in 2017. Mumbai is a hub for fisheries, along with landing centres in Raigad, Sindhugurg, Ratnagiri, Thane, and Palghar. Most fish in Maharashtra, however, are not stored at the required temperature of 4°C or below due to a lack of adequate cold storages or transportation vehicles. Fish can be seen transported across cities in large diesel-based trucks that do not have any refrigeration. As a result, by the time the marine produce reaches the consumer, it has already lost a considerable amount of freshness and quality, a loss that shall be exacerbated due to rising temperatures and urbanisation in the state. In addition to the agri-value chain, the fisheries, dairy, and meat sector must be also provided with the necessary cold-storage infrastructure to reduce losses, increase incomes, and improve the quality of produce.

7.3.2 Recommendations

It is the focus of the NCCD to promote an energy-efficient cold chain with improved insulation, both for reducing energy consumption and emissions as well as operational costs. Reducing these costs will eventually contribute to the policy objective of 'doubling farmers' income', as produce can fetch better prices due to reduced costs of storage. Increasing the disposable income of farmers enables them to invest in technologies like DRE-based cold chains, improved farming inputs, mechanised tools, etc. that go on to increase their adaptive capacity against weather extremes. Under the National Horticulture Mission, there is also a special thrust on the creation of market-linked cold-chain logistics, with a focus on the aggregation of farmer producers and linking them to markets for economies of scale and better value realisation. It will be important to leverage this national and state policy focus to accelerate an energy-efficient and sustainable cold-chain transition.

Table 7.7 Gaps and recommendations for sustainable cold chain in Maharashtra

S. no.	Target	Reduce losses of perishables by 10% through robust cold-chain infrastructure.
1	Actions recommended	Commissioning district-wise capacity gap assessment study for cold chain.
	Existing gap	After the national-level cold-chain infrastructure gap assessment done by the National Centre for Cold-chain Development (NCCD) in 2014, a comprehensive district-wise assessment has not been undertaken. There is no reliable data that provides information on the weak links for Maharashtra per district, per produce that quantifies the corresponding post-harvest losses. Understanding the district-level infrastructure gaps in the cold chain can facilitate targeted policymaking, appropriate subsidies, and subsequent capacity-building programmes. This capacity gap assessment must be conducted for all allied sectors as well, including dairy and fisheries.
	Focus districts	State-wide.
	Implementing agencies	Department of Agriculture, Department of Fisheries, Department of Animal Husbandry and Dairy, Department of Statistics, National Institute of Post Harvest Technology (NIPHT), National Centre for Cold Chain Development (NCCD). Integrate with National Mission for Sustainable Agriculture.
	Financial implications	The total budget estimate is provided at the end of this table. INR 1 crore.
	Outcome	Will help identify the existing refrigeration and cold-storage capacity gaps for agriculture, dairy, fisheries, and healthcare against the demand to create focused interventions for infrastructure and capacity building.
2	Actions recommended	Create a 'comprehensive cold chain skill development roadmap' for Maharashtra. Creative interventions include mobile-training trucks that can be commissioned that provide in situ training near the farm gate or at the local <i>mandis</i> for applied learning for the farmers. Audio-visual content must be designed in the local language as self-learning material for farmers to internalise and apply the learnings post-training. Given the product-specific and relatively complex operation of cold storages, the <i>Krishi Vigyan Kendras</i> , manufacturers, agricultural universities, and local skill-development centres must be involved to aid in the capacity building of the operators at the farm or FPO level.
	Existing gap	Many farmers across the horticulture belt, especially the guava-, sapota-, mandarin-, and custard apple-growing areas, are not aware of the option of pre-cooling their produce. An attempt was made by the Maharashtra State Agricultural Marketing Board (MSAMB) to establish 30 modern marketing centres with cold chain facilities, but the greatest challenge was the shortage of trained staff to operate the systems and manage the produce. Currently, there is only one three-day post-harvest training programme on cold-chain management in the state, offered by the National Institute of Post Harvest Technology (NIPHT). There is a need to build technical and administrative capacity as well as managerial acumen within FPOs and cooperatives to operate these new facilities as small and marginal farmers currently lack that know-how. Such training is also required for operators of reefer vehicles, as improper management of produce during loading and unloading leads to considerable wastage. The training material will need to be specifically curated to bridge these capacity gaps. There is also a need to develop more specialised diploma or certificate courses on cold chain, which also educate the farmers on its benefits. Programmes can be broadcasted on the regional radio on the benefits of such infrastructure and the various related schemes. Certain areas where capacity-building initiatives or courses must focus include but are not limited to commodity systems assessments (i.e., identifying the causes and sources of losses), benefits of preventive maintenance, basic cold-storage management and logistical practices for reducing loss of perishables, technical aspects of cold storage/reefer vehicles, food-safety issues, value-chain development, management topics (labour, finance, equipment, marketing), environmental issues, etc. Continuous evaluation and updation of these modules will be necessary to increase uptake and integrate enhancements in technology and operational practices and thereby build capacity.
	Focus districts	Priority districts identified under recommendation 1.
	Implementing agencies	Agricultural Technology Management Agency (ATMA), Maharashtra Farmers Producer Co. Ltd. (MAHAFPC), Agricultural Produce Market Committees (APMC) Maharashtra Council of Agricultural Education and Research (MCAER), Vasantrao Naik State Agriculture Extension Management Institute (VANAMATI), Krishi Vigyan Kendras, Agriculture Training Institute Ahmed Nagar, Maharashtra State Skill Development Society (MSSDS), National Institute of Post Harvest Technology (NIPHT), Indian Council of Agricultural Research (ICAR), National Dairy Development Board (NDDB), National Institute of Food Technology Entrepreneurship and Management (NIFTEM), District Skill Development Committees, Regional Directorate of Skill Development and Entrepreneurship.

S. no.	Target	Reduce losses of perishables by 10% through robust cold-chain infrastructure.
	Financial implications	The total budget estimate is provided at the end of this table. In Phase 1 of the technical training and capacity building, it is suggested that the focus be placed on the priority districts identified. Ten representatives from each FPO or milk cooperative were identified and provided off-site training at the National Institute for Post-Harvest Technology Infrastructure. After installation of the infrastructure proposed in action point 1, phase 2 of the training is suggested on-site, i.e., at the installed cold-chain infrastructure. The total cost of both the ex-situ and in-situ training including curriculum development, and travel costs of 10 representatives per FPOs for 50 FPOs is INR 45,00,000.
	Outcome	Training will improve efficiency and performance in multi-commodity cold storage applications due to proper handling of storage systems which optimise space, allows uniform air circulation through the product and meets the fundamental requirements of stock rotation which is time sensitive due to limited shelf life. The farmers will also develop the business acumen required to manage such facilities.
3	Actions recommended	Establish multi-commodity cold storages at the village level, with adequate pack houses and reefer-vehicle connectivity.
	Existing gap	It was learnt that nearly 90% of cold storages is located in Mumbai, Pune, Thane, Nashik, and Sangli, with nearly 80% of the state's cold storage being used for grapes. The bulk of the remaining cold storages in the state is used for bananas and pomegranates. Out of the 156 APEDA-owned pack houses in Maharashtra, 107 are exclusively for grapes or pomegranates, while the others are for mangoes and herbs (AEEE 2022). There is a need to plug the weak links of pack houses, pre-cooling units, and reefer vehicles, and build capacity in other districts. For the dairy sector, leak-proof refrigerators and refrigerated milk containers will be required to reduce the loss of milk. On account of leakage of refrigerants, cooling will be impacted, and this will impact the shelf life of the produce and the farmer's income.
	Focus districts	To be identified based on results of capacity gap assessment study.
	Implementing agencies	Department of Agriculture, Maharashtra State Agricultural Marketing Board (MSAMB), Agricultural and Processed Food Products Export Development Authority (APEDA), District-wise Agricultural Technology Management Agencies (ATMA), Maharashtra Farmers Producer Co. Ltd. (MAHAFPC), Agricultural Produce Market Committees (APMC).
	Financial implications	The total budget estimate is provided at the end of this table. The NHB cost norms for the Mission for Integrated Development of Horticulture (MIDH) prescribe the cost of INR 25 lakh per pre-cooling unit of 6 MT capacity, INR 26 lakh for a 9MT reefer vehicle, and INR 3 crore for a 300 MT ripening chamber (NHB 2023).
	Outcome	Increase the resilience of perishable produce to varying temperatures, also improving farmers' incomes.
4	Actions recommended	Provide credit guarantee from green cess Fund for farmers/FPOs purchasing DRE-based cold-chain equipment or meeting specified requirements of energy efficiency. Following the modus operandi of credit guarantee schemes for MSEs, the state may extend guarantee cover of up to 75% of the sanctioned loan amount up to an upper cap determined appropriately. This guaranteed cover will help increase the creditworthiness of FPOs and other cooperatives to avail loans from scheduled commercial banks listed under the support scheme. The eligibility conditions for the credit guarantee will include certain energy-efficiency criteria for the equipment, appropriately determined by the agencies involved, and/or be based on renewable energy.
	Existing gap	Under the existing central scheme for 'cold chain and value addition infrastructure' under the <i>Pradhan Mantri Kisan Sampada Yojana</i> , there is a mandatory eligibility criterion that a certain percentage of the project cost must be in the form of a loan from a scheduled commercial bank. The reality is that nearly 50% of small and marginal farmers do not have access to any source of credit or face high demands for collateral, which makes it difficult for them to avail themselves of the subsidies provided under the schemes. The overall perception of banks towards farmers and FPOs concerning loan repayment must be revisited.
	Focus districts	State-wide implementation.
	Implementing agencies	Department of Agriculture, Department of Fisheries, Department of Animal Husbandry and Dairy, Department of Energy, Maharashtra Energy Development Agency (MEDA), Maharashtra State Agricultural Marketing Board (MSAMB), Agricultural and Processed Food Products Export Development Authority (APEDA), Maharashtra State Warehousing Corporation (MSWC).
	Financial implications	The total budget estimate is provided at the end of this table. It is assumed that FPOs/farmers will avail of government subsidy under the PMKSY, where up to 75% of up to 20% of unit or project cost will be guaranteed under this recommendation to boost the creditworthiness of the applicant. As an example, the cost of providing a credit guarantee for one 5,000 MT multi-commodity cold storage per village would be around INR 75,00,000, while the cost to provide the credit guarantee to an individual farmer for one solar-based cold storage of 5MT would be INR 2,25,000 NHB 2023).

S. no.	Target	Reduce losses of perishables by 10% through robust cold-chain infrastructure.
	Outcome	Following the modus operandi of credit guarantee schemes for MSEs, the state may extend guarantee cover of up to 75% of the sanctioned loan amount up to an upper cap determined appropriately. This guaranteed cover will help increase the creditworthiness of FPOs and other cooperatives to avail loans from scheduled commercial banks listed under the support scheme. The eligibility conditions for the credit guarantee will include certain energy efficiency criteria for the equipment – appropriately determined by the agencies involved – or be based on renewable energy.
5	Actions recommended	Retrofitting 20% of the state's existing inefficient cold-storage installations by 2027, and creating demonstration projects for energy-efficient and renewable energy-based cold-chain installations. This will involve the following: 1. Deploying the highest standards of energy efficiency in upcoming cold-chain installations as identified in the capacity gap assessment, while integrating renewable energy-based technology (solar, biomass, thermal storage, geothermal, etc.) for reducing carbon footprint, grid dependency, and use of diesel generators. This could be done in existing or new cold-chain and food-processing clusters being developed under the PMKSY as 'green food parks' or 'solar food parks', or retrofitting existing or installing in new fish landing centres. 2. The state may also provide additional subsidy from its green cess fund corpus to farmers, registered FPOs/FPCs, or farmer cooperatives seeking to procure cold-chain infrastructure of specified energy consumption standards. Savings from the demonstration projects should be highlighted to increase awareness among design consultants, pack-house owners, FPOs, and manufacturers.
	Existing gap	Studies find that there is untapped potential for energy-efficiency improvements in the cold chain in Maharashtra, especially pack houses (AEEE 2022). While there is a larger need for national-level guidelines and specifications to be developed by the Bureau of Energy Efficiency for energy-efficient cold-chain equipment, a lack of awareness among stakeholders on savings from post-harvest energy efficiency is a major barrier.
	Focus districts	State-wide, with a focus on priority districts identified in recommendation 1.
	Implementing agencies	Department of Agriculture, Department of Fisheries, Department of Animal Husbandry and Dairy, Department of Energy, Maharashtra Energy Development Agency (MEDA), Maharashtra State Agricultural Marketing Board (MSAMB), Agricultural and Processed Food Products Export Development Authority (APEDA), Maharashtra State Warehousing Corporation (MSWC), National Centre for Cold Chain Development (NCCD). Integrate with National Solar Mission.
	Financial implications	The total budget estimate is provided at the end of this table. Biomass-based⁶ cold-storage technologies also exist in the market, which cost up to INR 13 lakh per unit (inclusive of GST, excluding transportation costs) with 15 MT capacity. Consultations with government officials in the state showed a clear inclination towards increasing the adoption of solar-powered cold storages, with estimates of procuring and installing 800 new units by 2027. It was learnt that such portable DRE-based units cost up to INR 15 lakh for a unit with a capacity of 5MT. The total cost of procuring 800 units would therefore amount to INR 120 crore as capital cost. Given the large number of small and marginal farmers in the state, as well as a strong collective of FPOs, providing additional state support to absorb the costs will be key.
	Outcome	As per CEEW's research, the state-level livelihood potential for DRE-based cold-chain technologies is significant. The market-potential analysis reveals that 2,21,119 solar refrigerators, 6,133 solar cold storages, and 4,532 milk chillers can together create nearly 3,57,220 jobs. This will also result in the reduction of energy consumption and indirect emissions.
Total budget outlay		INR 3,600 crore. The cost for implementation of these recommendations falls within the budget outlay for post-harvest infrastructure in Chapter 5.1 (Agriculture). As per PoCRA's budget expenditure, approximately INR 72 lakh was disbursed on average per village for various development-related interventions on water, support to horticulture, post-harvest infrastructure development, and natural resource management as per farmers' needs and applications. Using these estimates and an assumption to cover 20,000 vulnerable villages by 2030 (out of a total of 40,000 villages), a budget of approximately INR 14,400 crore would be needed for focus area no. 3, of which about one-fourth is allocated to post-harvest management.

Source: Authors' analysis

⁶ Including rice husk (parali), wheat husk, straw, biomass pellets, waste wood, dry dung cakes or any crop waste, etc.

7.3.3 Policy enablers

PM Kisan SAMPADA Yojana

A centrally sponsored scheme implemented by the Ministry of Food Processing Industries (MoFPI), the SAMPADA Yojana (*Scheme for Agro-Marine Processing and Development of Agro-processing Clusters*) aims to create modern food-processing infrastructure, effective linkage of farmers, markets, and processors, and effective cold chain to reduce spoilage and increase incomes. The umbrella scheme includes various sub-schemes in furtherance of its objective, of which the following are of direct relevance to Maharashtra's cold chain. In each of these projects, the state may push for energy-efficient equipment to the extent possible.

(i) Integrated cold-chain and value-addition infrastructure

The scheme aims to provide integrated cold-chain and preservation infrastructure facilities at the farm level, extending to the market level and includes the creation of infrastructure facilities along the entire supply chain for facilitating the preservation and circulation of non-horticulture, horticulture, fisheries/marine, dairy, etc.

The integrated cold-chain project can also be set up by FPOs and individuals alike, provided the scheme eligibility criteria are fulfilled. For cold-storage infrastructure, the scheme provides grant-in-aid at 35 per cent (for general areas) of the total cost of plant and machinery and technical civil works. For value addition and processing infrastructure, a grant-in-aid at 50 per cent is provided.

(ii) Mega food parks

Though discontinued, the model of this scheme is worth understanding for the sake of emulation. The model is based on the direct receipt of produce from farmers or FPOs or SHGs at the field collection centres (CCs) from where the produce is taken to the primary processing centre (PPC) for pre-cooling, grading, sorting, pulping, storage, etc. From the PPC, the produce is taken to the central processing centre (CPC) where either the fresh produce is taken from for domestic retail consumption or is processed to create a value-added product that is either sent for exports or domestic consumption.

