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Gujarat State Action Plan on Climate Change

Climate Change Department
Government of Gujarat

Supported by

Indian Institute of Technology Gandhinagar

Indian Institute of Management Ahmedabad

2021

सत्यमेव जयते

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The Inspiration and Vision
behind
Climate Change Department
Government of Gujarat

Shri Narendra Modi
Prime Minister of India

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Vijay Rupani
Chief Minister, Gujarat State

apro/ug/2021/06/04/dt

Dt. 04/06/2021

Message

Gujarat is one of India's leading States in terms of economic development. With 5% of India's population, the State contributes 8.11% of India's Gross Domestic Product and 17% of industrial production. Like any other State, Gujarat is also vulnerable to climate change. In this backdrop, it needs to take steps to mitigate and adapt to climate change, to ensure sustainable development. The Climate Change Department happens to be the first dedicated Department set up by any State Government in India under the visionary leadership of Hon'ble Prime Minister Shri Narendra Modi when he was the Chief Minister of Gujarat, to spearhead Climate Actions in the State.

As a part of Gujarat's proactive approach, the Department has recently upgraded its earlier State Action Plan on Climate change, to align its climate priorities with those of India's Nationally Determined Contributions and with India's national Action Plan on climate Change. The Plan showcases Gujarat's commitment to build a sustainable and climate-resilient future for the people of the State. It is a matter of great pleasure to release the **"State Action Plan on Climate Change"** prepared by the **Climate Change Department** with the support of **Indian Institute of Management (IIM), Ahmedabad and Indian Institute of Technology (IIT), Gandhinagar.**

I would like to acknowledge the support of the Ministry of Environment, Forests and Climate Change, Government of India in preparing this document and also commend the efforts of the Department, the team from **IIM, Ahmedabad and IIT, Gandhinagar** for their sincere efforts in formulating the Plan.

(Vijay Rupani)

Foreword

At the outset, we would like to extend our respectful greetings to one and all on the World Environment Day !

We feel honoured to present herewith Gujarat's State Action Plan on Climate Change (SAPCC).

Under the visionary guidance of the Hon'ble Prime Minister Shri Narendra Modi and the dynamic leadership of Hon'ble Chief Minister of Gujarat Shri Vijay Rupani, the State is fully geared up and committed to addressing the concerns of Climate Change.

As all of us know, Gujarat faces formidable climate challenges, especially temperature rise, precipitation extremes and sea-level rise. Coastal areas, tribal areas and districts like Kachchh happen to be more vulnerable. So are western and central districts. As such, it has always been imperative for Gujarat to be in a state of thorough preparedness in respect of Climate Action.

The SAPCC underlines actions that Gujarat proposes to reinforce to adapt and augment resilience to climate threats. Adaptation plans have been described at the sectoral level, with detailed programmes developed for nine thematic sectors in the State. Mitigation policies have also been provided for under the Plan at the sectoral level, and they subsume different emission groups in the State. The Plan also envisages strategies for financing climate action and appropriate institutional mechanisms to ensure ongoing sustained action. The roles and responsibilities of the various Departments of the State have been laid down ensuring that climate actions stand appropriately mainstreamed in all activities. Monitoring and evaluation also form a significant component to ensure that the outcomes are in line with desired goals.

The SAPCC represents Gujarat's efforts to be a frontrunner in climate action and to reinforce a meaningful profile to ensure sustainable development.

Last but not the least, we gratefully acknowledge the guidance and support of the Government of India and the State Government as imparted from time to time.

We are also indebted to the teams from the Indian Institute of Management (IIM), Ahmedabad and the Indian Institute of Technology (IIT), Gandhinagar for having duly supported the Department in the formulation of the State Action Plan on Climate Change which will go a long way in enabling Gujarat to play its role in the realization of the Country's Nationally Determined Contributions.

Gandhinagar
5th June 2021

S. J. Haider, IAS
Principal Secretary
Climate Change Department
Government of Gujarat

Executive Summary

Mainstreaming Climate change has been a priority area for Government of Gujarat. In light of this, the Government of Gujarat, at the highest level, established Climate Change Department on September 17, 2009 to build a sustainable and climate resilient future for the people of Gujarat. The department is the nodal entity for the subject of climate change in Gujarat and coordinates all actions that are directly or indirectly linked with climate change. In this context, the Government of Gujarat is hereby submitting its second State Action Plan on Climate Change in accordance with the guidance of Ministry of Environment, Forests and Climate Change, Government of India.

Gujarat is the only state in India to have established a climate change department over a decade back and takes climate change as a major concern for the state's natural ecosystems and manmade systems. Climate change offers both challenges and opportunities for the growth of the state. This document provides a glimpse of our main policies and thrust areas to transit Gujarat as a climate resilient and low carbon state that could provide guidance to other states of India and also to other countries. All the inputs received from across 26 departments of the Government of Gujarat over 5 discussions and consultations have been incorporated in this document, such as in chapters 5, 6, 7, 8 and 9.

The main climate change risks Gujarat faces are temperature and precipitation extremes, and sea-level rise. These impact agriculture, various economic sectors, infrastructure, and population groups in different ways. Agriculture is a major sector that employs 50% of the working population and contributes 9.5% to the Gross State Domestic Product. Higher projected rainfall variations threaten productivity, with 54% of the cultivated land dependent on rain-fed agriculture and more than 60% of the total land area lying in drought-prone zones. The agriculture sector is also threatened by a decline in the availability and quality of groundwater. Vulnerabilities are exacerbated in a scenario where 63% of farmers are small and marginal, and rely mostly on subsistence agriculture. The livestock and animal husbandry sector, with a population of 26.9 million livestock, could suffer productivity losses due to heat stress and grassland deterioration. A significant population is dependent on access to forests for daily needs. The Kuchchh and Saurashtra regions that support unique ecosystems in Gujrat are especially ecologically sensitive, with land-use change and climatic variations leading to desertification and habitat loss. Gujarat has India's longest coastline at 1,663 km, with 9.9 million people living in 40 coastal talukas (Census, 2011). This makes Gujarat vulnerable to the impacts of sea-level rise, cyclonic events, salinity ingress and shifts in fish breeding patterns, which may result in future migration and climate refugees (UN's World Migration Report, 2020). Climate change will impact temperature patterns and cause an increase in the frequency of extreme temperature events. According to the World Bank, 19 of the 26 districts in Gujarat could become climate change hotspots by 2050, with temperatures expected to rise by 2-2.5°C.[1]

Rural Gujarat constitutes about 2/3rd of the above concerns.

[1] https://timesofindia.indiatimes.com/city/ahmedabad/gujarat-a-degree-away-from-climate-calamity/articleshow/65825956.cms

Urban areas that account for 43% of the population and are growing at 35% per decade (Census, 2011). These are highly vulnerable to detrimental impacts of climate change, especially temperature extremes, urban flooding, and pressure on urban lands. Expanding cities have resulted in changed landuse patterns with pressure on urban green and blue spaces, exacerbating climate change impacts. About 4-5 urban flooding events happen each year in Gujarat over the last decade. The 2010 Ahmedabad heatwave caused about 1,344 excess deaths, including increased neonatal deaths Heatwaves are frequent in Kuchchh, Saurashtra and North Gujarat. Surat has experienced 23 floods in the last century, including highly destructive ones in 2006 and 2013. Climate change could also increase the prevalence of vector-borne diseases and cause public health issues that are known to disproportionately impact the elderly and poor populations in cities. Vulnerability at the district level, as a function of the interaction between climate hazards and socioeconomic conditions, is found to be highest in the northern districts (Kuchchh, Banaskantha, Patan) and some districts in the eastern part (Dahod, Panchmahal) of the state. Some of these districts (especially Kuchchh, Banaskantha and Patan) have a low population density, making it difficult for government services to reach these areas. While this vulnerability has been calculated at a district level, urban areas have different challenges as compared to the rural areas for which a separate vulnerability assessment is required.

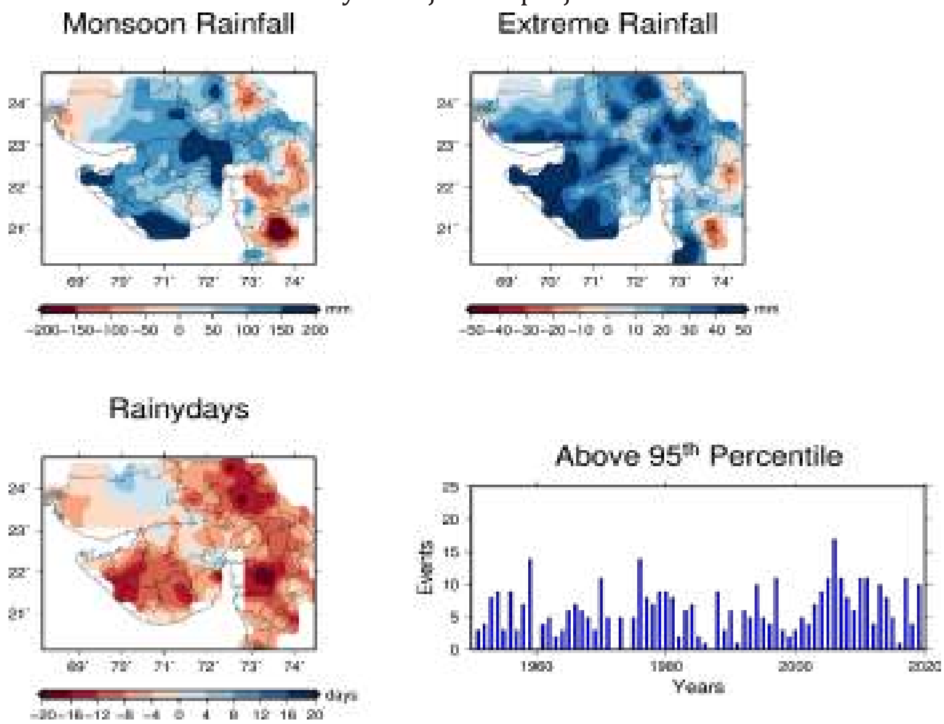
It is estimated that Gujarat emitted about 166.2 MT (in 2005), 219.1 MT (2015) and 245.8 MT (2018, initial estimates) greenhouse gas emissions. All these GHG emissions are reported on "as is where is" basis as per IPCC and UNFCCC guidelines. Gujarat Government has implemented more than 110 policies across 27 departments (including many national policies) that have direct and indirect reduction in GHG emissions from Gujarat state since 2005. These include promotion of solar power, wind power, other renewables, reduction in power transmission and distribution losses, installation of super critical power plants, UJALA scheme, Street Lighting National Programme, Perform Achieve and Trade scheme, drip irrigation, CDM projects, ethanol blending, bioenergy promotion, BRTS, 30 GW hybrid renewable energy park at Kachchh, and many others. As a result of these proactive actions, the cumulative impact of these major policies has translated into GHG emissions by 208 million tons (MT) over 2005-2015 and 379 MT over 2005-2018. Gujarat is therefore contributing hugely to national greenhouse gas mitigation targets.

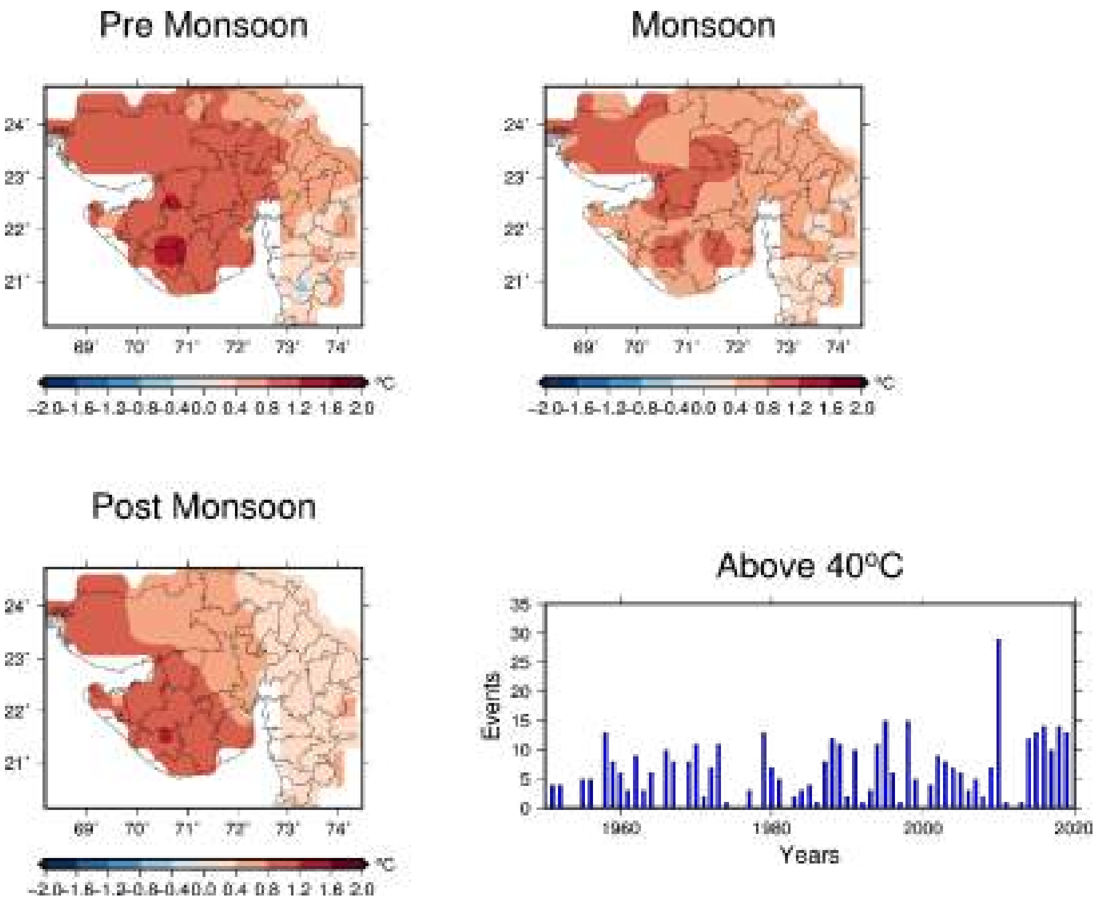
In India, the national actions have been accelerated to address climate change through various interventions. Gujarat has very sincerely attempted to recognize its role and responsibility in the sustainable development and inclusive growth of the nation. The state is working towards building a climate-resilient state while advocating climate mainstreaming. The initiatives have helped Gujarat develop a climate-resilient growth story.

Key Insights

Chapter -3: Climate Profile

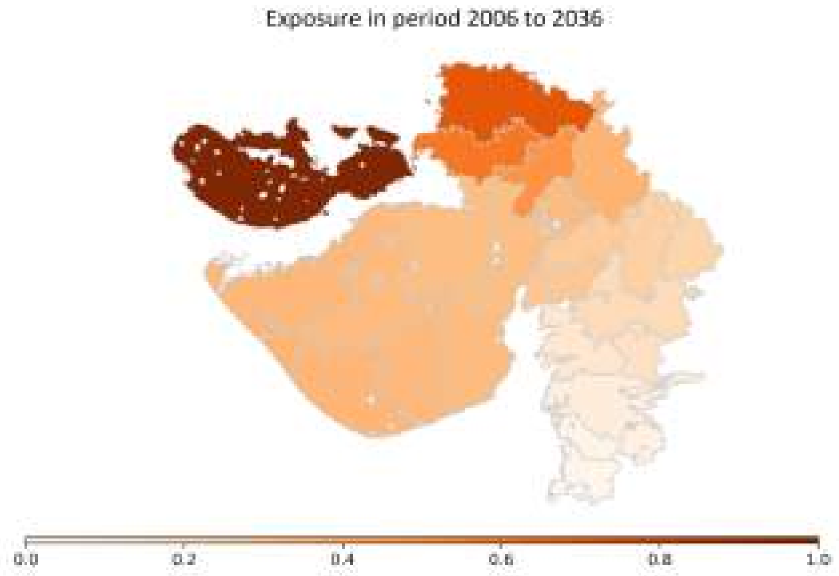
- Gujarat witnessed post-monsoon extremes in 1959 (124 mm), 1979 (101 mm), 1982 (102 mm) and 1998 (130mm) in the recent past.
- Southern districts Valsad, Navsari, and Dang shows Heavy monsoon season precipitation (>1800 mm)
- Gir Somnath, Devbhumidwarka, Surendranagar shows a increase in precipitation (1951-2019; >300 mm, during the monsoon season
- Valsad, Navsari, Dang, Tapi, Surat, and the Narmada received more than 4 such events during 1951 – 2019
- Girsomnath, Surendranagar, Ahmadabad, Sabar Kantha, and Aravalli districts shows increase in changes in the frequency of such events
- Under RCP2.6, Air Temperature is projected to increase by 0.5, 1 and 1.5 ºC in near, mid and end period, respectively
- Air Temperature is projected to increase by 5 ºC under high emission scenario (RCP8.5).
- The number of hot days are projected to increase under warming climate scenarios across Gujarat.
- Highest increase in hot day is observed in West coast of Gujarat.
- Significant increase in hot night under all three scenarios.
- The number of cold day in Gujarat is projected to decline in future.





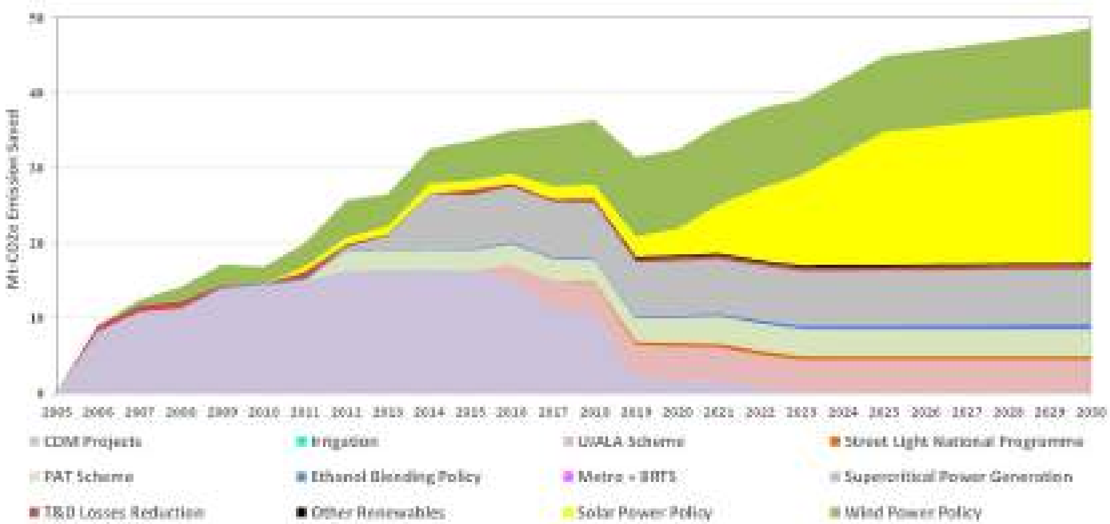
Chapter- 4: Vulnerability Assessment

- In the context of precipitation extremes, the western districts of Gujarat exhibit higher levels of risk. From policy perspective, this would translate to adaptation challenge for infrastructure managers as north-western Gujarat classified as extremely arid region.
- In addition to intensified exposure, western and central districts also exhibit higher magnitudes of vulnerability which can be attributed to higher fraction of marginalized workers, limited healthcare facilities in the remote areas and sparse transportation networks. Adaption planning and risk management measures in these areas need to account for strengthening of the essential functionalities and generate sustainable employment opportunities and healthcare packages to prepare against unanticipated but no longer surprising extremes.
- In the context of temperature extremes, north-eastern and eastern districts of Gujarat exhibit higher levels of risk. It is noted that these regions also coincide with the regions of high population density and urbanization.
- Due to high exposure in Kuchchh district, vulnerability is also high there though it has significant adaptability.
- There is a serious need of designing the infrastructure in Kuchchh very carefully taking into account the high volatility ratio and increasing magnitudes of the return levels with time to lessen the structural sensitivity of this area and hence ensuring the safety of people living there.



Chapter-5: Climate Change Strategy-Mitigation

- The estimated emission intensity of Gujarat's NSDP stands at 22.37 g/INR (FY19E) while that India's GDP stands at 22.70 g/INR (FY19E)
- Gujarat has saved an estimated 266 MtCO2eq (FY19E) emissions between 2005-2019.



- Gujarat's commitment towards combating threats of climate change: Renewable capacity addition of 30000 MW by December 2022
- Gujarat Solar Power Policy, Gujarat Wind Power Policy, Solar-Wind Hybrid Policy, Waste to Energy, Small Hydel Policy, Tariff for Biomass based power generation and Waste Water Policy have been launched to reinforce the progress on renewable energy
- Jump in Solar capacity addition: 5 MW ground mounted solar in 2011 to 2426 MW by March 2019, while the 12.7 MW rooftop solar capacity in 2016-17 jumped to almost 522 MW by March 2019 - Solar Power Policy 2009, 2015, Solar Roof Top Scheme, 2016, 5

MW Gandhinagar Rooftop Programme, Green Solar Projects, 2010-11, Solar and Carbon Neutral City (Gandhinagar), 2010-11, SKY Scheme, 2018, KUSUM, Gujarat Solar Park (Under solar power policy)

- Installed Capacity of Wind Power increased from 249.5 MW in 2005-06 to 7523.45 by July 2020 with almost 1471 MW being added in 2019-20 alone - Wind Power Policy 2007, 2009, 2013, 2016, Wind Solar Hybrid Policy, 2018, Wind Repowering Policy, 2018
- Perform, Achieve and Trade (PAT) to improve industrial energy efficiency across Thermal power, Iron & Steel, Cement, Aluminium, Fertilizer, Paper & Pulp, Textile, and Chlor-Alkali
- 10.53 $MtCO_2$ of emission reduction in PAT-I (2012-15), 11.85 $MtCO_2$ projected reductions in PAT-II (2016-19) for the designated consumers located in Gujarat
- UJJWALA: Subsidized LPG connections to the poor for cooking. Provided to over 19 lakh LPG connections households in Gujarat under PMUY.
- UJALA: Gujarat's share in UJALA installations stood at 41.41 million LED bulbs, 1.27 million tube light and 0.64 million efficient fans by October 2020.
- Street Lighting National Programme: 162 Municipalities and 8 Municipal Corporations in the State have approximately 11.76 lakh streetlights saving 1.4 Mt CO2e between 2016-2020
- Standards and Labelling (S&L) for efficient appliances continuously improves the appliance standards and implementation in the market
- Energy Conservation Building Codes (ECBC) for new and retrofitted buildings is being aggressively promoted in the urban areas of the State
- 10 million sq.ft. of green building footprint in Gujarat by 2022
- Forest and tree cover in Gujarat has sequestered almost 175 Mt-CO2e annually between 2005- 2014

Chapter-6: Climate Change Strategy- Adaptation

Priority sectors for adaptation

Water Resources

- Climate Impacts on Water Resources: Drought and famine, Ground water depletion, Ground water contamination & water pollution, Flood, Extreme precipitation & water logging
- Adaptation Strategies: Wetland restoration, Change irrigation patterns from flood irrigation to drip or sprinkle irrigation, Change in Crop pattern to conserve water-related, Early warning system, Village level awareness about new strategies to conserve water, Proper drinking water supply, Water shed management, Incentivising to promote recharging of ground water, Preserve and protect aquifers, Optimizing water use efficiency, Desalination systems installation, Wastewater treatment, Proper flood warning and management systems, River linking to supply water from wet region to dry region and Conserve, maintain, or rehabilitate wetland ecosystems.

Agriculture Sector

- Impacts on Agriculture Sector: Increased photosynthesis, but a reduction in quality of crops such as cotton, Crop yield has shown a declining trend with climate change, Increased susceptibility to pest attacks due to rising temperature Increased temperatures reduce fodder quality, increases heat stress on livestock, Non-availability of freshwater reduces output from livestock, Non-availability of freshwater reduces output from livestock, Increased Sea temperature and its salinity change will affect fish breeding grounds, More extreme rainfall events in both excess and deficit cause substantial crop losses, Erratic timings of rainfall negatively impact rainfall dependant agriculture, Droughts and floods cause massive damage to crops, Increased sea level associated with increased ingress of salinity at coastlines reduction in crop output in coastal regions

- Adaptation Strategies: as altering planting and harvesting time, collection of crops with short life cycles, crop rotation & cultivation of new crops, modern irrigation techniques, variation in cropping schemes and implementation of Crop-management techniques such as: choice of sowing time and planting density, Genetics and Genomics Strategies such as Genome Wide Association Studies (GWAS), Genome Selection (GS) and Genetic Engineered Plants

Disaster Management

- Gujarat is highly vulnerable to cyclones, that is because of the longest coastal area and climatic condition. Cyclones are more vulnerable in the coastal region of Saurashtra region and Kuchchh.
- The Gulf of Kuchchh and the Saurashtra region is very vulnerable to earthquakes.
- Parts of Surat, Vadodara and many more regions get affected most of the year due to flood events
- Cyclone & Tsunami Adaptation Strategies: Provide cyclone shelters, Strengthening/ Repair infrastructure, Forecasting and warning, Construct missing roads and bridges, Repair existing saline embankment
- Drought Management Strategies: Construct water infrastructure, Forecasting and warning, Supply Water, Construct warehouses and cold storages for preservation/ storage of food grains, Construct percolation tanks, check dams, farm ponds, etc, Repairs, up-gradation and strengthening of dams, reservoirs, lift irrigation and canals for surface irrigation, Apply advanced agro-Science technology and agro-engineering inputs to improve agriculture production
- Flood Management Strategies: Development of catchment area, Floodproofing, Distribute food and necessary things to survive, Strengthen dams and canals, Strengthen /repair of existing roads, bridges as well as critical infrastructure in flood plains, Strengthen Forecasting and warning

Coastal Regions

- Climate Change Impacts on Coastal Regions: Increased risk of flooding of inhabited islands and tidal wetlands, Vulnerability of coastal ecosystems, Development can block the inland migration of wetlands in response of sea level rise, Change in amount of sediment delivered to coastal area, Accelerated shoreline erosion, Salinity of ground water, Destruction of marsh lands, Flooding of low lying areas, Destroy habitats and threat to human life, Migration of species from warmer to much colder habitat, and Increased Coral Bleaching
- Adaptation Strategies: Identification of vulnerable area, Reducing greenhouse gas emissions, Proper monitoring of the changes happening, Preservation of habitats, Control of invasive species, Avoid overfishing to protect symbiosis of species, Enhance efforts to restore dead coral reefs, Maintain sediment transport, Control algal and phytoplankton growth, Early warning system, Conservation of mangrove forests, Maintaining water quality of wetlands and marshlands, Incorporating wetland protection into the planning of new infrastructure, Reduce marine pollution (due to ships), Prohibit or control the removal of beach sediment, Protection of marsh and wetlands

Rural Livelihood

- Impacts of Climate Change on Rural Livelihoods: Affects fisheries sector, Increase or decrease of rainfall affect farming and water sources, Floods affect their lives completely and hike in poverty, Transportation of their supply to city area is affected, High heat affects outdoor workers like farmers, High heat affects crop production and harvest, Scarcity of water for drinking and for other rural industries, Loss of gazing land affect livestock, Forest outputs like fruits and honey are damaged, Loss of homes, and Loss of Firewood
- Adaptation options: Proper awareness and preparedness, Drought tolerant crop varieties, Water Harvesting, Mixed Cropping practice, New farming adaptations, Use new varieties of fodder crops, Introduction of small Community organisations by NGO, Introduction of new technology and advanced skills, Early warning system, Specific need based assessments, Changing herd size and composition, grazing and feeding patterns,, Diversifying their livelihoods Increase in non-agricultural activities, Identification of vulnerable areas and population, Livelihood diversification and Risk management and crop insurance

Biodiversity

- Impacts of Climate Change on Biodiversity: Extinction of several species of flora and fauna due to rising temperature, Wildfire imposes great threat to millions of species, Changes in population and distribution of species, Alteration in phenology (natural migration & breeding cycles), Ocean warming affects marine ecosystem (e.g. Coral bleaching), Rise of invasive species due to extended growing season, Declining precipitation in tropical regions affect the diversity, Flooding conditions due to heavy precipitation leads to loss of animals and plants, Cyclonic winds damage several big and old trees and Disappearing wetlands due to inundation of rising sea level
- Adaptation options: Relocation of less adaptive species to favourable habitat regions, Fast and effective rescue schemes, Ensuring adequate space and resources for migrating species, more data accumulation and learning, Providing possible assistance in various phases, characterizing cyclone-prone areas; Mangrove rehabilitation in cyclone prone areas, Protect critical habitats for threatened species, Artificial implantation of indigenous species and artificial insemination, Preservation and protection of vulnerable species in artificial environments, Introducing timely relocation measures of species (rapid shift)

Forest Sector

- Impacts on forest sector: Reduction in carbon sequestration, Reduced growth and productivity of forest, Deforestation (land development, timber production), Forest fire and pollution, Forest pests and insects, Wildlife habitat & Biodiversity loss,
- Adaptation strategies: Less use of woody materials, Afforestation or reforestation, Enhanced natural regeneration, Re-vegetation of degraded lands, Less forest resource utilization during drought years, Plantation in forest region to recover , Identify the point and non- point sources of forest fire, Monitor the dry biomass to reduce the forest fire, Restrict burning materials in forest region, Monitor endangered species, Use some medicines are technology to divert pests from forest region, Extinction of particular species, Forest management and monitoring, Monitor wetland and coastal area, Restoring grasslands

Infrastructure

- Impacts on Health Facility: Loss of power and air conditioning to manage excessive heat increases health risk to patients

- Adaptation Strategies: **Harden:** Enhance design to enable additional cooling and ventilation capacity, **Accommodate:** Install emergency back-up generators
- Impacts on Trunk sewer system: Reduced flow in pipelines causes increased blockages, and potential for environmental pollution
- Adaptation Strategies: **Harden:** Redesign sewer for low flow conditions (e.g., install smaller pipes), **Accommodate:** Facilitate and increase maintenance
- Impacts on River embankment: More frequent submersion, lesser level of protection, and possible breach / failure of embankment
- Adaptation Strategies: **Harden:** Heighten or buttress embankment based on long-term projected floods, **Accommodate:** Slightly heighten embankment, **Relocate:** Build behind a new embankment (maybe only to protect sensitive or urban areas), **Accept:** Inform residents and farmers to expect lesser protection and increased flooding (possibly dismantle embankment to avoid disastrous failure)
- Impacts on Seawall: Structural damage and submersion leading to property or asset damage and potential loss of life
- Adaptation Strategies: **Harden:** Heighten and reinforce seawall, or build offshore breakwaters, **Accommodate:** Monitor and repair as needed, **Relocate:** Build new seawall further away from the coast, **Abandon:** Relocate properties and condemn area for future development (possibly dismantle seawall to avoid disastrous failure)
- Impacts on Coastal road: Often submerged at high tide, preventing traffic and distribution of goods
- Adaptation Strategies: **Relocate:** Move road inland, **Harden:** Elevate road or build sea wall, **Accommodate:** Monitor and close road at high tide, **Abandon:** Close road and redirect traffic permanently to more inland routes
- Impacts on Coastal wind turbines: Damage from windblown debris
- Adaptation Strategies: **Harden:** Enhance wind resistance design, **Accommodate**: Stop operation during storms, **Abandon:** Dismantle and build other energy production system (e.g., solar) as a substitute
- Impacts on Potable water supply:Burned catchment causes ash and sediments to impact water quality of water sources
- Adaptation Strategies: **Harden:** Install additional filtration, **Accommodate**: Reforest, stabilize slopes, build sedimentation traps, **Relocate**: Build raw water intake and conveyance from another nearby catchment

Health Sector

- Adaptation Strategies for temperature impacts: Air Conditionings and energy efficiency to the buildings, Identification of vulnerable population, Provision for rehydration, Increase community resilience, Awareness generation, Proper monitoring and their counter measures or climate warning
- Adaptation strategies for precipitation related impacts: Timely health services, Weather relationship to influenza and other causes of winter mortality, Water treatment measures, Restoration of communication facilities as early as possible, Reservoir Control and improved operation, Improved prediction, Epidemic/climate warning, Proper alerting system, Tracking of outbreaks of diseases and mapping
- Adaptation strategies for air pollution related impacts: Air quality improvement measures (promote use of environmentally friendly fuels and healthy transportation system, promotion of healthy environment housing,), Temporary relocation, Use of face masks to avoid triggering of asthma and other allergy issues, Chemical Control (near

river or water table), Integrated pest management systems

- Other adaptation strategies: Sanitary Education and awareness, Training and equipment, Legislation, Multidisciplinary approach and collaboration with other agencies—such as, agricultural, meteorological, environmental and planning, Database and information system to be established for accurate monitoring and data collation, Climate resilient health Infrastructure development

Chapter-7: Finance

- Overall state budget analysed for years 2017-18, 2018-19, 2019-20 and 2020-21
- Departments assessed here include Energy & Petrochemical, Climate Change, Food and Civil Supplies & Consumer Affairs, Urban Development and Urban Housing, Forest & Environment, Industry & Mines, Labour & Employment, Education, Agriculture & Co-operation, Health and Family Welfare, Roads and Buildings, Panchayat and Rural Development, Law and Order (Home), Narmada, Water Resources, Water Supply and Kalpsar, Revenue, Social Justice and Empowerment, Women and Child Development, Tribal Development, General Administration, Legal, Labour Welfare and Employment, Ports and Transports, Sports, Youth and Cultural Activities, Science and Technology, and Information and Broadcasting
- Government of Gujarat has already undertaken special efforts to mainstreaming climate actions in the state budget as well as the budgets of various line departments.
- The Government of Gujarat has allotted a special budget for Climate Change Mitigation and Adaptation Schemes through the Climate Change Department. The budget estimates for 2017-18 for the department of Climate Change was Rs. 97.96 crores, while the same for year 2018-19 was Rs. 102.1 crores.
- Gujarat has also undertaken initiative to compile schemes of various line-departments related to Climate Change adaptation and mitigation actions and published this as Climate Change Scheme as a part of climate change department's budget.
- 12th FYP, volume 1, paragraph 7.99 (pp. 260) Government of India, suggests that climate change adaptation costs for new infrastructure could be in the range of 3–10 per cent of the total investment, although for certain sectors and locations this may be higher. This, however, does not cover the cost of likely future damages due to climate change. For existing assets, the adaptation costs could be as much as 25 per cent of present costs of creating similar assets.".
- The present document analyses specific financial needs de novo towards climate resilience of various departments and also deepening GHG mitigation aligned with India's NDCs and additional policies and measures incorporated by the Government of Gujarat towards these. On an average, this works out to around 7.4% additional financing for new projects for climate resilience and about 16% additional financing for existing assets. The latter will be required in a phased manner wherein more vulnerable assets and communities would be made climate resilient first. A separate pilot proposal for Global Climate Finance (GCF) funding is being prepared for this purpose.