Under the scheme, two mega food parks were established in Aurangabad (Paithan) and Satara, Maharashtra. In terms of understanding the footprint of each mega park, it was estimated that each project will have around 25–30 food processing units with an expected annual turnover of about INR 450–500 crore and direct/indirect employment to about 5,000 persons. Nearly 25,000 farmers are expected to benefit from each MFP.

(iii) Creation/Expansion of food processing/preservation capacities (unit scheme)

This scheme also extends to the same group of eligible applicants and is aimed at creating processing and

preservation capacities and modernisation/expansion of existing food processing units with the aim of increasing the level of processing and value addition, leading to a reduction of wastage. The processing activities undertaken by the individual units cover a wide range of post-harvest processes, resulting in value addition and/or enhancing shelf life with specialised facilities required for the preservation of perishables.

(iv) Agro-processing clusters

The scheme provides support to clusters with a minimum of 5 food-processing units and a minimum investment of INR 25 crore for both enabling infrastructure as well as for core infrastructure, including cold storage, pre-cooling chambers, ripening chambers, etc.

(v) Creation of backward and forward linkages

This scheme extends monetary aid for establishing primary processing centres and collection centres at the farm gate (backward linkage) in addition to modernised retail outlets at the market end (forward linkage). Most importantly, the scheme also seeks to enhance connectivity between the farm gate, collection centres, and the retail end via insulated or refrigerated transport. It applies to both perishable and non-perishable horticulture products.

The ministry has engaged technical agencies (TAs) for assisting farmer/producer groups in providing information about participation in the scheme. The TAs are responsible for the preparation of the business plan, training, detailed project report, capacity building, and trainee and other related support services. Another arm of this scheme promotes R&D in the products and processes of food processing.

Maharashtra Agribusiness Network (MagNet) Project

With nearly 53 per cent of Maharashtra's population being directly or indirectly dependent on agriculture for their livelihood and subsistence, this project aims to increase farm income, farm and non-farm jobs, and reduce loss of perishables along the horticulture value chain in the state. This INR 1,000-crore state-government project, in collaboration with the Asian Development Bank, aims to improve processing and minimise the losses of fruits and vegetables in the state, while increasing profits of FPOs. Since Maharashtra's primary agricultural sector is dominated by small and marginal farmers, this project will provide incentives mainly to this target group.

Bulk procurement of solar-based cold stores

In response to the need for cold storage across Maharashtra due to the diversity of fruits, vegetables, and flowers spread across the state throughout the year, MEDA is scheduled to procure nearly 800 cold rooms in Maharashtra by 2027 to be operated on solar-based energy. The maintenance of such cold rooms can be deployed via innovative business models.

State of Maharashtra's Agribusiness Rural Transformation Project (SMART)

The project is aimed at developing inclusive and competitive value chains by focusing on small and marginal farmers along with agri-entrepreneurs. This is in furtherance of the state's 2030 vision, which seeks to create more capacity and value beyond core agricultural activities. The project aims to support value addition in the post-harvest segments of agricultural value chains, facilitate agri-business investments through inclusive business models for small farmers, stimulate the establishment of small and medium enterprises, and support the resilience of agriculture production systems against climate change.

National Horticulture Mission (under) Mission for Integrated Development of Horticulture (MIDH)

Established under the *Mission for Integrated Development of Horticulture* (MIDH), the *National Horticulture Mission* (NHM) is a centrally sponsored scheme aimed at achieving holistic growth of the horticulture sector – covering fruits, vegetables, flowers, nuts, etc. The Government of India contributes 60 per cent of the total

outlay for development programmes, with a 40 per cent share by the state government. In the annual action plan for 2022–23 for the state of Maharashtra, there is a total outlay of INR 19,933.97 crore, with further allocation for integrated post-harvest management through cold-chain infrastructure. This scheme in the state extends up to 50 per cent credit-linked back-ended subsidy for setting up pre-cooling units (10), cold rooms for staging (12), cold-storage units (8), and entire integrated cold-chain supply systems. There is further assistance provided in the form of covering up to 50 per cent of the capital cost for pack houses and on-farm collection centres, zero-energy cool chambers, vending carts with cool chambers, etc.

The scheme also provides the option to roll out other innovative interventions that are otherwise not covered in the scheme. These are to be performed within the purview of the terms and conditions mentioned in the scheme document, clause (xi) of which expressly promotes the creation of cold-chain infrastructure clusters. It promotes the protected cultivation of vegetables in clusters in and around major cities/metros well-equipped with cold-chain infrastructure, including pre-cooling facilities, cold storages, reefer vehicles, vending carts, and appropriate marketing arrangements.

Climate finance

8.1 Climate finance

Climate finance refers to local, national or transnational financing – drawn from public, private and alternative sources of financing – that seeks to support mitigation and adaptation actions that will address climate change (UNFCCC n.d.a).

India, as a developing nation, faces the difficult task of providing relief and rehabilitation efforts for disaster-hit communities and economies with limited financial resources. The growing impact of climate-induced events and disasters adds an additional and unjust burden to the country's developmental challenges. To address this situation, it is essential to prioritise sustainable development. In doing so, finance will play a crucial role in implementing climate change action programmes.

India has consistently advocated for international climate-action funding support to emerging and developing countries, owing to their needs and climate change vulnerability. To achieve India's updated NDCs submitted in August 2022 to the United Nations Framework Convention on Climate Change (UNFCCC 2022), at least USD 2.5 trillion (~ INR 162.5 lakh crore) is required between 2015–30 for climate change initiatives (CPI 2022a). This equates to around USD 170 billion (~ INR 10.84 lakh crore) in yearly funding needs. During FY 2019–20, however, financial flows were just USD 44 billion (~ INR 309 thousand crores) (ibid).

Due to the limited scale of financial assistance being made available from global sources, financing climate change mitigation and adaptation activities remain a serious challenge for national, state, and local governments

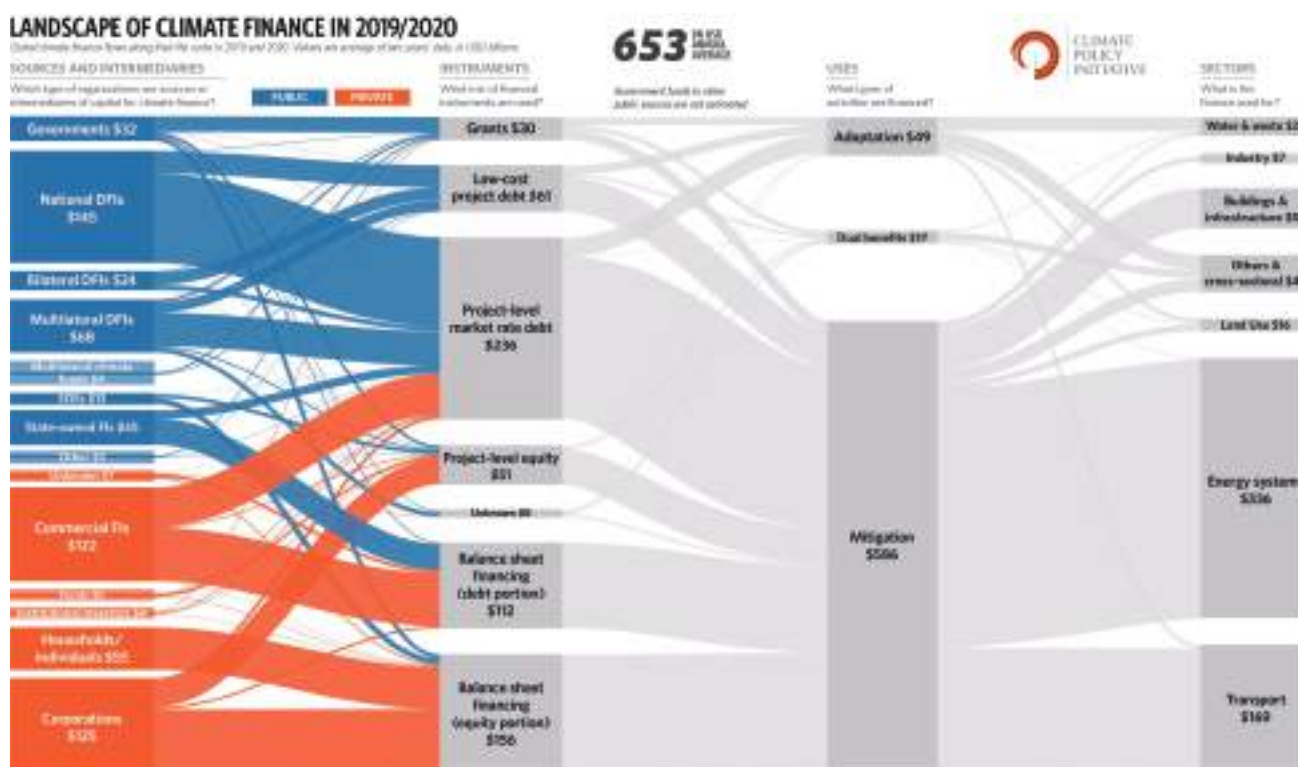
in India. Some of the challenges behind limited climate finance from international sources in emerging economies and developing countries are high perception risk and currency risk. These challenges require government interventions such as climate budgeting to minimise the bottlenecks in climate finance flows.

This chapter lays out the landscape for climate finance at the global, national, and regional levels. It discusses the existing sources and channels of financing climate change in the state of Maharashtra like the Urjankar Nidhi Fund, subsidy programmes from the national and state governments, green tax, green cess, and plans to stimulate private investment, such as the *MAHA-PARVANA Plan*. It is followed by the climate budget in Maharashtra in FY 2023–24. Thereafter, the chapter discusses the proposed climate budget for the period 2024–2030. The chapter concludes with a discussion of the financial instruments and actions that could be used to implement mitigation and adaptation projects and programmes.

8.2 Climate finance: Global perspective

According to the *Global Landscape of Climate Finance 2022* report, global climate finance has increased over the last decade and has reached USD 653 billion in the years 2019–20, but still, it is not sufficient to limit global warming to 1.5°C (CPI 2022b). Climate finance is essential for the power generation transition from fossil fuels to clean energy systems, industries, transport, and mitigation and adaptation solutions. The details of the sources and destination of global climate finance are shown in Figure 8.1.

Figure 8.1 Global climate finance flows in 2019–20



Source: Climate Policy Initiative 2022b

Globally, climate finance is mobilised through various sources, which can be categorised as bilateral, domestic, and international. The composition of climate finance sources includes development financial institutions (DFIs), climate funds, institutional investors, and bilateral agreements between countries.

As per Figure 8.1, the public sector accounted for USD 334 billion (51 per cent) and the private sector accounted for USD 318 billion (49 per cent). It is also observed that the share of multilateral DFIs and climate funds is only 11 per cent, amounting to USD 72 billion. The mobilisation of climate finance from international sources such as developed countries and multilateral development banks (MDBs) to developing countries has been limited in scale (OECD 2022). Additionally, the funds have been majorly deployed in the form of direct lending instead of de-risking instruments (ibid).

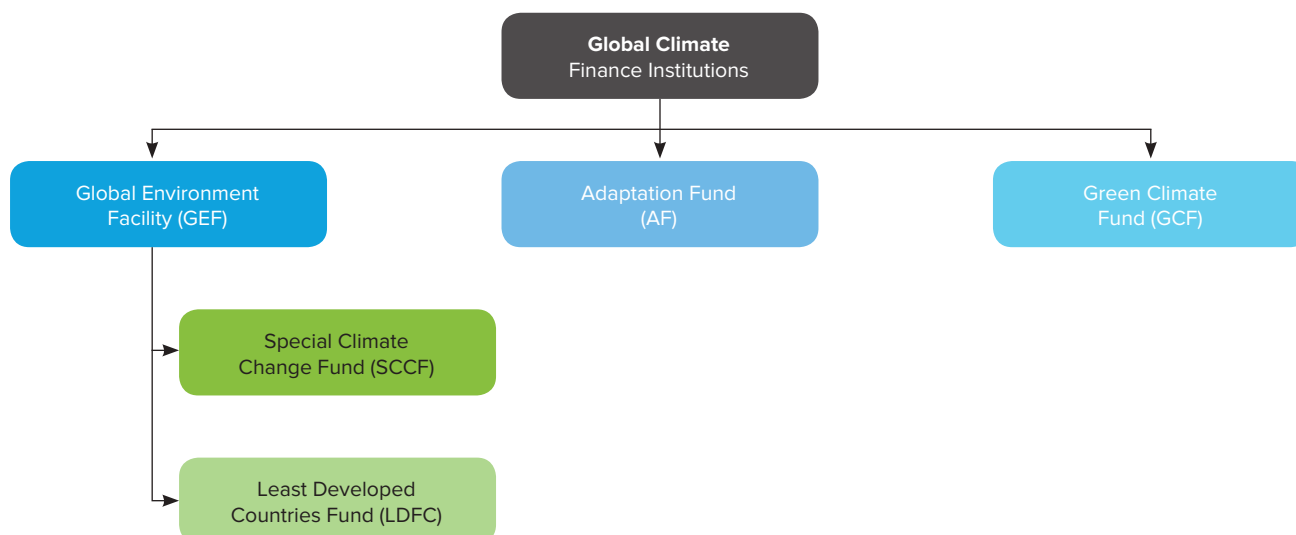
In the context of international sources of climate finance, the UNFCCC has been instrumental in the creation of several sources of financing globally that aid in serving the Paris Agreement and Kyoto Protocol, including:

1. **Global Environment Facility (GEF):** The GEF was established in 1992 during the Earth Summit in Rio. It is administered by the United Nations Development Programme (UNDP), the World Bank, and the United Nations Environment Programme (UNEP) in collaboration. It administers the UNFCCC financial mechanism and provides funding to developing

and transitioning economies in six priority areas: biodiversity, climate change, international waterways, ozone depletion, land degradation, and persistent organic pollutants.

2. **Green Climate Fund (GCF):** In 2010, UNFCCC formally established GCF as a financing mechanism. It is the world's largest environmental fund and aims to support developing nations in reducing their GHG emissions and preparing for climate change.
3. **Special Climate Change Fund (SCCF):** While SCCF is currently operated under GEF, it was originally established under the UNFCCC in 2001 to finance projects relating to adaptation; technology transfer and capacity building; energy, transport, industry, agriculture, forestry, waste management; and economic diversification.
4. **Least Developed Countries Fund (LDCF):** GEF administers the LDCF, which was established in 2001 to support the work programme of the least developed countries (LDCs) under the UNFCCC, including the formulation and implementation of national adaptation plans (NAPs).
5. **Adaptation Fund (AF):** In 2001, the Kyoto Protocol of the UNFCCC established the Adaptation Fund. It finances initiatives and programmes that help vulnerable communities in developing countries adapt to climate change.

Figure 8.2 Global climate funds architecture



Source: Authors' compilation

Entities and funds like the GEF, GCF, and Climate Investment Fund (CIF) are some of the international sources of financing sustainable projects and low-carbon intensive activities, such as deployment of solar power plants, production of electrolyzers for hydrogen generation, and R&D of EVs. These projects and activities help in reducing carbon emissions in the atmosphere and enhancing carbon sinks. The GCF has financed seven projects as of 2022 with a total capital budget of USD 528.9 million in India (Green Climate Fund n.d.).

One of the key funds in climate change financing, other than those established by the UNFCCC, is the Climate Change Fund (CCF), which was set up by the Asian Development Bank (ADB) in May 2008. It was established to encourage increased investments in developing member countries (DMCs) to address the causes and effects of climate change more effectively. This was accomplished by strengthening support for climate-resilient and low-carbon development in DMCs. As the third operational focus of Strategy 2030, combating climate change, increasing environmental sustainability, and enhancing climate and disaster resilience, the CCF plays a crucial role in integrating climate activities into ADB's operations. The fund offers finance in three different ways: investment through grants, technical support, and direct charge. It consists of three parts: (i) reduced emissions from deforestation and forest degradation; (ii) improved land-use management; (iii) adaptation and development of renewable energy.

While global climate finance flows have been increasing over the years and there are several initiatives in the form of international sources of funds, the pace and scale of climate actions to reach the Paris Agreement goals need to increase.