Chapter-8: Institutional Mechanism

- Gujarat proposes to establish Chief Minister's Executive Council on Climate Change (CMECCC) in alignment with the Prime Minister's Council on Climate Change.
- Climate Change Department will be the nodal department for coordinating the activities of the council with members from public entities (around 12 nos), private sector (around 6 nos) and Academia/research institutes (around 6 nos).

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CHAPTER - 1

Introduction

Picture Courtesy: Dreamstime.com

Introduction

Climate change is indeed a problem but balancing it with our development needs is imperative for the welfare of the world at large. It is here that India can show the way forward, guided by its ancient wisdom, of living in harmony with nature by identifying the divine in everything. Today, climate change has emerged as the biggest developmental challenge for the planet. It is not just an environmental concern. Its economic impacts, particularly on the poor and vulnerable, make it a major governance challenge.

1.1 National Action Plan on Climate Change

The National Action Plan on Climate Change (NAPCC) in India came into existence in 2008. The NAPCC is founded on the philosophy of achieving the development objectives while simultaneously taking care of the climate change related objectives. The NAPCC has outlined actions and steps through eight missions. These missions include the following:

1.1.1 National Solar Mission

Launched in 2010, the National Solar Mission envisioned a target of achieving 20 GW of grid connected solar power generation capacity by 2022. This target has been updated to 100 GW by 2021-22 after 2014 through 40 GW Rooftop and 60 GW through Large and Medium Scale Grid Connected Solar Power Projects at an overall cost of Rs. 6,00,000 crores. The mission also provides for 20 million sq.m solar thermal collector area, creating favorable conditions for developing solar manufacturing capability in the country and Support R&D and capacity building activities to achieve grid parity by 2022. By 2018-19, 9012.66 MW of grid-connected solar generation capacity installation and 382.01 MW equivalent of off-grid solar generation capacity installation had been undertaken. Gujarat's target under this mission is 8000MW of grid connected solar power- 40% of which is to be covered through roof-top systems. Gujarat is ranked 1st in India in solar rooftop installations. This mission has a direct bearing on the NDC targets of the country as well as its mitigation efforts.

1.1.2 National Mission for Enhanced Energy Efficiency (NMEEE)

This mission aims to strengthen the market for energy efficiency services and equipment. The mission has been operationalized through four initiatives namely the Perform, Achieve and Trade (PAT), Energy Efficiency Financing Platform (EEFP), Market Transformation for Energy Efficiency (MTEE) as well as the Framework for Energy Efficient Economic Development (FEEED). NMEEE plays a pivotal role in achieving India's mitigation related NDC aims. Up till 2018-19, the mission achieved the following milestones:

- Total of 10.49 mtoe energy savings would be achieved which corresponds to avoiding emission of 52.45 million tonnes of CO_2 under PAT Scheme.
- 29 million CFLs have been distributed and avoided generation capacity of 4115 MW has been achieved under Bachat Lamp Yojana (BLY) scheme during XI Plan.
- 20, 00,120 CERs equivalent to as many tonnes of CO_2 reduction have been issued till

now by UNFCCC under BLY.

- EESL has initiated action to procure and deploy super-efficient ACs and fans under super-efficient equipment programme.
- Under this mission, Gujarat has installed 1151100 energy efficient LED streetlights, 41409679 LED bulbs, 642550 energy efficient fns, 7207282 efficient tube lights ditributed under the UJALA scheme, and 537 units in Gujarat are a part of the PAT scheme.

1.1.3 National Mission on Sustainable Habitat

It was launched in 2011, with an aim to make cities sustainable through improvements in energy efficiency in buildings, management of solid waste and shift to public transport. The Ministry of Housing and Urban Affairs holds the primary implementation responsibility for this mission. It is being implemented through four flagship missions/programmes:

- Atal Mission on Rejuvenation and Urban Transformation (AMRUT)
- Swachh Bharat Mission
- Smart Cities Mission
- Urban Transport Programme

Successful implementation of these flagship missions has a potential to mitigate the GHG emission of 133 Mt CO2e by 2021 and 270Mt by year 2031. 6 cities from Gujarat have been selected in the final 100 under the Smart Cities Mission. Also, development priorities for 31 cities of Gujarat have been identified to benefit from AMRUT mission.

Swachh Bharat Mission aims at making urban India free from open defecation and achieving 100% scientific management of municipal solid waste in 4041 statutory towns in the country to be achieved in five years, i.e. by 2nd October 2019. The main objectives are:

- Elimination of open defecation
- Eradication of manual scavenging
- Modern and scientific Municipal Solid Waste Management
- To effect behavioral change regarding healthy sanitation practices
- Generate awareness about sanitation and its linkage with public health
- Capacity Augmentation for Urban Local Bodies
- To create an enabling environment for private sector participation in Capex and Opex (operation and maintenance)

Urban and rural areas in Gujarat have consistently put in efforts to achieve the targets of this mission. The results are seen in the performance of the state in Swachh Sarvekshan across years- for instance, Gujarat received 11 awards in Swachh Sarvekshan 2019.

1.1.4 National Water Mission

The National Water Mission supplements the National Water Policy. The mission aims to create comprehensive water data base, conduct assessment of impact of climate change on water resource, promotion of citizen and state action for water conservation, augmentation and preservation, attention to vulnerable areas including over-exploited areas, increasing water use efficiency by 20%, and promotion of basin level integrated water resources management. The major achievements till-2018-19 are:

- 702 Hydrological Observation Stations and 65 Automatic Satellite based Telemetry system have been established during XII plan period
- Aquifer mapping of 6.31 lakh sq.km up to March 2017
- Delineation of Contamination -free aquifers in the Arsenic – affected States of UP, Bihar, Jharkhand & West Bengal.
- Mega Recharge Project in Tapi River basin
- In drought affected areas of Latur district, 25 wells constructed on sites for tackling drinking water crisis.
- Max yield – 5.8 lps, all wells handed over to the state govt.
- Ground Water Management plan developed for reviving Rajgir hot springs.
- Through convergence with MGNREGA, 7.86 lakh water conservation structures have been made during 2016-17.

Gujarat has implemented various measures under this mission and has been the top position for the third consecutive year under the Comprehensive Water Management Index (CWMI) (Niti Aayog, 2019)

1.1.5 National Mission for Sustaining the Himalayan Ecosystem

The National Mission for Sustaining the Himalayan Ecosystem was approved by the Union cabinet in 2014 to understand the complex processes affecting Himalayan Ecosystem and evolve suitable management and policy measures for sustaining and safeguarding the Himalayan Ecosystem. Till 2018-19, following progress has been made under the mission:

Outcomes of the Centre for Himalayan Glaciology at Wadia Institute of Himalayan Geology, Dehradun

- Installation of six Automatic Weather Stations in the Upper Ganga Valley for real time weather data collection; installation of three Aethlometers in the Bhagirathi Valley to monitor black carbon and aerosols; establishment of Laser Isotope Laboratory to analyse stable isotopes of oxygen and carbon in water and establishment of Remote Sensing and GIS Lab.
- Monitoring of 8 glaciers namely Gangotri and Dokriani in Bhagirathi River basin, Chorabari and Companion in Mandakini River basin, Dunagiri and Bagni in Dhauliganga River basin and Pindari & Kafni in Pindar River basin in Uttarakhand region of Central Himalaya.
- 6 Thematic Task forces anchored around lead institutions working in the areas of Himalayan ecosystem has been set up to undertake following technical work elements:
    - Establishing database
    - Designing monitoring systems
    - Modeling and simulation
    - Vulnerability assessment
    - Adaptation policy research
    - Pilot studies for revalidation.

1.1.6 Green India Mission

Efforts of greening under this mission are expected to go beyond trees and plantation so that greening encompasses both protection and restoration. The aim is to enhancing carbon sinks in sustainably managed forests and other ecosystems; adaptation of vulnerable species/ ecosystems to the changing climate; and adaptation of forest dependant local communities in the face of climatic variability. The targets under this mission are:

- To increase forest/tree cover to the extent of 5 million hectares (mha) and improve quality of forest/tree cover on another 5 mha of forest/non-forest lands;
- To improve/enhance eco-system services like carbon sequestration and storage, hydrological services and biodiversity; along with provisioning services like fuel, fodder, and timber and non-timber forest produces (NTFPs)
- To increase forest-based livelihood income of about 3 million households.

The targets achieved till now include:

- Increase in forest cover by 32368.7 ha (2015-16)
- Promoting alternate fuel energy by 11015.1 ha
- Devices for households by 2500 ha
- Area afforested by 41266.12 ha (2016-17)

1.1.7 National Mission for Sustainable Agriculture

This mission aims at promoting sustainable agriculture through a series of adaptation measures focusing on ten key dimensions encompassing Indian agriculture namely; 'Improved crop seeds, livestock and fish cultures', 'Water Use Efficiency', 'Pest Management', 'Improved Farm Practices', 'Nutrient Management', 'Agricultural insurance', 'Credit support', 'Markets', 'Access to Information' and 'Livelihood diversification'. It has following four major programme components – 1) Rainfed Area Development, 2) On Farm Water Management, 3) Soil Health Management and 4) Climate Change and Sustainable Agriculture: Monitoring, Modeling and Networking.

Status/Outcome during 2012-17:

- 18.70 lakh ha area has been brought under the organic farming as organic farming reduces of greenhouse gases, and sequestration of CO2 in soil.
- Annual production of bio-fertilizers has increased up to 3.96 lakh MT.
- Coverage under Micro Irrigation System was 28.46 lakh ha to improve water use efficiency, reduce irrigation cost, reduce electricity consumption and decrease fertilizer usage.
- The coverage under System of Rice Intensification (SRI) was 7.42 lakh ha
- The coverage under crop diversification was about 2.6 lakh ha, led to reduction in water use.
- 8.01 lakh ha has been brought under plantation in arable land for CO2 sequestration of in soil
- About 450 climate resilient varieties have been identified/released under National Innovation for Climate Resilient Agriculture.
- 50 lakh farmers are working on zero budget natural farming neither fertilizer nor pesticide is used and only 10 per cent of water is to be used for irrigation
- On December 10, 2015, the National Green Tribunal (NGT) banned crop residue burning in states of Rajasthan, Uttar Pradesh, Haryana and Punjab.

1.1.8 National Mission on Strategic Knowledge for Climate Change

This mission is required to undertake the action on a) Formation of well-designed knowledge networks with a well-structured framework for harmonization, interoperability, sharing and exchange of data of relevance to climate change and responses b) Enhancing the research capability in climate science, c) Positioning a technology watch system for key sectors related to economic development, likely to be affected by climate change, d) Leveraging development of suitable technologies for adaptation and mitigation of climate change under various missions, e) Assisting other agencies engaged in the implementation of the National Action Plan for Climate Change and supporting the actions under the other Missions, as and if necessary. Till 2018-19, the mission achieved:

- Eight Centres of Excellence and 20 Major R&D Programmes
- 10 State Climate Change Centres
- Three National Network Programmes
- Seven Human Capacity Building Programmes
- Eight Global Technology Watch Groups (GTWGs)
- Indo-US Fulbright-Kalam Doctoral and Post-Doctoral Fellowships in Climate Change

Out of the 10 state centres, Gujarat hosts one – a collaborative effort between IIT Gandhinagar and GEER Foundation.

Based on the India's NDC commitments and the global Sustainable Development Goals, the NAPCC and the missions therein are under revision. Three new missions are anticipated

1. **National Mission on Health**

The targets here in are expected to be addressing the health-related aspects of climate change, strengthening the health of citizens of India against climate-sensitive illness, especially among the vulnerable populations like children, women and marginalized population and reducing morbidity, mortality, injuries, and health vulnerability to climate variability and extreme weather (MoHFW, 2016).

2. **National Coastal Mission**

The proposed mission would prioritize preparation of an integrated coastal resource management plan and mapping of vulnerabilities along the entire shoreline.

3. **National Mission on Transformative Mobility and Battery Storage**

This mission could work to promote clean, connected, shared, sustainable and holistic mobility initiatives as well as Phased Manufacturing Programme (PMP) valid for 5 years until 2024 (PiB, 2019).

These missions are very much relevant for Gujarat since we have the longest coastline in India. Moreover, Ahmedabad was the first Indian city to come up with a heat-health action plan since the health-related impacts on climate change are already being faced. The state would thus want to invest on strengthening and upgrading its health systems.

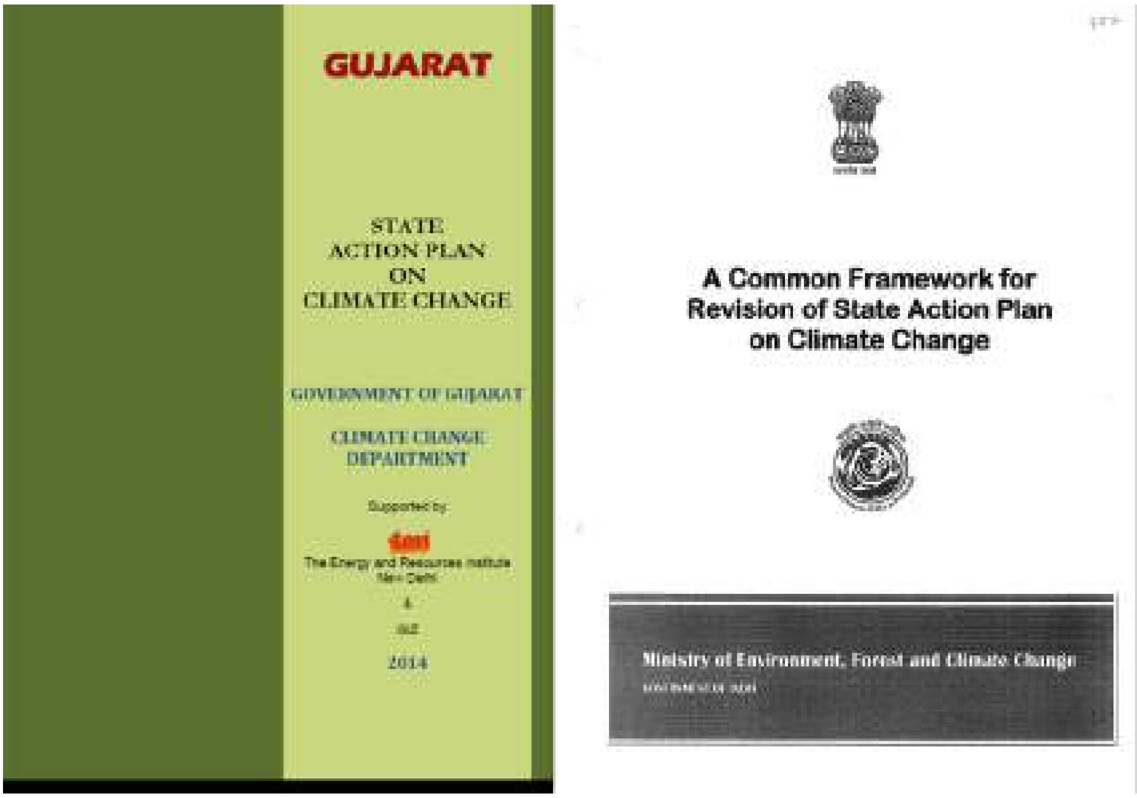
1.2 State Action Plan on Climate Change

After the formulation of the NAPCC, the Government of India directed state governments and union territories in 2009 to prepare their own respective action plans on climate change. The State Action Plans were to be developed in congruence with the national vision and strategy put forth under NAPCC. The State Action Plan on Climate Change (SAPCC) for

Gujarat was developed in 2014 on the lines of the NAPCC and endorsed by the Ministry of Environment and Forest, Government of India. The state plan envisioned a climate resilient accelerated economic growth. In order to do so, the SAPCC, identified 9 key sectors for Gujarat to undertake action efforts. These sectors are Agriculture, Water, Health, Forests and Biodiversity, Sea level-rise and coastal infrastructure, Energy Efficiency and Renewable Energy, Urban Development, Vulnerable Communities, and Green Jobs. Across and between sector policies and actions had been proposed in the plan.

The Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India, in a DO letter (07007/12/2017-CC) dated 3rd January 2018 addressed the States and Union Territories for revising of State Action Plan on Climate Change (SAPCC) considering India's commitments under the NDCs. Further, the MoEFCC directed the states to follow guidelines outlined in a framework developed for revision of SAPCC (F.NO. 08007/3/2017-CC dated 2nd April 2019).

Figure 1.1: (a) Gujarat's initial SAPCC (b) MoEFCC guiding framework on SAPCC Revision



1.3 India's Nationally Determined Contributions (NDCs)

The Intended Nationally Determined Contribution (INDC) for India became its Nationally Determined Contribution (NDC) on 2nd October 2016, a year after it was ratified during the Paris Climate Change Agreement (PCCA, COP21) in 2015 and the agreement came into force on 4th November 2016.

The NDC provides an overarching framework and targets to guide the government on tackling climate change. The NDC is themed on the efforts that India is putting efforts to work towards a low-carbon emission pathway, while simultaneously attempting to meet the developmental challenges. The NDC describes eight targets for achieving sustainable development.

- To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.
- To adopt a climate-friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.
- To reduce the emissions intensity of its GDP by 33 to 35 per cent by 2030 from 2005 level.
- To achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel- based energy resources by 2030, with the help of transfer of technology and low cost international finance, including from Green Climate Fund.
- To create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.
- To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.
- To mobilize domestic and new and additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap.
- To build capacities, create domestic framework and international architecture for quick diffusion of cutting edge climate technology in India and for joint collaborative R&D for such future technologies.

1.4 Sustainable Development Goals

'Transforming our world: the 2030 Agenda for Sustainable Development' resolution was adopted by the United Nations General Assembly in September 2015. The Agenda outlines 17 Sustainable Development Goals (SDGs) and the 169 associated targets. India has committed to achieving all the 17 SDGs. These SDGs comprehensively cover the social, economic and environmental dimensions of development and focus on ending poverty in all its forms and dimensions (Niti Aayog, 2020). NITI Aayog is the nodal institution responsible for co-ordination of all the SDG related activities at nation and sub-national level in India. India is home to 17 per cent of the global population and hence, India's progress on SDGs becomes crucial in achieving the global targets. The federal structure as designed in the constitution of India ensures that states have a very important role in achieving these development goals.

Although SDGs and NDCs have a high degree of political backing from the government, the onus of implementation largely lies with the states. Thus, the state governments are revising their State Action Plans on Climate Change in reference to India's NDCs. This document presents Gujarat's vision on tackling the issues of climate change.

CHAPTER 2
State Profile

Picture Courtesy: Dreamstime.com

State Profile

Gujarat came into existence on 1st May 1960 when the erstwhile Bombay state was re organized to form Maharashtra and Gujarat. It is the western most state in India. Gujarat is 6th largest state in India and contributes 7.5% of total India's GDP. The economy of Gujarat is mainly driven by agriculture and industry sectors. However, both sectors are sensitive to climate conditions. In recent years, Gujarat has faced flood, drought, and cyclone events over last two decades. To prepare climate resilience strategy for vulnerable regions, it is essential to understand the historical change in climate and future projections derived from experiments.

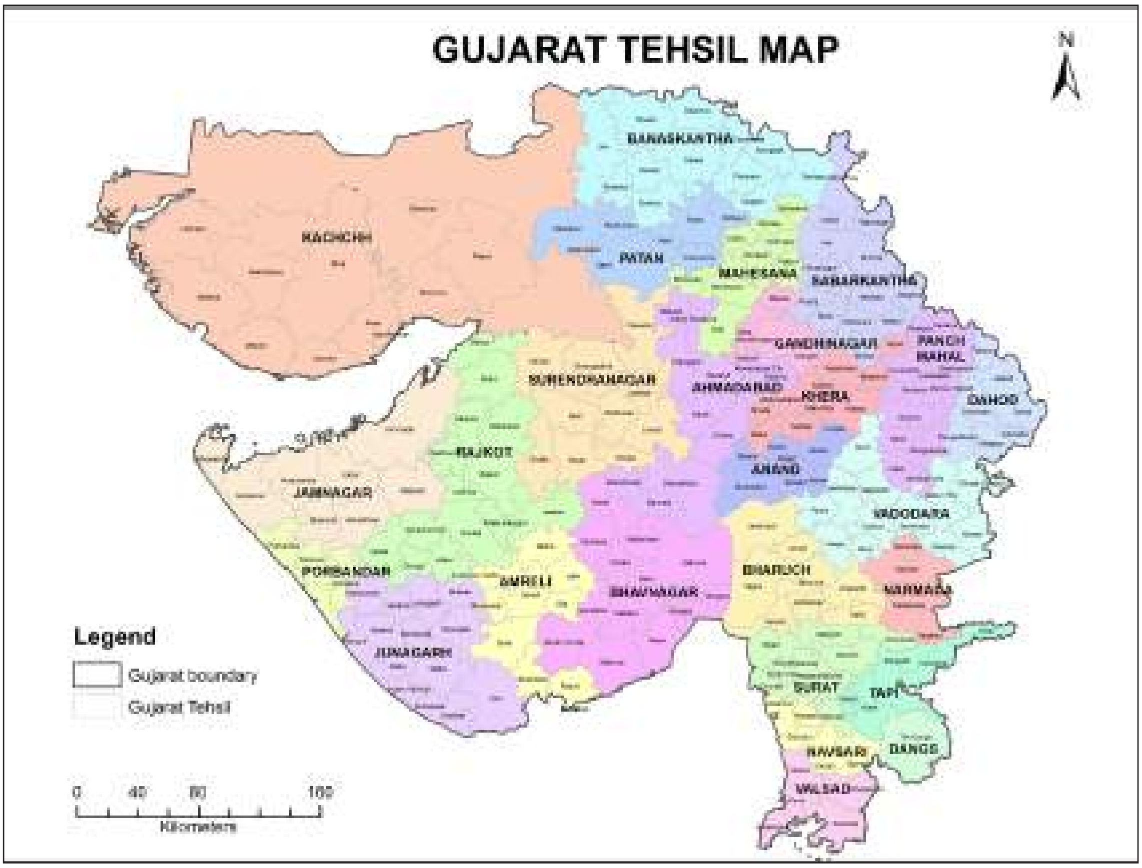
2.1 Location, Geography and Size

Located on the western coast of India between 20-6' N and 24-42'N latitude and 68-10'E and 74-28'E longitude, Gujarat shares its boundaries with states of Rajasthan in the North East, Madhya Pradesh to the East, and Maharashtra in the South East, along with Union Territories of Dadra and Nagar Haveli and Diu and Daman to the South East and South respectively. It shares an international border with Pakistan in the North West. The Arabian Sea lies to the West and South West of the state forming a 1600 km long coastline. Figure 2.1 depicts the location of Gujarat within India.

Figure 2.1: Map of India showing the location of Gujarat

The state was carved out of the 17 northern districts of the erstwhile Bombay state. Over the years these 17 district boundaries have been re-drawn to form 33 administrative districts composed of 252 talukas (tehsils) as shown in Figure 2.2. The state covering the area of 196,024 km2 comprises of five eco-regions that include the hills, beaches and mangroves, deciduous forests, as well as the dessert region- specifically 1) Indus River Delta-Arabian Sea mangroves, 2) Kathiarbar-Gir dry deciduous forests, 3) North Western Ghats moist deciduous forests, 4) Northwestern thorn scrub forests, and 5) Rann of Kuchchh.

Figure 2.2: Taluka Map of Gujarat

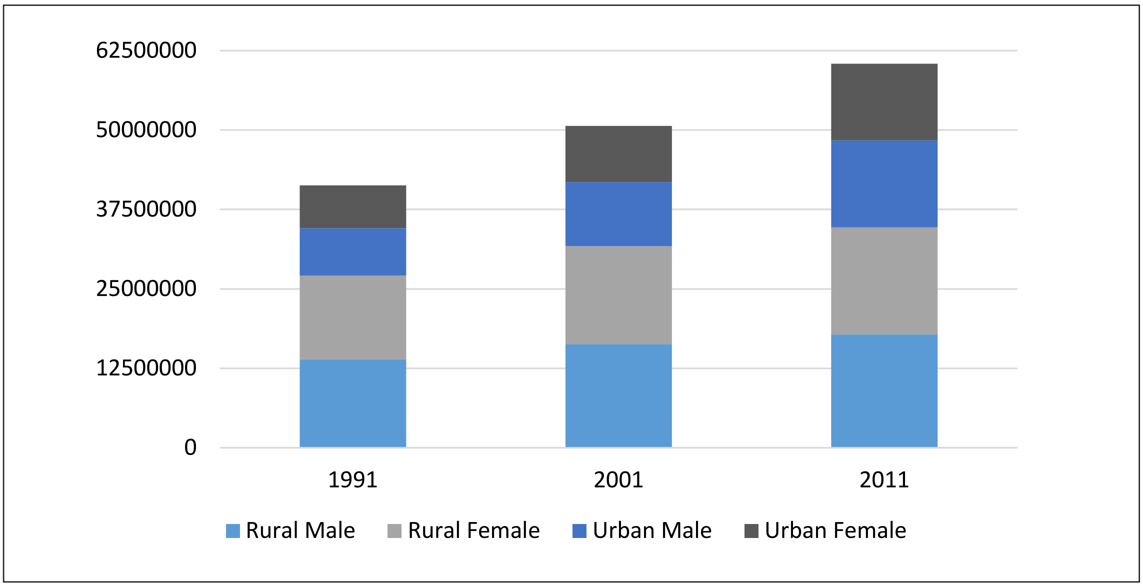


2.2 Demographic profile

As per the Census of India's 2011 enumeration, the state of Gujarat housed a population of 60,383,628 (almost 6.03 Crore – 5 per cent of India's population in 2011) which grew at a rate of 19.17 per cent from 50,671,017 in 2001 (Figure 2.3 (a)). The share of urban population in Gujarat increased from 34.50 per cent in 1991 to 42.60 per cent in 2011. The urban population resides in the 159 municipalities and 8 municipal corporations across the state, while the rest of the 57.40 per cent rural population resides in the 18584 villages of the state. The sex-ratio of the Gujarat stood at 918 as per Census of India, 2011, the male literacy rate at 87.23, female literacy rate at 70.73 and overall literacy rate at 79.31 per cent. Gujarat's population density increased from 258 to 308 persons per km2 between 2001 and 2011 (Refer Figure 2.3 (b)). Surat district recorded the highest density 1337 persons per km2 and Kuchchh is the least densely populated district with 46 persons per km2. Navsari district reported the highest share of literate females (71 per cent) and Gandhinagar district reported to the highest in male literacy rates (80.5 per cent) while Dahod was the lowest for both male and female literacy rate at 56.1 and 38.6 per cent respectively.

Figure 2.3: Demographic Distribution in Gujarat

(a) Residence and Gender-wise Population Growth in Gujarat between 1991 and 2011



Source: Census of India, 1991, 2001 and 2011

(b) Population Density in Gujarat in 2011

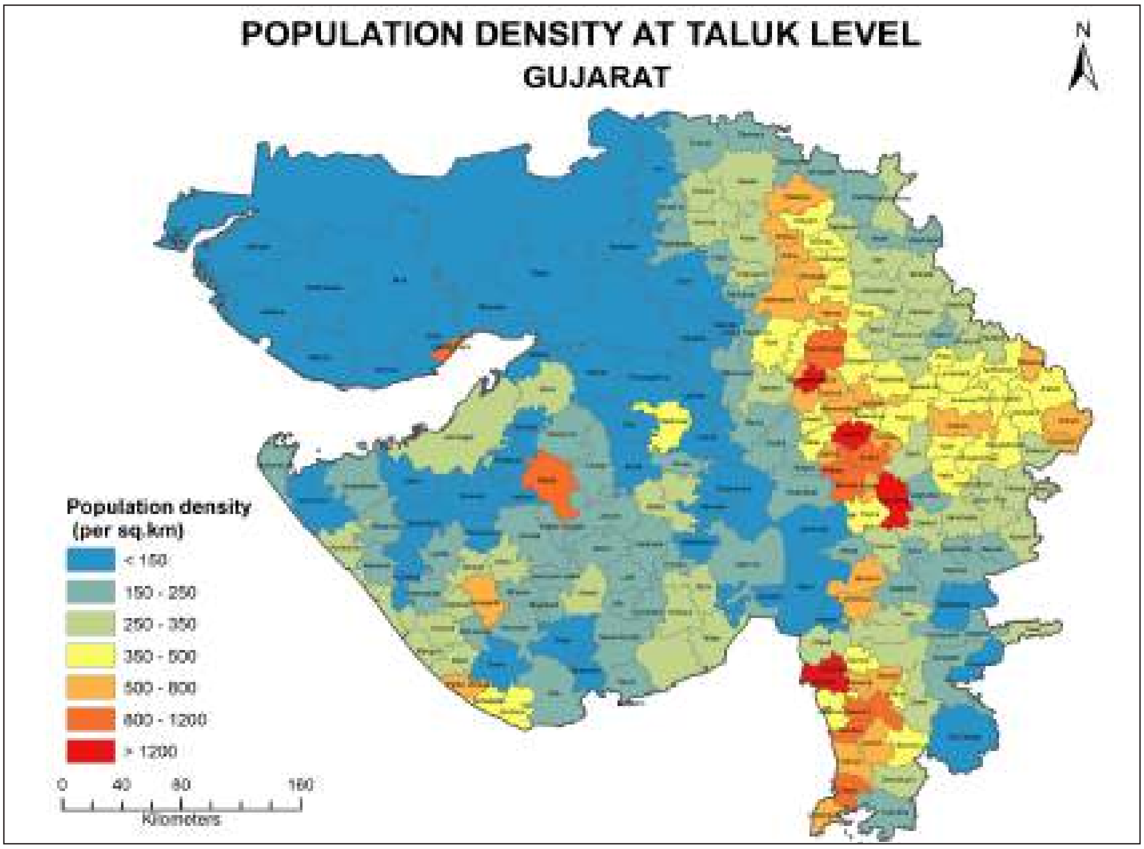


Table 2.1: District-wise Population and Literacy Rates in Gujarat as per Census 2011

District	Total Households	Total Population	Male Population	Female Population	Total Literacy	Male Literacy	Female Literacy
Ahmadabad	1510134	7214225	3788051	3426174	75.30%	79.90%	70.30%
Amreli	294837	1514190	771049	743141	65.70%	72.40%	58.80%
Anand	427605	2092745	1087224	1005521	74.10%	80.40%	67.30%
Banaskantha	560411	3120506	1610379	1510127	54.60%	65.10%	43.50%
Bharuch	333483	1551019	805707	745312	72.10%	77.30%	66.40%
Bhavnagar	538605	2880365	1490201	1390164	65.50%	73.00%	57.50%
Dang	44699	228291	113821	114470	61.70%	67.90%	55.60%
Dohad	334272	2127086	1068651	1058435	47.30%	56.10%	38.60%
Gandhinagar	289990	1391753	723864	667889	74.00%	80.50%	67.00%
Jamnagar	430941	2160119	1114192	1045927	64.70%	71.40%	57.50%
Junagadh	527326	2743082	1404356	1338726	67.20%	74.60%	59.40%
Kheda	466856	2299885	1185727	1114158	72.20%	79.50%	64.40%
Kuchchh	445672	2092371	1096737	995634	59.90%	67.40%	51.50%
Mahesana	424479	2035064	1056520	978544	73.80%	80.20%	67.00%
Narmada	122174	590297	301086	289211	62.70%	70.30%	54.80%
Navsari	295131	1329672	678165	651507	75.40%	79.50%	71.00%
Panchmahal	446611	2390776	1226961	1163815	60.30%	69.90%	50.10%
Patan	267633	1343734	694397	649337	62.40%	71.20%	52.90%
Porbandar	124556	585449	300209	285240	67.20%	73.80%	60.30%
Rajkot	786586	3804558	1974445	1830113	71.60%	76.70%	66.20%
Sabarkantha	481414	2428589	1244231	1184358	65.00%	73.80%	55.70%
Surat	1333200	6081322	3402224	2679098	75.20%	79.00%	70.30%
Surendranagar	343213	1756268	909917	846351	62.30%	70.70%	53.20%
Tapi	177091	807022	402188	404834	60.70%	66.90%	54.60%
Vadodara	877106	4165626	2153736	2011890	69.50%	74.90%	63.60%
Valsad	364403	1705678	887222	818456	68.60%	73.90%	62.90%

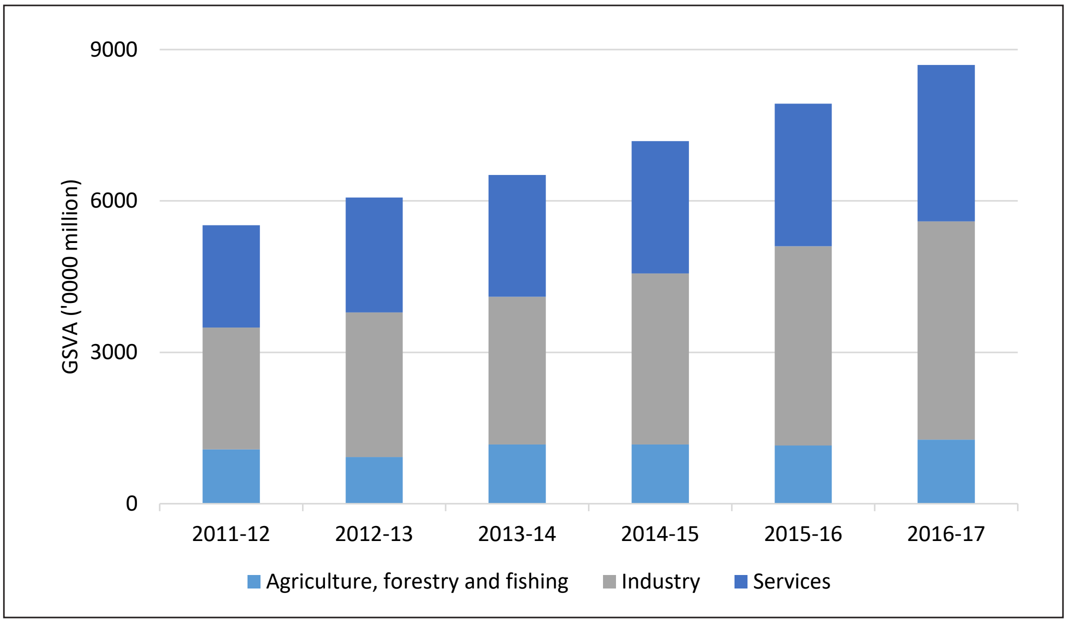
Source: Census of India, 2011

2.3 Economic profile

The state of Gujarat contributes almost 7.6 per cent to India's Gross Domestic Product (GDP). It is one of the most industrialized states in the country. Figure 2.4 below shows the Gross State Value Added (GSVA) for Gujarat between 2011-12 and 2016-17 at 2011-12 constant prices. The total GSVA for Gujarat in 2011-12 stood at Rs. 5,520 thousand million that grew to Rs. 8,694 thousand million by 2016-17 at 2011-12 constant prices. Figure 2.5 shows the increase in the per capita GSDP of Gujarat between 2011-12 and 2017-18.

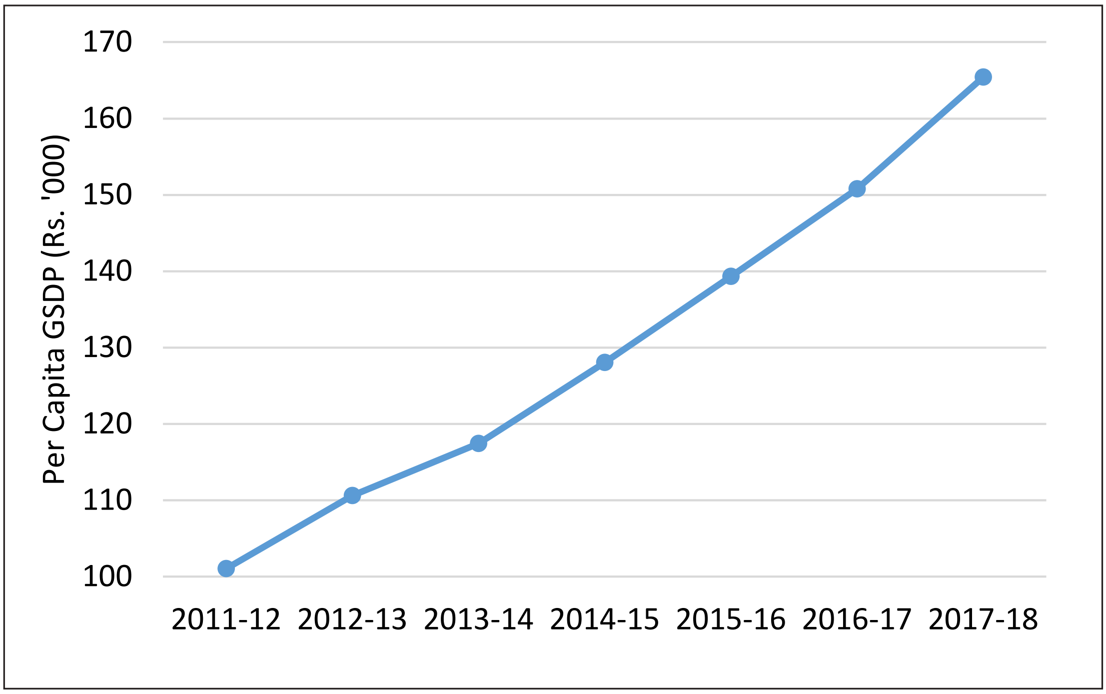
The growth rate of the state product in current price between 2011-12 and 2016-17 has been 13 percent. This growth in the economy can primarily be attributed to the increased contribution from the manufacturing sector (industry). Share of Gujarat's industrial output in All India industrial output reached 18.4 per cent by 2014-15 – highest across all states (GoG, 2018). Figure 2.6 shows Gujarat's output share in key products of India's production. The industrial sector has been increasing over the years. The major industries present in the state cement, pharmaceuticals, dairy, chemicals, engineering, petrochemicals, textiles, gems and jewellery and ceramics. With a largest coast line in India, the ports in the state are responsible for almost 20 percent of the export of goods.

Figure 2.4: GSVA for Gujarat between 2011-12 and 2016-17 at 2011-12 constant prices



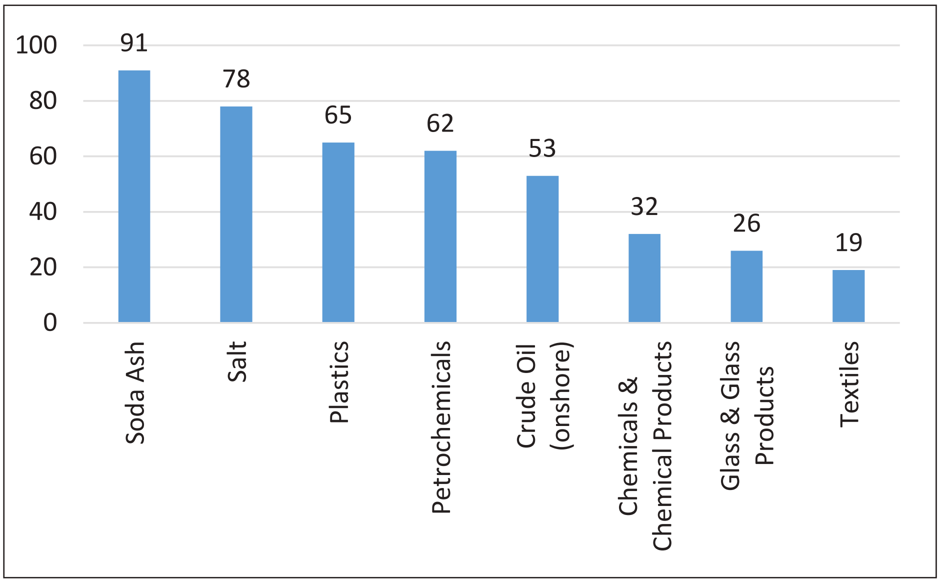
Source: Directorate of Economics and Statistics, Gujarat

Figure 2.5: GSDP per capita for Gujarat between 2011-12 and 2017-18



Source: Directorate of Economics and Statistics, Gujarat

Figure 2.6: **Gujarat's contribution to India in key products (% output)**



Source: http://indextb.com/documents/VG%202019_MSME_Sector%20Profile.pdf

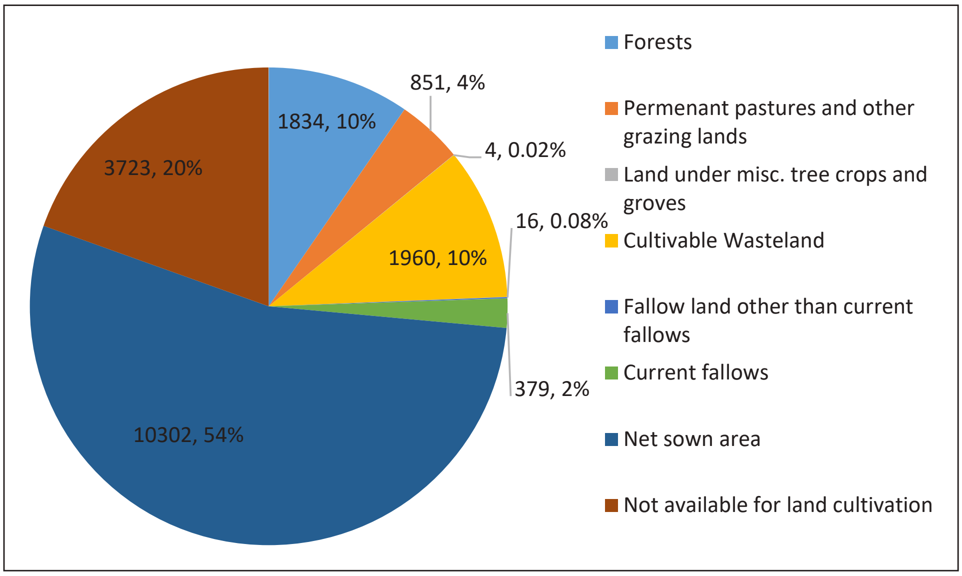
The share of primary sector- agriculture, forestry and fishing is the lowest across the years. The major crops grown in the state include cash crops like tobacco, cotton, groundnuts and other oilseeds, as well as food grains like rice, wheat, jowar, bajra, maize, tur, and gram.

2.4 Natural resources like availability of land, water, energy, forestry and biodiversity resources

2.4.1 Land Resources

Gujarat covers a geographic area of 196024 sq. km almost 6 per cent of India's total area. This land is put under different uses as described in Figure 2.7. The area under cultivation forms 54 per cent of the total land use share while the forests cover almost 10 per cent of the land.

Figure 2.7: **Land use Classification for Gujarat (2014-15)**



Source: Agricultural Statistics at a Glance 2017, Ministry of Agriculture and Farmer Welfare, Government of India

An assessment of the status of land resource in Gujarat and the degradation impacts undertaken by the Gujarat Ecology Commission (GEC) in April 2017 indicates that Water erosion, Salinity and Vegetation degradation are the leading causes of land degradation observed in the state between 2003-05 and 2011-13. Table 2.2 describes the change in amount of land degradation by its cause during 2003-05 and 2011-13.

Table 2.2: Land Degradation Status in Gujarat between 2003-05 and 2011-13

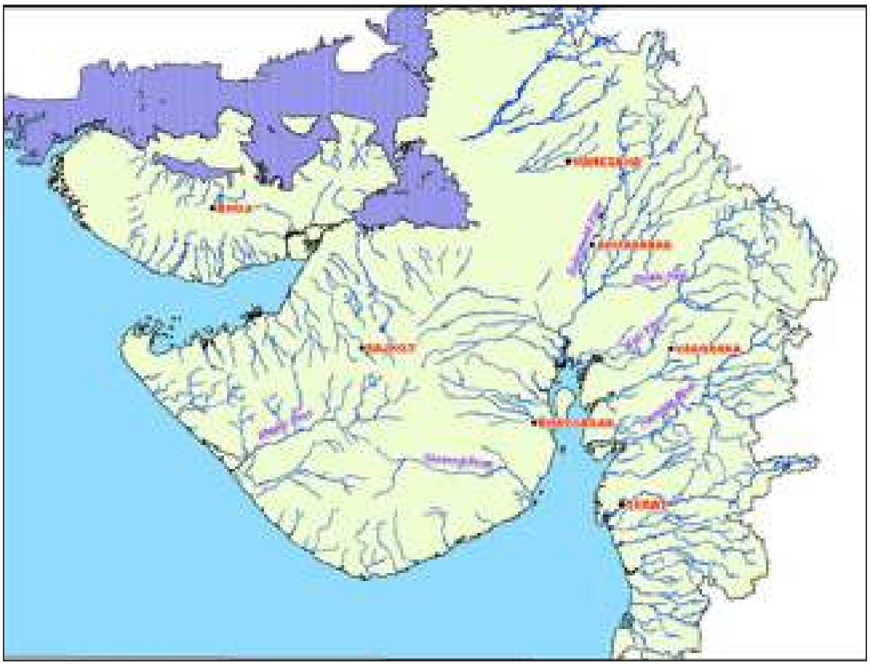
Process of Desertification / Land Degradation	Change in area (hectares)	Change in area (%)
Vegetation Degradation	64409	0.32
Water Erosion	71398	0.36
Wind Erosion	-2443	-0.01
Salinity	1578	0.01
Water Logging	0	0
Manmade	1113	0.01
Barren/Rocky	0	0
Settlement	48131	0.25
Total Area under Desertification	184186	0.94
No Apparent Degradation	-185437	-0.94

Source: GEC, 2017

2.4.2 Water Resources

Gujarat has access to 1600 km coastline and a river system consisting of 185 minor, major, seasonal and perennial rivers and river basins, Narmada, Sabarmati, Tapi and Mahi being the 4 largest ones. Figure 2.8 shows the rivers flowing through Gujarat.

Figure 2.8: Rivers of Gujarat



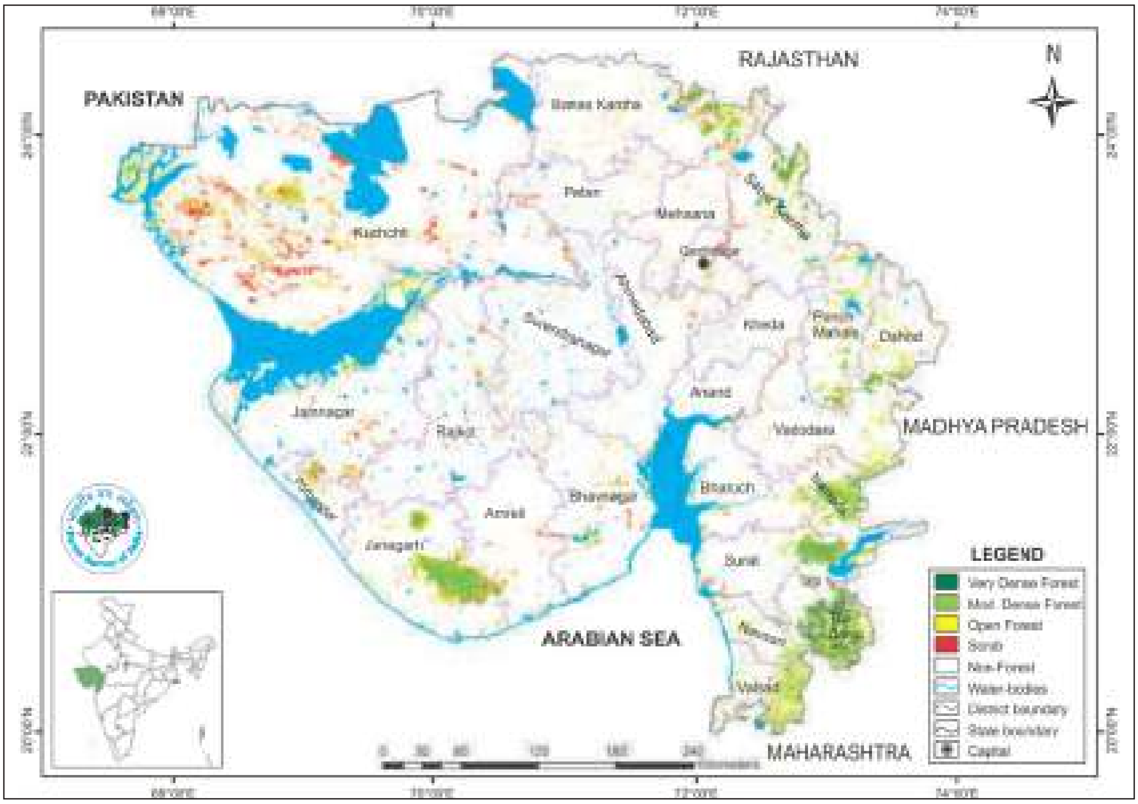
Source: Narmada, Water Resources, Water Supply and Kalpsar Department (https://guj-nwrws.gujarat.gov.in/showpage.aspx?contentid=1465&lang=English)

Based on the water resources availability, the state is bifurcated into four distinct regions of Kuchchh, North Gujarat, South & Central Gujarat and Saurashtra. Kuchchh falls under the arid zone as it experiences very little rainfall and lack of any perennial rivers. The Saurashtra region is made of rocky formation leading to very low water recharge potential while the South and Central Gujarat have large ground water resources, they are heavily polluted due to salinity ingress and presence of large industrial areas. Gujarat state's surface water availability is 38.1 billion m3 while groundwater resources is 17.51 billion m3 and total water quota is 55.61 billion m3.

2.4.3 Forest Resources

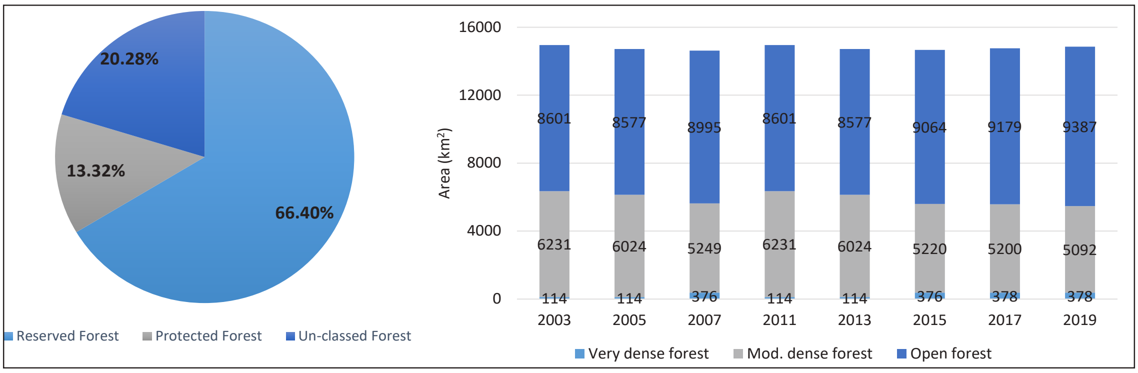
The forests of Gujarat occupy 2.83 per cent of India's forest areas and 11.04 per cent of Gujarat's total geographical area in 2015. As per the India State of Forest Report, 2019, 9.62 per cent area of Gujarat is under forest. 21647 km2 area of the total 196024 km2 are the recorded forest areas (Figure 2.9). Figure 2.10 (a) shows the share of reserved forest area in Gujarat in 2015 while Figure 2.10 (b) shows the trends in change of forest types between 2003 and 2017. It can be observed that the moderately dense forests are decreasing while the open forest areas are increasing. The mangrove cover on the large coastline of Gujarat has been increasing over the past almost 2 decades (Figure 2.11).

Figure 2.9: Forest Cover Map of Gujarat



Source: India State of Forest Report, 2019

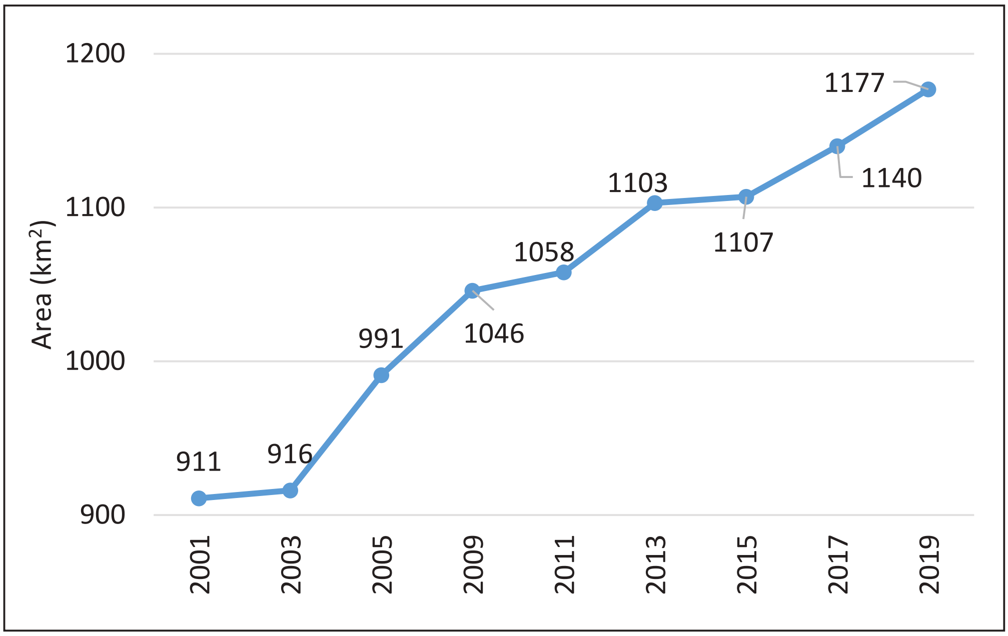
Figure 2.10: Forest type and area in Gujarat



(a) Share of type of forest in Gujarat (2015)

(b) Trends in forest density in Gujarat (2003-2019)

Figure 2.11: Area under Mangrove cover in Gujarat



Source: India State of Forest Report, 2015, 2017, 2019

2.4.4 Biodiversity

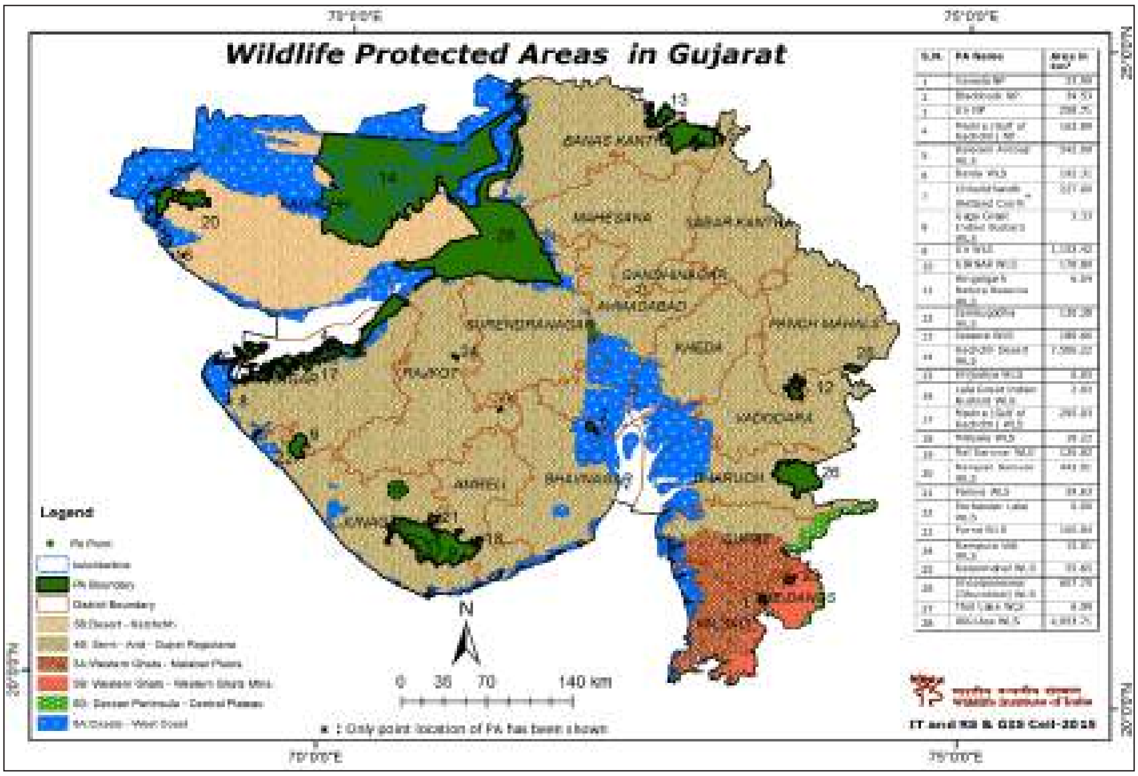
The Gujarat Biodiversity Board indicates that Gujarat has several ecosystems like Forests Ecosystems, Desert Ecosystems, Wetland Ecosystems, Coastal & Marine Ecosystems and Agro-ecosystems in different regions culminating in ecosystem biodiversity. The species biodiversity is also monitored in the state for both flora & fauna in wild as well as cultivated plants and domestic animals' breeds. Table 2.3 depicts the list of the flora and fauna species found in Gujarat. Moreover, there are 4 national parks in the state of Gujarat that includes a Marine National Park in the Gulf of Kuchchh and the Gir Forest national Park which serves as the only habitation of the Asiatic Lions. Further there 23 Wildlife Sanctuaries that serve as protected areas for several species of indigenous and migratory birds as well as sloth bears, wild ass, leopards and blackbucks among other avian, terrestrial and marine species (Figure 2.12).

Table 2.3: **List of number of species found in Gujarat**

Living Organisms	No. of Species in Gujarat
Viruses	-
Bacteria	-
Algae	1,933
Fungi	164
Bryophyta	08
Pteridophyte	16
Gymnosperms	01
Angiosperms	2,198
Total (Plants)	4,320
Lower Animals	1,736
Fish	606 (Marine - 487 + Freshwater - 119)
Amphibians	19
Reptiles	107
Birds	479
Mammals	107
Total (Animals)	3,054
Grand Total (Plants+ Animals)	7,374

Source: https://forests.gujarat.gov.in/wl-intro.htm

Figure 2.12: **Map showing Wildlife Protected Areas in Gujarat**



Source: ENVIS

2.5 Agriculture and livestock

Almost 65 per cent of the land in Gujarat is either under cultivation or is cultivable. 57 per cent of the population of Gujarat lives in rural areas and is dependent on agriculture and allied activities. The state has nearly 45.90 % of the area under irrigation, though the irrigated wheat comprises 94 % of the total area. The major crops grown in Gujarat include wheat, bajra, paddy, maize, groundnut, mustard, sesame, pigeon pea, green gram, gram, cotton and sugarcane. The major Kharif season cropping includes Bajra, paddy, maize, groundnut, castor, cotton, tobacco and pulses while in the rabi season, the cultivation of wheat, mustard and rapeseeds are undertaken. Rice occupies about 10.61 % of the gross cropped area of the State and accounts for around 25.5 % of the total food grain production and Wheat is grown on 23 % of the land used for cereals. Oilseeds are important next to food grains in terms of area, production and value in the state. Cotton is cultivated in all the districts of the state except Valsad, Navsari and Dang. Nearly 26.8 % cropped area of the state is occupied by cotton.

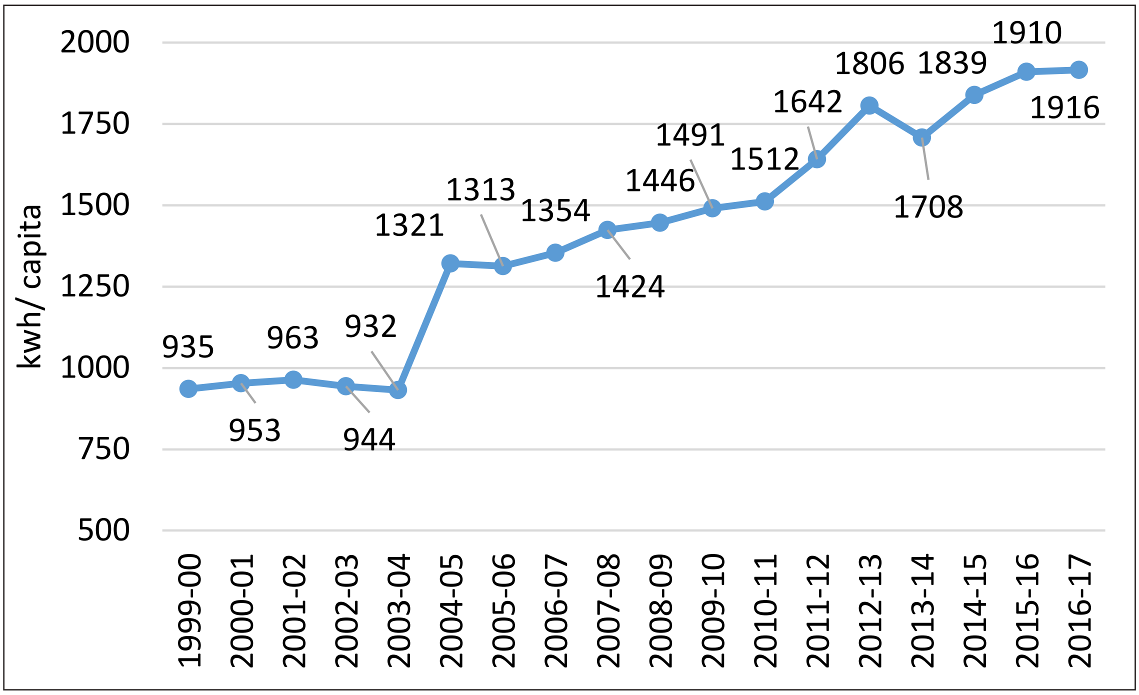
Further, horticultural crops like mango, banana, sapota, lime, guava, tomato, potato, onion, cumin, garlic, Isabgul and fennel are grown in about 14.04 lakh hectares of land contributing about 29 per cent of GDP and 37 per cent of export of the agricultural commodities. The state has a wide range of cropping systems viz. Cotton-Wheat-Bajra, Mung-Wheat-Bajra, Cotton-Wheat-Mung, Cotton-Wheat, Groundnut- Wheat, Paddy-Wheat-Bajra, Paddy, Wheat etc. Gujarat is the largest producer of castor, fennel, tobacco and Isabgul (psyllium), and second largest producer of sesame seeds, cotton and groundnut in the country. Gujarat has highest productivity in mustard, castor and cotton also has second highest productivity in groundnut and bajra, and third highest productivity in gram and guar in the country. In the country, Gujarat has highest productivity in guava, potato, onion, cumin and fennel and third highest productivity in banana and Isabgul. With production of 195.98 thousand MT of flowers under 20641 hectares area, Gujarat ranks fifth in India in Floriculture.