8.3 Climate finance: National perspective

India's updated NDCs seek to enhance India's contributions towards the strengthening of the global response to the threat of climate change as agreed under the Paris Agreement (MoEFCC 2022). India now stands committed to reducing the emissions intensity of its GDP by 45 per cent by 2030 from the 2005 levels and achieving about 50 per cent cumulative electric power installed capacity from non-fossil-fuel-based energy resources by 2030. India has made headway toward these objectives, but more remains to be done. Given the urgency, India submitted 'five nectar elements' or '*panchamrit*' as a supplementary contribution to climate action during the COP26 Summit in Glasgow. By the year 2030, India will:

1. Scale up its non-fossil energy capacity to 500 GW.
2. Meet 50 per cent of its energy requirements from renewable energy.
3. Reduce the total projected carbon emissions by one billion tons from now.
4. Reduce the carbon intensity of its economy by more than 45 per cent.
5. India will achieve the target of net zero by 2070.

India requires about USD 2.5 trillion from 2015–30 to achieve the NDCs under the Paris Agreement, which accounts for USD 170 billion per year (CPI 2022a), and India would need cumulative investments of USD 10.1 trillion to significantly scale up the climate transition and achieve net-zero emissions by 2070 (CEEW 2021). Substantial financial support and policy interventions play a critical role in climate financing. It is thus imperative that policymakers identify and analyse the key sources of

finance, as well as plan and monitor the disbursement of funds for the green transition in the country.

To cope with the effects of climate change and reach its goal of low carbon emissions under the Kyoto Protocol, India released the National Action Plan on Climate Change (NAPCC) in 2008. The NAPCC focuses on energy efficiency, clean technology, and making the most of the resources India has. The MoEFCC is responsible for formulating, implementing, coordinating, and supervising India's climate policy. The key purpose of the NAPCC and climate policies in India is to help transition from fossil fuel-based activities and projects to low-carbon alternatives and thus achieve the NDCs. To ensure this transition and fulfil the climate obligations, climate finance flows play a critical role by providing much-needed support in implementing the projects.

In India, climate finance flows can be traced to a number of international and domestic sources. These funds move through a national or sub-national level or direct funding at the project level. For effective sustainable development, it is very important to ensure that the funds are directed to the appropriate sector, project, or department, and that the goals for reducing climate change and adapting to it are met. Of these twin considerations, the hardest part

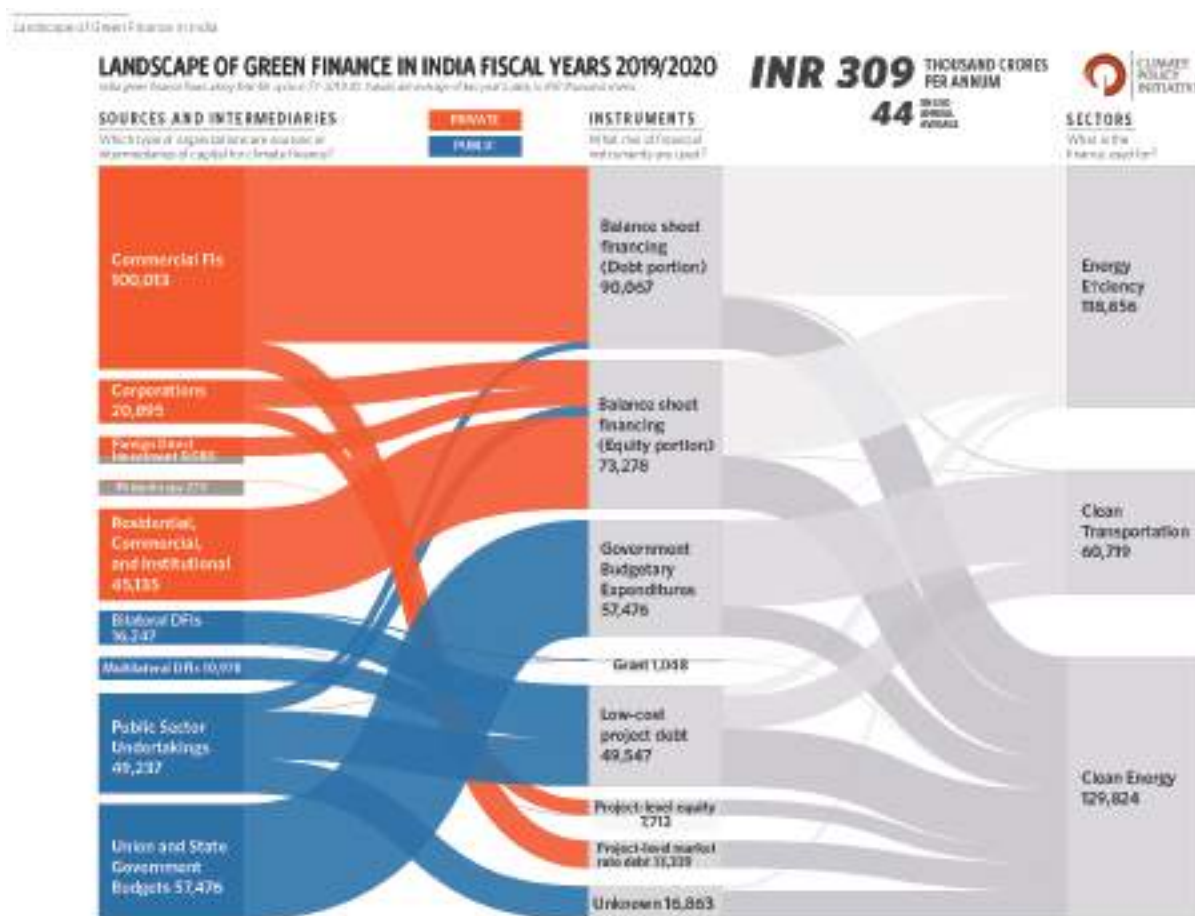
arguably is making sure that the funds reach the right projects or sectors in each department.

To cover the costs associated with climate change adaptation for the Indian states and union territories (UTs) that are most susceptible to its negative consequences, the National Adaptation Fund for Climate Change (NAFCC) was set up in August 2015 (MoEFCC n.d.). With an expected requirement of INR 181.5 crore for the financial year 2017–18 for the NAFCC, the government has set up a budget allocation of INR 350 crore for the years 2015–16 and 2016–17. The NAFCC initiatives give priority to the requirements that increase climate resilience in the regions mentioned in the SAPCC and the pertinent NAPCC missions.

In India, the total amount of climate finance, across all sources, in fiscal years 2019 and 2020 was USD 44 billion (~ INR 309 thousand crores). The details of climate finance in India are shown in Figure 8.3.

Domestic finance raised accounts for USD 37 billion, of which the public sector accounted for USD 15 billion and the private sector for USD 22 billion. The share of multilateral DFIs is approximately 4 per cent. Public finance in the form of government budgets has a share

Figure 8.3 Climate fund sources in India



Source: Climate Policy Initiative 2022a

of 19 per cent. It can be observed from Figure 8.3 that the combined share of corporations, foreign direct investments (FDIs), bilateral DFIs, and multilateral DFIs is lower than that of the budgetary allocation by the union and state governments. To attract more private capital, the government would require de-risking instruments that lower the risk perception of private players.

To achieve net zero by 2070, India will require increased support from international sources such as MDBs since domestic sources cannot mobilise the finance requirement that is estimated to be in trillions.

8.4 Climate finance: Maharashtra

While the per capita GSDP of Maharashtra has risen multi-fold over the past decade from INR 99,597 (~ USD 1,865) in FY 2012 to INR 2,25,073 (~ USD 2,863) in FY 2022, the state has also witnessed adverse impacts of climate change every passing year (GoM 2022). The state sees flourishing development trends in the context of credit size, development of industry and cooperation, and infrastructure. However, the perils of climate change loom over the progress and development of Maharashtra.

The change in weather patterns along with unseasonal rainfall and wastage of crops have been evident and explicit throughout the state of Maharashtra. The majority of districts had excess rainfall in 2021, while some districts experienced deficient rainfall (GoM 2022). Agriculture is the worst-affected sector by climate change, owing to hailstorms, cyclones, and untimely rainfall. However, not the only one badly affected. Maharashtra, having witnessed a three-fold increase in such events, is one of the top three states in India that is exposed to extreme drought events (Mohanty and Wadhawan 2022). Additionally, it has witnessed a two-fold increase in cyclones in the last 50 years (ibid). Eleven out of 36 of Maharashtra's districts are exposed to flood extremities (ibid). In 2021, Maharashtra witnessed the highest number of deaths of any state in India from adverse and extreme weather conditions (Centre for Science and Environment 2022).

Due to its exposure to increased and extreme natural calamities, there is an urgent need in Maharashtra to develop climate-resilient solutions to cope with the impacts on lives and infrastructure. It is imperative to establish mechanisms to cope with the state's climate vulnerability such that citizens can adapt to the impacts of climate change as well as mitigate future adverse impacts. While it is crucial to attract national and international finance flows in the state, regional efforts are also needed to mitigate and adapt to the degradation of the environment caused by climate change.

While it is essential to address the impacts of climate change, it is also important to note that these solutions would require financial, technological, and regulatory support from government entities.

8.4.1 Efforts by global, national, and regional entities to mitigate and adapt climate change in Maharashtra

Some of the non-financial regulatory efforts by the Government of Maharashtra to address climate change:

1. Mumbai's climate action plan was established in December 2021 with the purpose of shaping activities that could lead to reduced emissions and contribute to the goal set by the Paris Agreement. It was drafted by the Municipal Corporation of Greater Mumbai (MCGM) (Brihanmumbai Municipal Corporation n.d.).
2. Maharashtra formed the State Council for Climate Change, which will be headed by the Chief Minister of Maharashtra (Rawal 2021).
3. The UN Environment Programme (UNEP) signed an MoU with the Government of Maharashtra to support the *Majhi Vasundhara* campaign in February 2022 (ET Energyworld.com 2022). This campaign is targeted to educate citizens about the impacts of climate change and to encourage them to make more environmentally conscious choices. UNEP will support the government to develop carbon-neutral environmental strategies and educate the youth about pollution (ibid).
4. Maharashtra Energy Development Agency (MEDA) was established to aid state and central governments in developing and promoting new renewable sources of energy (MEDA n.d.).

In addition to regulatory initiatives to cope with climate change and its impacts, the Government of Maharashtra and the Government of India have launched various schemes with technical, operational, and financial support from various organisations. The schemes and programmes help in reducing the cost of projects which are otherwise difficult to operationalise by providing subsidies or finance to the project. Another channel of support is through penalising fossil fuel-based projects or activities and using the tax fund to finance renewable projects.

Some of the current sources (international, national, and regional) and scale of financing for mitigation and adaptation projects in Maharashtra are displayed in Tables 8.1, 8.2, and 8.3.

While there have been several initiatives towards clean energy projects, sustainable agriculture, and preventing air pollution, there is still a lot required from the central as well as state government – especially on the finance front – to transition the Maharashtra economy towards low-carbon or net-zero emissions. Various clean-source technologies are at their infancy stage and require financial support to become commercially viable. Providing climate finance to transition to low-carbon energy sources is a need of the hour to minimise the risks and vulnerabilities arising from

Table 8.1 International sources and scale of financing for mitigation and adaptation projects in Maharashtra

Institution/ Programme	Scheme	Year of establishment	Finance allocated
The World Bank	<i>Maharashtra Project on Climate Resilient Agriculture</i> : It aims to enhance the adaptation capacity of farming systems in Maharashtra.	2018–24	USD 420 million (~ INR 2,87,320 lakh)
The World Bank	<i>State of Maharashtra's Agribusiness and Rural Transformation Project</i> : Its objectives include supporting small-holder farmers in joining competitive agriculture value chains, facilitating agri-business investments, improving market access and productivity for priority commodities, and bolstering crop resilience against frequent floods or droughts.	2020–27	USD 210 million (~ INR 1,55,670 lakh)
Asian Development Bank	<i>Maharashtra Agribusiness Network Project (MAGNET)</i> : It aims to strengthen the network and marketing management of value chains of crops by incorporating both mitigation and adaptation activities.	2021	USD 0.37 million (~ INR 270.35 lakh)
Asian Development Bank	<i>Maharashtra Rural Connectivity Improvement Project</i> : It aims to improve rural roads and bridges with all-weather standards.	2018–22	USD 96.65 million (~ INR 68,045 lakh)

Source: The World Bank (n.d.) and Asian Development Bank (n.d.)

Table 8.2 National sources and scale of financing for mitigation and adaptation projects in Maharashtra

Institution/ Programme	Scheme	Year of establishment	Finance allocated
NABARD	<i>Climate Change Adaptation (CCA)</i> : It aims to enhance the adaptation capabilities of rural communities in 25 villages across the Ahmednagar district in Maharashtra to the adverse impacts of climate change.	2015	USD 3.5 million (~ INR 2,244 crore)
NABARD	It aims to improve efficient water management and agriculture technology adoption for climate-adaptive and resilient farming systems in 51 villages of the Nandurbar and Buldhana districts of the Maharashtra state.	2016	INR 22.95 crore
NABARD	It aims to restore degraded landscapes to the natural state of the ecosystem for climate resilience and livelihood improvement of vulnerable communities.	2015	INR 126.1 crore

Source: National Bank for Agriculture and Rural Development (n.d.)

Table 8.3 Regional/Local sources and scale of financing for mitigation and adaptation projects in Maharashtra

Institution/Programme	Scheme	Year of establishment	Finance allocated
Green tax / Environment tax	Under this tax regime, petrol-powered two-wheelers and four-wheelers older than 15 years will pay INR 2,000 and INR 3,000 over a period of 5 years, respectively, while diesel-powered vehicles will pay INR 3,500. Auto rickshaws with a lifespan of 8 years (15 years for CNG/LPG autos) will be levied INR 750 for 5 years. Battery-powered and electric vehicles are exempt from this tax entirely.	2010	Amount collected in 2010–11: INR 1,18,230 thousand crore 2011–12: INR 4,22,680 thousand crore 2012–13: INR 3,85,004 thousand crore
Green cess	Applicable at a rate of INR 0.04 per unit for industrial and commercial electricity consumers. In 2008, the rate was revised to INR 0.08 per unit. The green cess fund is dedicated to supporting renewable energy projects.	2004	Amount of funds used from 2006–07 to 2011–12: INR 1,347 lakh
Non-Conventional Energy Department, Government of Maharashtra	Urjankur Nidhi: A fund set up to establish non-conventional energy projects.	2006	INR 418 crore

Institution/Programme	Scheme	Year of establishment	Finance allocated
Government of Maharashtra	<i>Maha-Parwana Plan</i> : It offers incentives and a single-window clearance system for project execution for all proposals of foreign direct investment and investment proposals of INR 50 crore and above to be made in the state in the 'green' and 'orange' categories as fixed by the Maharashtra Pollution Control Board.	2020	-

Source: Mandal and Rangarajan 2015

climate change. It is also crucial to increase the level of penetration of the already existing clean technologies, like improving access to EVs. Therefore, the task at hand is not only to provide funds and financial assistance to upcoming technologies but also to ensure that the funds are being used effectively.

8.5 Climate budget in Maharashtra (2023–24)

Although both public and private sources contribute to climate finance in India, the majority of the country's spending comes from public sources (ORF 2023). The central and state budgets are the primary domestic sources of adaptation funding. Additionally, public spending acts as a catalyst to attract private funding for climate change initiatives. Therefore, it is imperative to have dedicated government expenditure on climate action.

Climate budget refers to the expenditure relevant to the climate action that falls under the government's budgetary structure (ORF 2023). With the help of a climate budget, government spending on climate action can become more transparent, accountable, and reliable.

Mitigation activities require large-scale investments to reduce emissions and adaptation activities necessitate financial resources to cope with the impacts of climate change. There is an urgent need for climate finance in Maharashtra's budget to develop resilient solutions for coping with climate impacts on lives and infrastructure.

The sources of funds in the Maharashtra budget, and thereby in the climate budget prepared hereafter, include state funds, central funds, funds from development finance institutions (DFIs), and externally aided projects (EAP).

8.5.1 Methodology

- Examining the state policies' expenditures: The analysis begins by reviewing the department-wise expenditure under all policies that are planned to be implemented in Maharashtra in FY 2023–24.
- Mapping policies to NAPCC and NDC objectives: Each policy is assessed and mapped to the objectives outlined in the NAPCC and India's NDC. The NAPCC encompasses a total of eight national missions on climate change, majorly focusing on adaptation and

resilience, while the NDC majorly emphasises the need for mitigation activities (MOEFCC 2021; UNFCC 2022).