Livestock raring is a very important livelihood for rural Gujarat. Total 42.66 lakh families keep livestock as primary or secondary source of income. Gujarat is one of the largest milk producing states in India with the contribution of 7.75% share in the total milk production of India. The state having 17 Cooperative dairy milk unions & 25 private dairy plants has a milk collection of 3.45 billion litres with over 30 lakhs milk producers, affiliated to more than 15,000 Primary Milk Cooperative Societies. Milk contributes to 22% to the Agricultural GDP of Gujarat and is one of the biggest sectors for supporting livelihood in the state. 19th Livestock census conducted in 2012 has reported a Total population of 27.12 million animal in Gujarat.

2.6 Energy profile including primary energy supply, energy demand, electricity installed capacity etc.

Gujarat has high per capita consumption of electricity which is manifested into significant economic growth over the past decades. Huge investments that are planned to add to its economic momentum, and the resultant increase in industrialization will lead to increase in urbanization and income levels, that results in substantially higher demand for power. The per capita electricity consumption almost doubled from 953 kwh/capita in 2000-01 to 1916 by 2016-17 (Figure 2.13).

Figure 2.13: **Per-Capita Electricity Consumption in Gujarat (1999-00 to 2016-17)**

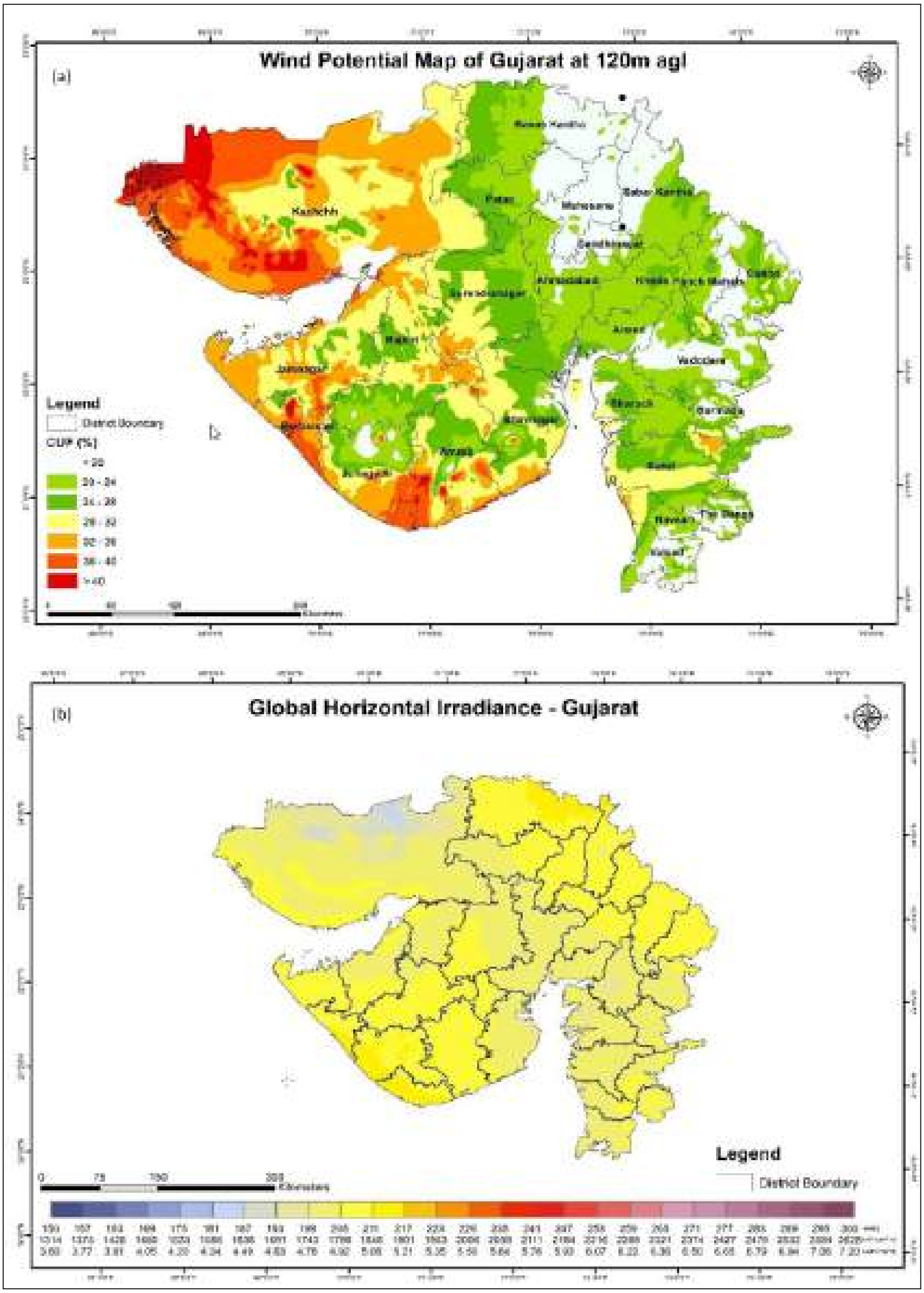


Source: Statistical Abstract of Gujarat State, 2018

2.6.1 Primary Energy

The primary energy availability in Gujarat includes the Oil reserves, Natural gas, Lignite and Renewable potential. The total oil reserves estimates for Gujarat are at 20 per cent of India's reserves of 594.49 Million tonnes as per the Energy Statistics, 2019 (MoSPI, 2019). The Natural gas reserves in Gujarat estimates at 51.59 billion m3 (4 per cent) of total reserve of 1289.81 billion m3. While the total renewable energy potential of Gujarat (Figure 2.14) stands at 11 per cent (122086 MW) second highest in India after Rajasthan. Gujarat also contains Lignite reserves. The total Lignite reserves in India estimate at 45.66 billion tonnes with Gujarat housing almost 6.09 per cent share.

Figure 2.14: **Renewable Energy Potential of Gujarat**

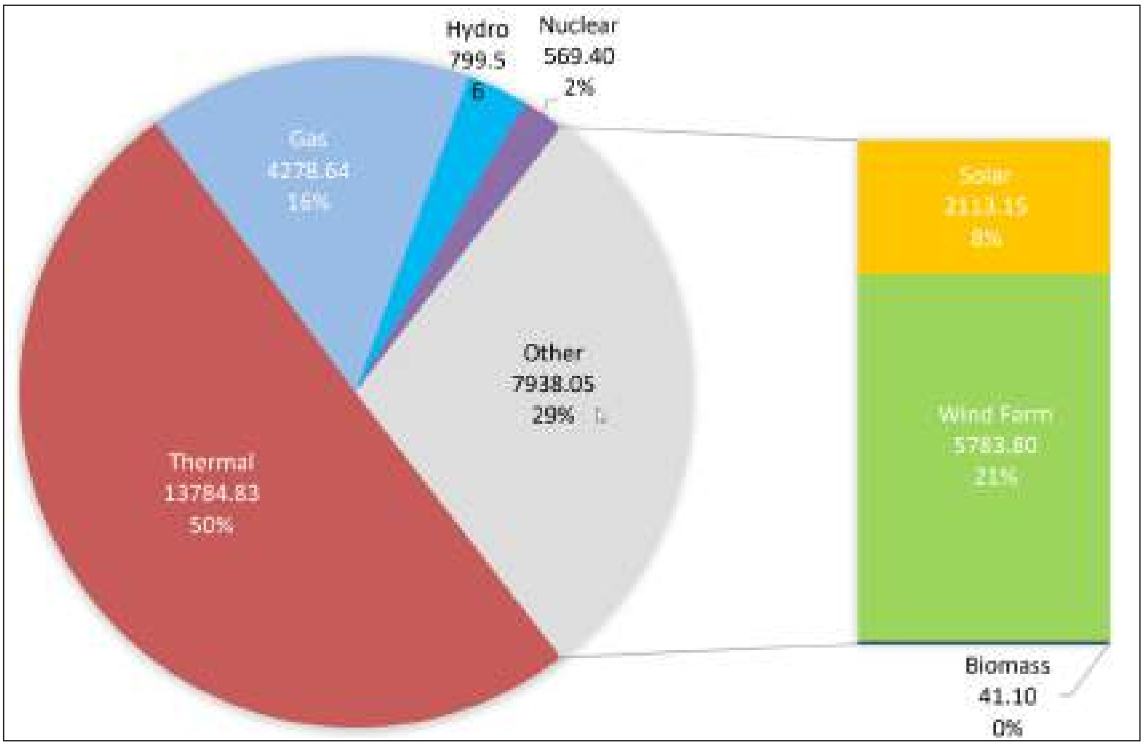


Source: GEDA

2.6.2 Electricity

The total conventional installed capacity for electricity generation in Gujarat grew almost 4 fold between 1990-91 (5094 MW) and 2016-17 (19888 MW). Meanwhile, the non-conventional energy grew from nil to 6635.80 MW in the same period. As discussed in section 2.6.1, the renewable potential of Gujarat is very large. Figure 2.15 shows the source distribution of power generation in Gujarat with thermal power share at 50 per cent.

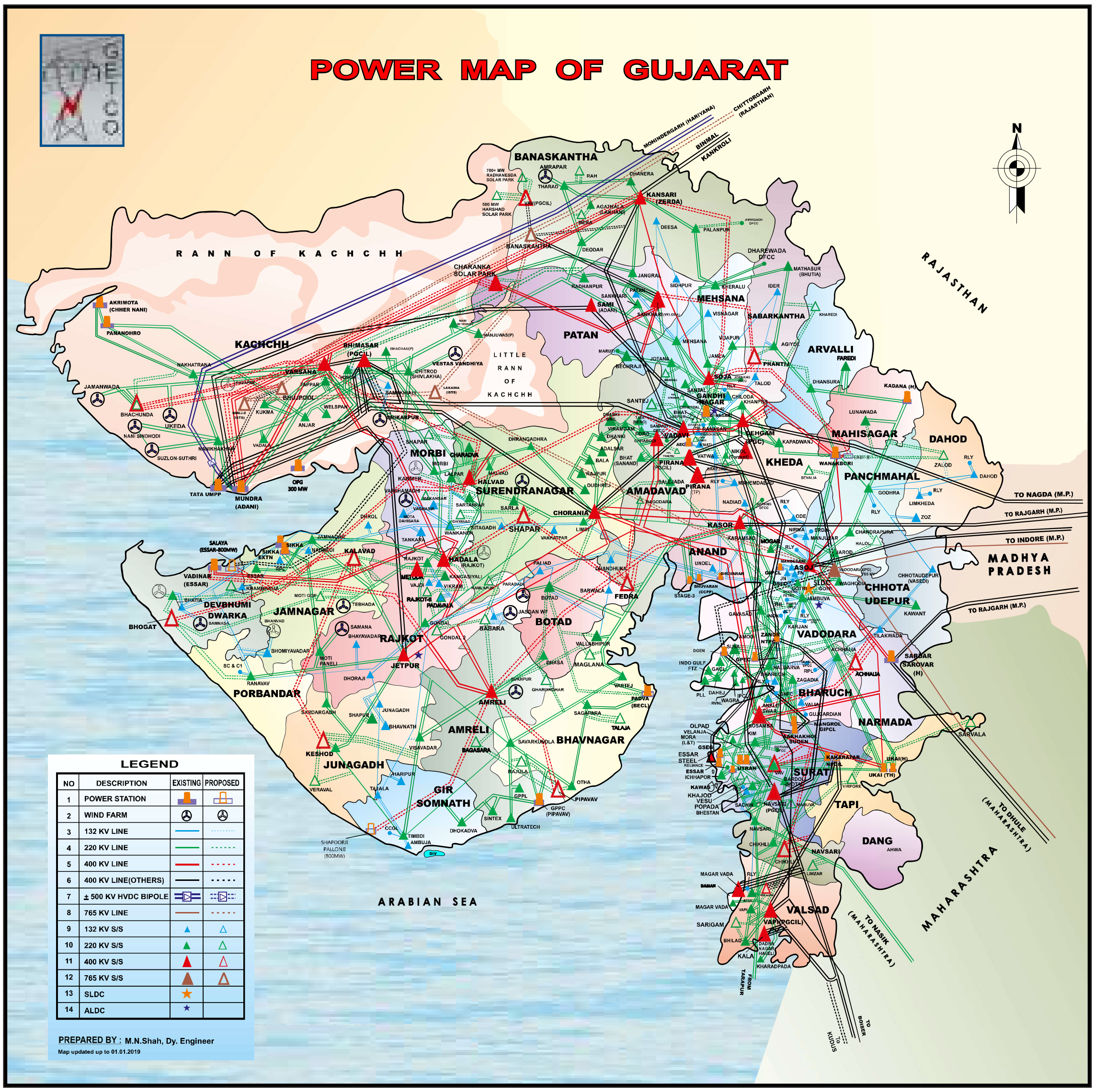
Figure 2.15: Fuel-wise Capacity of electricity in Gujarat



Source: https://www.sldcguj.com/compdoc/SLDC%20Annual%20Report_18-19.pdf

There are 60 operating power units (multiple units may exist under one plant) in Gujarat with 47 proposals that stand cancelled. One Ultra Mega Power Plant is operating in Gujarat. In September 2019, Gujarat decided not to add new coal based thermal power plants. Figure 2.16 shows the power generation and supply grid in Gujarat while Figure 2.17 shows the thermal power plants in Gujarat.

Figure 2.16: **Power Generation and Supply Map of Gujarat**



Source: https://www.sldcguj.com/compdoc/SLDC%20Annual%20Report_18-19.pdf

Figure 2.17: Thermal Power plants in Gujarat

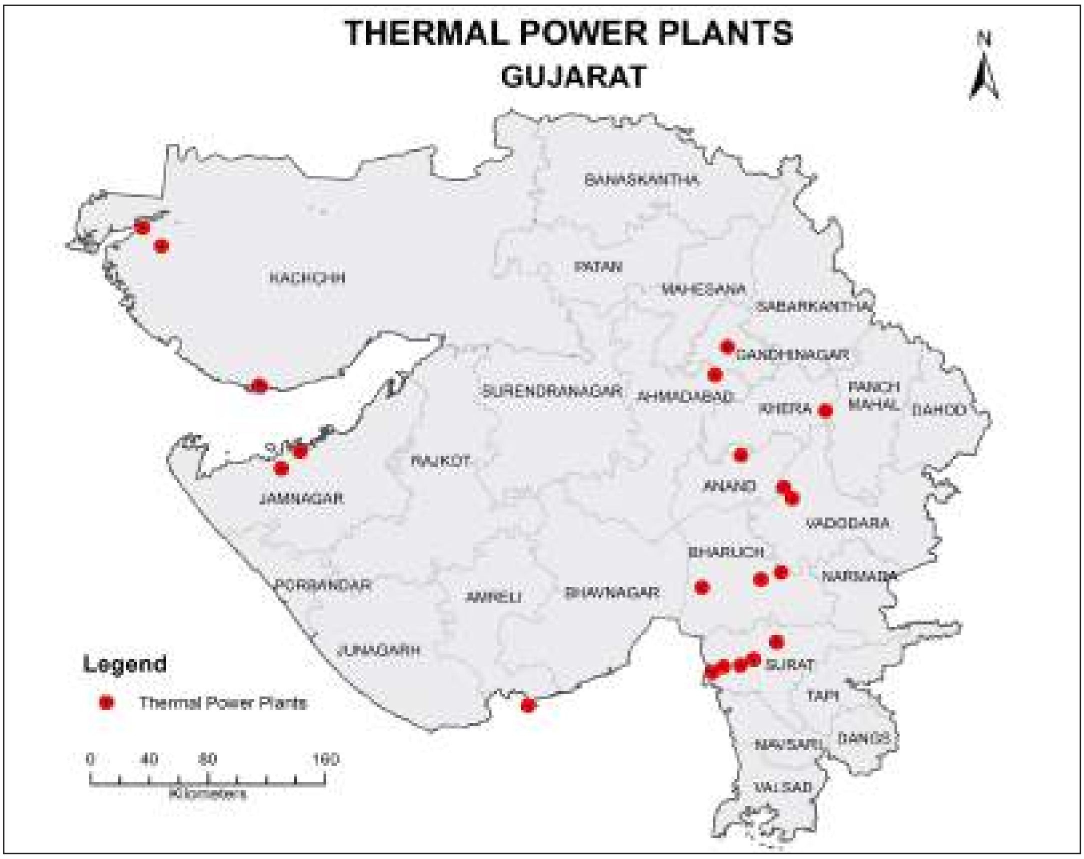
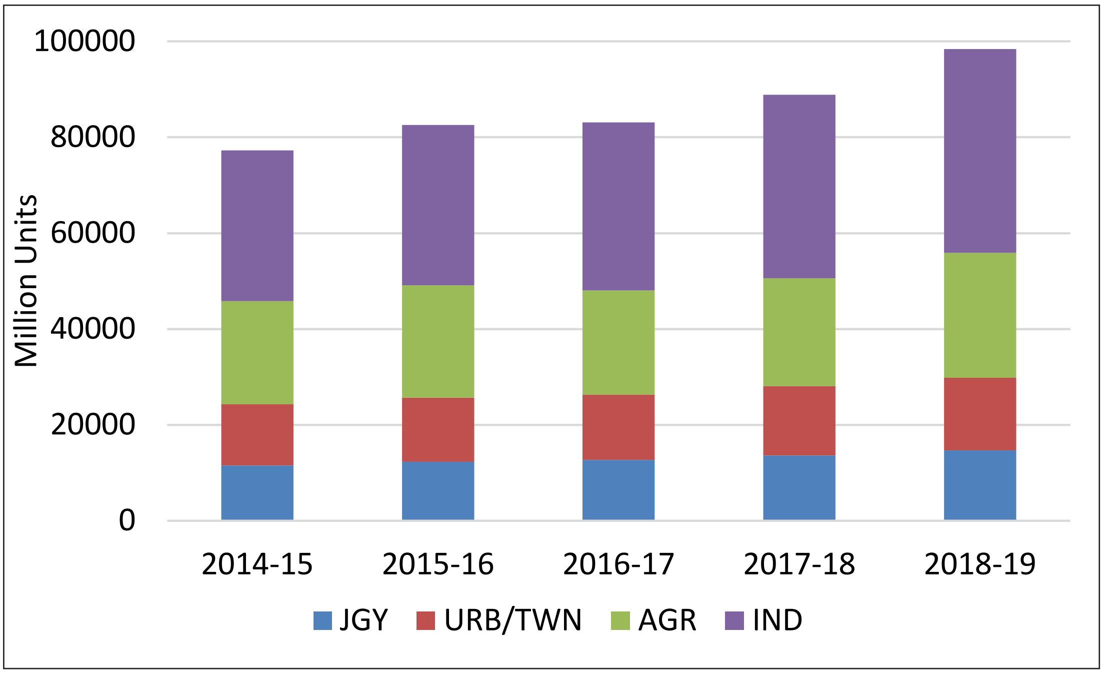


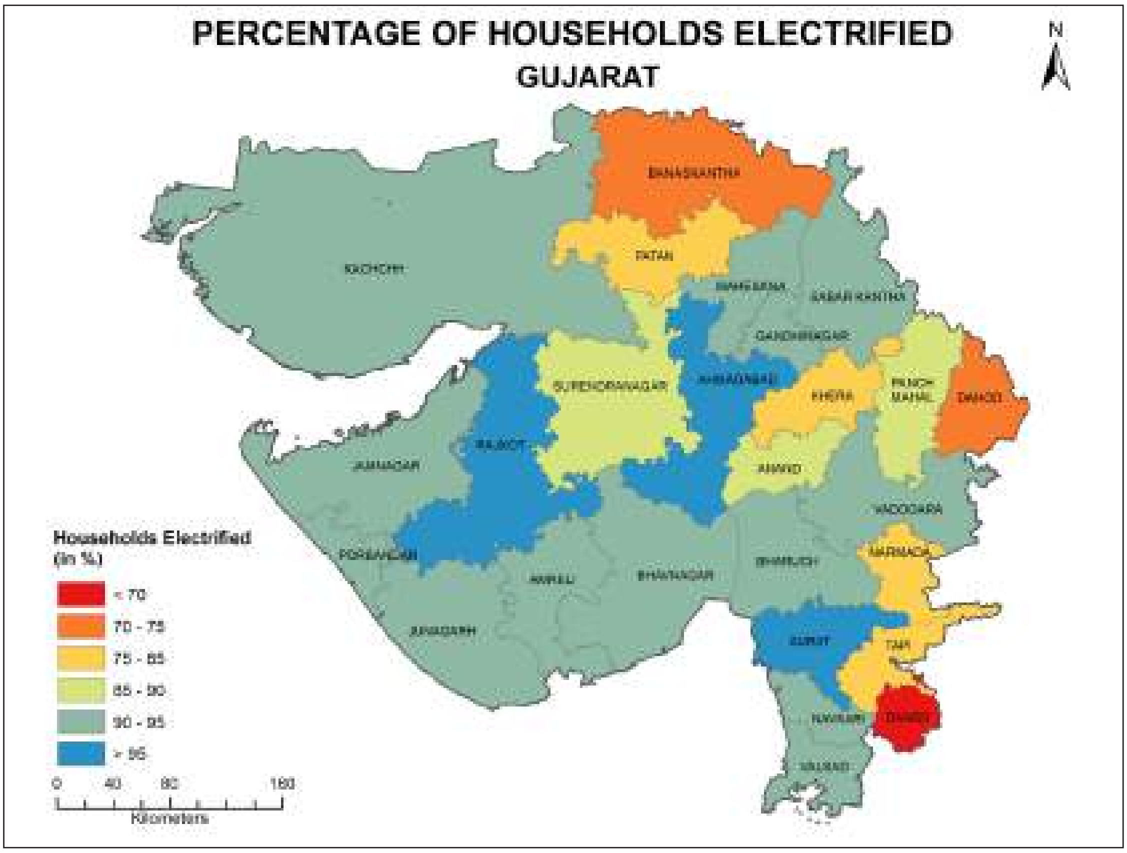
Figure 2.18 shows the sector-wise electricity supply in Gujarat. Industries take up the largest amount of electricity followed by agriculture and urban. While Figure 2.19 shows the per centage of households in the state with access to electricity.

Figure 2.18: Sector-wise electricity Supply in Gujarat (2014-15 to 2018-19)



Source: GSEB

Figure 2.19: **Percentage Households Electrified in Gujarat**



Source: GUVNL

2.7 State development issues and priorities

2.7.1 Sustainable Development Goals (SDGs) and Gujarat's efforts

State governments are a key to India's progress on the SDG agenda which, inter alia, incorporates goals of clean water and sanitation, affordable and clean energy, sustainable cities & communities, responsible consumption and production, climate action, life below water and life on land. Few states have taken concrete steps towards integrating the human development concerns into the planning process and Gujarat is one of them. The Gujarat state government has been working with NITI Aayog – the co-ordinating body for SDG implementation for Government of India, to prepare a roadmap and a Vision document for the state for 2030. The state has mapped all the schemes and programmes including Centrally Sponsored Schemes (~ 700 nos.) to align them to the SDGs. The state has clubbed the 17 SDGs into 7 themes rather than undertaking a sectoral approach. A working group for each theme has been created comprising of representatives from the relevant state departments. These themes are:

- Theme-1: Ending Poverty, including food security through Sustainable Consumption and Production (Goals-1, 2, and 12)
- Theme-2: Healthcare, improved water and sanitation (Goals- 3 and 6)
- Theme-3: Ensuring education for all (Goal- 4)
- Theme-4: Sustainable development of urbanization including modern energy, economic growth through employment, resilient industrialization, and sustainable city (Goals- 7, 8, 9, and 11)
- Theme-5: Issues of inequality (Goals- 5 and 10)

- Theme-6: Action against climate change, sustainable use of oceans and ecosystem (Goals-13, 14, and 15)
- Theme-7: Technology facilitating trade, innovative mechanism and institutional strengthening concerned goals e, sustainable use of oceans and ecosystem

The state is also linking the budgetary provisions to the development outcomes designed in the Vision 2030. The progress on SDG process included the following actions taken:

- State Level Management Information System (MIS) Dashboard
- Integration of state outcome budget with the goals
- District level SDG vision documents initiated
- State SDGs Composite Index with NITI Aayog priority indicators
- Documentation of Best Practices on effective implementation schemes by districts
- Making films on SDG in local language

The NITI Aayog SDG India Index suggests that Gujarat is a front runner state in achieving 8 of the 17 goals namely Goals 3- Good Health and Well-being, Goal 6- Clean Water and Sanitation, Goal 7- Affordable and Clean Energy, Goal 8-Decent Work and Economic Growth, Goal 9- Industry, Innovation and Infrastructure, Goal 11- Sustainable Cities and Communities, Goal 15- Life on Land and Goal 16- Peace, Justice and Strong Institutions. The state ranks 1st cross India for its performance under Goal 9.

Theme 6 here is dedicated to climate action. The state has prioritized to focus on promoting renewable energy, clean fuel, and energy efficiency measures, reducing pollution from all possible sources, adapting to climate change, raising awareness and including climate change as part of education, promoting research on climate change, clean energy and technology, improved disaster management to save life and assets. This is reflected in its 5th rank in achieving Goal 13- Climate Action as per the Niti Aayog's SDG India Index Dashboard . In order to achieve these, the state government plans to rapidly implement the state action plan on climate change with due periodic updating. The second action is to reduce greenhouse gases through low carbon energy production, demand side management through use of energy efficient technologies and increased carbon sequestration. The state also has plans for capacity building and institutional strengthening.

2.7.2 Development Concerns and Priorities

Some of the concerns identified by the state in reference to the changing climate range across sectors. This section describes the major concerns within some of the crucial sectors.

2.7.2.1 Agriculture

Agriculture is a major sector that employs 50 per cent of the working population and contributes 18.3 per cent to the Gross State Domestic Product of Gujarat. Higher projected rainfall variations due to climate change threaten productivity, with 54 per cent of the cultivated land dependent on rain and more than 60% of the total land area lying in drought-prone zones (Bandyopadhyay et al., 2020). The agriculture sector is also threatened by a decline in the availability and quality of groundwater. Vulnerabilities are exacerbated in a scenario where 63 per cent of farmers are small/marginal and rely mostly on subsistence agriculture. The livestock and animal husbandry sector, with a population of 26.9 million livestock, could suffer productivity losses due to heat stress and grassland deterioration. Thus, the state aims towards - Doubling the farmers' income and increasing the food security of the country by enhancing the agricultural productivity through modern & sustainable agricultural practices

2.7.2.2 Coastal Areas

Gujarat has India's longest coastline at 1,663 km almost 22 per cent of India's coastline. Coastal regions of the state harbour some of the diverse and productive ecosystems and act as an active interface between land and water. The coastline is dotted with more than 41 ports and has a strong industrial presence. Almost 9.9 million people living in 40 coastal talukas (Census, 2011) and many of these areas are economically active zones. The economy of Gujarat, to a significant level is linked to the coastal region and coastal resources. This makes Gujarat vulnerable to the impacts of sea-level rise (Kulp and Strauss, 2019), cyclonic events, salinity ingress and shifts in fish breeding patterns, which may result in future migration and climate refugees (WMR, 2020). Sea level rise poses a threat to the coastal infrastructure as it can lead to inundations, flood and storm damages in form of cyclones, erosion, saltwater intrusion and wetland loss.

2.7.2.3 Health

Climatic conditions play an important role in the distribution, degree of endemicity and epidemicity of diseases in an area. Climate Change is expected to adversely impact human health by increasing the risk of exposure to vector, water and food-bourne diseases, aggravating malnutrition and increasing injuries and deaths from extreme rainfall events and thermal stresses. Climate Change can have both direct and indirect human health impacts. Indirect impacts arise from changes in temperature patterns, which may disturb natural ecosystems, change the ecology of infectious diseases, harm agriculture and fresh water supplies, exacerbate air pollution levels, and cause large-scale reorganization of plant and animal communities. However, the severity of climate change impact on health also depend largely on the socio-economic indicators e.g. poverty, food and nutritional intake; environmental pollution and healthcare system delivery. Gujarat's performance is better than all India aggregates in case of vital statistics.

2.7.2.4 Water

In Gujarat, water level could be declining in all the regions of the state. The water-level decline in the lower alluvial sub-aquifer in the past decades was to the extent of 40-60 meters, which indicates that this sub-aquifer may be over-drafted. Almost 50 per cent of the state falls under water stressed area and more 20 talukas have medium to low ground water levels (WBCSD, 2019) than the state Climate change poses uncertainties to the supply and management of water resources. Changes in climate variables like temperature increase affect the water cycle by directly increasing evaporation of available surface water and vegetation transpiration. Scientific assessments also show the climate change will have a significant impact on Gujarat's fresh water resources.

2.7.2.5 Environment, Forest & Biodiversity

Gujarat has a total forest cover of over 14, 857 sq.km. with about 1177 sq.km. of mangrove forests. Climate is an important determinant of the geographical distribution, composition and productivity of forests, species populations and migration, the occurrence of pests and diseases and of forests regeneration. Climate change could have profound implications on traditional livelihood, industry, biodiversity, soil and water resources, and hence, agricultural productivity. Moreover, the climate change induced effects would aggravate the existing stresses due to non-climate factors such as land use changes and the unsustainable exploration of natural resources. These impacts on forests will have adverse socio-economic implications for the forest-dependent communities and the national economy. The impacts of climate change on forest ecosystems are likely to be long-term and irreversible.

2.7.2.6 Vulnerable Communities

Climate change impacts are seen more profoundly on the vulnerable communities in the rural areas who are not as well equipped to cope with the changes and the extreme weather events. These communities tend to have challenges around accessing safe drinking water and energy. With the changes in the temperature and rainfall patterns these communities are more vulnerable to the anticipated changes due to climate change. Gujarat has over 50 per cent of its population residing in the rural areas. Considering the diverse spread of the state, the climate vulnerabilities too change with the landscape across the state impacting the availability of water, access to fresh water, changes in the temperature and rainfall pattern along with sea level rise leading to inundation of coastal area. These changes are likely to impact the rural economy that is dependent on the ecosystem or agriculture.

Further, in order to bring in enhanced resilience to impacts of climate change, as a part of the Gujarat's Sustainable Vision 2030, the following points have been highlighted:

- Ensuring economic growth of the rural population and minimizing the below poverty line (BPL) population
- Reducing number of undernourished and anemic children and women
- Generating more livelihood opportunities for inclusive growth
- Strengthening eco-system for promoting skill development and entrepreneurship
- Social protection for poor and vulnerable population
- Enhancing mobility of poor
- Improved disaster management to save life and assets
- Providing food security to all
- Improving agricultural productivity
- Comprehensive life cycle approach for improving reproductive, maternal and child healthcare
- Training and capacity building of healthcare service providers
- Strengthening healthcare system inputs
- Reducing school dropouts
- Enhancing higher education to achieve excellence and equity
- Safeguarding birth of girl child
- Strengthening women cooperatives and SHGs
- Encouraging women participation in decision making and leadership
- Improved women participation in labor market
- Ensuring housing, drinking water and sanitation to all for improving quality of life
- Conservation of Mangrove forests

Many of these align with Gujarat's contribution to India's NDCs

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CHAPTER 3
CLIMATE PROFILE

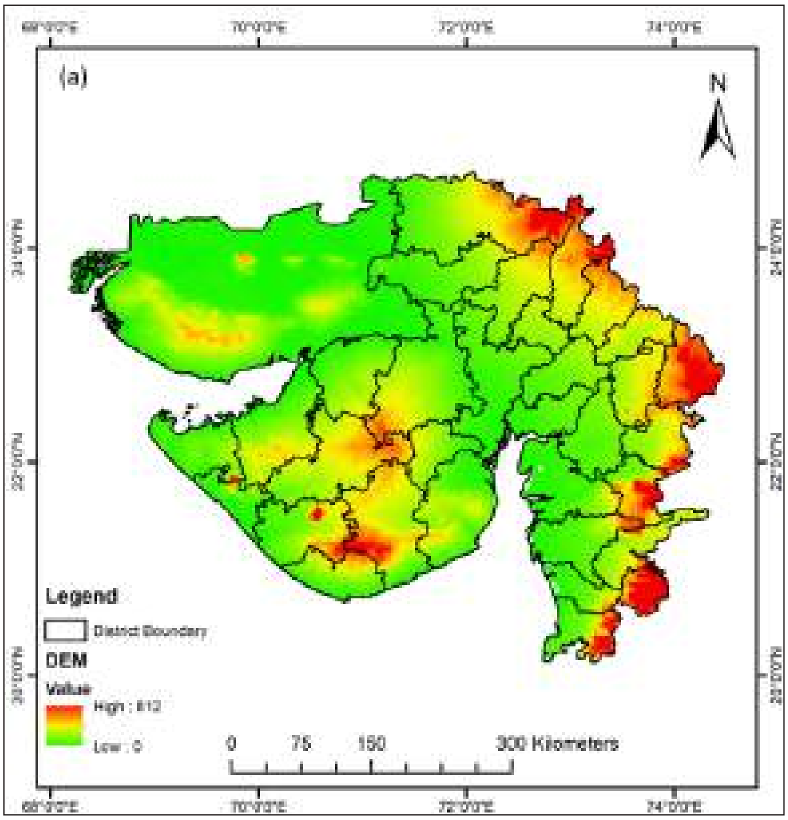
The coastal villages of Gujarat face the pressures on their fresh water supply and crop productivity due to salinity ingress.
Picture Courtesy: Darpak Joshi, GEER Foundation

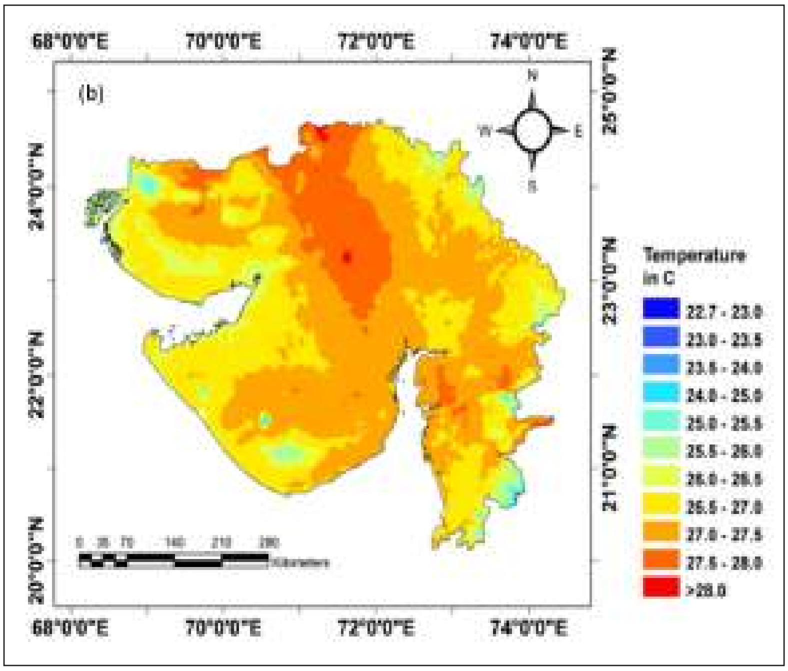
Climate Profile

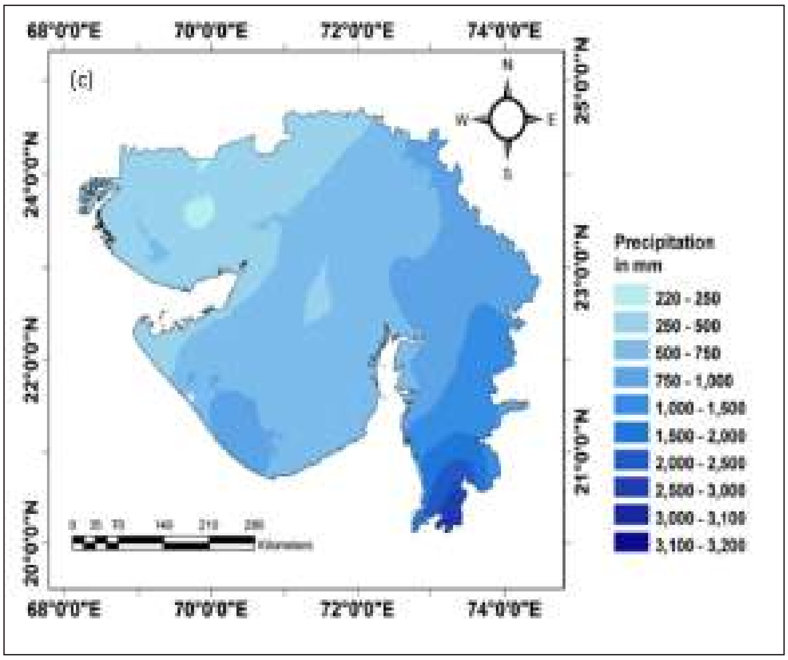
3.1 Climate profile and characteristics such as annual average temperature, rainfall, climatic variability and geographical features that influence climate

The study region (Figure 3.1) is located between longitude 68.75° E - 74.5° E and latitude 20° N - 25° N. Topography of the study region is shown in Figure 3.1 (a). The elevation of the State varies from 0 to 812 meters from the datum, with the highest elevations on the Aravalli regions rest of the regions share almost a flat terrain. State experiences semi-arid climate. Summers are extremely hot and dry with daytime temperature around 49° C and nights around 30° C. Winters are mild and dry with average daytime temperature around 29°C and nights around 12°C. Distribution of annual average temperature and rainfall are shown in Figure 3.1 (b) and (c) (Fick and Hijmans, 2017) respectively. Rainfall is unevenly distributed over the study region. Major rainfall activity occurs during the India summer monsoon months i.e. June, July, August and September (JJAS). Rainfall in Gujarat is governed by the southwest monsoon, which receives 90% of annual rainfall (Bhuiyan et al. 2017). Annual average rainfall 800-1000 mm.

Figure 3.1: (a) shows topography (m) of the state of Gujarat. (b) and (c) represents annual average temperature (°C) and precipitation (mm).

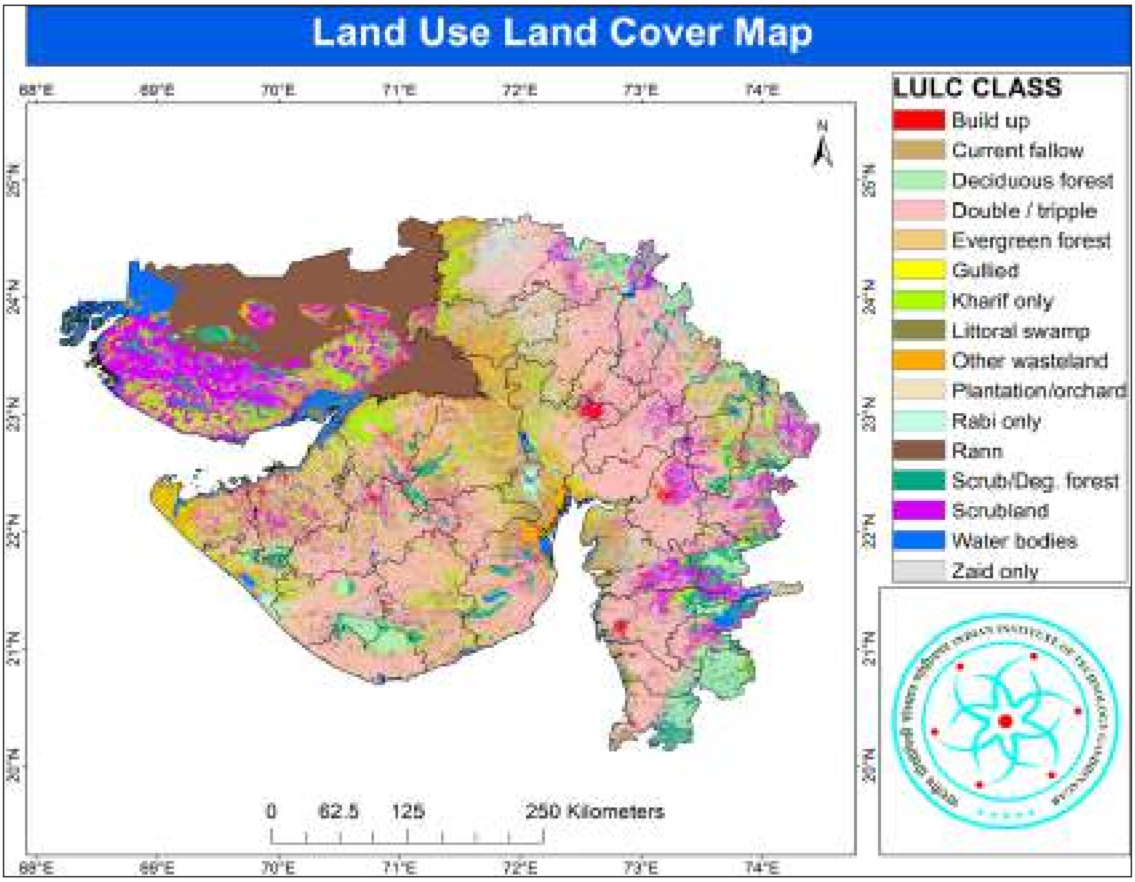






The Land Use and Land Cover map of Gujarat reveals the urban area is mostly confined to Ahmedabad, Vadodara, Surat and Rajkot. The Rann covers most of the Kuchchh district in the north-western side and the rest of the area is mostly covered by forest and agricultural land (Figure 3.2).

Figure 3.2: Land Use Land Cover Map of Gujarat



Hydro-meteorological hazards:

Precipitation and temperature were considered for identifying hydro-meteorological hazards. The hazards caused by these two said variables are categorized into two, precipitation based and temperature-based events. The precipitation-based events are droughts and extreme precipitation events, while temperature-based events are heatwaves, and hot and cold day/night events.

Droughts can be classified into meteorological, agricultural, hydrological, and socioeconomic droughts. Generally, droughts are observed in the scale of months (1, 3, or 5) or years (1 or 2), comparing the past reference period observations. In this study, the reference period is considered as 1970-2000 and used a 12-month scale (1 year). Standardized Precipitation Index (SPI) and Standardized Precipitation-Evapotranspiration Index (SPEI) are used to quantify droughts. Extreme Precipitation events deal with flood conditions of an area, which can also be indicated by above-said indices.

Heatwaves are extreme temperature events that persist over several days. We used the definition of Russo et al., (2015) to identify heatwaves in this study. In technical terms, heatwave may be defined as the event wherein the daily maximum temperatures (Tmax) are higher than the 90th percentile value of the daily maximum temperature of the hottest three months, and the temperatures remain higher than the threshold value for three days or more. This period of excess temperature is known as heatwave spell. In simpler terms, the heatwave is a period of prolonged hot weather.

Extreme hot-cold day/night events are those days/nights which experience rare hot or cold temperatures in the region during the observation period. The rarity of such events is defined by temperatures below or exceeding a threshold value (90th percentile). This threshold is defined based on the climatological mean of a reference period. In the case of hot days, daily maximum temperatures exceeding a threshold value (90th percentile), whereas for hot nights daily minimum temperatures exceeding a threshold value (90th percentile) is considered for identifying the events. In the case of cold days, daily maximum temperatures below a threshold value (10th percentile), whereas for cold nights, daily minimum temperatures below a threshold value (10th percentile) is considered. The threshold temperatures are not the same for the whole area; instead, it is determined on pixel-by-pixel order (or grid), that is, a day may be considered hot if the maximum temperature (Tmax) at a place (or pixel) is higher than the 90th percentile value of Tmax of the temperature distribution of that place (or pixel).

The same temperature may not be considered as hot at another place (or pixel), since the threshold temperature for that place may be higher or lower than that of the other place. The frequency of occurrence of the events exceeding a particular threshold is estimated to understand the changes in extreme temperature. Extreme precipitation events, droughts, heatwaves are results of climate anomalies, and they result in flooding, infrastructure damage, and crop failure.

3.2 Past and on-going climate trends including changes in temperature, precipitation, sea-level rise etc., specific impacts, climate risks, and socioeconomic consequences and costs of projected impacts

3.2.1 Datasets and Methodology

The different datasets and methodology used in this study is discussed briefly in this section.

3.2.1.1 Datasets

The study required observed datasets and climate model projections at high spatial resolution. The climatic variables required were precipitation and temperature (diurnal variation) on a daily scale.

Data obtained from the Indian Meteorological Department (IMD) is treated as observed datasets for the analysis. The data collected is in a gridded format with a 0.25 x 0.25-degree resolution. The data is available from 1951 to 2019 for both daily precipitation and temperature. The temperature data consist of maximum, mean, and minimum temperature for the chosen study period.

We used five models that participated in the Climate Model Intercomparison project (CMIP5) for future projections. The five models selected for the future projection are BNU-ESM, CESM1-CAM5, GFDL-ESM2M, MPI-ESM-LR, and NorESM1-M in gridded format with a resolution of 0.5x0.5 degree. The projected data period is from 1951 to 2100, with a reference dataset (historical period) from 1971 to 2000. This time duration is further divided as near term (2011-2040), mid-term (2041 – 2070) and far-term (2071 – 2100) future projections. The models were analyzed for the three Representative Concentration Pathways (RCPs), RCP 2.6, RCP 4.5, and RCP 8.5. These pathways are a means to represent alternative scenarios based on economy, scientific advancement, and mitigation efforts. RCP 8.5 considers the most pessimistic scenario for the future, while RCP 2.6 takes a comparatively optimistic future scenario. RCP 4.5 lies between the other two scenarios.

3.2.1.2 Methodology

To determine the hydro-meteorological variations in the State of Gujarat, some indicators such as SPEI and SPI were used. Historical analysis is done using the data from the Indian Meteorological Department (IMD), and for the future projections, multiple climate model projections were used. All spatial variations were determined by analyzing the data on a pixel-by-pixel basis, whereas state averages were calculated based on the spatial average of the associated attributes. In the purview of this study, precipitation and rainfall were used interchangeably. Seasonal analysis was conducted to analyze the seasonal variations in the meteorological variables. We selected four seasons based on the IMD classification vice winter (December - March), pre-monsoon (April - May), monsoon (June - September) and post-monsoon (October - November).

Observed period analysis

The observed period analysis is carried out from 1951 to 2019 using IMD (Indian Meteorological Department) data. The data comprises of daily precipitation and temperature, which are used for the respective analyses. The precipitation data was used to understand the temporal and spatial distribution of precipitation within the state and to estimate the precipitation extremes. The seasonal variation of the rainfall over the State is also analyzed. The 90th percentile of the rainy days has been used to calculate the extreme wet events. The rainy days are the days with rainfall greater than 1mm. The same datasets are also used estimate the trend in total precipitation during the period using Sen's slope and to understand the change in extreme events. The SPI and SPEI calculation are also carried out to understand the wet and dry spells and to identify the extent of drought and wet events. Temperature datasets were used to calculate the pattern of temperature variation. Temporal and spatial variation of daily Maximum, Minimum, and mean temperature and their changes using Sen's slope were considered separately. Spatial and temporal variation of the frequency of Hot days, Hot Nights, Cold days, and Cold nights were calculated along with their change. Temporal and Spatial variation of heatwaves occurred during 1951-2019 was as well estimated using the IMD observation datasets.

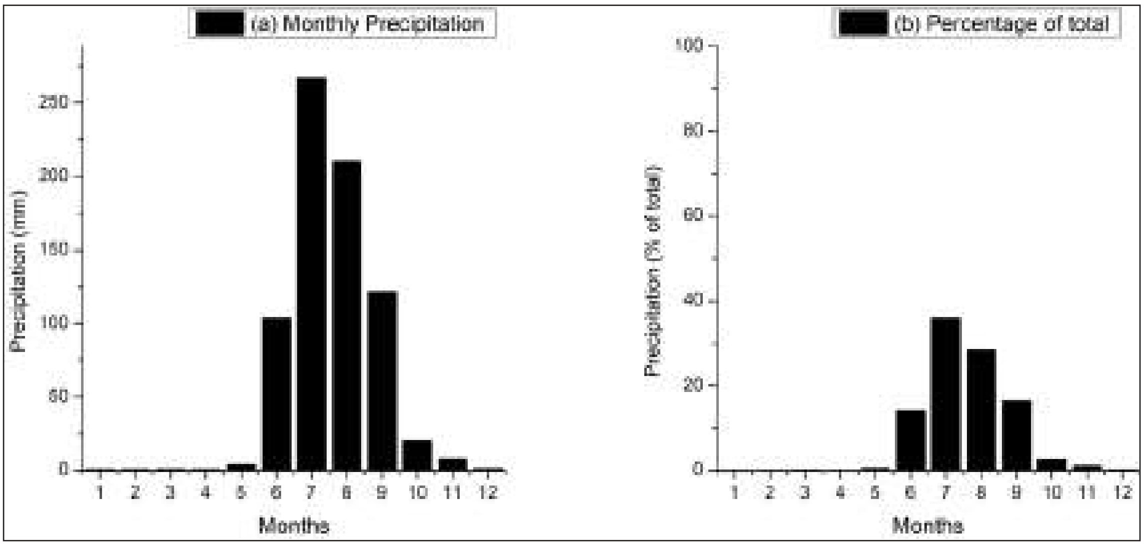
Projected period analysis

The future projections of meteorological hazards are carried out from 2011to 2100, using multi-model datasets of three different RCPs, namely RCP 2.6, RCP 4.5, and RCP 8.5. The climatic projections also simulate historic data from 1971-2000 which is used as a reference period to understand the future changes. The simulations of the future climate can be further classified into near-term (2011-2040), Midterm (2041-2070), and far-term (2071-2100) future projections. The datasets collected contain daily precipitation and temperature, which are used for the respective analyses. The daily projections of precipitation data have been used to understand the future spatial variation of precipitation in Gujarat. We used the 90th percentile of the rainy days as the threshold value to estimate the future extreme wet events. The SPI and SPEI calculation is also carried out to understand how the intensity, duration and spatial extent of wet and dry spells will change in the future. The temperature datasets were used to calculate the pattern of temperature variation for future projections. Temporal and spatial variation of mean annual daily maximum, minimum, and mean temperature and their changes against the reference period were considered separately. The spatial and temporal variation in the frequency of hot days, hot Nights, cold days, and cold nights were calculated along with their change against the reference period. The spatial variation of heatwaves that can occur during the time frame was also estimated.

3.2.2 Precipitation

The precipitation data for the period of 1951-2019 was analyzed for the Gujarat state to understand seasonal contribution towards the total annual precipitation received by the State. We confined the study to changes in precipitation and did not calculate the changes in streamflow response to precipitation changes.

Figure 3.3: Mean monthly average precipitation received from 1951 to 2019 and (b) percentage of total precipitation in each month for Gujarat state.

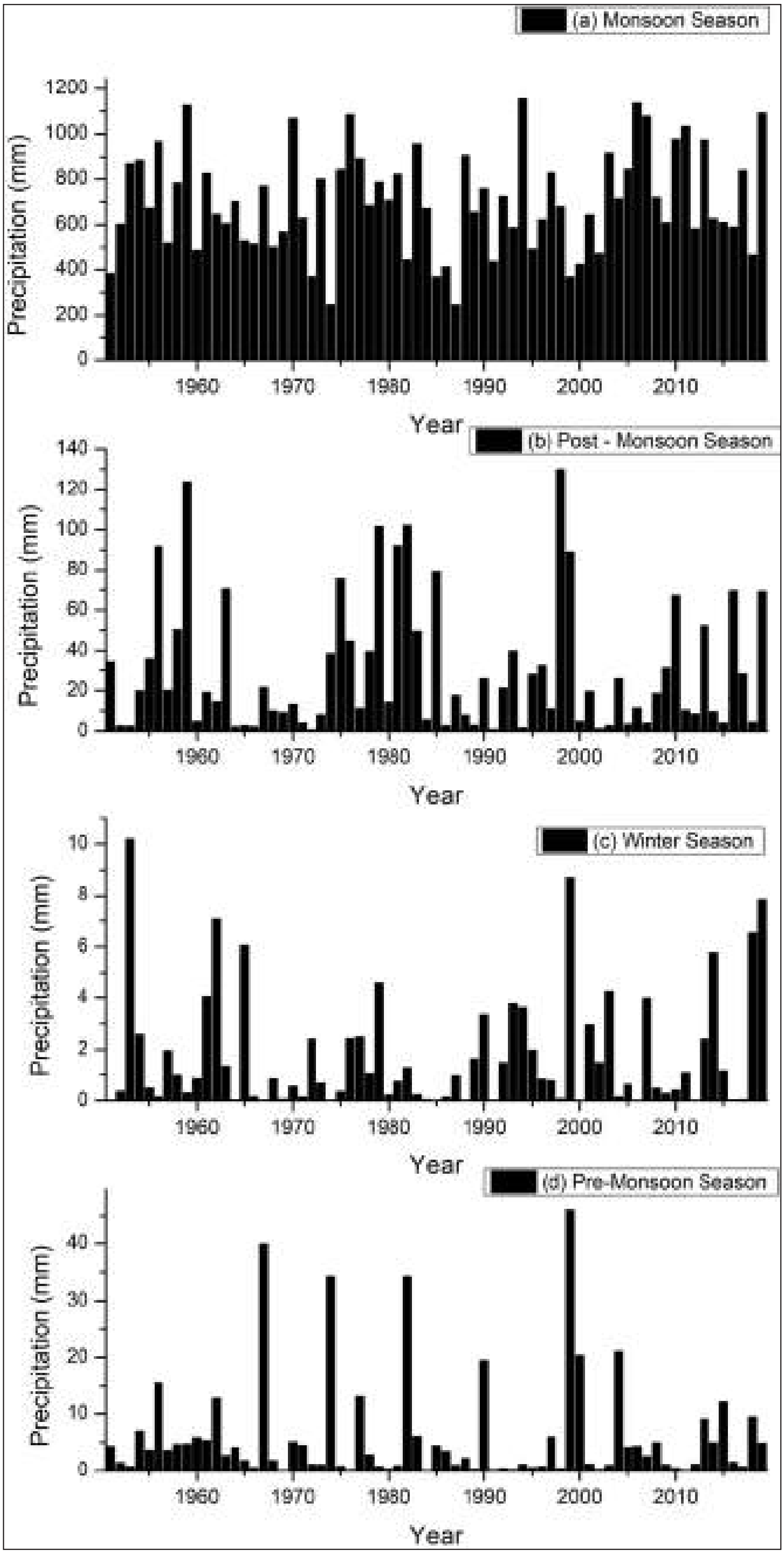


The long term temporal average precipitation indicates that most of the precipitation occurred in the monsoon season (June, July, August, and September) during the observation period. Figure 3.3 shows that the largest portion, around 700 mm, of annual spatial average rainfall occurs during June - September, which is 94 percentage of the total precipitation.

Temporal analysis of seasonal precipitation received in the state shows huge variability during the 1951-2019 period. The monsoon season precipitation received in this period varies from 300mm to 1000mm with a few years even crossing this range (Figure 3.4 (a)).

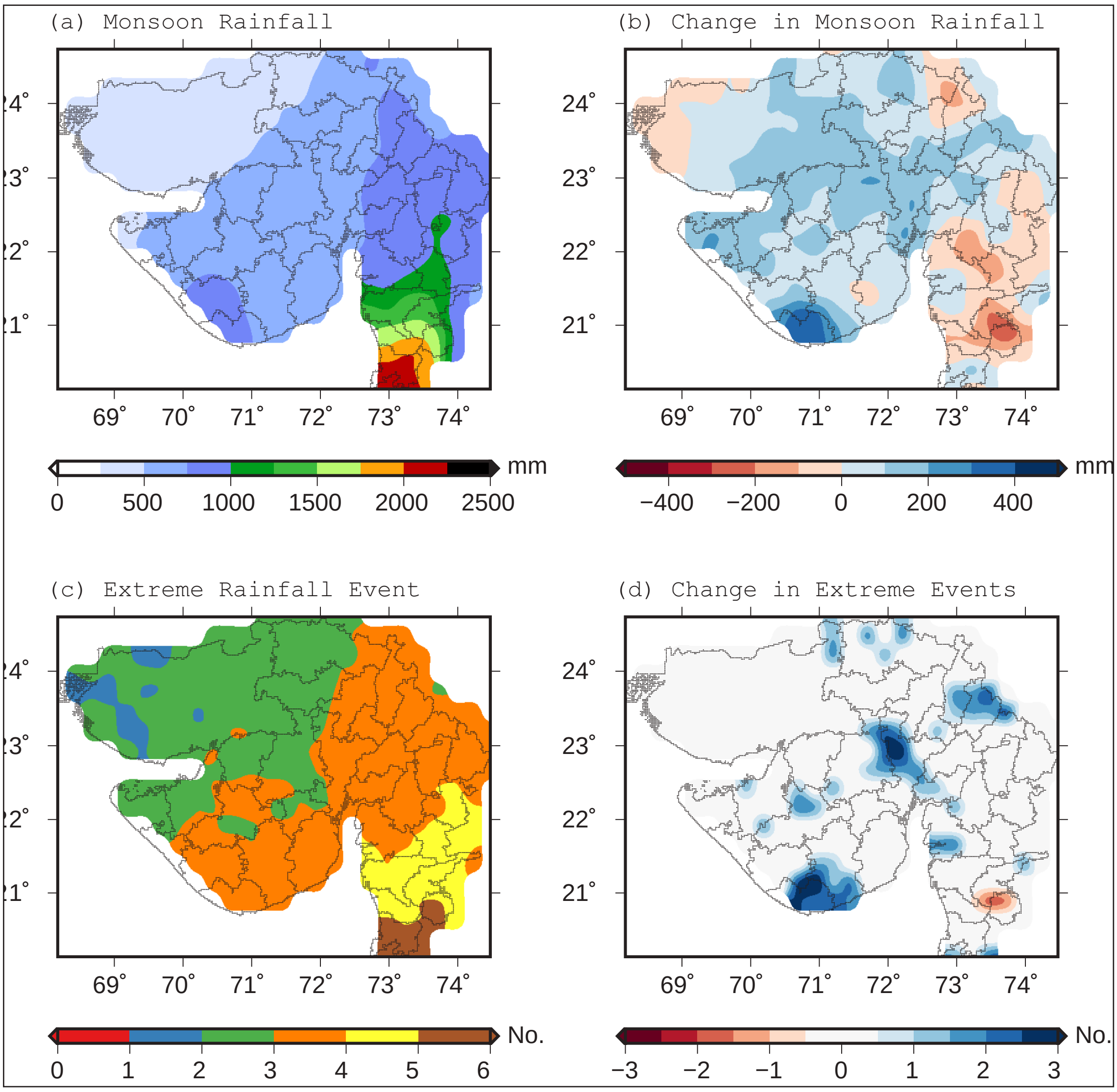
Nevertheless, we observed a few instants of non-monsoon season extremes during this period, wherein the precipitation amount exceeded the mean precipitation during that particular season. The state witnessed post-monsoon extremes in 1959 (124 mm), 1979 (101 mm), 1982 (102 mm) and 1998 (130mm) in the recent past (Figure 3.4 (b)).

Figure 3.4: State average precipitation for (a) monsoon, (b) post-monsoon, (c) winter, and (d) pre-monsoon season for the period of 1951 – 2019



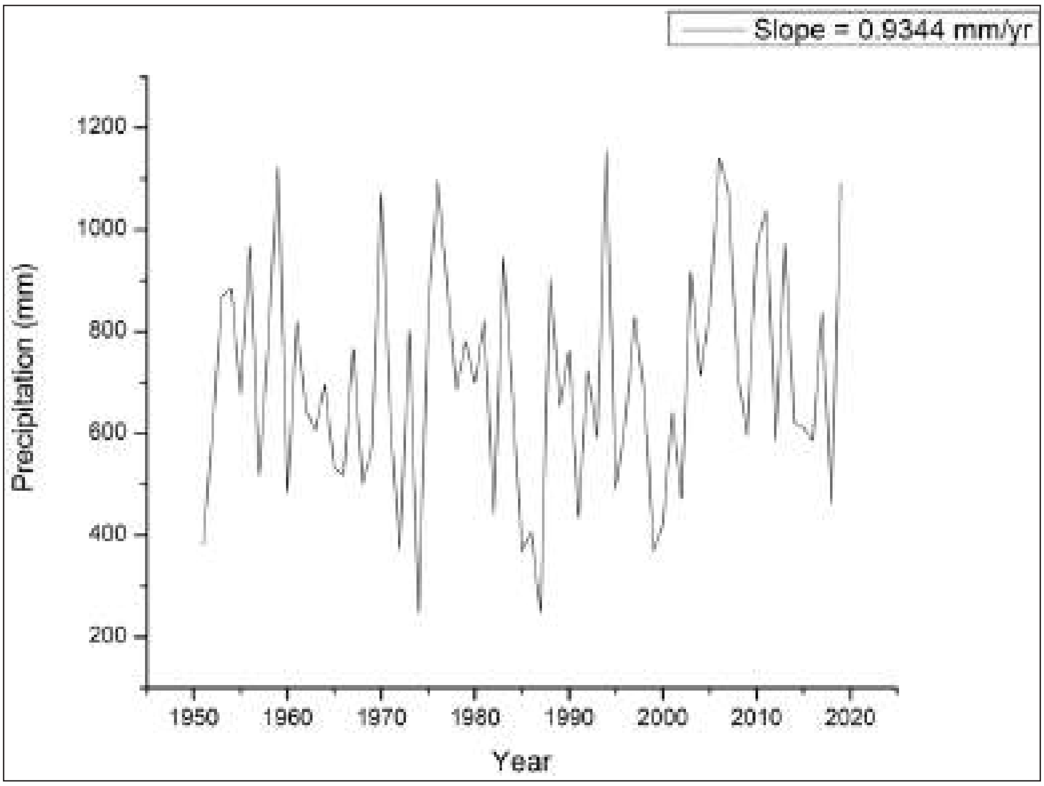
Winter season showers were usually very light rain but, in 1953, it reached closer to 10 mm and in recent years it as closer to 7mm (Figure 3.4 (c)). The pre-monsoon rainfall usually contributed within 20 mm, but in certain years exceeded this amount, such as in 1999 (46 mm) and 1967 (39 mm) (Figure 3.4 (d)).