- Calculation of climate budget: The total budget allocated to climate-related policies is determined by only including the policies that either correspond to the NAPCC objectives or NDC objectives. The total expenditure of these policies represents the climate budget.
- Share of climate budget: The share of the climate budget is calculated by dividing the climate budget by the total Maharashtra budget for FY 2023–24.
- Activity-wise climate budget: The schemes mapped to climate action are categorised into mitigation, adaptation, and cross-cutting activities based on their objectives.

This methodology ensures comprehensive assessment of climate-related expenditures which includes both adaptation and mitigation actions. It also ensures the alignment of state's expenditure with the overarching national objectives.

8.5.2 Climate budget findings

Based on our analysis of Maharashtra's department-wise policies expenditure, Maharashtra's budget for FY 2023–24 amounts to INR 1,79,231 crore. Of this, the allocated climate budget amounts to INR 21,420 crore. In the Maharashtra budget allocation for FY 2023–24, the share of the climate budget is 11.95 per cent. These figures highlight the proportion of funding dedicated to addressing climate-related initiatives within the overall budgetary framework of Maharashtra. Enhancing climate education across all levels of education in Maharashtra. Currently the state's secondary and higher secondary education comprises Environmental science as a subject. We propose some portion of the current budget of education and skills and entrepreneurship departments to promote schools to conduct science exhibitions on "Climate change solutions" and the relevant departments can conduct competitions and give prizes for practical and scalable solutions.

Schemes in the Maharashtra budget are focused on three kinds of climate action:

1. Mitigation: Mitigation efforts are focused on reducing GHG emissions and increasing carbon sinks (UNFCCC n.d.b).

Table 8.4 Department-wise climate finance allocation in the Maharashtra budget plan for FY 2023–24

Department	Climate budget (INR crore)	Total budget (INR crore)	Share of climate budget (%)
Relief and Rehabilitation	638.23	638.23	100.00
Environment & Change to Climate	429.00	429.00	100.00
Kharland	114.00	114.00	100.00
Water Supply and Sanitation	5,620.20	7,218.11	77.86
Fisheries	285.47	445.35	64.10
Horticulture	350.00	768.00	45.57
Forest	1,349.54	3,309.15	40.78
Agriculture	1,544.00	4,243.37	36.39
Urban development	6,267.50	20,910.29	29.97
Water Resources	3,119.72	14,648.82	21.30
Soil & Water Conservation	352.24	4,981.95	7.07
Energy	715.07	13,141.62	5.44
Rural development	438.14	15,745.81	2.78
Home – Ports	12.00	443.00	2.71
Public Works – Roads (excluding public undertakings)	160.00	14,365.41	1.11
Home – Transport	25.00	3,345.25	0.75
Minorities development	0.10	863.00	0.01
Labour	0.00	156.00	0.00
Marketing	0.00	324.00	0.00
Skill, Employment, Entrepreneurship and Innovation	0.00	1,241.63	0.00
School education	0.00	5,885.54	0.00
Total	21,420.22	1,79,231.29	11.95

Source: Authors' analysis based on the Maharashtra 2023–24 budget allocation

Note: The table does not include departments that have zero direct budgetary allocations toward climate action.

2. **Adaptation:** Adaptation efforts involve making necessary changes in ecological, social, or economic systems as a response to current or anticipated climate-related factors and their consequences (UNFCCC n.d.c). It encompasses modifying existing processes, practices, and structures to reduce potential harm or take advantage of opportunities that arise due to climate change. In essence, adaptation is about adjusting and preparing our systems to cope with and benefit from the impacts of climate change.
3. **Cross-cutting:** Cross-cutting efforts are focused on both mitigation and adaptation.

The share of adaptation schemes in the total climate budget of Maharashtra is the highest (88.43 per cent). Approximately, 9.13 per cent of the climate budget is allocated to mitigation schemes. Lastly, the remaining share of the climate budget is focused on cross-cutting schemes, that is, schemes that target both mitigation and adaptation.

8.6 Proposed climate budget based on MHSAPCC recommendations (2024–30)

Based on our analysis of chapter-wise recommendations of MHSAPCC, Maharashtra's proposed required climate budget till 2030 amounts to INR 297558.74 crore. The proposed climate budget also focuses on three kinds of climate action – mitigation, adaptation, and cross-cutting. The water department requires the highest amount in the proposed budget, with adaptation as the focus action. The forest department requires finance for all three climate actions, with the highest share in mitigation.

Table 8.5 Climate budget categorisation

Category	Climate budget (INR crore)	Share of total climate budget (%)
Mitigation	1,955.41	9.13
Adaptation	18,941.63	88.43
Cross-cutting	523.16	2.44
Total	21,420.21	100%

Source: Authors' analysis based on the Maharashtra 2023–24 budget allocation

Table 8.6 Department-wise segregation of proposed climate budget based on MHSAPCC recommendations (2024–30)

Departments	Adaptation Budget (in INR crore)	Mitigation Budget (in INR crore)	Cross-cutting (in INR crore)	Climate Budget (in INR crore)	Cumulative Climate Budget Incremented by 50% (in INR crore)
Water	207760	0	0	207760	311640
Agriculture	17408.57	19690.6	0	37099.17	55648.755
Relief and Rehabilitation (Disaster Management)	78.4	0	0	78.4	117.6
Energy	0	546.8	0	546.8	820.2
Environment and Climate Change	166	0	0	166	249
Habitat and disaster risk	0	190	0	190	285
Forest	3.6	12604.5	572.9	13181	19771.5
Industries	0	26350	0	26350	39525
Public health	8249.56	0	0	8249.56	12374.34
Public works	2500	5.61	0	2505.61	3758.415
Tourism	32.2	0	0	32.2	48.3
Transport	0	1400	0	1400	2100
Total	236198.33	60787.51	572.9	297558.74	446338.11

Source: Authors' analysis

Note: The recommended budget is not the total climate budget but only the intervention-specific budget.

Considering the current outlay of Maharashtra, the estimated climate budget for MH SAPCC 2.0 by 2030 is 297558.74 crore and by increment of upto 50 per cent the estimated climate budget is 446338.11 crore.

The share of adaptation activities in the total proposed budget of Maharashtra remains the highest (79.39 per cent). Approximately, 20.42 per cent of the climate budget is allocated to mitigation activities, a significant increase from the Maharashtra budget of FY 23–24. Lastly, the remaining share of the climate budget is focused on cross-cutting activities.

Table 8.7 Proposed climate budget activity-wise categorisation

Category	Climate budget (INR crore)	Share of total climate budget (%)
Mitigation	60787.51	20.42
Adaptation	236198.33	79.39
Cross-cutting	572.9	0.19
Total	297558.74	100%

Source: Authors' analysis

8.7 Proposed strategies for mobilising mitigation and adaptation financial requirements

Climate change adaptation activities require financing on a large scale as they include infrastructure development that is resilient to climate disasters and establishing risk-management procedures and tools. Currently, sources of funds which finance mitigation and adaptation projects are limited in scale and come majorly from international sources.

To ensure that lives, livelihoods, and infrastructure are safeguarded against the adverse impacts of climate extremities in the form of disasters, the state government may undertake the following recommendations to further enhance climate budget:

1. To ensure climate finance flows, the state of Maharashtra has already implemented fiscal measures/tools, namely, green cess and green tax (Mandal and Rangarajan 2015). However, there is a transparency challenge in respect of the activities financed from the revenue generated from these mechanisms. The information on the amount collected under environmental tax is publicly available. However, the information on its utilisation is not public (ibid). A similar pattern of lack of transparency is seen in the case of funds collected under the green cess (ibid).

Thus, actions that can be taken to enhance transparency in mobilising revenue generated through green taxes and green cess include:

- a) Clear and transparent reporting: The government can provide clear and transparent reporting on the revenue generated from green tax and green cess, including the amount collected and how the funds will be used.
- b) Independent oversight: An independent oversight body could be established to monitor the collection and use of revenue from green taxes and green cess. This can help ensure

that the funds are being used for their intended purpose.

- c) Clear objective of investment in green projects: Specific objectives can be laid out which suggest that the revenue generated from green tax and green cess must be invested in projects that reduce GHG emissions and promote climate change adaptation. The eligibility of projects as green projects could be dependent on the criteria established by a standard or recognised taxonomy.
- d) Monitoring and evaluation: Regular monitoring and evaluations could be conducted to ensure that the funds are being used effectively and that the intended outcomes are being achieved.

Implementing these recommendations could include some potential costs, including administrative costs, auditing costs, legal expenses, and operational costs. However, the benefits would provide assurance that the funds are being used for the intended purposes, and the monitoring system would provide assurance that the funds are being used effectively. It would also help build public trust in the revenue-collection process and increase the effectiveness of the government's efforts to address climate change.

- 2. In addition to the existing climate mitigation tools, de-risking financial instruments can also play an important role in mobilising finance for climate change by reducing the perceived risks of investing in emerging technologies. They can help in reducing risks faced by businesses and individuals and crowd in private investments. Some examples of de-risking financial instruments that can be used to mobilise finance for climate change:

- a) Insurance products: Insurance products such as the weather index insurance can be explored by authorities to protect against financial losses resulting from frequent extreme weather events.
- b) Guarantees: Guarantees can be provided by governments or DFIs to reduce the credit risk of investing in climate-related projects. For example, the state government may provide a guarantee to a private-sector investor to cover a portion of the potential losses associated with a renewable energy project. This can help to reduce the overall risk of investing in the project and make it attractive to private-sector investors.

Providing insurance and guarantees by the government can have significant financial implications for the government in the form of the following potential costs:

- a) Losses: The government may need to pay out claims if the insured events occur, which could

be substantial and result in significant financial losses for the government.

- b) Administrative costs: The government may need to hire staff and invest in technology to administer the insurance and guarantee programmes, which will incur a cost.
- c) Credit risk: The government may be exposed to credit risk if the entities receiving the insurance or guarantee default on their obligations.
- d) Fiscal risks: The government may be exposed to fiscal risks if the insurance or guarantees are not priced correctly, which can result in higher costs than expected.

- 3. It is a laborious procedure to get access to GEF and GCF financing, which oftentimes discourages market participants from reaching out and seeking financing to deploy clean energy projects. We've attempted to highlight some of the GEF and GCF's processes and modalities, along with the relevant documents, concerned entities, and guidelines.

- a) The Global Environment Facility functions as the financial mechanism of the UNFCCC and the Paris Agreement by funding several multilateral environmental accords. The funds for GEF are replenished every four years. The GEF-8 replenishment pledge is USD 5.33 billion (approximately INR 4 lakh crores). Eligible countries are those that have ratified the UNFCCC and conform with the eligibility criteria decided by the COP of the UNFCCC, are already eligible to receive World Bank funds, or are recipients of technical assistance from the UNDP. Further, to be eligible, all projects and programmes must fulfil the national priorities, GEF priorities, financing and participation (must involve the public in project design), and the four modalities with different proposal submittals ruled out in the Project and Programme Cycle Policy provided by the GEF.

Only accredited institutions can access GEF funding directly, such as UN agencies and multilateral development banks. There are presently 18 GEF institutions that act as GEF agencies, which create project proposals and then manage these projects on the ground. In addition, all GEF projects and programmes are equipped with a GEF operational focal point (OFP) and a GEF focal point that serves as liaison agencies. Each nation that receives GEF assistance designates an OFP, and GEF focal points are government officials appointed by member countries. On the GEF website, country-specific focus points may be accessed.

b) The Green Climate Fund was created in 2010 by the UNFCCC to assist developing nations in the adaptation and mitigation of climate change. GCF enables the governments to direct access the fund through the *Readiness Programme*. GCF also offers *private-sector facility* to mobilise institutional investors such as pension funds, insurance companies, and commercial banks. Furthermore, GCF collaborates with small- and medium-sized enterprises (SMEs) in developing countries to uncover new climate change mitigation solutions.

The GCF architecture is composed of the following entities:

- i. *National designated authorities (NDAs)*: Ensure that projects and programmes benefit the country and are aligned with national strategies and plans. The NDAs approve the selection of projects in the country. They serve as liaisons between the government and the GCF.
- ii. *Accredited entities (AEs)*: Funding is channelled through AEs; only AEs can receive GCF funding; and there are currently 114 AEs. The process of accreditation

is rigorous, and all subnational, national, and regional organisations must obtain a nomination letter from the government. On the GCF website, accreditation is briefly explained. However, institutions can partner with AEs without being accredited.

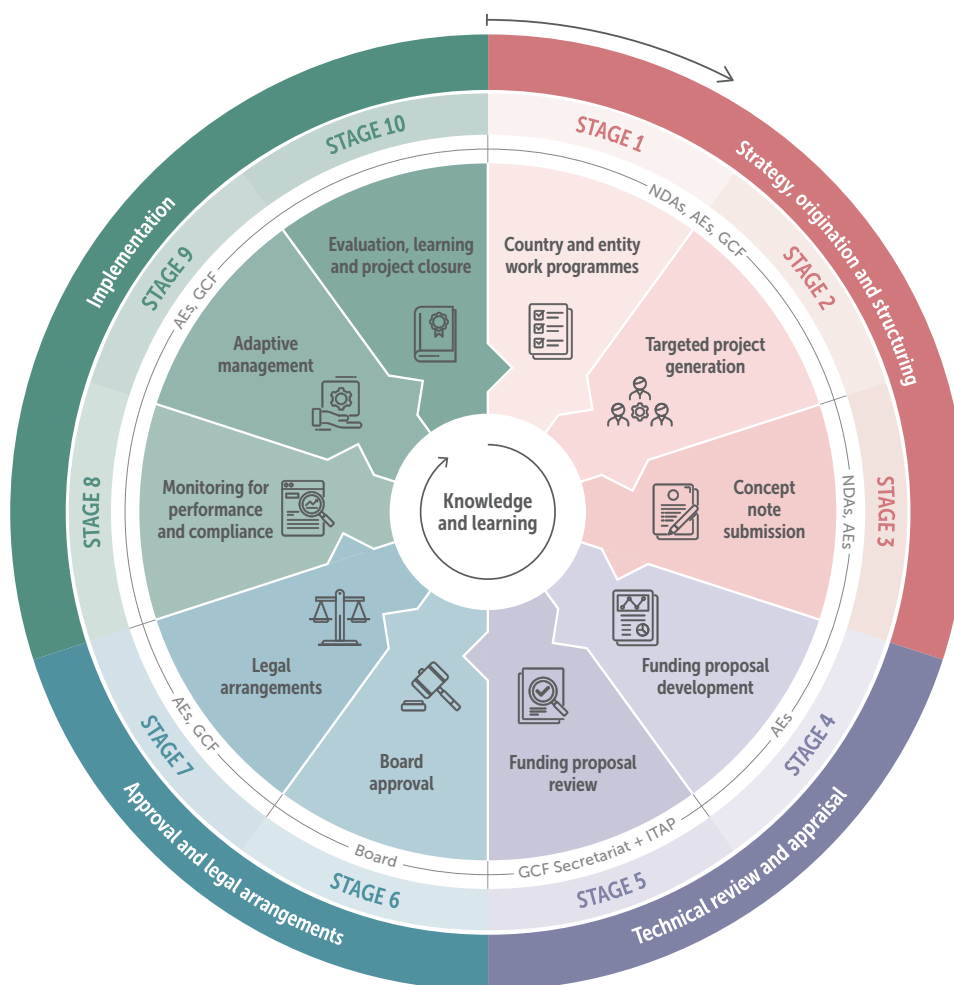
- iii. *Execution entities (EEs)*: They are the project implementers; EEs are accountable to AEs.

The funding proposals undergo a ten-step procedure prior to implementation.

The GCF has also developed a *proposal toolkit 2020* to assist stakeholders in developing GCF project proposals. The GCF also provides project lifecycle information on its website. Additionally, the GCF facilitates access to resources for small-scale activities with minimal environmental and social risks and impact. Projects with up to USD 10 million in GCF contributions may seek approval via the simplified approval process.

These recommendations can help achieve transparency in the procedures of accessing the funds, building investor confidence, and crowding-in private capital in the state of Maharashtra.

Figure 8.4 Ten-stage project proposal cycle



Source: Green Climate Fund n.d.

Table 8.8 CEEW Recommendations for mobilising climate finance

S. no.	Recommendations/ Targets	Actions to be undertaken
1	Enhancing transparency in mobilising revenue generated through green tax and green cess.	1. Clear and transparent reporting: The government should provide clear and transparent reporting on the revenue generated from green taxes and green cess, including the amount collected and how the funds will be used. 2. Independent oversight: An independent oversight body could be established to monitor the collection and use of revenue from green taxes and green cess. This can help ensure that the funds are being used for their intended purpose and that the revenue collection process is free from corruption. 3. Clear objective of investment in green projects: Specific objectives can be laid out which suggest that the revenue generated from green taxes and green cess should be invested in projects that reduce GHG emissions and promote climate change adaptation. The eligibility of projects as green projects could be dependent on the criteria established by a standard or recognised taxonomy. 4. Monitoring and evaluation: Regular monitoring and evaluations should be conducted to ensure that the funds are being used effectively and that the intended outcomes are being achieved.
2	De-risking the private investments in green and sustainable projects.	By providing a level of protection against potential losses, de-risking financial instruments can help attract private-sector capital and investment to climate change projects, which is crucial for addressing the challenges of climate change and transitioning to a low-carbon economy. Some examples of these instruments are insurance products and guarantees. Additionally, the state can implement carbon-pricing mechanisms such as carbon taxes. These can be used to put a price on carbon emissions and encourage businesses and individuals to reduce their GHG emissions. This can help mobilise finance for climate change by creating an economic incentive for reducing emissions and investing the collected revenue in low-carbon technologies.

Source: Authors' analysis

The Environment and Climate Change Department's strategy gradually directs the state's financial resources towards prioritising the actions for combating climate change and promoting environmental sustainability. The above section explores the possibilities in the suggested climate budget outlined in the MH SAPCC 2.0 from 2023-2024 to 2029-2030. The departments aim to increase the financial outlay via targeted increments in the state's climate budget within existing financial constraints. It is proposed that various line departments gradually boost their spending on climate-related activities, aiming for a yearly increase of 5 per cent. By 2030, it is envisioned that almost half of the state's budget will be allocated to green initiatives, signifying a commitment to address climate change and promote environmental sustainability as a top priority.

State climate action cell in close collaboration with relevant stakeholders and line departments will develop a robust green finance framework that can provide innovative business models for enhancing the flow of adaptation finance in the state for boosting the financing for implementation of the SAPCC. Blended finance mechanisms such as those through public-private partnerships should be promoted to catalyse private-sector investment.

Furthermore, by encouraging the line departments to raise their climate-related budgets significantly, it is aimed to promote synergy across different government departments. This collaborative approach is crucial for effectively implementing climate change adaptation and mitigation measures across various sectors. This strategy acknowledges the significant challenge climate change poses to the state and the need for substantial investment in adaptation and mitigation measures to combat the same.

Geographic areas impacted	Implementing government departments	Financial implications	Outcome
The state of Maharashtra	Department of Finance	Setting up a reporting mechanism for transparency would increase government expenditure as the costs would include administrative costs, auditing costs, legal expenses, and operational costs. However, the benefits would be the appropriate allocation of funds toward eligible green projects, assurance that the funds are being used for the intended purposes, and assurance that the monitoring system ensures that the funds are being used effectively.	Enhanced transparency would build public trust and a positive shift in investor sentiments. It could drive private capital towards green and sustainable projects, which will be relevant in helping the transition to a low-carbon or net-zero economy.
The state of Maharashtra	Department of Finance	Providing insurance or guarantees could incur administrative and compliance costs along with credit and fiscal risks. However, these instruments can help to protect vulnerable communities and individuals from the impacts of climate change.	It can crowd in private investments in high-risk regions or sectors.

Box - 8

Voluntary carbon market toolkit

Maharashtra can harness significant opportunities provided by the Voluntary Carbon Markets (VCM) under Article 6 of the Paris Agreement to generate climate finance through offset projects. India boasts the largest portfolio of VCM projects globally, with 921 projects registered under Verra VCS (Verified Carbon Standard) and Gold Standard as of January 19, 2022. Conservative estimates suggest a potential to generate 132.60 million and 17.4 million tons of CO₂ and GHG emission reduction from these projects over the next decade (GIZ, CII. 2022).

An essential segment involves the participation of private businesses in Article 6 VCM, which offers a vast opportunity for states to leverage this potential and attract industry investments into offset projects. However, VCM in India's Article 6 strategy is crucial to pave the way for private sector investments into large-scale emission reduction projects.

At a country-to-country level, India has identified 13 activities for participation under Article 6, presenting a significant opportunity for collaboration between the Centre and States to unlock climate finance potential.

For Maharashtra, projects in agriculture and bio-diversity offer substantial opportunities for climate finance through offset projects. For instance, a high-quality, forestry-based offset project could help farmers earn supplemental income from climate-resilient forest harvests and carbon credits while also protecting and restoring forest cover. Reforestation and assisted natural regeneration can revive lost biodiversity, addressing the decline of tree species like amla, hirada, and beheda caused by unsustainable harvesting and forest fires. These projects offer dual benefits by helping communities mitigate and adapt to climate change, particularly as climate warms, rainfall patterns become erratic, and extreme weather events become more frequent. Carbon markets are increasingly being used for blended finance, with the following examples illustrating their application, for details refer Annexure - Table A10.

Source: Author's compilation

Implementation strategies of the SAPCC

9.1 Mainstreaming climate change adaptation into development policies

As global emissions continue to rise and the intensity and frequency of extreme events caused by climate change increase, it has become difficult for policymakers and the concerned governments to prioritise climate change adaptation policies into sector-specific developmental plans.

Mainstreaming climate change adaptation is the iterative process of incorporating adaptation-related concerns into policymaking, budgeting, implementation, and monitoring procedures at the national, sectoral, and subnational levels. It is a multi-year, multi-stakeholder undertaking that is based on the idea that adaptation to climate change is important for economic development that benefits the poor and for achieving the sustainable development goals (SDGs). It involves collaborating with various governmental, intergovernmental and non-governmental, and other developmental professionals and key stakeholders.

The mainstreaming of climate change adaptation into development plans can be accomplished, according to the UNEP report, in the following manner:

1. **Finding entry points and setting the stage:** This focuses on preparing the foundation for mainstreaming. Understanding the links between climate change and national development priorities as well as the governmental, institutional, and

political contexts that affect these efforts is necessary in order to define pro-poor adaptation outcomes, identify entry points into development planning, and present the case for adaptation mainstreaming.

2. **Mainstreaming adaptation into policy processes:** Integrating adaptation into current policy processes, such as the State Action Plans on Climate Change (SAPCCs), national plans on disaster management, and state- and region-specific development plans, focuses on incorporating climate change adaptation considerations into these processes. This process will also involve a comprehensive mapping of hazards, vulnerability, and risk of climate extreme events.
3. **Budgeting and climate financing:** This involves the process of ensuring the mainstreaming of climate adaptation activities into the national and state budgets.

It is very important to involve the right stakeholders for the smooth implementation of the above-mentioned frameworks and action plans. The execution and monitoring should also be done conscientiously.

9.1.1 Prioritising strategies against maladaptation

Maladaptation is a phenomenon whereby a nation's or a state's capacity for adaptation may be harmed by poor decisions and action plans made while setting priorities and carrying out development plans. Maladaptation often makes a community or country more vulnerable to and

exposed to climatic extremes. For example, destruction of mangroves for developmental activities can increase the risk of and vulnerability to extreme climate events such as coastal flooding, cyclones, and high-wave activities along the coastline (Organization for Economic Cooperation and Development 2009). Similarly, long-term sustainability of an irrigation plan may not be possible if climate-related fluctuations in rainfall are not taken into consideration. In the light of this, each state/country should make sure that their action plans and strategies work and that they don't encourage the process of maladaptation while mainstreaming climate change adaptation into their development policies.

While specific departments are enjoined to take the responsibility of identifying and implementing action plans in Maharashtra, it is imperative to mainstream the climate change adaptation into sector-wise development policies.

Key action points and recommendations against maladaptation

1. Integrate the future climate projections into state disaster management plans

It is crucial to integrate the future climate projections into state and district disaster management plans. Contingency planning and standard operating procedures could be formulated based on the scientific findings and results from global and regional climate models.

2. Incorporating regional and hazard-specific action plans into developmental planning

The state should ensure that hazard-specific action plans for infrastructural development are integrated into developmental planning. For example, the construction of roads and other public infrastructure should be based on the multi-hazard vulnerability of and risk assessment pertaining to specific regions.

3. Incorporating land use planning into the developmental process of the state

While planning developmental projects, it is very important for the state to be meticulous about land use planning. For instance, if land use and land cover change continue in the same trend, there may be greater forest degradation and fragmentation, which would make these ecosystems and the dependent species and livelihoods more susceptible to climate change. Such ecosystems may be protected, restored, and strengthened to withstand climate change via proper land use zonation and development planning.

9.2 Mainstreaming women in Maharashtra's SAPCC

Men and women play different roles in society due to the uneven distribution of decision-making power. For women, this leads to lack of education, skills, and training opportunities and unequal allocation of resources. Thus, the impact of climate change is different for men and women because of the differences in interests, needs, and demands. Even among the poor, women are the first to experience poverty traps during the calamities caused by climatic changes. It is essential to acknowledge the differences in constraints and opportunities that women face while dealing with the impacts of climate change and develop participatory approaches by putting gender equality at the centre of climate change solutions. It will be necessary to incorporate various gender-specific views in the policies and programmes if we want to empower women as change agents rather than just seeing them as victims of climate change. Without gender equality, a sustainable, more equal future is not achievable. Thus, integrating gender components is essential for successful implementation of the SAPCCs in Maharashtra.

To ensure the successful integration of women's concerns in the various sectors under the climate action plan, the state will adopt the following five-fold approach:

Table 9.1a Framework to mainstream women in the SAPCC

Intervention areas	Action points
 Awareness generation and capacity building	- Gender-inclusive Information, Education and Communication (IEC) will be the important components of the programme to make women aware of the challenges and opportunities to combat climate change. - Build the capacity of individual women by forming cadre- and women-focused community-based organisations such as producer groups, common interest groups, self-help groups, women Panchayati Raj Institutions (PRIs), etc. - Create training programmes for women, so they can execute participatory plans and adaptation techniques at the village level and actively participate in the governance institution's three tiers of decision-making. - Train women in the application of new and sustainable agri-allied technologies that are adaptive and appropriate, so that their livelihood is ensured.

Intervention areas	Action points
 Asset creation and decision-making	It is important to create similar assets for women and men in areas such as: • ownership of land titles and rights, • management of livestock, • lease on forest land, and • community institution infrastructure. There should be equal opportunities for livelihood activities and for exercising control over the generated income, so women will have equal participation as well-equipped decision-makers in household and community matters.
 Gender budgeting	Appropriate funding should be provided to women via financial products which are easily available to them. Thus, there will be a focus on gender budgeting within each action point for mitigating climate change based on gender-differential data. Some steps to be taken include the following: • Setting aside money for programmes that incorporate gender issues into adaptation and mitigation efforts. • Allocation of Kisan Credit Cards (KCC) through women farmers' groups/women-led farmer producer organisations (FPOs)/self-help groups (SHGs). • More adaptation funds to be targeted and accounted for by women farmers and women as they are more engaged in farming due to the extensive migration of men.
 Gender-focused monitoring and evaluation	For other departments' adaptation-related programmes, more pertinent data and measures will be used. The following actions will be taken to ensure gender integration: • Sex-disaggregated baseline data will be collected. • Gender-specific objectives will be set in programmes and schemes. • A gender-responsive communication strategy will be developed to create awareness and collect inputs from citizens on adaptation measures. This will provide women a platform to share their challenges and also suggest solutions based on their needs and requirements. It will also support the active participation of women in public debates and will make the process robust. • Gender-specific indicators in programmes will be set in such a way that the agenda of gender integration is not diluted. • Gender-focused monitoring and evaluation, as well as audits of adaptation programmes, that take gender into consideration will be carried out. • The team will ensure systematic documentation and widely share case studies to a larger ecosystem to demonstrate the benefits of applying gender-sensitive approaches.
 Convergence with other stakeholders	On climate change mitigation and adaptation programmes, it's crucial to learn from the ground up and collaborate with a variety of stakeholders, especially organisations that support women. A special working relationship with the Rural Development & Panchayat Raj Department, Women and Child Development Department, Gram Panchayat, etc. will be encouraged to make the process easier as well as a holistic one: • All governance institutions, including PRIs, line agencies and district rural development agencies (DRDAs), to perform gender and adaptation capacity-building activities. • Support and work together on adaptation programmes and schemes with the Department of Women and Child Development to help develop internal capacity to work on gender-based climate change adaptation and teach women how to create resilient and sustainable livelihoods. • Partnerships with the Panchayati Raj department will be launched to support the Gram Panchayats in developing participatory and gender-focused action plans on adaptation at the panchayat level, so women are included while developing the village-level development plans.

Source: Authors' compilation

Table 9.1b Key priority areas to engage women in the SAPCC

Sector	Action points and women's engagement
 Agriculture	• Women farmers should be involved in kitchen gardening and crop diversification to encourage climate-resilient agriculture. • Women SHG members should be involved in generating awareness among farmers regarding climate-friendly agricultural techniques
 Energy	• Support women in replacing fuelwood-based energy with solar cooking gas or biogas-based cooking stoves. • The livelihoods of women can be linked to decentralised renewable products, such as solar pumps, solar dryers, etc., for long-term sustainability of income. • Create a cadre of women named 'Urja Didi' in each Gram Panchayat. This is a new strategy for raising awareness of energy conservation among rural housewives, and these women would train other women on energy-saving activities in the domestic sector
 Forestry	• Women's participation needs to be improved, and equity in sharing benefits, such as land rights and forest produce, should also be ensured
 Health	• Anganwadi and Accredited Social Health Activist (ASHA) workers should be trained to support women in managing and overcoming climate-related stress and anxieties

Source: Authors' compilation

9.3 Role of youth in implementation of the SAPCC

According to the 2011 census, youth constitute almost one-quarter of the population of Maharashtra (Ministry of Home Affairs 2011). Their population is set to increase in the future, and they will represent a major percentage of the people who are impacted by climate change (United Nations (UN n.d.). Owing to the effects of climate change, they will be inheriting a challenging world. In this context, it is important that youth from rural and urban Maharashtra are equipped with the necessary skills and resources to adapt to such changes.

It is imperative that youth be considered and included as part of the solution to address climate change. They will be better positioned to combine traditional Indian practices with modern technologies to develop solutions for problems in different sectors, such as agriculture, water conservation, waste management, and the production of renewable energy.

This potential has been recognised by the Indian government in the National Action Plan on Climate Change (NAPCC). One of the eight missions of the NAPCC is the National Mission on Strategic Knowledge for Climate Change (NMSKCC). The mission intends to create infrastructural and human resource systems for knowledge that would support national action for effectively addressing the goal of ecologically sustainable development. The mission identifies youth as key stakeholders and aims to build a community of young climate advocates to spread

awareness about the issues and solutions related to climate change (Department of Science and Technology, Ministry of Science and Technology 2010).

A paper titled 'The Climate Crisis Is a Child Rights Crisis: Introducing the Children's Climate Risk Index' was recently released by the United Nations Children's Fund (UNICEF 2021) in partnership with Fridays for Future. It is the first in-depth analysis of climate risk from the viewpoint of a child. The impact of climate change on children around the world was previously demonstrated in a study based on the Notre Dame Global Adaptation Initiative (ND-GAIN) index. It evaluates nations according to how exposed and vulnerable children are to climatic and environmental shocks, such as heat waves and cyclones, based on their access to basic services. India is one of four South Asian nations where children are most at risk from the effects of climate change because of its effects on their education, health, and safety.

The Government of India has also identified the potential of youth in adopting new technologies to solve different issues pertaining to the environment. This has led to the formation of the Youth Co:Lab, which is a joint initiative taken by NITI Aayog and the United Nations Development Programme (UNDP). This initiative focuses on conducting youth-focused dialogues and supporting enterprises which tackle social as well as climate-related issues (NITI Aayog 2022). In order to inspire youth between the ages of 18 and 23 to pursue sustainable lifestyles, the National Museum of Natural History and the Ministry of Environment, Forest and Climate Change jointly launched the 'In our LiFetime' campaign at COP27. With the Lifestyle

for Environment (LiFE) initiative (Ministry of Environment, Forest and Climate Change 2022), the campaign seeks to recognise youth around the world who have contributed to climate action efforts.