Figure 3.5: (a) Observed mean monsoon season precipitation, (b) Change in monsoon season precipitation, (c) Observed number of extreme precipitation events and (d) Change in number of extreme events during the period of 1951 – 2019



The spatial analysis of the precipitation events and intensity reveals that similar to the temporal variability, the spatial distribution shows a wide variability across the state during the monsoon season. There were no distinct patterns of trends throughout the state except in the southern districts (Figure 3.5). The trends and changes calculated based on Sen's slope method show that southern districts Valsad, Navsari, and Dang received heavy monsoon season precipitation which is greater than 1800 mm (Figure 3.5 (a)). The districts of Gir Somnath, Devbhumi Dwarka, Surendranagar shows a considerable increase in precipitation in the period of 1951-2019 which amounts to increase of above 300 mm during the monsoon season (Figure 3.5 (b)). The frequency of extreme events which exceed the 90th percentile annual maximum precipitation during the reference period is in the range of 1 to 5 across the state. The districts of Valsad, Navsari, Dang, Tapi, Surat, and the Narmada received more than 4 such events during 1951 - 2019 (Figure 3.5 (c))

Figure 3.6: State averaged monsoon season precipitation and its trend for the period of 1951-2019



The changes in the frequency of such events increased considerably in the districts of Gir Somnath, Surendranagar, Ahmadabad, Sabar Kantha, and Aravalli during the period of 1951-2019. The rest of the portion of the State faced normal changes in the frequency of such extreme wet events, especially southern districts like Dang (Figure 3.5 (d)). These districts received increased precipitation levels as well as an increased number of extreme wet events (Figure 3.5 (b) and 3.5 (d)).

The State averaged annual precipitation gave us a general trend of change in monsoon season precipitation levels for the period of 1951-2019, which suggested a change of 0.934 mm per year (Figure 3.6). Except for a few monsoon seasons with high peak, the rest of the monsoon season precipitation seems steady, as indicated in Figure 3.4 (a).

Due to the wide spatial variability in the distribution of precipitation in the state, we need to be cautious when we make comments based on the state aggregated precipitation time series. Figure 3.5 suggests that the Southern part of the State (Valsad, Navsari, and Dang) receives heavy rainfall (greater than 1800 mm) compared to the rest of the state (Figure 3.5 (a)), and also receives relatively more number of extreme precipitation events (Figure 3.5 (c)). On the other hand, the districts like Girsomnath, Surendranagar which receives relatively low rainfall amount, show a considerable increase in the precipitation amount as well as the number of extreme precipitation events during this the observation period from 1951-2019 (Figure 3.5 and 3.5 (d)).

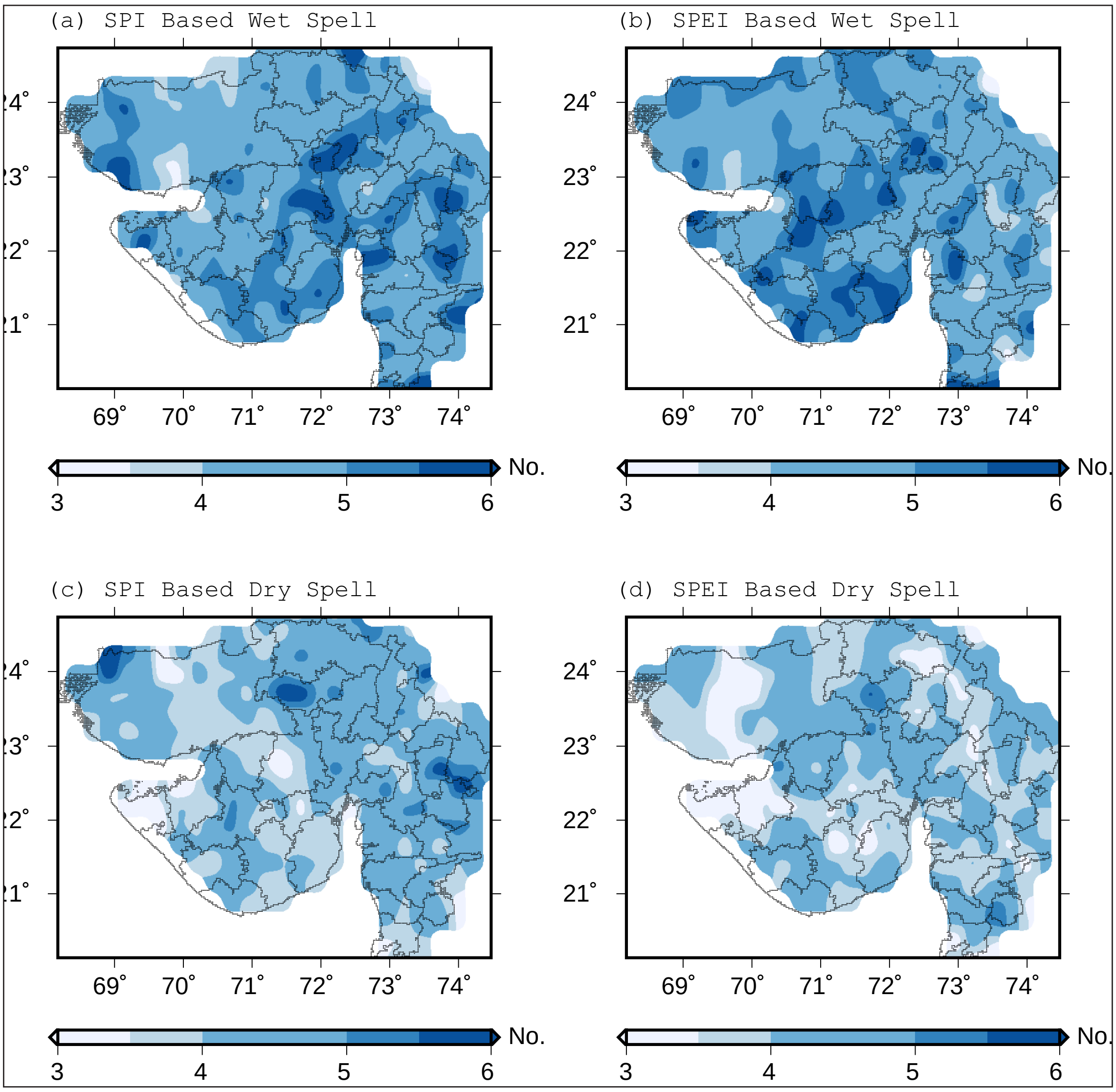
3.2.3 Extreme precipitation events: Drought and Wet periods

Estimation of extreme precipitation related events are significant in identifying vulnerable areas. In this study Standardised Precipitation Index (SPI) and Standardised Precipitation and Evapotranspiration Index (SPEI) were used to identify such events. The SPI/SPEI values less than 1.3 shows moderate to extreme drought events while such values greater than 1.3 shows moderate to extreme wet events. Since SPI does not take evapotranspiration factor into account, SPEI is also taken into consideration. SPEI incorporates changes in evapotranspiration, and it is also sensitive to the changes in temperature. The SPI/SPEI values considered here are the 12 months SPI/SPEI values. The base period for all calculations for SPI and SPEI is 1971-2000.

Figure 3.7 shows variations in the determination of drought spells and wet spells frequency, and their spatial variations throughout the State. The determination of drought and wet spells using SPI identifies lesser number of extreme events compared to the SPEI index. The SPEI based values show a higher frequency of such events in the period of 1951-2019. The districts such as Surendranagar, Ahmadabad, and parts of Amreli, Gir Somnath, Bhavnagar show a higher number of wet spells between 5-7, and the rest of the districts faced fewer number, 0-4, of such events, based on the SPI values (Figure 3.7 (a)). The SPEI values give a little different picture where all parts of Amreli, Gir Somnath, Bhavnagar, Surendranagar, Ahmadabad, Morbi, and Rajkot received 5-7 extreme wet events. The lowest number of extreme events were observed in the districts of Kachchh based on the SPI index whereas the SPEI index identifies some parts of Panchmahals, Dang, Surat and Dahod districts as the regions with lower number of extreme events (Figure 3.7 (b)).

The picture portrayed by SPI and SPEI values for the drought-affected part is significantly different (dry spells). Figure 3.7 (c) shows most of the district faced fewer droughts (especially the Northwestern side of Gujarat), and the rest of the state faced drought events in the range of 5-7 during the 1951-2019 period, based on SPI values. The SPEI based drought frequency figures show most of the drought-affected areas is in the districts of Surendranagar, Ahmedabad, and Patan. These districts faced around greater than five such drought events. The districts of Jamnagar and Devbhumi Dwaraka faced the lowest number of drought events (up to 3) in the same period (Figure 3.7 (d)).

Figure 3.7: **SPI based number of observed extreme (a) wet events and (c) dry events for the period of 1951 - 2019; SPEI based number of observed extreme (b) wet events and (d) dry events for the period of 1951 - 2019.**



3.2.4 Air Temperature

The daily maximum, mean, and minimum temperatures were considered for this study. The maximum temperature records the highest day temperature and the minimum temperature records the lowest night temperature. The mean temperature of the day is also included in the study.

The mean annual temperature in the state varies from 30 - 35 °C (max.), 23 - 29 °C (mean), and 16 - 22 °C (min.) (Figure 3.8 (a), 3.8 (c), and 3.8 (e)). The districts are Valsad, Navsari, Surat, Bharuch, Vadodara, and some parts of Tapi and Narmada that recorded temperature greater than 31°C experience the highest mean annual daily maximum temperature (Figure 3.8 (a)). The rest of the state experiences a mean annual daily maximum temperature less than 31°C. The minimum temperature in the districts of Banaskantha, Sabarkantha, Patan, Mehsana, and Aravalli varies in the range of 23 - 25 °C (Figure 3.8 (c) and 3.8 (e)).

We observed a positive trend (temperature rise by 1°C) in the mean annual daily maximum temperature in the majority of the regions in the state except for the southern districts that experience a negative trend. In the case of mean annual daily minimum and mean temperature, a slightly positive trend is observed in most of the state which amounts to a rise by 0.1 to 1.5°C (Figure3. 8 (b), 3.8 (d), and 3.8 (f)).

Figure 3.8: (a), (c) and (e) Observed annual mean of daily max, mean and min temperatures

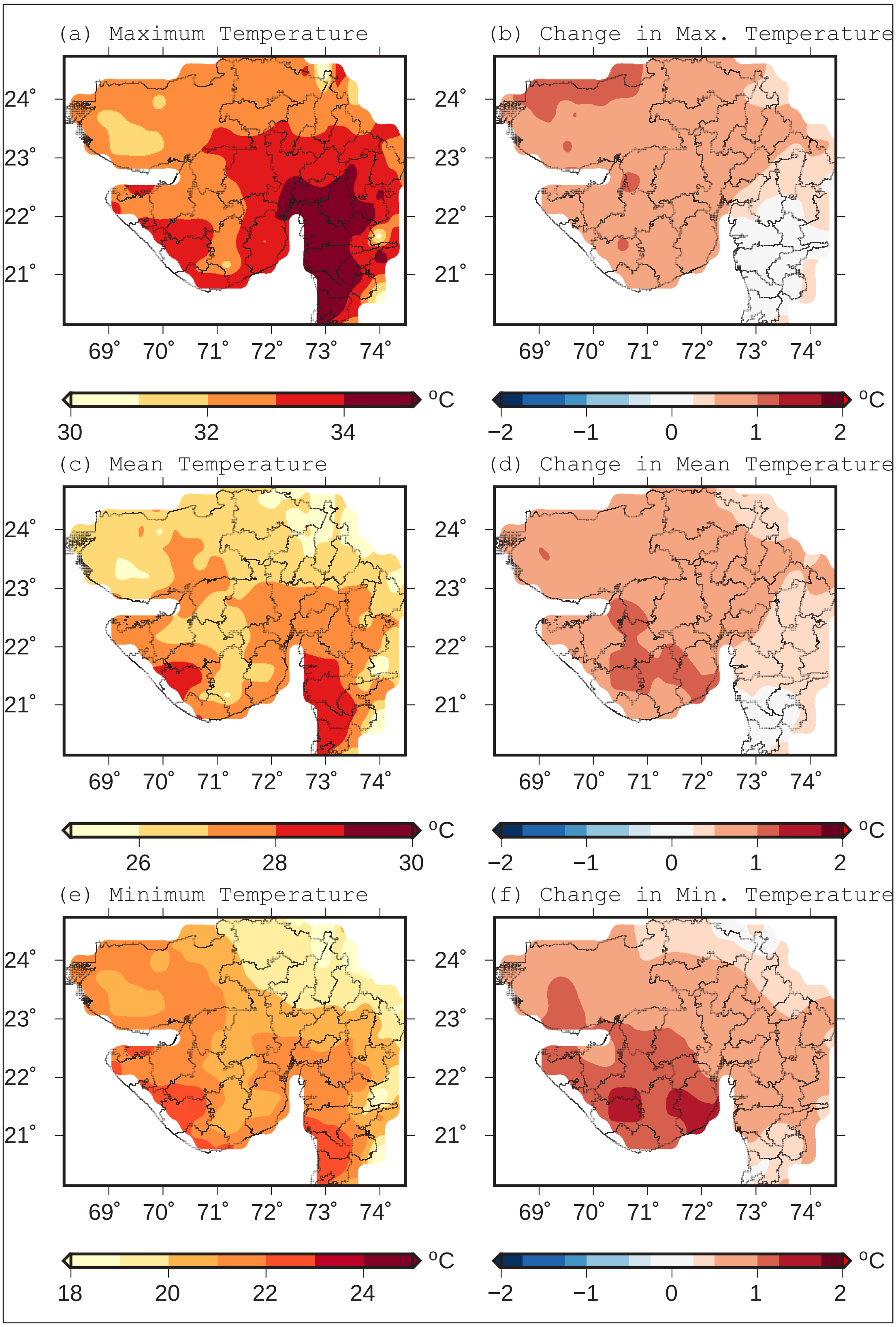
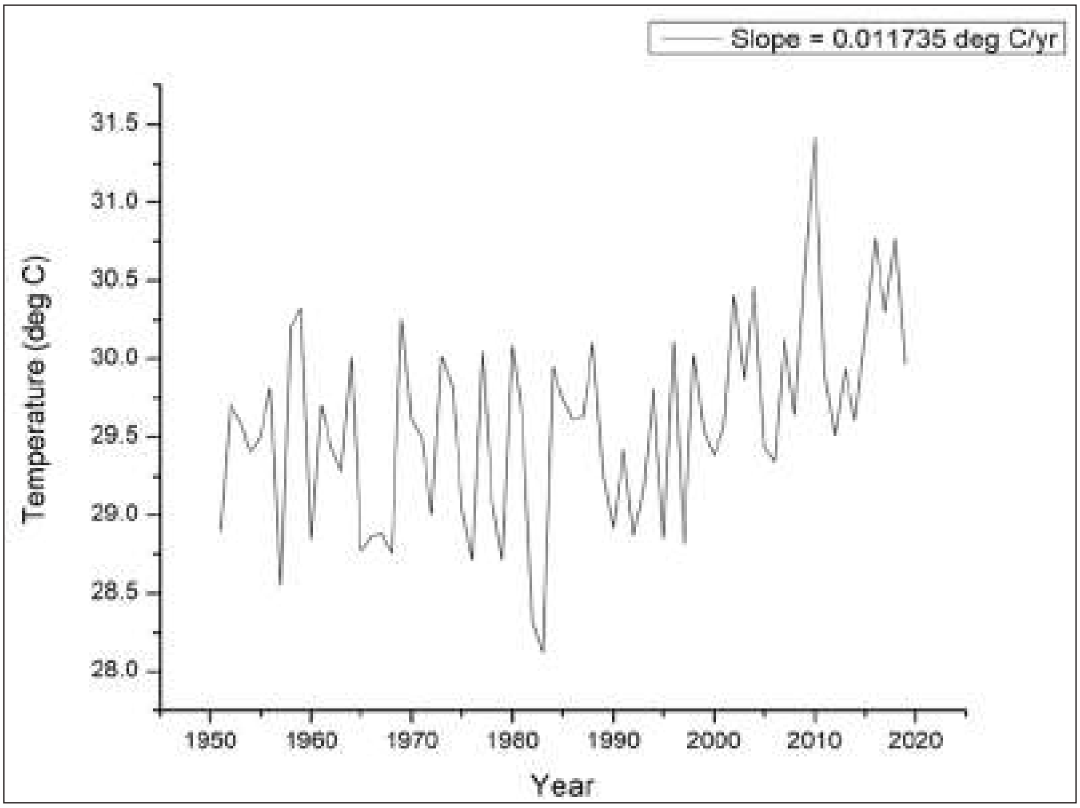


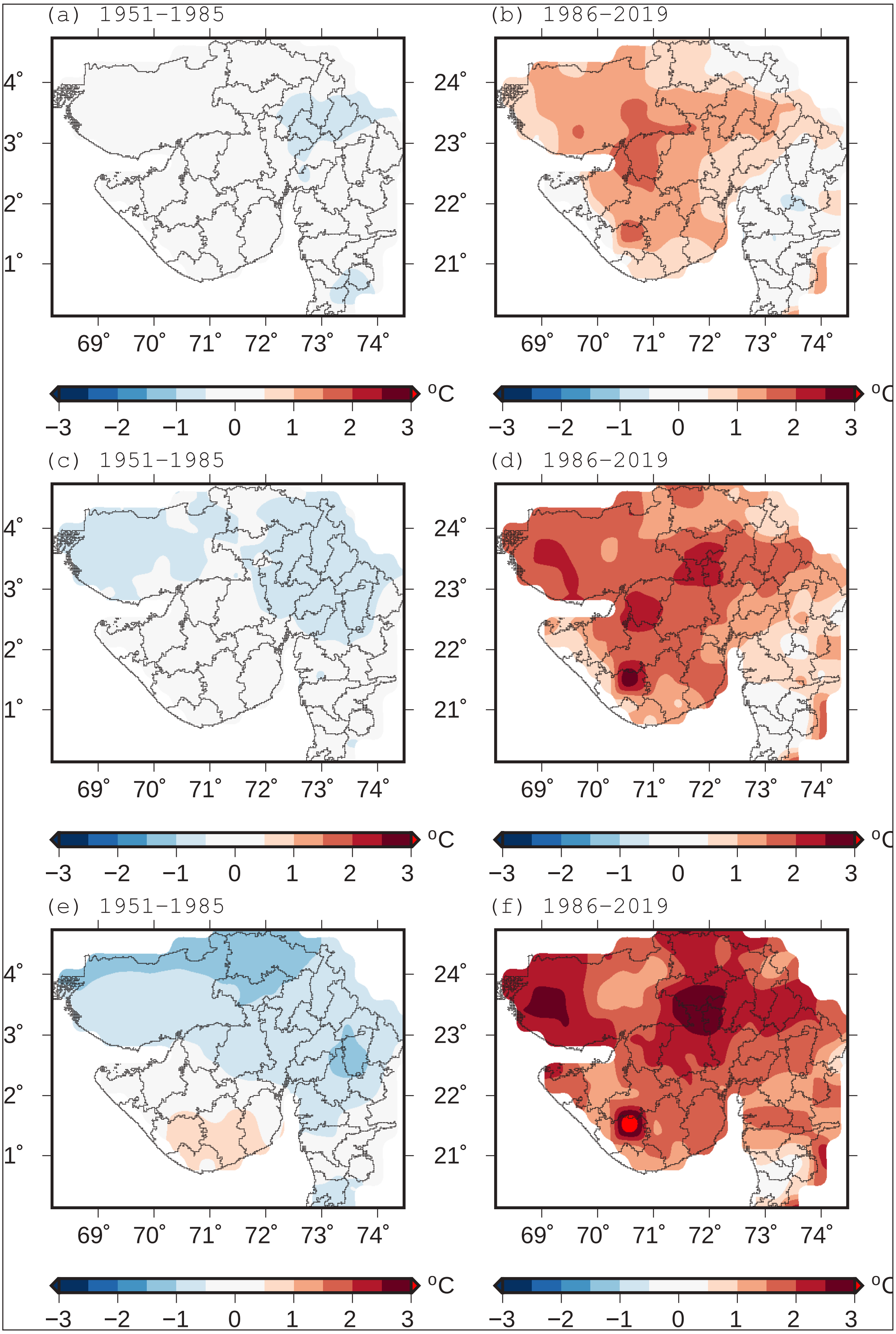
Figure 3.9: **State averaged annual mean summer temperature and its trend for the period of 1951 – 2019**



On closer inspection, the state averaged annual mean temperature suggests a change in trend centered in 1985. The overall average slope was negligible, but the contrasting feature is that the slope during 1985-2019 shows a considerable average positive rate in annual mean temperature, in 1985-2019, as compared to the overall mean slope for 1951-2019 (Figure 3.9). This significant increase in temperature during this short period (1985-2019), could be attributed to anthropogenic emissions.

To investigate further, separate analyses for the periods in question were considered (Figure 3.10). Changes in maximum, mean, and minimum temperature is analyzed based on Sen's slope values obtained on a pixel-wise basis. There are different change patterns in the two-time intervals, which are 1951-1985 and 1986 - 2019. The former time period shows mostly negative changes, -0.6 to 0.4 °C, -0.7 to 0.4 °C and -1.2 to 0.7 °C across the districts for maximum, minimum, and mean temperature changes in the region, respectively. The latter time period shows a completely different picture. The daily maximum, minimum and mean temperature changed in the range of -0.5 to 1.8 °C, -0.2 to 2.5°C and 0.2 – 2.9 °C, respectively across the state from 1986-2019.

Figure 3.10: **Observed change in max, mean, and min temperature**



3.2.5 Extreme temperature events: Hot and Cold days/nights and Heat-waves

The temporal analysis of area averaged annual mean temperatures shows high variability in the frequencies of hot days, hot nights, cold days, and cold nights in the state. Gujarat faced an exceptional number of hot days in the years 1980 (55), 1998 (53), 2002 (52), 2009 (53), 2010 (75), 2015 (64), 2017 (53), 2018 (71) and 2019 (55) (Figure 3.11 (a)).The number of exceptional hot nights was observed in 1958 (51), 1987 (67), 1988 (51), 1995 (53), 2002 (55), 2007 (53), 2009 (51), 2010 (60), 2014 (58), 2015 (59), 2016 (62), 2018 (60) and 2019 (62) (Figure 3.11 (b)). The exceptional cold days were in the years 1968 (52), 1973 (53), 1979 (60), 1981 (53), 1983 (51), 1984 (58), 1997 (64), 2005 (56), and 2014 (51) (Figure 3.11 (c)).The exceptional cold nights occurred in the years of 1951 (56), 1956 (51), 1964 (51), 1970 (61), 1971 (63), 1972 (54), 1974 (53), 1975 (66), 1983 (52), 1984 (63) and 2005 (59) (Figure 3.11 (d)).

The State faced mostly positive changes in the frequency of hot days, and it was in the ranges of 36 - 37 days per year, 0.01 – 30.6 days per year, respectively. It's observed that the number of hot days is higher for the Kachchh area, and the change is more for Kachchh, Jamnagar, Rajkot, Amreli, Gir Somnath, Junagadh, Porbandar, Devbhumi Dwaraka, Morbi and Bhavnagar (Figure 3.12 (a)). The frequency of the number of hot nights varied between the ranges of 36.4 - 36.9 days per year. Change in frequency of hot nights seems to be varying from 2.3 – 33.4 and the highest increase is found in some parts of Amreli, Bhavnagar, Junagadh, and Rajkot (Figure 3.12 (b)).

When we consider the frequencies of cold days and nights, the picture seems different. The number of cold days in the region varied considerably. Since the threshold for considering a day or night as cold or hot is determined on a pixel basis, so the number of such days and nights depends on the long-term temperature distribution of that pixel. The frequency of the number of cold days varied between the ranges of 36.4 - 36.7 days per year, and its change in frequency of cold days seem to be varying from -11.7-11.4. South-eastern districts, such as Valsad, Navsari, Dang, Surat, Tapi, Narmada, Bharuch, Vadodara, and some parts of Chhota udepur, Panchmahals and Dahod experienced a higher number of cold days. Though the change in frequency of cold days was high, there was a general negative change in frequency throughout the region, especially in Northwestern Gujarat (Figure 3.13 (a)).

Figure 3.11: State averaged frequencies of (a) hot days, (b) hot nights, (c) cold days, and (d) cold nights.

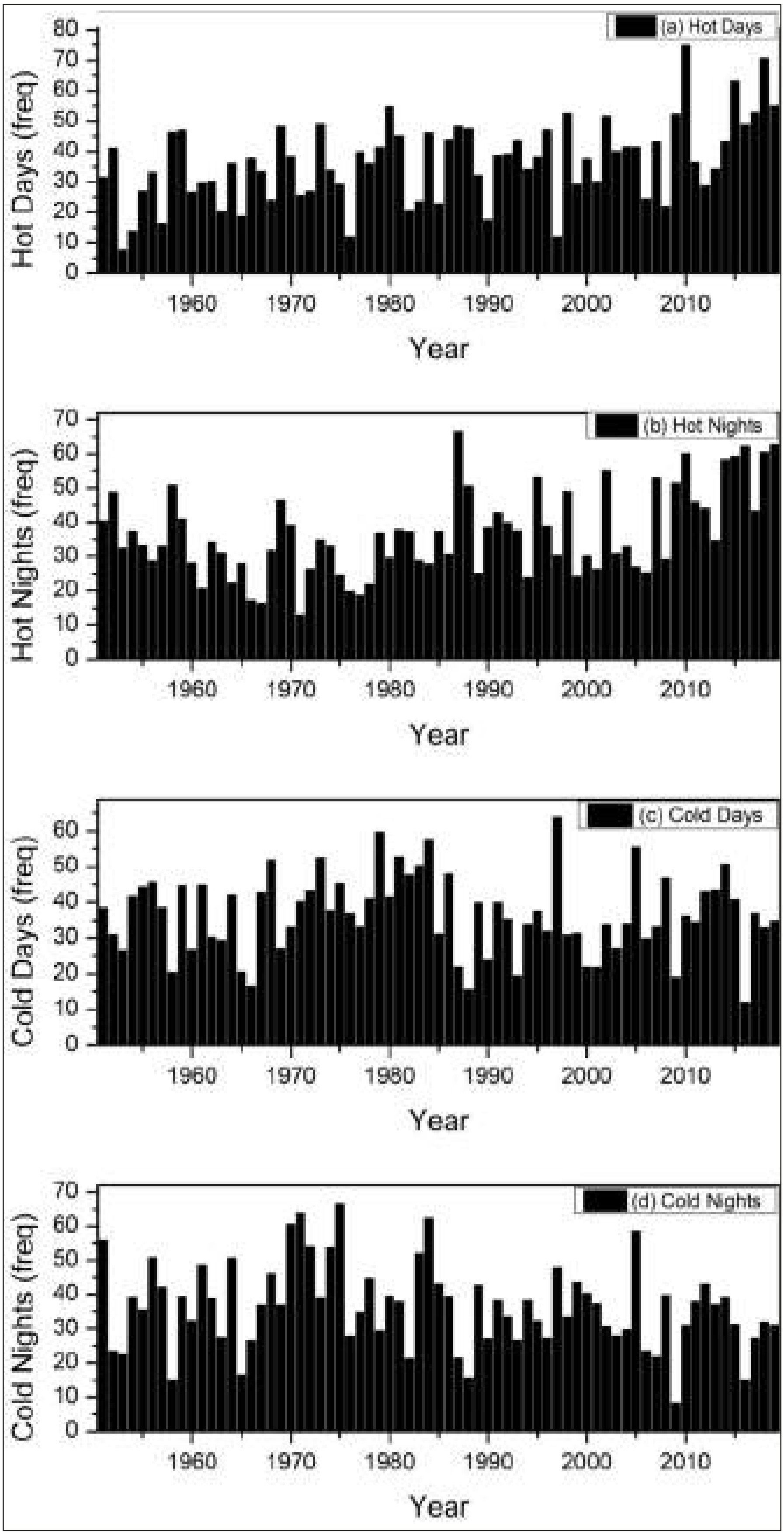
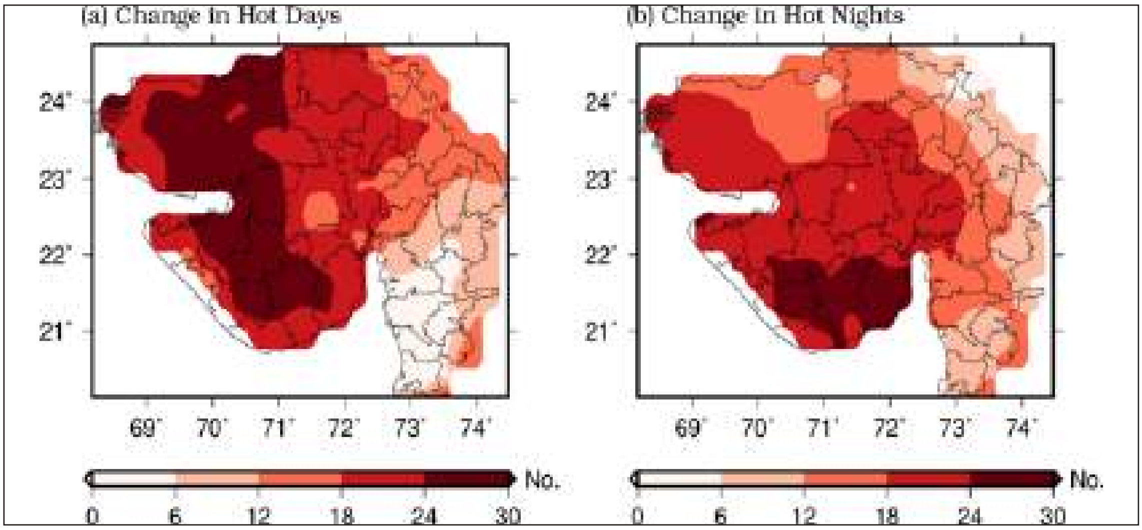


Figure 3.12: **Annual average frequency of (a) change in the number of hot days, and (b) change in the number of hot nights for the period of 1951 – 2019.**



The frequency of the number of cold nights in Gujarat is within the range of 36.4 - 36.7, and change in the number of cold nights are between -21.8-4. The changes in the number of cold nights in the state are comparatively less. However, an increase in the frequency of cold nights are expressed by Banaskantha, Sabarkantha, Patan and Mehsana compared to other districts (Figure 3.13 (b)).