Key initiatives by the Government of Maharashtra (GoM) to engage youth in climate action

The GoM has also ensured that youth action to address climate change receives resources and support through state-specific missions and policies. The state government in its 'Vision 2030' identifies youth as among the most important stakeholders in their mission to develop public awareness of climate change and encourage people's participation (Planning Department 2017). It aims to upskill youth by providing training to the local communities for alternative livelihoods which are climate resilient, such as urban agriculture.

Recently, UNICEF Mumbai and the Centre for Environment Education (CEE) conducted a state-wide survey to understand the perception of youth with regard to climate action (UNICEF 2022). The survey titled 'Youth Climate Advocates and Activists in Maharashtra: Call to Action for Youth Engagement in Climate' received over 270 responses from youth in the age group 10–29 in urban and rural Maharashtra. The respondents identified issues pertaining to both geographies and have demonstrated interest in working on issues related to tree plantation, wildlife and water conservation, waste management, and pollution mitigation.

In an attempt to include youth in its efforts to combat climate change, the Department of Environment and Climate Change, GoM, launched an initiative titled 'Majhi Vasundhara Curriculum under Majhi Vasundhara Abhiyan', with technical support from UNICEF Mumbai, The Regional Centre for Urban & Environmental Studies (RCUES) of All India Institute of Local Self Government (AIIILSG) Mumbai, and the CEE. It aims to strengthen the existing curriculum to include material about climate action, worsening natural disasters, and promoting 'green habits', which would promote the shrinking of the carbon footprint at the individual and household levels (Environment and Climate Change Department 2020).

The GoM has also partnered with the UNEP to implement a series of climate initiatives. UNEP will be supporting the state government through the programme 'Tide Turner Challenge', which aims to educate youth on plastic pollution and marine litter and mobilise them to combat this problem. This challenge will be implemented in all educational institutes across Maharashtra ('UNEP Signs MoU' 2022).

UNICEF Mumbai and CEE have also launched MYCA (Maharashtra Youth for Climate Action), which provides reading materials to guide the youth and improve their awareness of topics such as biological diversity, energy actions, tackling solid waste management, and water conservation and management (UNICEF n.d.). In 2022, UNICEF Mumbai and the Higher and Technical Education Department (HTED) collaborated to impart skills to and

empower 7,10,000 youth between the ages of 17 and 25. The topics covered included climate change and water conservation practices, and more than 3,000 colleges and technical institutions of the state participated (Jog 2022). Within this collaboration, the youth or 'climate warriors' will get to implement ideas to improve water conservation facilities and spread awareness about their importance in relation to climate change and improved water use efficiency. The collaboration also launched a self-paced online course on climate change titled 'Youth Leadership for Climate Action', with certification from the state government, encouraging youth to enhance their knowledge, participate in activities, and become agents of change within their communities.

The state government has taken initiatives to include youth as part of the solution to tackle climate change and has also made attempts to support entrepreneurial interventions which hold the potential of addressing several challenges. The youth will play an important role in implementing the strategies proposed in the state action plan. To create a sustainable environment for today's youth to inherit in the future, the government has placed major emphasis on the SDGs. The following section provides key recommendations for the government that would promote the participation and inclusion of youth in climate action.

Key recommendations to improve youth engagement in climate change

The primary objective of youth engagement should be to allow youth from various regions of Maharashtra to participate in the implementation of state policies and support the government in providing climate-resilient services in as many areas as possible. Some recommendations for this are listed below.

1. Encouraging youth to develop climate-resilient solutions

The age of artificial intelligence and entrepreneurship has motivated a large number of young people to come up with innovative ideas and design products which have the potential to address issues related to climate change. The GoM could hold competitions in the form of 'Innovation Challenges', inviting youth from all over the state to present their ideas. This will also help the government to identify, support, and scale solutions which hold relevance to the state. The incorporation of such ideas into the state's current development plans will also support the 'Make in India' campaign, which was introduced by the Government of India to encourage entrepreneurship.

2. Skill-building through mainstreaming educational material and skill development programmes implemented in the state

A young person's skill development is greatly influenced by education. The state government could produce material showcasing its knowledge on climate change. These materials would include overviews of the problems caused by climate change

that the state's residents must deal with, descriptions of climate action that can be taken at the individual, household, community, and local government levels, and briefs of state-specific policies and initiatives that would inform the youth about the platforms of action already in place. The UNICEF–CEE survey cited earlier highlighted the key skills demanded by the youth of Maharashtra, which included project and campaign management and finding green and sustainable jobs along with understanding existing state, national, and global policies and negotiation processes.

Such material could be circulated through schools, newspapers, and social media platforms. The reach of this material would also increase with the availability of such information in English, Marathi, and Hindi. The state government could also invite content through consultations with youth groups to encompass a diversity of views. Youth could also be appointed to undertake activities for Information, Education, and Communication (IEC) and behaviour change with regard to climate-related actions. Using the Majhi Vasundhara curriculum, teachers are currently being trained to teach children about climate change. Young people can be encouraged to use IEC material and support teachers and local governments to conduct awareness activities with children through community outreach and engagement activities in consultation with the HTED and the rural and urban development departments.

The state is running several skill-building programmes through its dedicated skill development and entrepreneurship department. Youth from across the state can be mobilised and trained in skills related to environment and climate change mitigation and adaptation on a priority basis.

3. Youth Parliament on climate change

The Ministry of Parliamentary Affairs launched the 'National Youth Parliament Scheme' and has been conducting Youth Parliaments all over the country since 1966 with the aim of making the youth aware

of the ethos of democracy. The state of Maharashtra could invite youth organisations and young citizens of the state to participate in the Youth Parliament on Climate Change annually, which would allow them to discuss topics related to the environment and climate change and understand the state-specific processes involved in making decisions. This will enable them to provide formal suggestions to the state government and suggest steps to be taken. Moreover, this platform may also be used for knowledge sharing, development of practical solutions, and training youth for the future.

4. Creating institutional mechanisms for youth to engage with policy processes

A key insight from the UNICEF–CEE survey points to the lack of a formal mechanism for youth to engage with environmental and climate-related policymaking. There are primarily two ways in which the GoM could ensure the participation of youth. First, the government could encourage youth to provide suggestions and participate in the implementation of environmental schemes related to afforestation, water rejuvenation programmes, climate-resilient agriculture, and so on. This will not only allow youth to gain practical experience in climate action – thus enabling them to learn about state-specific issues – but will also ensure community action in the implementation of schemes. Second, the state can establish annual district-level dialogues to build an effective interface for the youth to communicate their issues directly to the concerned authorities and decision-makers. These steps will build confidence in the youth to work together with the government, thus resulting in effective climate action. The state could also appoint 'Climate Resilience Fellows' and '*paryavaran rakshaks*' in every district and block, along the lines of CM Fellows and ASHA workers, to ensure last-mile reach in the area of climate change and as a mechanism to engage with and promote climate-focused programmes. Thus, youth can act as active mediators between the government and communities.

Monitoring and Evaluation Mechanism

10.1 Overview

Monitoring and Evaluation frameworks are crucial to assess and monitor the progress of implementation of an action plan. It is important to ensure that a methodical learning and course-correction process is established and operates concurrently with the application of the policies.

Monitoring	Evaluation
Monitoring is the continuous, methodical gathering and evaluation of data as a project develops. Its goal is to track progress towards the accomplishment of programme objectives	The process of evaluating a programme assesses if it has achieved its goals and the degree to which changes in outcomes can be attributed to the programme

10.2 Institutional Mechanism for SAPCC Implementation

The State Adaptation Action Plan on Climate change (SAAPCC) for Maharashtra was released in 2014. According to the goals of the NMSKCC, the SAAPCC advised Maharashtra to build a State Knowledge Management Centre on Climate Change (SKMCCC). The Department of Science and Technology (DST), Government of India, supported the establishment of the SKMCCC within the Environment and Climate Change Department of the GoM. The SKMCCC acted as the state's focal point for matters relating to climate change.

Figure 10.1 Monitoring and Evaluation Mechanisms



Source: Authors' compilation

The broad goals of the SKMCCC were as follows:

1. Act as a knowledge repository for climate change information.
2. Provide assistance to carry out research, with a regional emphasis unique to the state.
3. Create the State Consortium for Climate Change Assessment (SNCCA), a group of academic institutions, NGOs, corporations, and research organisations with an emphasis on advancing knowledge.

4. Raise awareness and build capacities of many stakeholders in relation to climate issues.

SKMCCC had been solely responsible for coordinating the implementation the activities for the state's overall climate change adaptation and mitigation. However, a dedicated State Climate Action Cell was created in August, 2023 to work as the nodal agency of the state government to combat climate change. It is a body of experts headed by the Director, who is the state nodal officer for climate change, guided by the Principal Secretary, the Environment and Climate Change Department. The State Level Steering Committee on Climate Change (SLSCCC), headed by the Chief Secretary, GoM, is the apex body which oversees SAPCC implementation under the guidance of the Chief Minister's Governing Council on Climate Change. Members of this committee include Secretaries of the departments of Agriculture, Finance, Planning, Public Health, Water Resources, Urban Development, Industries, Transport, Rural Development, Dairy, Amlinal Husbandry and Fisheries, Soil and Water Conservation and Skill Development, Public Works Department, Forests, Public Health, Energy, and Environment, along with the Member Secretary of the Maharashtra Pollution Control Board (MPCB). The roles and responsibilities of the SLSCCC include providing guidance on the formation and implementation of the Maharashtra SAPCC and on different projects under the Climate Change Innovation Programme (CCIP), availing national and international funding for various projects related to climate change, and providing guidance on various issues related to climate change.

In August, 2023, the Maharashtra government approved the formation of a State Climate Action Cell (SCAC) that will focus on implementing adaptation and mitigation

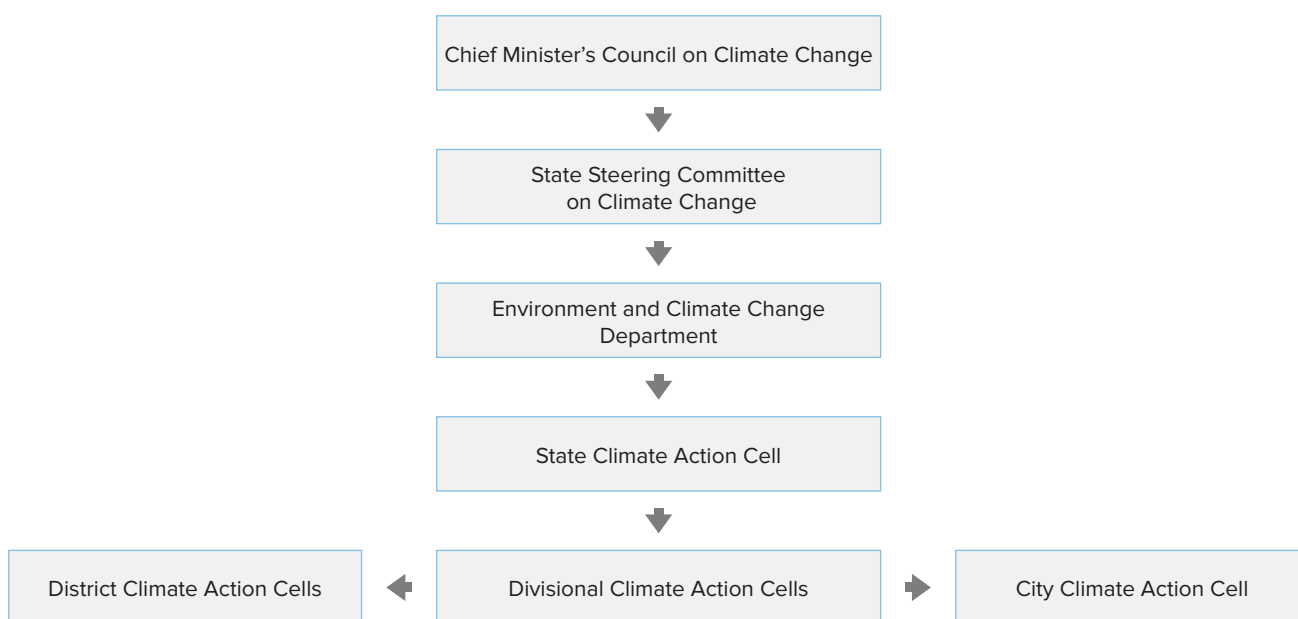
strategies enshrined in the State Action Plan on Climate Change (SAPCC). The SCAC will provide guidance on implementation of the National Action Plan on Climate Change (NPACC) and Mission LiFE in the state, coordinate between the Union government and the state government, various departments of the state government, local self-governing bodies, NGOs, institutions working in the field of environment research and development, international financial institutions and other stakeholders.

10.3 Mechanism for Monitoring of Plan Progress

Periodic progress monitoring at designated intervals is crucial to ensure timely implementation and assess the on-ground effectiveness of strategies outlined for each sector. At the same time, seamless coordination between government departments and external stakeholders is necessary to maintain accountability and transparency and enable a feedback loop. Furthermore, defining institutional roles is key to a robust monitoring process and effective implementation. Therefore, the responsibilities of each implementing agency have also been discussed as a part of the monitoring mechanism.

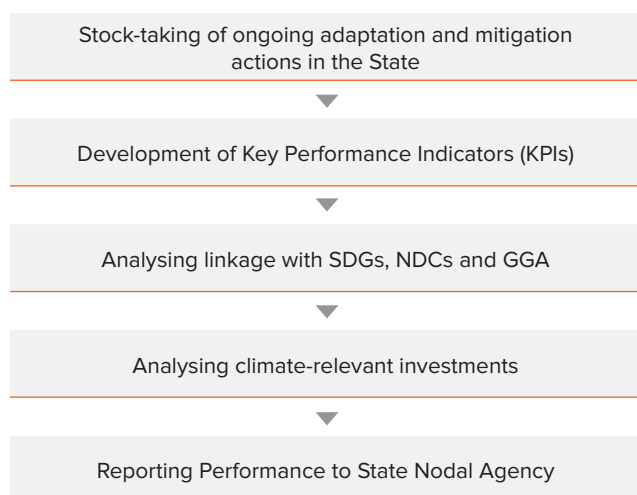
After the SAPCC is published, the implementation process must start with a stock-taking exercise by line departments to document the progress of ongoing adaptation and mitigation activities within the State, as illustrated in Figure 10.3. In parallel, this should be accompanied by the development of Key performance indicators (KPIs) that can scientifically monitor the progress of each strategy against mid-term and end-term targets. These KPIs must be so designed that they assess the contribution of

Figure 10.2 Governance for the MH SAPCC (DoECC)



Source: State Climate Action Cell, Environment and Climate Change Department, Government of Maharashtra, 2024

Figure 10.3 Steps for effective monitoring and evaluation



Source: Authors' compilation

each strategy towards achieving global targets, such as the Sustainable Development Goals (SDGs), Nationally Determined Contributions (NDCs) and the Global Goal on Adaptation (GGA).

However, developing KPIs for each strategy is a time-and-resource-intensive process and should be developed by institutions with the required scientific expertise and knowledge of the local factors of influence so that they can identify measurable parameters to assess the performance of each strategy at the grassroots. Therefore, institutes that are a part of the State Consortium for Climate Change Assessment (SNCCA) should develop KPIs and seek approval from the State Climate Action Cell. Based on the finalised KPIs, mid-term and end-term targets would be set for each of the line departments of the State. These targets would be informed by the prior knowledge of the baseline by each department and the budget allocated for the identified period.

The State Climate Action Cell (SCAC) would act as the nodal agency for conducting monitoring exercises by periodically assessing the progress of each strategy

against the set targets and providing support to respective departments through capacity-building initiatives. It can thus collect and aggregate data on the implementation progress and steer development in alignment with the objectives of the State Action Plan on Climate Change (SAPCC).

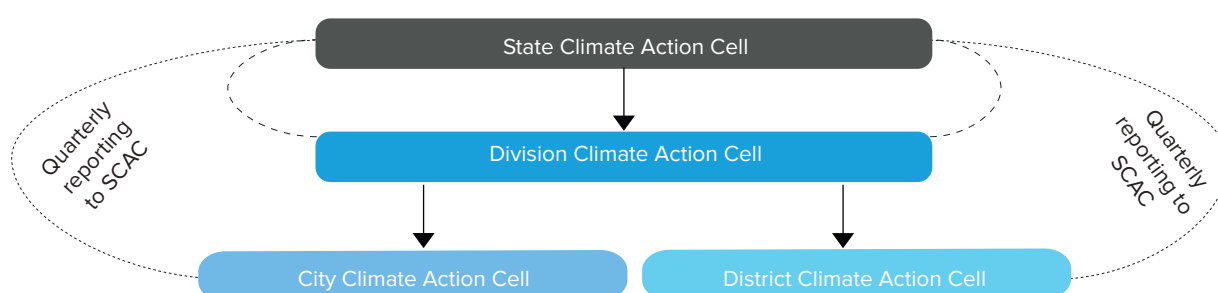
Strengthening Climate Governance at the Grass Roots:

Climate Action Cells will be set up at the District level and at the City level. The District Climate Action Cell will be headed by the District Collector while the City Climate Action Cell will be headed by the Municipal Commissioner. Local officers from the line departments will be the members of these Cells. The Cells will be mandated with the task of preparing District/City Climate Action Plans in alignment with the SAPCC. They will also monitor the implementation of the SAPCC in their respective jurisdictions. A divisional-level Climate Action cell chaired by the Divisional Commissioner will provide supervision and oversight of the functioning of the District and City Climate Action Cells.

The reporting mechanism within the monitoring and evaluation framework of MH SAPCC would include a monthly meeting at the District level/City level, chaired by the District Collector/Municipal Commissioner to review the progress of implementation of the SAPCC. These meetings would involve officers from various line departments such as Transport, Health, Environment, Disaster Management, Tribal Affairs, Tourism, Forest, Energy and others. Copy of the minutes will be sent to both the Divisional and the State Climate Action Cells. Additionally, the District, City and Divisional Climate Action Cells will submit a quarterly progress report to the State Climate Action Cell (SCAC) to ensure comprehensive oversight and coordination, as shown in Fig. 4.

The State Climate Action Cell (SCAC) will also help line departments with the preparation of department-wise implementation strategies, by converting the recommendations in the SAPCC into time-bound concrete actionable. Each department will appoint its nodal officer for the SAPCC and the SCAC will conduct a mid-annual review of the departments through their respective nodal

Figure 10.4 The hierarchy of the M&E reporting



Source: Authors' compilation

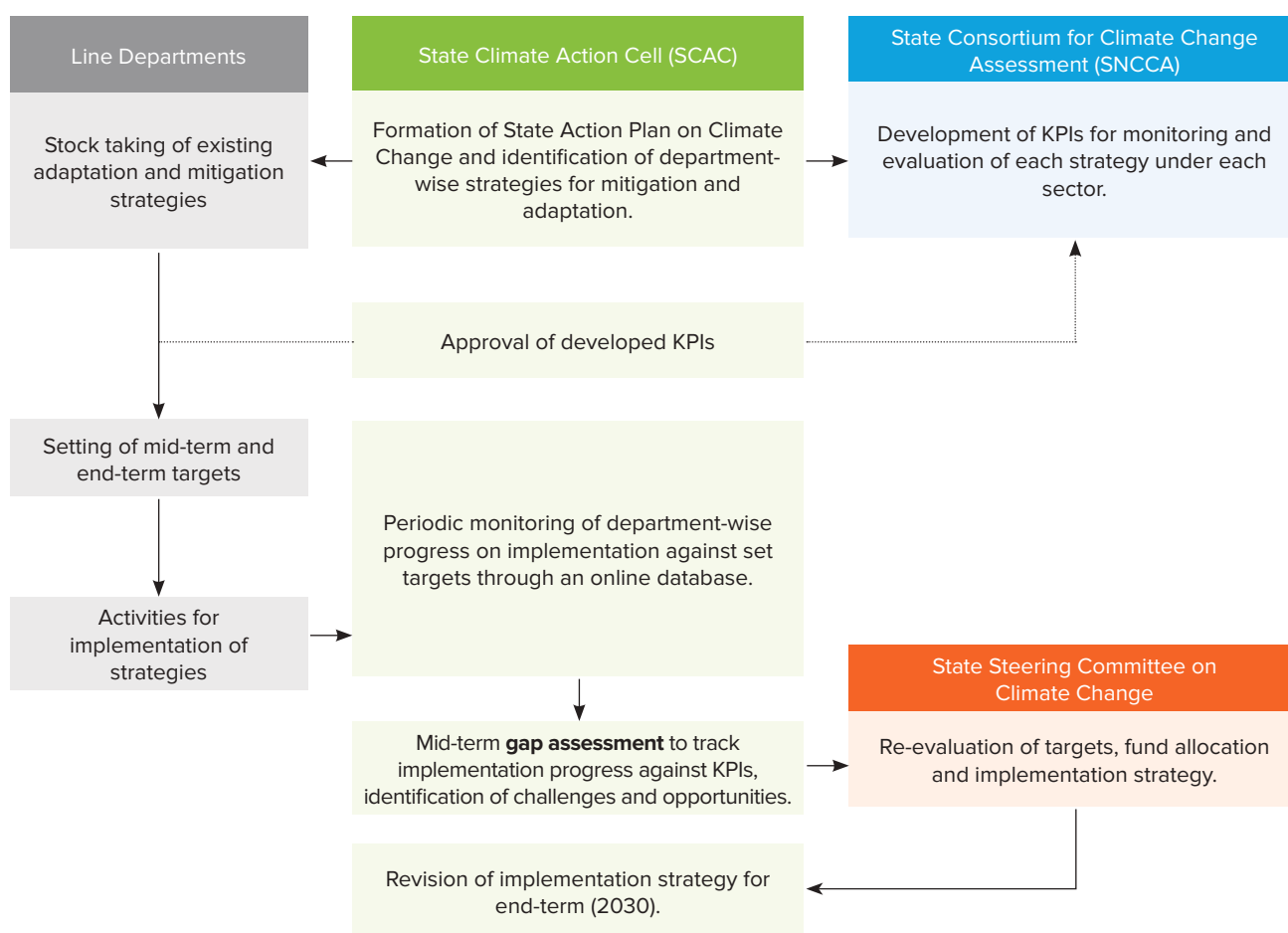
officers to assess the progress of their implementation strategies. The progress will be reported to the State Level Steering Committee on Climate Change (SLSCCC) by way of the Annual Progress Report. The SLSCCC can then use the feedback from the SCAC to make informed decisions to revise resource and budget allocation, revise timelines, and re-evaluate targets for the end term. This circular monitoring mechanism has been outlined in Figure 10.5.

To further enhance the standardisation and interoperability of the monitoring process, a state-level Monitoring, Evaluation, and Learning (MEL) Dashboard will be created, which can track the progress on implementing adaptation actions and mitigation actions across different sectors, as reported in the SAPCC. Through the interdepartmental reporting structure, the plan envisages multiple partnerships and knowledge sharing between the government, research organisations, private players and civil society to strengthen its on-ground impact. The mechanism for implementation of the SAPCC thus stands on three pillars: digitisation, decentralisation and democratisation.

10.4 Evaluation of Mid-term and End-term Targets

The progress on adaptation and mitigation will be monitored against the recommendations and priority actions defined across different sectors in Chapters 5 and 6. Following the plan's implementation timeline from 2024 to 2030, the evaluation framework is designed to review progress in 2027 after 3 years of implementation are completed. Thus, measurable targets will be designed for each sector based on the recommendations and key actions for the duration of mid-term (2027) and end-term (2030). However, considering the rapid changes observed in certain key areas, such as GHG emissions, the baseline targets will be discussed and decided based on the multistakeholder process for each sector. The State Climate Action Cell (SCAC) will work closely, coordinate with the different line departments relevant to the MHSAPCC sectors, and develop the theory of change framework for each sector. The targets set for each strategy will be elaborated by line departments into

Figure 10.5 Institutional Process for Monitoring of Plan Progress



Source: Authors' compilation

Table 10.1 Illustration of activities, outputs, outcomes and impact for a specific target

	Explanation	Example
Recommendation/Target	An adaptation or mitigation strategy outlined for a specific sector in Chapter 5 or 6	Target to install and assess the potential of bulk water meter in the urban areas of Maharashtra, to be extended to rural areas after preliminary assessment.
Activities	The implementation actions and processes that will help achieve the target.	Installation of bulk water meters
Output	Measurable and immediate results of successfully implementing the strategy	No. of bulk water meters installed by 2027 and by 2030.
Outcome	Short-medium term effects of implementing the strategy	Reduction in water losses from the public domestic water conveyance infrastructure.
Impact	Long-term effect of the results obtained by implementing the strategy	Climate proofing of water supply infrastructure in the State.

Source: Authors' compilation

outputs, outcomes and impacts to measure the short-term and long-term progress and account for intangible benefits at scale. Line departments can plan activities to be executed during the implementation period under these specific targets in alignment with global goals, facilitating an iterative evaluation process.

The finalised M&E mechanism would allow flexibility and re-evaluation of targets to accommodate changing

priorities, risk factors, and resource constraints. Therefore, stakeholders would be encouraged to actively measure results, evaluate achievements and identify gaps through a data-driven approach. Furthermore, when contextualised, targets would reflect the needs and priorities of communities as identified during the plan implementation process to result in a participatory and inclusive approach.

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Annexures

Table A1 Districts exposed to extreme drought events

District	Event	Exposure
Ahmednagar	Drought	Very high
Osmanabad	Drought	Very high
Beed	Drought	Very high
Buldhana	Drought	Very high
Dhule	Drought	Very high
Latur	Drought	Very high
Parbhani	Drought	Very high
Sangli	Drought	Very high
Satara	Drought	Very high
Solapur	Drought	Very high
Hingoli	Drought	Very high
Nanded	Drought	Very high
Nandurbar	Drought	Very high
Pune	Flood and drought	High
Nashik	Flood and drought	High
Akola	Drought	High
Gadchiroli	Drought	High
Nagpur	Drought	High
Jalgaon	Flood and drought	High
Amravati	Flood and drought	High
Chandrapur	Drought	Moderate
Gondia	Drought	Moderate
Jalna	Drought	Moderate
Raigad	Drought	Moderate
Washim	Drought	Moderate
Yavatmal	Drought	Moderate

District	Event	Exposure
Wardha	Flood and drought	Low
Bhandara	Drought	Very low
Kolhapur	Drought	Very low

Source: Authors' analysis

Table A2 Districts exposed to extreme flood events

District	Event	Exposure
Mumbai City	Flood and cyclone	Very high
Mumbai Suburban	Flood and cyclone	Very high
Pune	Flood and drought	High
Nashik	Flood and drought	High
Jalgaon	Flood and drought	High
Amravati	Flood and drought	Moderate
Wardha	Flood and drought	Low
Ratnagiri	Flood and cyclone	Low
Thane	Flood and cyclone	Low
Sindhudurg	Flood and cyclone	Low

Source: Authors' analysis

Table A3 Districts exposed to extreme cyclone events

District	Event	Exposure
Mumbai	Flood and cyclone	Very high
Mumbai Suburban	Flood and cyclone	Very high
Ratnagiri	Flood and cyclone	Low
Thane	Flood and cyclone	Low
Sindhudurg	Flood and cyclone	Low

Source: Authors' analysis

Table A4 Sensitivity of districts in Maharashtra

District	Event	Sensitivity
Sangli	Drought	Very high
Jalgaon	Flood and drought	Very high
Ratnagiri	Flood and cyclone	Very high
Nagpur	Drought	Very high
Pune	Flood and drought	Very high
Amravati	Flood and drought	Very high
Mumbai City	Flood and cyclone	Very high
Dhule	Drought	Very high
Solapur	Drought	Very high

District	Event	Sensitivity
Wardha	Flood and drought	Very high
Akola	Drought	Very high
Ahmednagar	Drought	Very high
Buldhana	Drought	Very high
Jalna	Drought	Very high
Satara	Drought	Very high
Aurangabad	Flood and drought	Very high
Mumbai Suburban	Flood and cyclone	Very high
Sindhudurg	Flood and cyclone	Very high
Nashik	Flood and drought	High
Beed	Drought	High
Nandurbar	Drought	High
Osmanabad	Drought	High
Bhandara	Drought	High
Hingoli	Drought	High
Washim	Drought	High
Kolhapur	Drought	High
Chandrapur	Drought	High
Raigad	Drought	High
Nanded	Drought	High
Parbhani	Drought	Moderate
Gondia	Drought	Moderate
Latur	Drought	Moderate
Gadchiroli	Drought	Moderate
Thane	Flood and cyclone	Moderate
Yavatmal	Drought	Low

Source: Authors' analysis

Table A5 Talukas prone to extreme drought events

District	Taluka
Nandurbar	Akkalkuwa, Talode, Shahade, Nandurbar, Nawapur
Dhule	Shirpur, Sindkhede, Sakri, Dhule
Jalgaon	Chopda, Yawal, Raver, Muktainagar (Edlabad), Bodvad, Bhusawal, Jalgaon, Erandol, Dharangaon, Amalner, Parola, Bhadgaon, Chalisgaon, Pachora, Jamner
Buldhana	Jalgaon (Jamod), Sangrampur, Shegaon, Nandura, Malkapur, Motala, Khamgaon, Mehkar, Chikhli, Buldhana, Deolgaon Raja, Sindkhed Raja, Lonar
Akola	Telhara, Akot, Balapur, Akola, Murtijapur, Barshitakli
Washim	Malegaon, Manora, Risod
Amravati	Chikhaldara, Anjangaon Surji, Achalpur, Chandurbazar, Morshi, Warud, Teosa, Amravati, Bhatkuli, Daryapur
Wardha	Ashti, Karanja, Arvi, Seloo, Deoli, Hinganghat, Samudrapur

District	Taluka
Nagpur	Narkhed, Katol, Kalameshwar, Ramtek, Nagpur (rural), Hingna, Umred, Kuhl
Bhandara	Tumsar, Pauni
Gondia	Tirora, Goregaon, Gondia, Arjuni Morgaon, Deori
Chandrapur	Warora, Chimur, Nagbhir, Brahmapuri, Sindewahi, Bhadravati, Mul, Pombhurna, Ballarpur, Rajura, Gondpipri
Yavatmal	Ner, Babulgaon, Kalamb, Yavatmal, Darwha, Pusad, Umarkhed, Mahagaon, Ghatanji, Kelapur, Ralegaon, Maregaon
Nanded	Kinwat, Hadgaon, Mudkhed, Umri, Dharmabad, Biloli, Naigaon (Khaurgaon), Loha, Deglur
Hingoli	Sengaon, Hingoli, Kalamnuri, Basmath
Parbhani	Sailu, Jintur, Manwath, Pathri, Sonpeth, Gangakhed, Palam, Purna
Jalna	Bhokardan, Jaffarabad, Jalna, Badnapur, Ambad, Ghansawangi, Partur, Mantha
Aurangabad	Kannad, Soegaon, Sillod, Phulambri, Aurangabad, Khuldabad, Vijapur, Gangapur, Paithan
Nashik	Kalwan, Deola, Baglan, Malegaon, Nandgaon, Chandvad, Dindori, Nashik, Igatpuri, Sinnar, Niphad, Yevla
Palghar	Talasari
Pune	Junnar, Ambegaon, Shirur, Khed, Mulshi, Haveli, Daund, Purandhar, Velhe, Bhor, Baramati, Indapur
Ahmednagar	Sangamner, Kopargaon, Rahta, Shirampur, Nevasa, Shevgaon, Pathardi, Nagar, Rahuri, Parner, Shrigonda, Karjat, Jamkhed
Bid	Ashti, Patoda, Shirur (Kasar), Georai, Manjlegaon, Wadwani, Bid, Kaij, Dharur, Parli, Ambejogai
Latur	Latur, Renapur, Ahmadpur, Jalkot, Chakur, Shirur-Anantpal, Ausa, Nilanga, Deoni, Udgir
Osmanabad	Paranda, Bhum, Washi, Kalamb, Osmanabad, Tuljapur, Lohara
Solapur	Karmala, Madha, Barshi, Solapur North, Mohol, Pandharpur, Malshiras, Sangole, Mangalvedhe, Solapur South, Akkalkot
Satara	Wai, Khandala, Phaltan, Man, Khatav, Koregaon, Satara, Patan, Karad
Kolhapur	Panhala, Hatkanangle, Karvir, Bhudargad, Gadhinglaj
Sangli	Palus, Kadegaon, Khanapur, Atpadi, Tasgaon, Miraj, Kavathemahankal, Jat
Gadchiroli	Desaiganj (Vadasa), Armori, Kurkheda, Korchi, Dhanora, Gadchiroli, Chamorshi, Mulchera, Etapalli, Bhamragad, Aheri, Sironcha
Thane	Thane, Bhiwandi, Shahapur, Kalyan, Ulhasnagar, Ambarnath, Murbad
Raigarh	Uran, Panvel, Karjat, Khalapur, Pen, Alibag, Murud, Roha, Sudhagad, Mangaon, Tala, Shrivardhan, Mhasla, Mahad, Poladpur
Ratnagiri	Mandangad, Dapoli, Khed, Chiplun, Guhagar, Ratnagiri, Sangameshwar, Lanja, Rajapur