Figure 3.13: **The annual average frequency of (a) change in cold days and (b) change in cold nights for the period of 1951 – 2019**

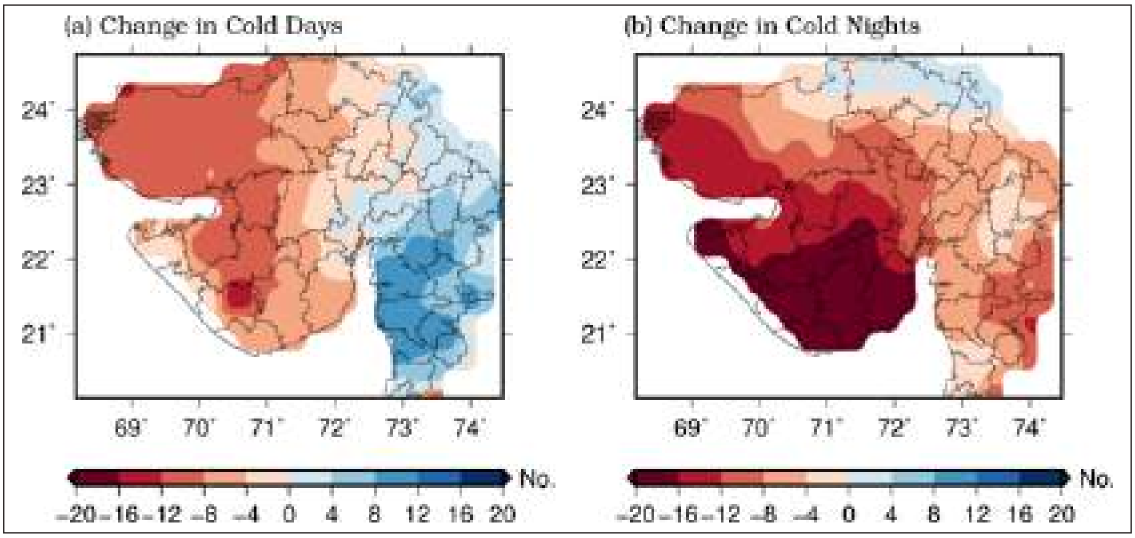
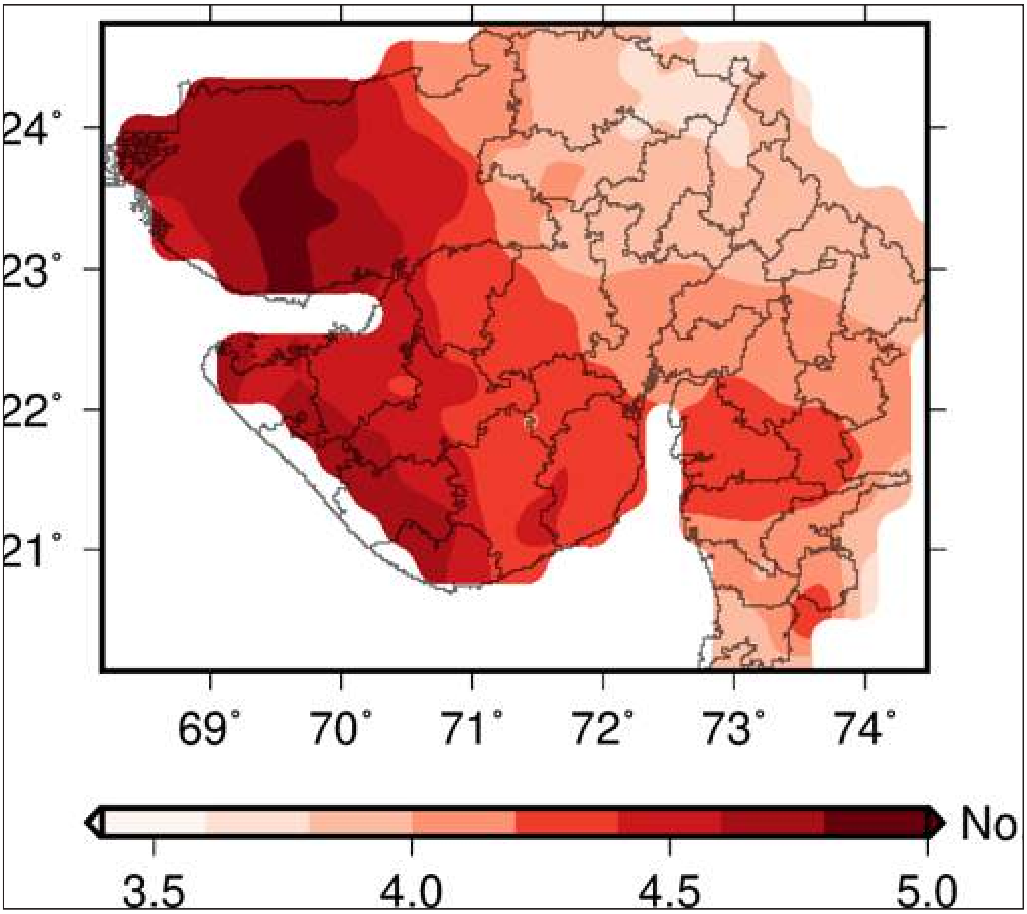


Figure 3.14: **(a) Spatial variations of heatwaves per year for the period of 1951-2019**



(b) State averaged frequency of heatwaves per year from 1951 to 2019

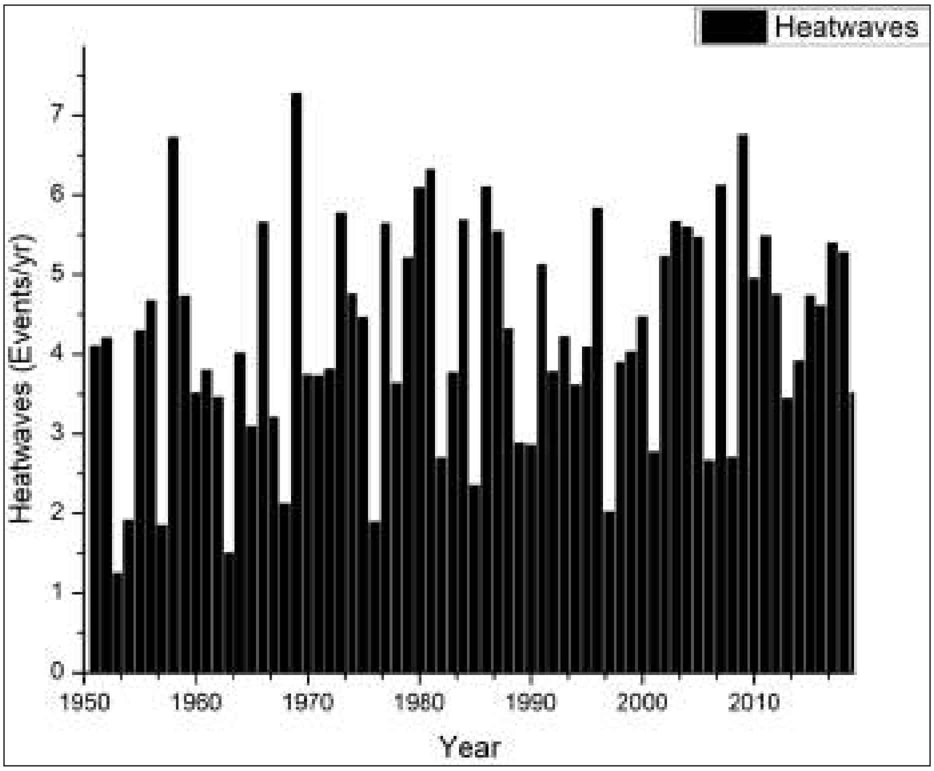


Figure 3.14 (a) shows the spatial variations of average frequencies of occurrence of heatwaves. On average, Gujarat faced 3.7 – 4.8 heatwaves per year, considering the period 1951-2019. Kuchchh, Devbhumi Dwaraka, Porbandar, Junagadh, and Gir Somnath faced a higher number (above four heatwaves) of these events. Banaskantha, Sabarkantha, Aravalli, Mahisagar, Dahod, Patan, Mahesana, Gandhinagar, Kheda, and Panchmahals faced the lowest heatwave in this period. Here, if the yearly average of occurrence is considered, then years 1958 (6.7), 1969 (7.2), 1980 (6), 1981 (6.3), 1986 (6), 2007 (6.1), 2009 (6.7) (Figure 3.14 (b)).

3.3 Development of climate change scenarios, i.e. projection of possible climate changes at relevant spatial and temporal scales

3.3.1 Precipitation

Projections of precipitation were observed for spatial variations throughout Gujarat for near-term (2011-2040), mid-term (2041-2070) and far-term (2071-2100) for RCPs 2.6, RCP 4.5, and RCP 8.5.

The RCP 2.6 emission pathway projects moderate change in precipitation in the range of -28 to 24 mm in the near term, -90 to 0.73 mm in mid-term and 14 to 73 mm in the far-term as compared to the historic reference base period of 1971-2000. In this scenario, most of the parts of Gujarat are showing an increase in precipitation, especially from the mid future. (Figure 3.15, RCP 2.6).

The RCP 4.5 projection indicates change with ranges from -38 to 41 in the near-term, -16 to 36 mm in the mid-term and -1.3 to 178 mm in the far future. In this scenario, decrease in precipitation is predominant in the near and mid future but in the far future, precipitation increases drastically across the state (Figure 3.15, RCP 4.5).

The RCP 8.5 shows even higher values in the ranges 2 to 53 mm for near-term, -4.7 to 102 mm for mid-term projections and -4.2 to 90 mm for far-term future projections (Figure 3.15, RCP 8.5). All the scenarios suggested an overall increase in the precipitation amount concentrated mostly along the southern parts of the state as compared to the northern parts.

Figure 3.16 shows the number of exceptional precipitation events that are determined by the frequency of the precipitation events, greater than the 90th percentile values of rainy day precipitation. It shows a consistent trend in all the near, mid, and far future term projections. The mid and far projections are indicating a net positive trend of wet events, but in the near-term projections, near neutral to small positive changes were observed in all RCP 2.6, RCP 4.5, and RCP 8.5 scenarios. Relatively, north-western parts of the State (Kachchh) are facing higher changes in most scenarios of projections when compared to the other parts of the state in all the three RCP scenarios.

In the RCP 2.6 scenario the frequency of wet events in the near-term change between -0.4 to 0.6, for mid future it changes from -0.9 to 0.5, and for the far future, it was 0 to 0.9. Whereas in the RCP 4.5 scenario near term, change was -0.9 to 0.7, for mid future -0.4 to 0.9, and for the far future, it was 0.3 to 1. In the RCP 8.5 scenario near term, change was -0.7 to 0.6, for Midterm -0.3 to 0.8, and for the far-term future, it was -0.3 to 1 (Figure 3.16).

Figure 3.15: **Multi-model ensemble mean projected changes (mm) in monsoon season precipitation for the Near, Mid and Far term temporal range. Changes were estimated against the historical mean for the reference period (1971 - 2000)**

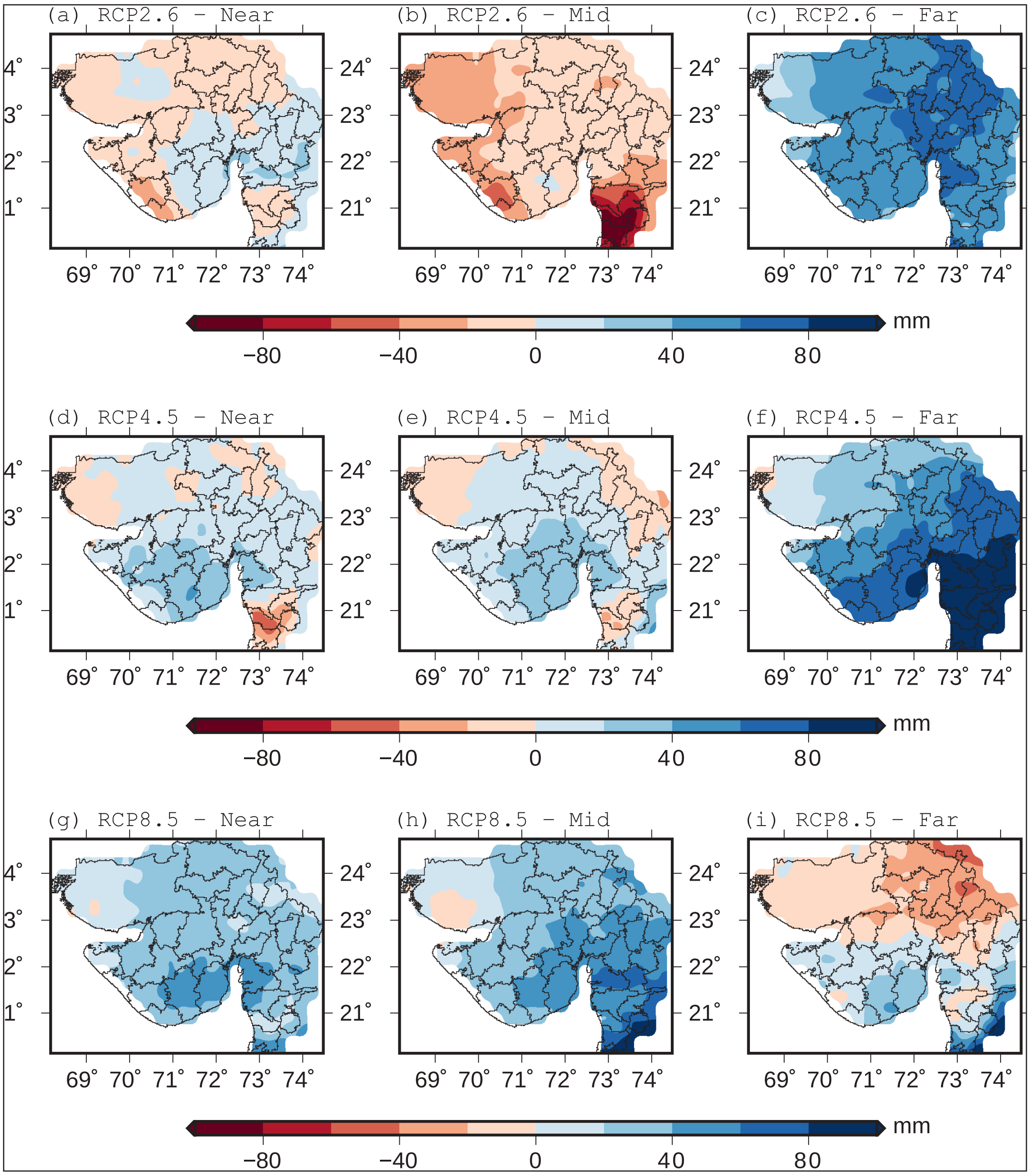
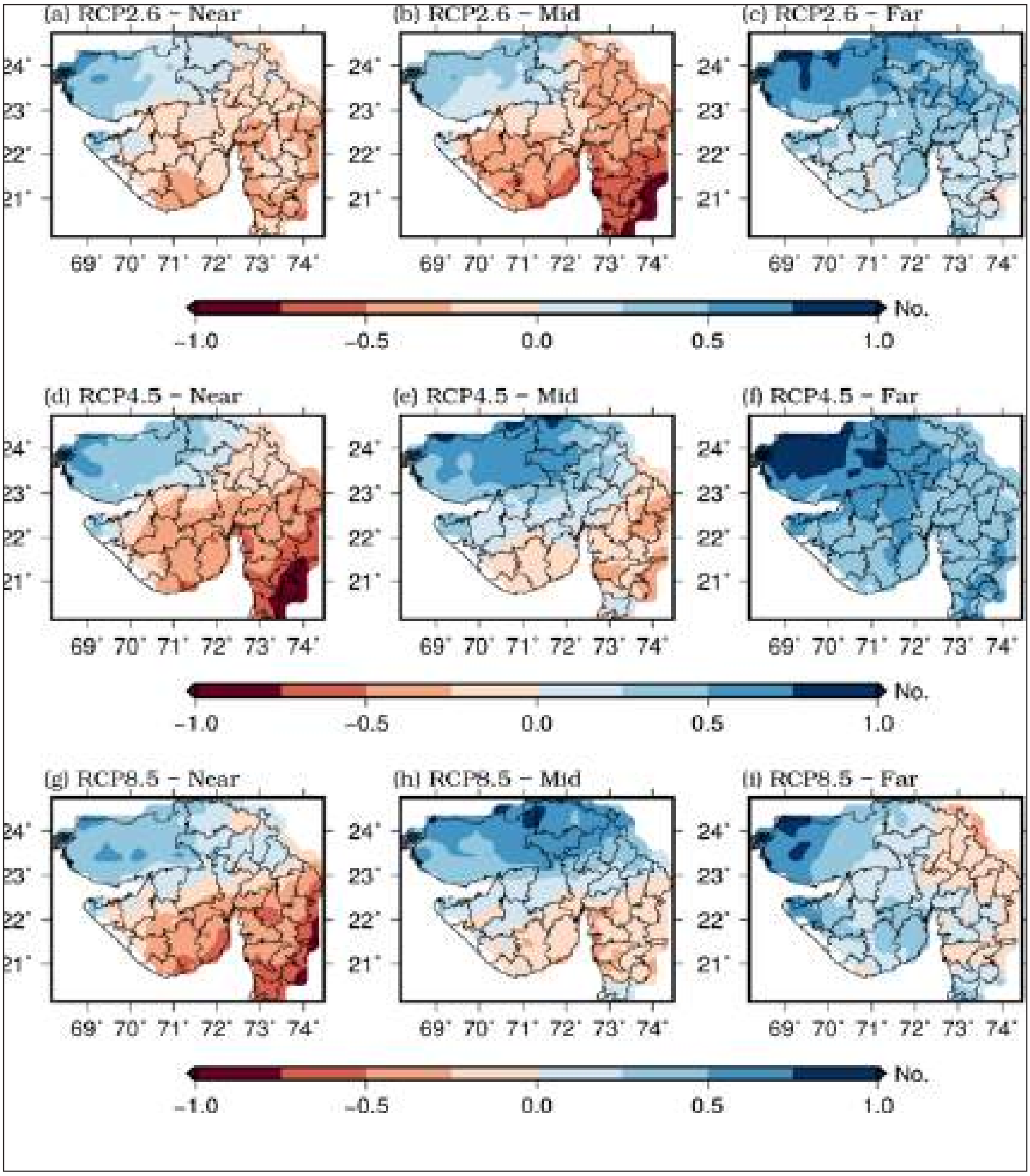


Figure 3.16: **Multimodel mean projected change in the number of extreme precipitation wet events**



3.3.2 Air temperature

The projection for the mean annual maximum temperature suggests that there is an overall tendency of increase in temperature extremes as well as the mean temperature. The near, mid, and far-terms projections for RCP 2.6 of annual daily maximum temperatures indicate changes in the range of 0.9-1.2 °C, 1.2- – 1.6 °C, and 1.1-1.4, respectively (Figure 3.17, RCP 2.6).

The RCP 4.5 scenarios suggests higher changes in the daily maximum temperature, and it is in the range of 0.9-1.2 °C, 1.2-1.6°C and 1.1- – 1.4°C for near, mid and far terms (Figure 3.17, RCP 4.5). The RCP 8.5 scenario shows substantial changes in the mean annual daily maximum temperature in the near, mid and far terms, which is in the range of 0.9- – 1.2 °C, 1.7- – 2.1°C and 2.1 – 2.5°C, respectively (Figure 3.17, RCP 8.5).

The mean annual temperature shows quite similar patterns as that of the mean annual maximum temperature. The RCP 2.6 indicates changes in the near-term in the range of 0.8-1.1 °C, for mid-term in the range 1.2-1.5 °C and for far-term 1.2-1.5°C per year (Figure 3.18, RCP2.6).

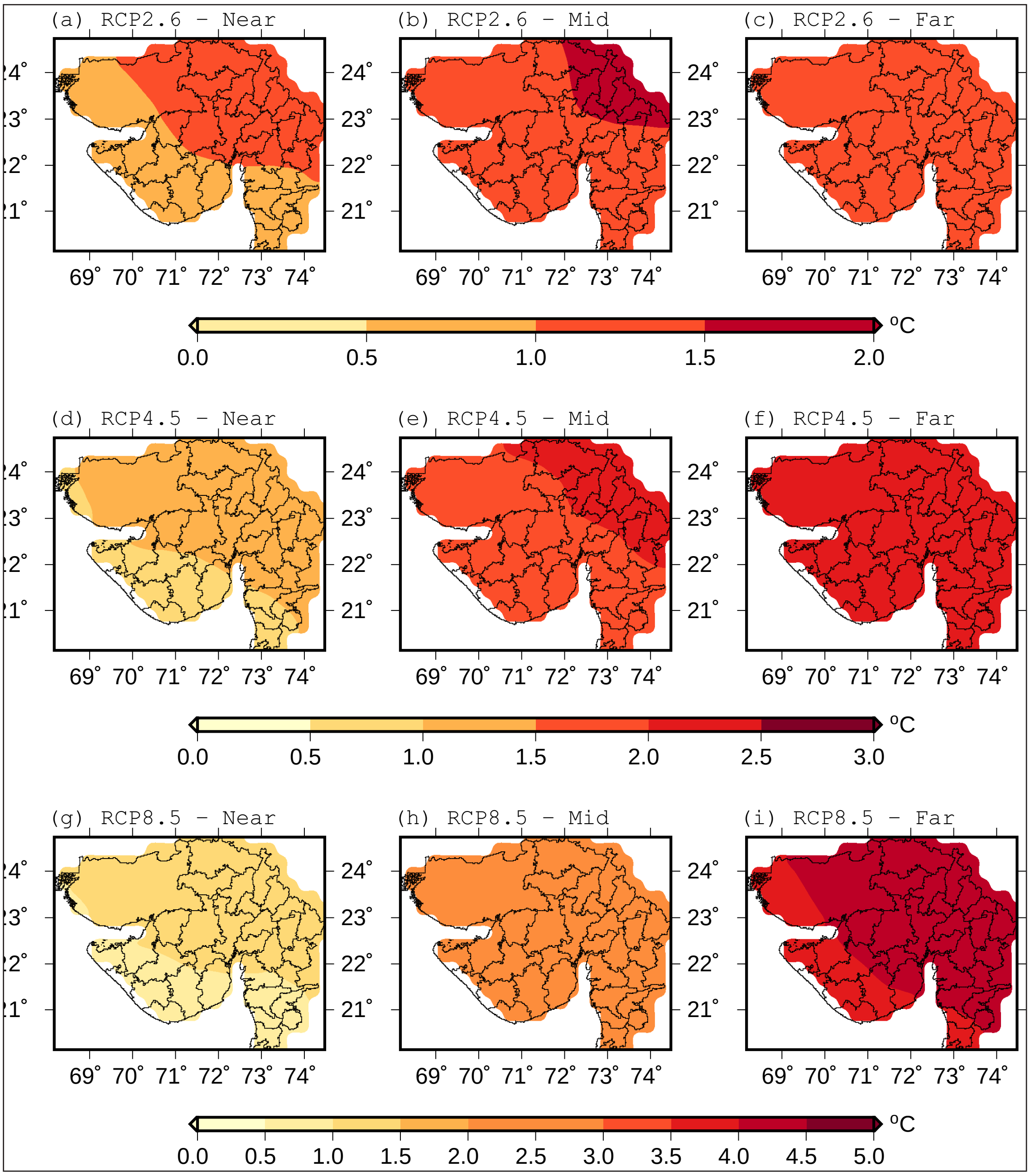
RCP 4.5 indicates the changes in the near-term to be in the range of 0.9 – 1.2 °C, mid-term change in the range of 1.6 – 2.1 °C, and far-term range is of 2 – 2.6°C (Figure 3.18, RCP 4.5).

RCP 8.5 indicates higher changes while comparing with the other two scenarios. The near term shows a range of 1 – 1.3 °C, the mid-term is in the range of 2.2 - 2.7 °C and for far-term 3.7 – 4.6°C (Figure 3.18, RCP 8.5).

The ranges of mean annual daily minimum temperature indicate a steady increase in the near, mid, and far-term projections. RCP 2.6 suggests the ranges of change for the near term as 0.9 – 1.2 °C, 1.2 – 1.6 °C for mid-term, and 1.2 – 1.6 °C in the far-term (Figure 3.19, RCP 2.6). In the RCP 4.5 scenario, the near-term changes are in the range of 0.8 – 1.2 °C. For mid, it is 1.5 – 2.1 °C, and for the far-term, it is 1.8 – 2.6 °C (Figure 3.19, RCP 4.5).

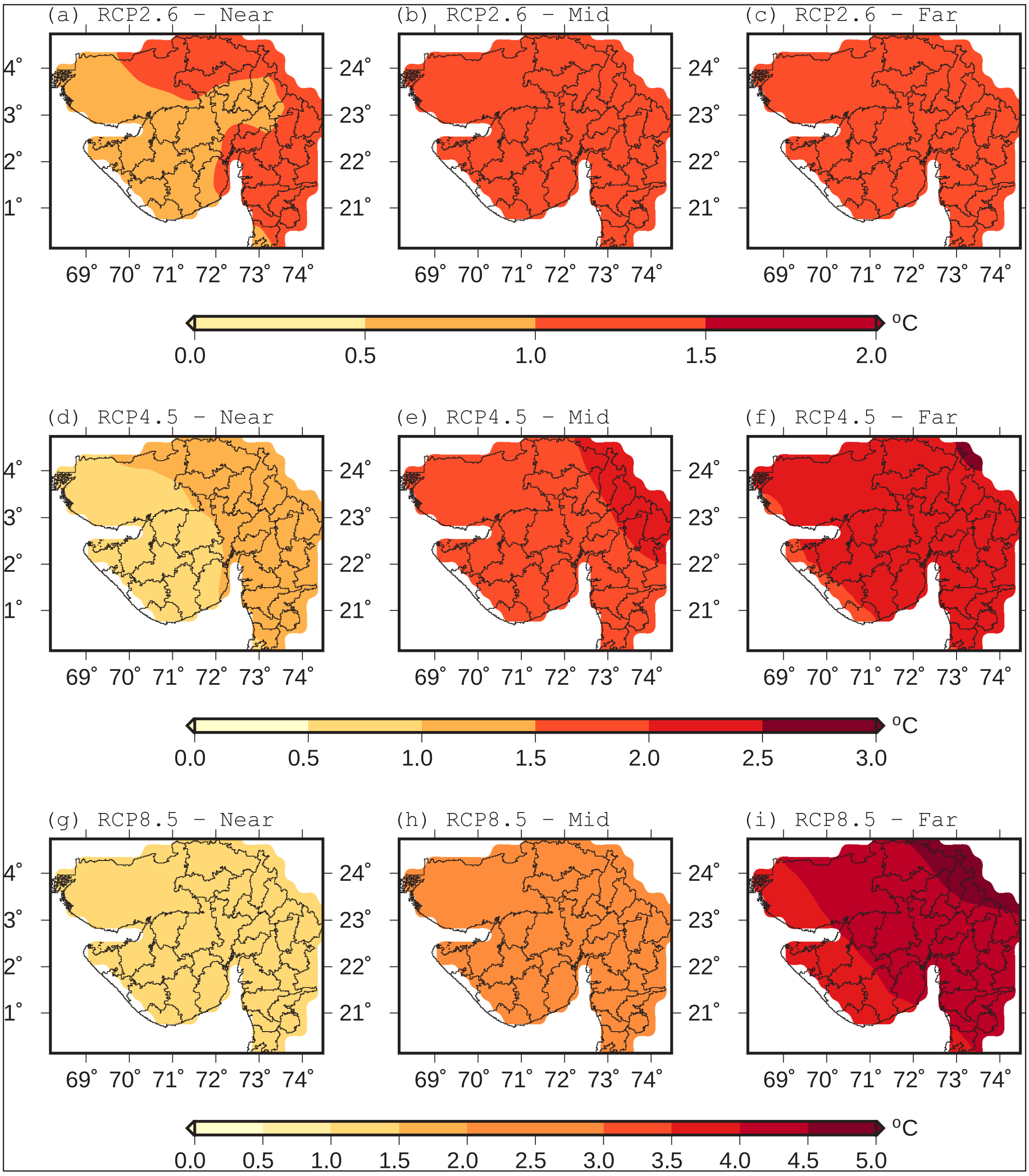
RCP 8.5 shows significantly higher changes in the mid-term projected changes for the mean annual daily mean temperature as compared to that of the near-term changes. These are in the ranges of 1.1 – 1.4 °C, 2.2 - 3 °C, and 3.7 – 4.9 °C for near, mid, and far-terms, respectively (Figure 3.19, RCP 8.5).

Figure 3.17: **Ensemble mean projected change in the mean of an annual mean of daily maximum temperature**



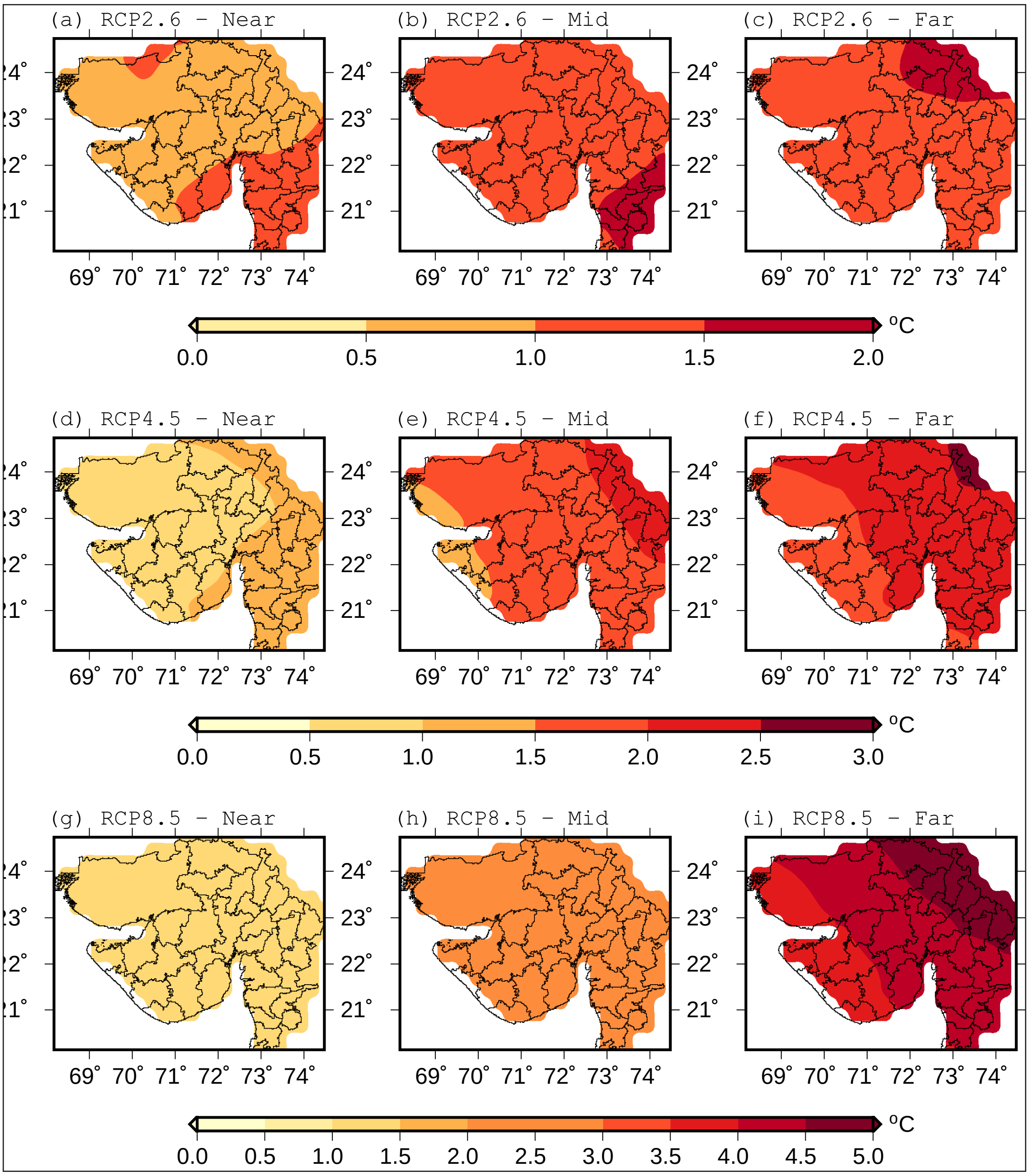
In this case of mean annual maximum temperature, an increase in temperature is observed more towards the north and north-eastern parts of the states in the districts of Banas Kantha, Sabar Kantha, Aravalli, Dahod, Patan, Mahesana, Gandhinagar, Kheda, Panch Mahals, Anand. Some parts of Kachchh, Ahmadabad, and Surendranagar are projected to have a huge increase in temperature (Figure 3.17).

Figure 3.18: **Ensemble mean projected change in the mean of an annual mean of daily mean temperature**



In this case of mean annual daily mean temperature increase in temperature is observed more towards the north and north-eastern parts of the state in the districts Banaskantha, Sabarkantha, Aravalli, Dahod, Patan, Mehsana, Gandhinagar, Kheda, Panchmahals, Anand. Some parts of Kuchchh, Ahmadabad, and Surendranagar are projected to have major increase in temperature. The near and mid-terms in the RCP 2.6 scenario, and the near-term in the RCP 4.5 scenario, the mean annual daily mean temperature is projected to increase in the southern districts as well (Figure 3.18).

Figure 3.19: Ensemble mean projected change in the mean of an annual mean of daily minimum temperature



In the case of mean annual daily minimum temperature, an increase in temperature is observed more towards the north and north-eastern parts of the state in the districts of Banaskantha, Sabarkantha, Aravalli, Dahod, Patan, Mehsana, Gandhinagar, Kheda, and Panchmahals. However, in the near and mid-term in the RCP 2.6 scenario, and in the near-term in the RCP 4.5 scenario, temperature is projected to increase in the southern districts like Valsad, Dang, Navsari, Surat, Tapi, Narmada, and Bharuch (Figure 3.19).

3.3.3 Extreme temperature events: Hot and Cold days/nights and Heat-waves

Extreme events related to temperature were studied for different scenarios considering hot days, hot nights, cold days, and cold nights. The base period considered is 1951 -2000. The frequency of hot days in the RCP 2.6, RCP 4.5, and RCP 8.5 scenarios do not show much variation and seems to be quite consistent. The frequency of hot days in the are projected to increase in the future in Gujarat (Figure 3.20). Similarly, the frequency of hot nights is projected to increase significantly in the future in Gujarat (Figure 3.21). On the other hand, cold days and cold nights are likely to decline in the future in all the scenarios (Figure 3.22 and Figure 3.23).