Source: Authors' analysis

Table A6 Talukas prone to extreme flood events

District	Taluka
Nandurbar	Akkalkuwa, Akrani, Talode, Shahade, Nandurbar
Dhule	Shirpur, Sindkhede, Sakri, Dhule
Jalgaon	Chopda, Yawal, Raver, Muktainagar (Edlabad), Bodvad, Bhusawal, Jalgaon, Erandol, Dharangaon, Amalner, Parola, Bhadgaon, Chalisgaon, Pachora, Jamner
Buldhana	Sangrampur, Motala, Khamgaon, Mehkar, Buldhana, Deolgaon Raja
Akola	Telhara, Akot, Balapur, Akola, Murtijapur, Patur, Barshitakli
Washim	Mangrulpir, Karanja, Washim, Risod
Amravati	Dharni, Chikhaldara, Anjangaon Surji, Achalpur, Chandurbazar, Morshi, Warud, Teosa, Amravati, Bhatkuli, Daryapur, Nandgaon-Khandeshwar, Chandur Railway, Dhamangaon Railway
Wardha	Ashti, Karanja, Arvi, Seloo, Wardha, Deoli, Hinganghat, Samudrapur

District	Taluka
Nagpur	Narkhed, Katol, Kalameshwar, Savner, Parseoni, Ramtek, Mauda, Kamptee, Nagpur (Rural), Nagpur (Urban), Hingna, Umred, Kuhi, Bhiwapur
Bhandara	Tumsar, Mohadi, Sakoli, Lakhani, Pauni, Lakhandur
Gondia	Tirora, Goregaon, Gondia, Amgaon, Salekasa, Sadak-Arjuni, Arjuni Morgaon, Deori
Gadchiroli	Desaiganj (Vadasa), Armori, Kurkheda, Korchi, Dhanora, Gadchiroli, Chamorshi, Mulchera, Etapalli, Bhamragad, Aheri, Sironcha
Chandrapur	Chimur, Nagbhir, Brahmapuri, Sawali, Sindewahi, Bhadravati, Pombhurna, Ballarpur, Korpana, Rajura, Gondpipri
Nanded	Ardhapur, Nanded, Mudkhed, Bhokar
Parbhani	Parbhani, Palam, Purna
Jalna	Bhokardan, Jafferabad, Jalna, Badnapur, Ambad, Ghansawangi, Partur, Mantha
Aurangabad	Kannad, Soegaon, Sillod, Phulambri, Aurangabad, Khuldabad, Vaijapur, Gangapur, Paithan
Nashik	Surgana, Kalwan, Deola, Baglan, Malegaon, Nandgaon, Chandvad, Dindori, Peint, Trimbakeshwar, Nashik, Igatpuri, Sinnar, Niphad, Yevla
Thane	Thane, Bhiwandi, Shahapur, Kalyan, Ulhasnagar, Ambarnath, Murbad
Raigarh	Uran, Panvel, Karjat, Khalapur, Pen, Alibag, Murud, Roha, Sudhagad, Mangaon, Tala, Shrivardhan, Mhasla, Mahad, Poladpur
Pune	Junnar, Ambegaon, Shirur, Khed, Mawal, Mulshi, Haveli, Pune City, Daund, Purandhar, Velhe, Bor, Baramati, Indapur
Ahmednagar	Akola, Sangamner, Kopergaon, Rahta, Shrirampur, Nevasa, Shevgaon, Rahuri, Shrigonda, Karjat, Jamkhed
Bid	Georai, Manjlegaon, Parli
Osmanabad	Paranda, Bhumi, Washi, Kalamb, Osmanabad, Tuljapur, Lohara, Umarga
Solapur	Karmala, Madha, Barshi, Solapur North, Mohol, Pandharpur, Malshiras, Sangole, Mangalvedhe, Solapur South, Akkalkot
Satara	Wai, Khataav, Satara, Patan
Ratnagiri	Mandangad, Dapoli, Khed, Chiplun, Guhagar, Ratnagiri, Sangameshwar, Lanja, Rajapur
Sindhudurg	Devgad, Vaibhavvadi, Kankavli, Malwan, Vengurla, Kudal, Sawantwadi
Kolhapur	Shahuwadi, Panhala, Hatkanangle, Shirol, Karvir, Radhanagari, Kagal, Bhudargad, Gadhinglaj, Chandgad
Mumbai Suburban	Kurla, Borivali, Andheri
Mumbai	Mumbai

Source: Authors' analysis

Table A7 Talukas prone to extreme cyclone events

District	Taluka
Mumbai	Mumbai
Mumbai Suburban	Kurla, Borivali, Andheri
Ratnagiri	Dapoli, Guhagar, Ratnagiri
Thane	Thane, Dahanu, Palghar, Vasai

Source: Authors' analysis

Table A8 DRE potential for building sustainable livelihood for women

Maharashtra	Product Deployment potential	Livelihood impact potential	Market potential INR	Market potential USD	Potential for women users	Reason
Bulk Milk Chiller	4532	4532	3326179824	42103542	Medium	Maharashtra has 3rd highest in Milk Production in the country. However, the major challenges lies in timely milk collection and fodder availability in the state. To this,a solar Bulk Milk chiller and fodder grower unit provide solutions to strengthen this value chain, on the lines of Amul Cooperative movement, which has revolutionised rural women livelihoods in Gujarat (National Dairy Development Board, n.d.).
Vertical Fodder unit	286529	1005717	12381204619	156724109	Medium	
Solar Cold Storage	6133	183990	8694447450	110056297	High	Maharashtra is the 2nd highest state in the country for fisherwomen population undertaking marine fisheries as their full time occupation and the highest for Part time involvement. Solar refrigerators and Solar Dryers / Dehydrators are major value chains that need to be strengthened amongst these target groups. Solar Dryers can also be integrated with the papad-making industry, which is a significant activity amongst women SHG (Tanuja et al. 2024).
Solar refrigerator	71630	71630	6804850000	86137342	High	
Solar Dryer	221119	442238	24378369750	308586959	High	
Solar Loom	4449	8898	668035146	8456141	High	Maharashtra is a leading non-traditional silk-producing state in India. The silk reeling industry in Maharashtra is poised for growth and has substantial potential to provide employment opportunities. Government policies have favored the cultivation and development of silk, creating labor opportunities in the state. Introducing solar looms not only provides clean energy production but also reduces drudgery, enhancing working conditions of the artists ((Directorate of Sericulture, Govt. of Maharashtra, n.d.), (Sinha and Kutala 2012)).
Reeling	278	278	7136816	90339	High	
Charkha	26372	26372	1149792828	14554340		
Micro food processing	23063	46126	2767560000	35032405	High	Maharashtra is one of the leading states in the country in Horticulture Development. The diverse agro-climatic conditions are very congenial for cultivation of horticultural crops engaging about 28% agricultural land. The state also had 16% forest land blessed with varieties of MFPs and herbs consumed as food in a processed / semi-processed and unprocessed format. Coupled with a high network of micro and small-scale food-based industries, this women-dominated sector can enhance women livelihood while ensuring food security and minimising post-harvest wastage.

Maharashtra	Product Deployment potential	Livelihood impact potential	Market potential INR	Market potential USD	Potential for women users	Reason
Micro Solar Pump	176938	176938	7962210000	100787468.4	High	In Maharashtra, 88.46% of rural women are employed in agriculture, the highest percentage in the country. However, women own only 15.6% of the agricultural land holdings in the state, amounting to 14% of the total cultivated area. The manifesto from the Mahila Kisan Adhikaar Manch (<i>Makaam</i>) state chapter states that despite 40% of total agricultural workers being women in Maharashtra (2011 census), the proportion of women landholders is only 15% ((Nair 2024), (Raman 2019)).
Grain Milling	132261	264522	96296456619	1218942489	High	The Government of Maharashtra is already implementing the 'Floor Mill Scheme', 2023 "Flour Mill Yojana" through the Department of Women and Child Development. Introducing Solar Grain Mills under such schemes will not allow convergence but also ensure sustainable and green interventions.
Total	1525604	2803541	3.08E+11	3892547380		Maharashtra has the highest percentage of women-owned MSMEs at 18% of the total 4,667,278 women-owned MSMEs in India. The women entrepreneurs are engaged in a variety of sectors, including agriculture, food processing, handicrafts, textiles, and other cottage industries (Jadhav 2024). Specific: Agri-businesses and post-harvest management Micro-manufacturing and production of goods Retail and trading of products

Source: Author's compilation

Table A9 Waste to Energy technologies

S. No.	Name of the Plant	Type of Waste Input	Place	Processing Capacity
1.	Nisargruna Plant	All types of Biodegradable kitchen wet waste (cooked and precooked) and raw vegetable and fruit waste.	Shatabdi Hospital Site at Govandi, Mumbai	2 TPD
2.	Katraj Biogas Plant	Segregated organic waste	Katraj, Pune	5 tons/ Day X 2 (there are 2 plants)
3.	Mathikere Biogas Plant	Segregated organic waste biogas Plant	Mathikere, Bangalore	5 MTPD
4.	Aundh Biogas Plant	Segregated organic waste biogas Plant	Aundh, Pune	5 MTPD
5.	Yerwada Biogas Plant	Segregated organic waste biogas Plant	Yerwada, Pune	5 MTPD
6.	Nashik Integrated Waste to Energy Plant	Integrated waste (organic and inert)	Moshi, Pimpri, Nashik, Maharashtra	14MW/1000TPD
7.	Biomethanation plant	Food waste (10-15 metric tons/day) and blackwater (10-20 m ³ /day)	Nashik, Maharashtra (Year 2017)	
8.	Biomethanation plant		Keshvrao Khade road near Haji Ali Circle, Mumbai, Maharashtra	600 metric tons of waste
9.	Bio-CNG plant		Bio-CNG plant at Talegaon, Pune	

Source: Authors's compilation

Table A10 a Examples of Offset Projects using blended finance

Project Name	Location	Estimated GHG Reduction	Key Activities
Solar PV Project	India (State not specified)	Not specified	170 MWp distributed generation (DG) assets, including 75 MWp offsite solar park and 95 MWp rooftop solar assets
BioCarbon Fund ISFL - Jambi Sustainable Landscape Management Project (J-SLMP)	Jambi, Indonesia	Not specified	REDD+ activities, sustainable agriculture, land use planning

RE projects, clean cooking, agriculture and bio-diversity are also, increasingly utilised in VCM in India; following are some examples:

Implementing Agency	Technology	Quantity of Gas Produced	Power/Energy Generated	Source
	Aerobic and Anaerobic process Developed by BARC	Average 150 m ³ /tonne of input but depend on type of waste	108 kwh of electricity produced in 12 hours	https://sbmurban.org/storage/app/media/pdf/Waste%20to%20Wealth.pdf
Pune Municipal Corporation; Mailhem IKOS Environment Pvt. Ltd.	Biogas Plant			https://mailhem.com/we-serve/municipalities/
Bruhat Bangalore Mahanagar Palike (BBMP); Mailhem IKOS Environment Pvt. Ltd.	Biogas Plant			https://mailhem.com/we-serve/municipalities/
Pune Municipal Corporation; Mailhem IKOS Environment Pvt. Ltd.	Biogas Plant			https://mailhem.com/we-serve/municipalities/
Pune Municipal Corporation; Mailhem IKOS Environment Pvt. Ltd.	Biogas Plant			https://mailhem.com/we-serve/municipalities/
Pimpri Chinchwad Municipal Corporation (PCMC) and Antony Waste	Combustion			https://www.punekarnews.in/pune-waste-to-energy-plant-in-moshi-reaches-12-mw-capacity-set-to-expand-to-14-mw/
Nashik Municipal Corporation and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	Biomethanation (Anaerobic digester)		2100 m ³ /day	https://s3.amazonaws.com/resources.cwis.com/evidence/files/3-3148-7-1523540104.pdf
BMC	Biomethanation (Anaerobic digester)	Biogas (80-110 m ³ /day)	125-250 electricity units/ metric ton of waste	https://memumbai.com/facts-about-first-waste-to-energy-plant-in-mumbai/
PMC with Noble Exchange Environment Solutions Pvt. Ltd. (NEX)	Biomethanation (Anaerobic digester)	Bio-CNG (45 Tons/day)		https://www.pmc.gov.in/en/biogas-initiative

Social and Environmental Impact	Blended Finance	Credits Generated
Provides clean, reliable, cost-effective power to C&I companies, promotes decarbonisation of India's power sector	Yes (IFC-Finland Blended Finance for Climate Program, Canada-IFC Blended Climate Finance Program)	Not specified
Reduced deforestation, sustainable land management, better land use practices	Yes (World Bank, Jambi Provincial Government)	Not specified

Table A10 b Examples of VCM Projects in India

Project Name	Location	Estimated GHG Reduction	Key Activities
Suzlon Wind Power Projects	India (Headquarters in Pune)	20,120 MW capacity	Installation of wind turbines, renewable energy production
Greenway Cookstoves Project	India and Zambia	Not specified	Distribution of improved cookstoves (Chulika Greenway Jumbo Stove and Greenway Smart Stove)
Gujarat Wind Farm Project	Gujarat, India	1,01,234 tonnes CO ₂ annually	Utilises 63 Enercon wind turbines, generates 107 GWh annually

Developing countries other than India, have been significantly utilising Carbon Projects for Mitigation as well as climate finance under VCM mechanism

Table A10 c Examples of VCM Carbon Projects in Indonesia

Project Name	Location	Estimated GHG Reduction	Key Activities
Rimba Raya Biodiversity Project	Indonesia	3,527,171 tonnes	Tree planting, income diversification
Katingan Mentaya Peat Conservation and Restoration Project	Central Kalimantan, Indonesia	7 billion tonnes CO ₂ e	Ecosystem restoration, community engagement
Bujang Raba Community Carbon Project	Jambi, Indonesia	Not specified	Forest cover maintenance, carbon level calculation, PDD preparation

Maharashtra is endowed with rich flora and fauna. The Western Ghats, declared by UNESCO as the World Heritage Site, With its rich biodiversity and diverse landscape, the state has a significant opportunity to attract global attention and investments through well-structured carbon offset projects. By leveraging the potential of voluntary carbon markets and Article 6, the state can mobilise substantial climate finance, foster sustainable development, and enhance ecosystem resilience.

Source: Author's compilation based on GIZ, CII; 2022, IFC, 2023; Asha Impact, ICC, 2023; PwC, 2024; Accenture, 2022 and others.

Social and Environmental Impact	Blended Finance	Credits Generated
Significant contribution to renewable energy capacity, challenges due to competition, financial distress, and supply chain issues	No	Not specified
Reduced greenhouse gas emissions, improved energy efficiency, better air quality, health benefits for users	No	Not specified
Reduces greenhouse gas emissions, addresses power demand-supply gap, promotes sustainable growth, benefits local communities with employment, health, education, and infrastructure	No	Over 6 million

Social and Environmental Impact	Blended Finance	Credits Generated
Community-based programs, enhanced biodiversity, diversified income sources	No	Not specified
Income generation for locals, high local employment (75%), innovative and transparent business practices	No	Not specified
Health and education support, strengthened village forest institutions, improved community economy	No	6,000 tonnes in 2018

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Notes

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