Figure 3.20: Ensemble mean projected changes in the frequency of hot days

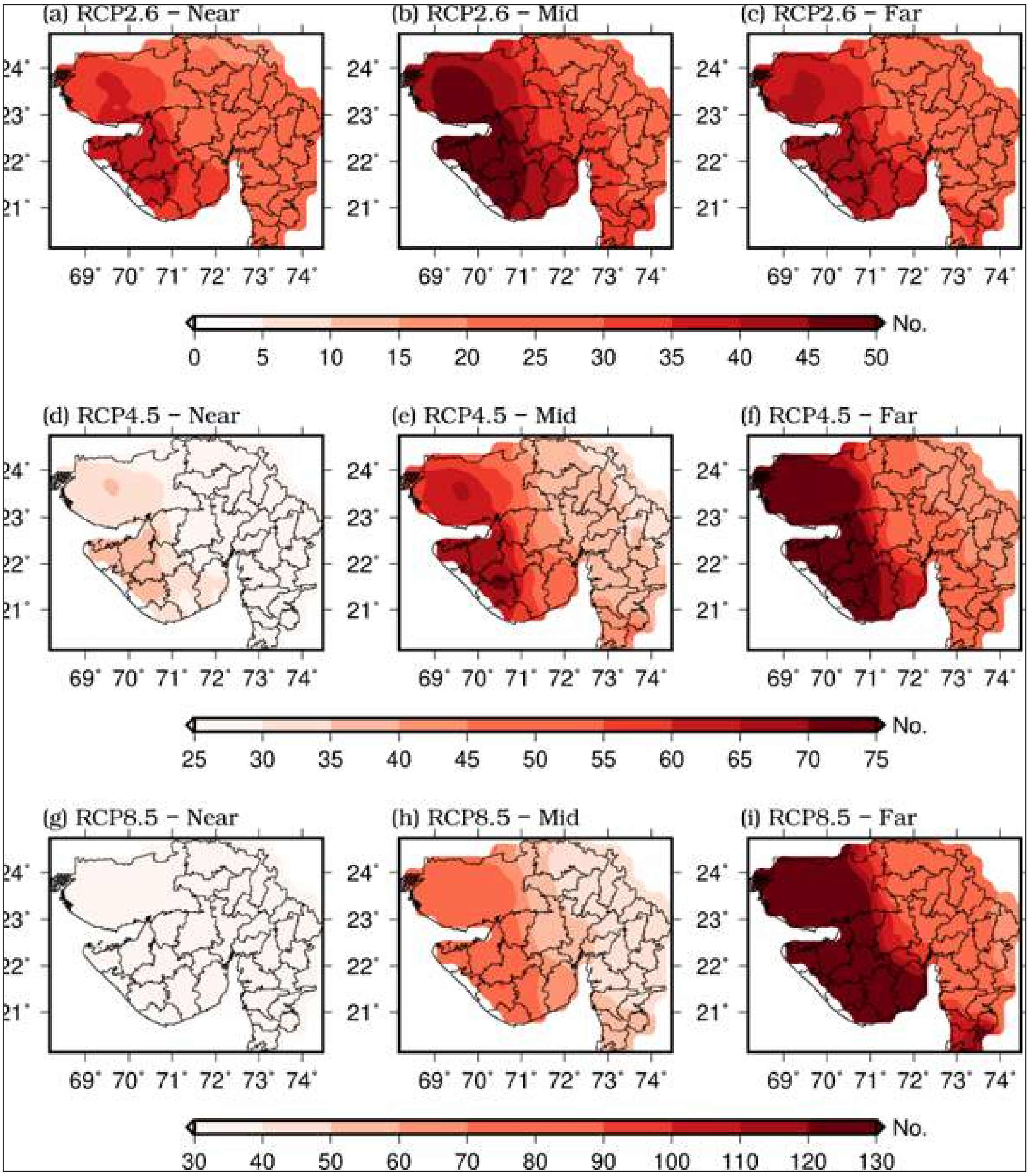


Figure 3.21: Ensemble mean projected changes in the frequency of hot nights

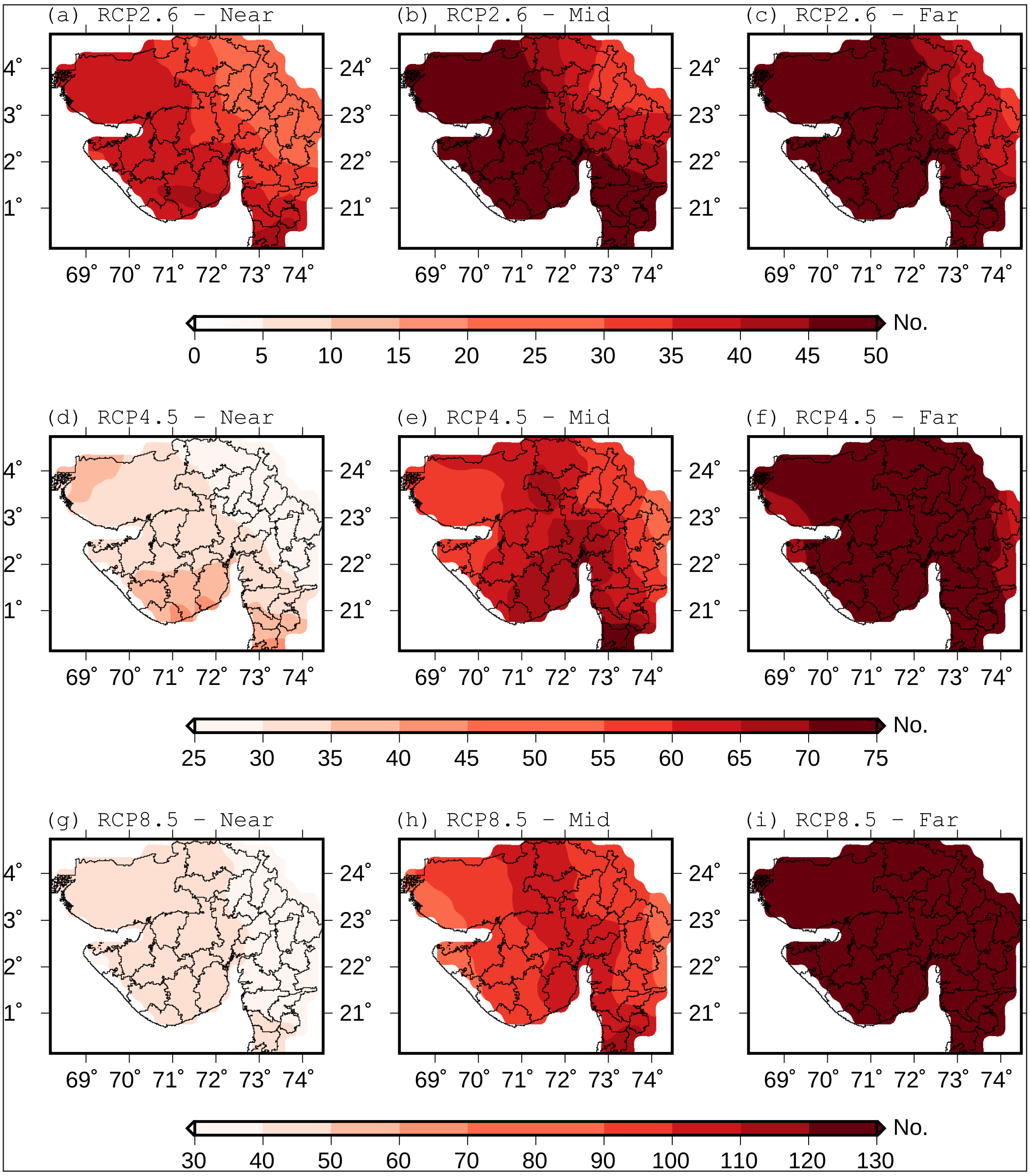


Figure 3.22: Ensemble mean projected changes in the frequency of cold days

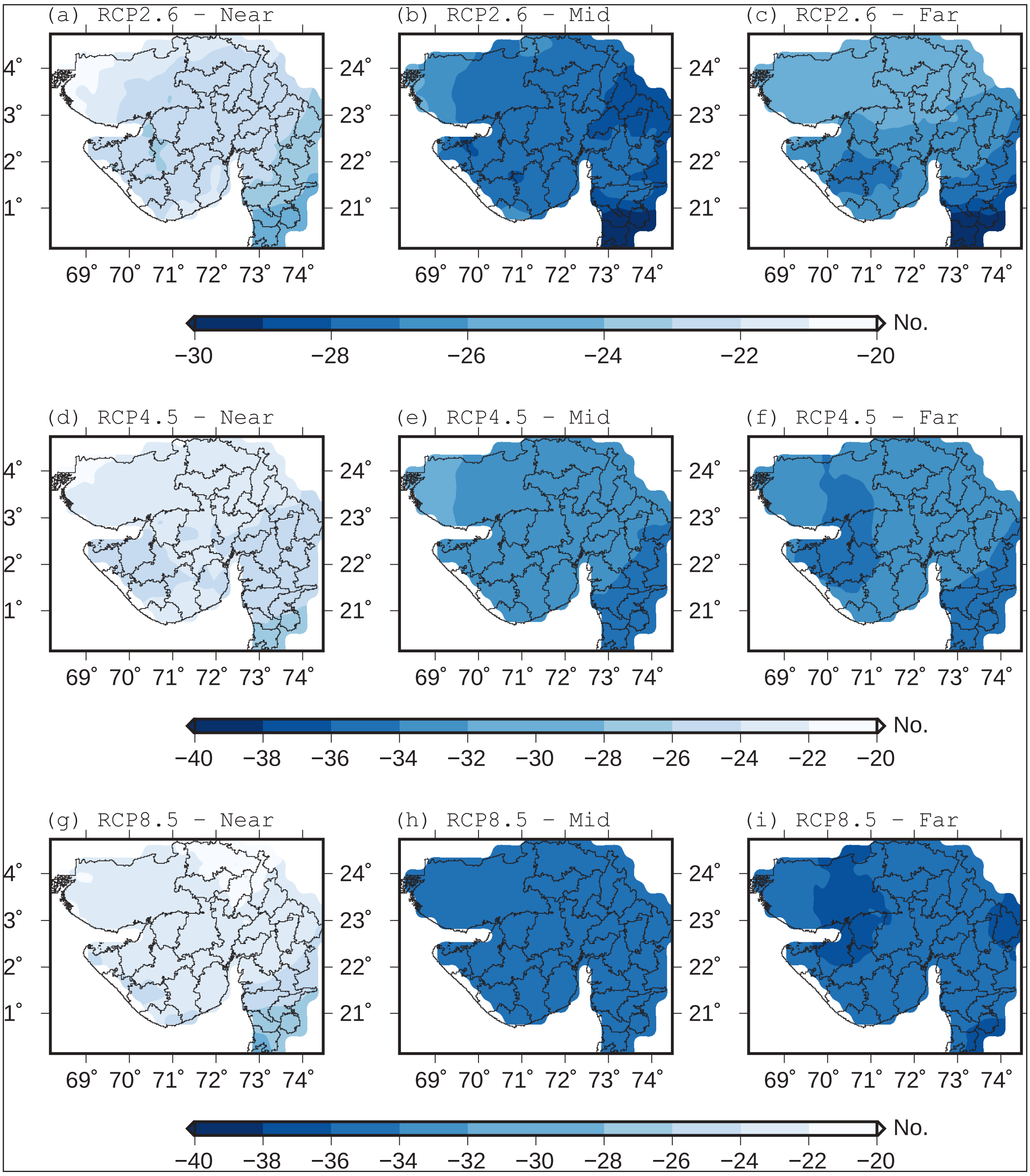
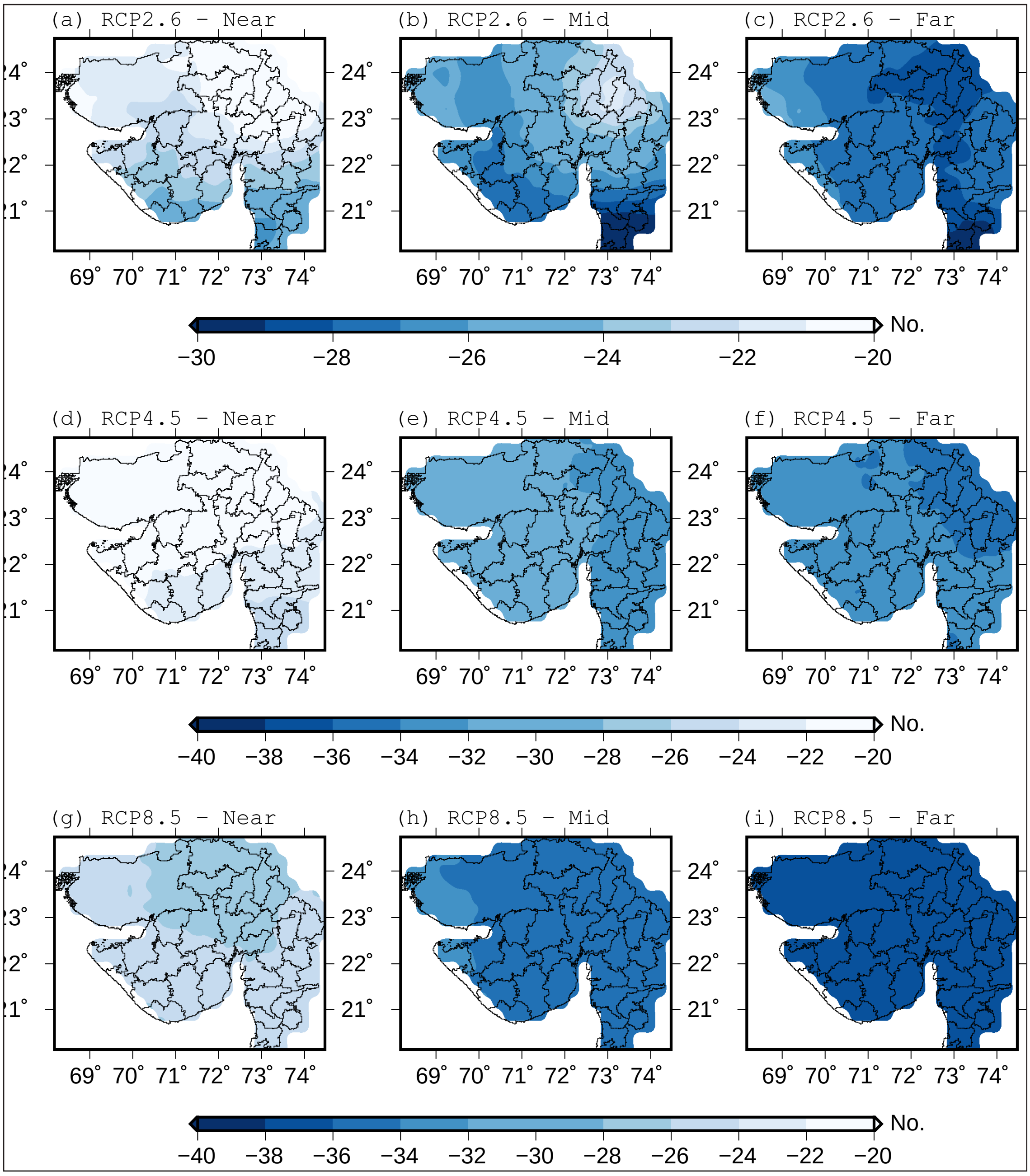
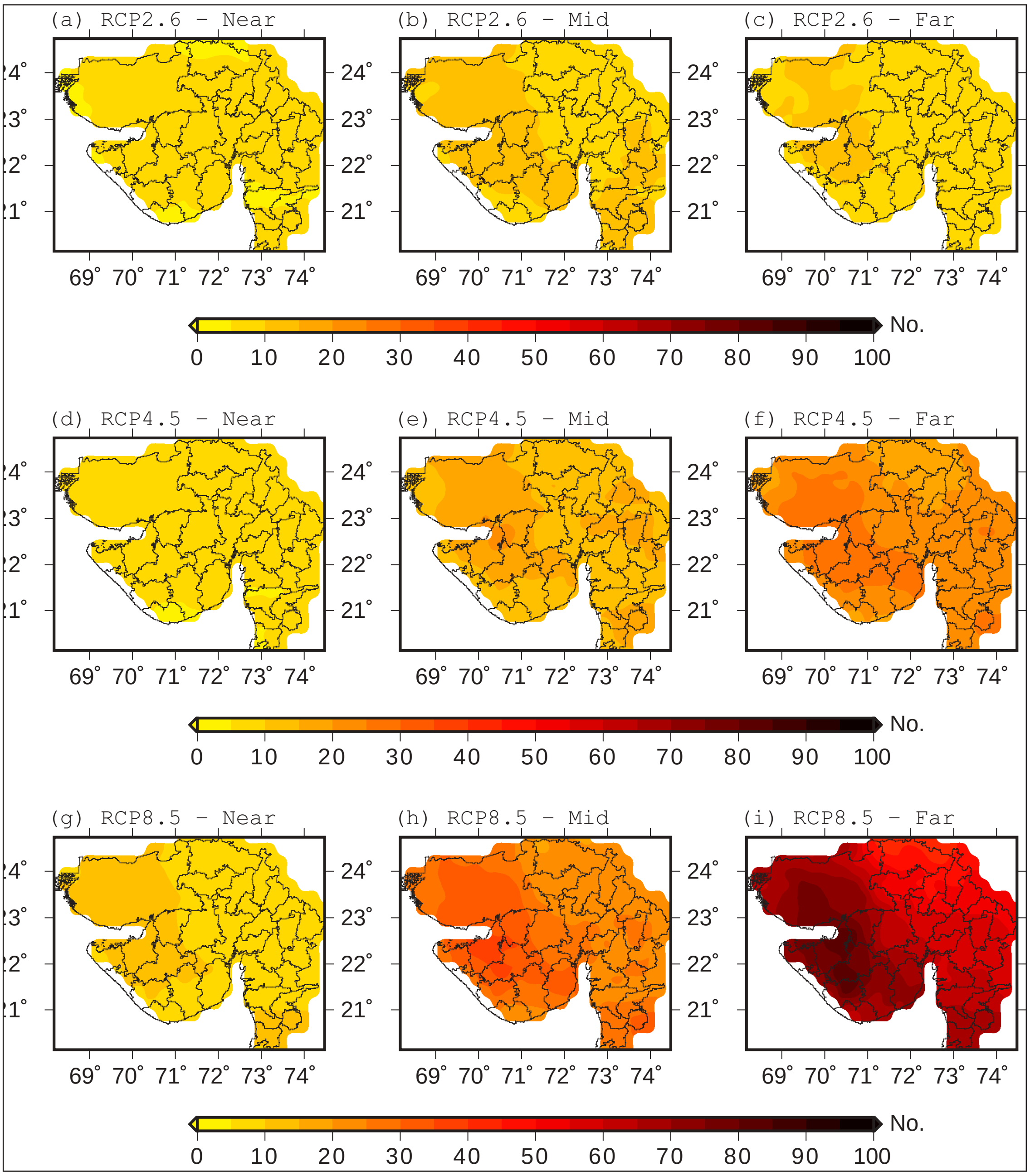


Figure 3.23: **Ensemble mean projected changes in the frequency of cold nights**



The spatial variation and trends in changes in the frequencies of heatwaves in near-term, mid-term, and far-term do not provide any significant information about any temporal pattern within the state. Similar to hot days and hot nights, the frequency of heat waves is projected to rise significantly in the future in Gujarat (Figure 3.24).

Figure 3.24: Ensemble projected mean number of heatwaves per year



3.3.4 Inferences

Based on this study, the following conclusions may be drawn:

1. Most of the precipitation occurred in the monsoon season (June, July, August, September), contributing about 700mm, which is 94 % of the total annual precipitation. The temporal variation of precipitation for the period 1951-2019 shows a few years received rainfall above 1000mm, and there were also a few instants of non-monsoon season extremes.
2. The monsoon season precipitation and frequency of extreme precipitation are found highest in the southern part of Gujarat during the observed period from 1951-2019.
3. The drought events and wet periods were calculated using SPI and SPEI index. The districts such as Surendranagar, Morbi, Rajkot, Ahmadabad, and parts of Amreli, Gir Somnath, and Bhavnagar show a higher number of wet spells around 5-7. The districts

of Surendranagar, Ahmedabad, and Patan faced around greater than five drought events while the districts of Jamnagar, Devbhumi Dwaraka faced the lowest number of drought events (3) events in the same period.

4. The state of Gujarat experiences a mean annual temperature in the bands of 30-35 °C (maximum), 23-29 °C (mean), and 16-22 °C (minimum). In maximum temperature, most affected districts are Valsad, Navsari, Surat, Bharuch, Vadodara, and some parts of Tapi and Narmada districts recorded temperature greater than 31°C. The changes in temperature during the observation period show a positive trend of temperature rise by 1°C in case of mean annual daily maximum; in the case of mean annual daily minimum and mean temperatures, the increase is around 0.1 to 1.5°C.
5. The frequency of hot days was 36-37 days per year, hot nights was of 36.4-36.9 days per year, cold days was of 36.4-6.7 days per year, and the frequency of the number of cold nights was of 36.4-36.7 days per year.
6. Gujarat experienced 3.7–4.8 heatwaves per year. In contrast, Kachchh, Porbandar, Devbhumi Dwaraka, Junagadh, and Gir Somnath districts faced a higher number (above four) of heatwaves. If the annual average of heatwave occurrence is considered, then years 1958, 1969, 1980, 1981, 1986, 2007, 2009 experienced more than 6 heatwaves per year.
7. In the projection scenario, monsoon season precipitation is increasing with RCP 8.5 scenario showing the highest increase, but in the case of extreme precipitation events, the mid and far-term projections in all the three emission pathways indicate a net positive trend of extreme events. However, the near-term projections indicate, near neutral to small positive changes.
8. The projections of mean annual daily maximum temperature suggest that there is an overall tendency of increase in temperature. The mean annual daily maximum temperature increase is observed more towards the north and north-eastern side in the districts of Banaskantha, Sabarkantha, Aravalli, Dahod, Patan, Mehsana, Gandhinagar, Kheda, Panchmahals, and Anand. Some parts of Kuchchh, Ahmadabad and Surendranagar are showing heightened temperature increase up to 4.4 °C.
9. The mean annual daily mean temperature increase is observed more towards the north, and northeastern parts of the state in the districts of Banaskantha, Sabarkantha, Aravalli, Dahod, Patan, Mehsana, Gandhinagar, Kheda, Panchmahals, Anand, parts of Kuchchh, Ahmadabad, and Surendranagar. In the near and mid-term projections of the RCP 2.6 scenario and in the near-term projection of the RCP 4.5 scenario an increase in the mean annual mean temperature is exhibited in the southern districts as well.
10. The frequency of hot days, hot nights, and heatwaves are projected to rise considerably in Gujarat. In contrast, cold days and cold nights are projected to decline in all the scenarios in Gujarat.

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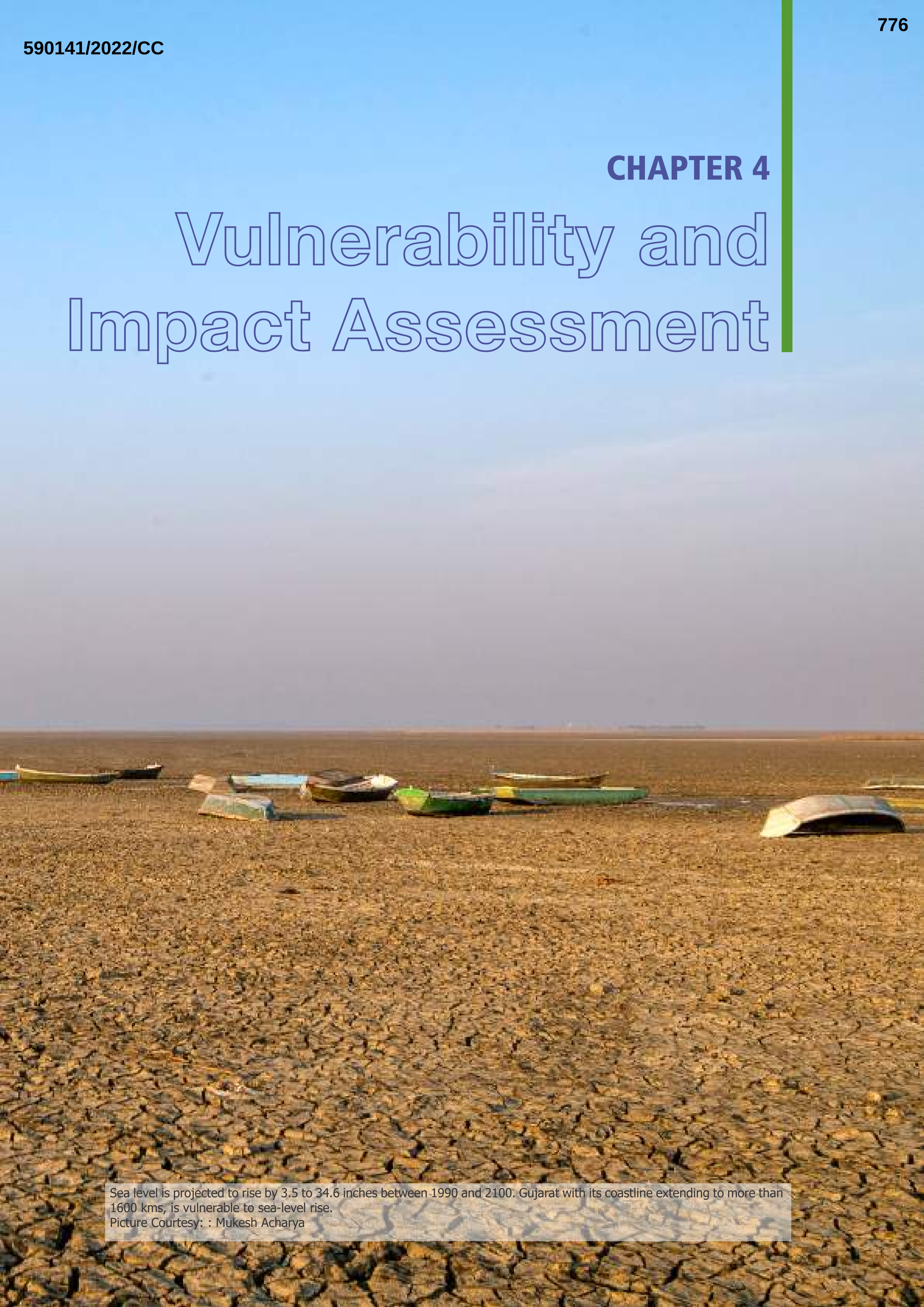
CHAPTER 4

Vulnerability and Impact Assessment



Sea level is projected to rise by 3.5 to 34.6 inches between 1990 and 2100. Gujarat with its coastline extending to more than 1600 kms, is vulnerable to sea-level rise.
Picture Courtesy: : Mukesh Acharya

Vulnerability and Impact Assessment

In terms of climate change, the main risks Gujarat faces are temperature and precipitation extremes, and sea-level rise. These impact agriculture, various economic sectors, infrastructure, and population groups in different ways. Agriculture is a major sector that employs 50% of the working population and contributes 9.5% to the Gross State Domestic Product. Higher projected rainfall variations) threaten productivity, with 54% of the cultivated land dependent on rain and more than 60% of the total land area lying in drought-prone zones (Bandyopadhyay et al., 2020). The agriculture sector is also threatened by a decline in the availability and quality of groundwater. Vulnerabilities are exacerbated in a scenario where 63% of farmers are small/marginal and rely mostly on subsistence agriculture. The livestock and animal husbandry sector, with a population of 26.9 million livestock, could suffer productivity losses due to heat stress and grassland deterioration. Gujarat has India's longest coastline at 1,663 km, with 9.9 million people living in 40 coastal talukas (Census, 2011). This makes Gujarat vulnerable to the impacts of sea-level rise (Kulp and Strauss, 2019), cyclonic events, salinity ingress and shifts in fish breeding patterns, which may result in future migration and climate refugees (WMR, 2020).

Urban areas that account for 43% of the population and are growing at 35% per decade (Census, 2011), are also highly vulnerable to detrimental impacts of climate change. Climate change will impact temperature patterns and cause an increase in the frequency of extreme temperature events (Mukherjee & Mishra, 2018). According to the World Bank, 19 of the 26 districts in Gujarat could become climate change hotspots by 2050, with temperatures expected to rise by 2-2.5°C[2]. The 2010 Ahmedabad heatwave caused about 1,344 excess deaths, including increased neonatal deaths (Azhar et al., 2014). Heatwaves are frequent in Kuchchh, Saurashtra and North Gujarat. Surat has experienced 23 floods in the last century, including highly destructive ones in 2006 and 2013. Climate change could increase the prevalence of vector-borne diseases and cause public health issues that are known to disproportionately impact the elderly and poor populations in cities (Dholakia & Garg, 2014).

Urbanization and changes in land-use patterns have also added to significant pressures on forest cover, mangroves, corals, and wetlands. According to the Space Application Centre (SAC, ISRO), 52% of Gujarat's land area was degraded/under desertification in 2012. The area under dense and moderately dense forest cover has declined by 11%, from 6,138 km2 in 2005 to 5470 km2 in 2019 (Forest Survey of India, 2015, 2019), which is a matter of concern for forest health. A significant population is dependent on access to forests for daily needs, and is vulnerable to the impacts of deforestation. The Kuchchh and Saurashtra

[2]https://timesofindia.indiatimes.com/city/ahmedabad/gujarat-a-degree-away-from-climate-calamity/articleshow/65825956.cms

regions that support unique ecosystems in Gujrat are especially ecologically sensitive, with land-use change and climatic variations leading to desertification and habitat loss.

As the climate continues to change, the significant hazards which are likely to impact Gujarat are: increase in maximum temperatures, precipitation extremes, and sea-level rise in coastal regions (Field et al, 2012). Each of the hazards interacts with infrastructures, economies, and societal dimensions in different ways (Cimellaro, Reinhorn & Bruneau, 2010), (Ganguly, Bhatia & Flynn, 2018). This chapter analyzes reports of the vulnerability assessment findings for the state of Gujarat at district scales. The districtwide exposure, sensitivity, and adaptability analysis include the discussion of groups who are more vulnerable to weather and climate-related extremes, which are likely to intensify in changing climate scenarios. This analysis also considers the nature of climate hazards and their interaction with sensitive and vulnerable groups at both rural and urban scales. As climate change is expected to exert surmounting pressure upon the livelihoods, the exposure, sensitivity, and adaptability analysis is carried out to identify the regions that are at high risk to hazard.

Based on the observed datasets and simulations of 5 CMIP5 models in combination with socio-economic data, the spatial distribution of the vulnerability to climate change in India is estimated for the past term with the period (1970 - 2001) and (1981-2015) and projected under the RCP8.5 (Representative Concentration Pathway 8.5) for the near term period (2006–2036), medium-term period (2037–2076) respectively. The results show the vulnerability of the rural region of each district in each state. From the observed datasets, past precipitation extremities i.e., 30-year return levels and 100 return levels of 1-day, 2-day, 3- days and 5-day cumulative rainfall, are calculated. Under the RCP8.5 greenhouse gas emissions scenario, future precipitation extremes, and hence exposure index is estimated by calculating the volatility ratio (Khan et. al, 2007).

Compared with the baseline period, the return levels turned out to be increasing with time, although the volatility ratio change is small as both 30-year and 100-year return levels tend to increase (Khan et. al, 2007), (Fuller et. al, 2006). Due to the unavailability of the year-wise consistent socio-economic data and the linear approach followed for the estimation of vulnerability and independency assumed amongst the indicators for determining the weight coefficients, uncertainty still exists in the assessment however the results give the idea about the vulnerability associated with each region relative to another area. They can highlight the areas with high vulnerability in the states for different periods.

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2014). Vulnerability is a function of magnitude and the rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. Similar definitions are also used in city-scale studies elsewhere (City of Boston, 2016).

Cities and states in India are likely to experience abrupt climate change and its consequences. Both built and natural systems are likely to face problems in coping up with it due to lack of enough resources (adaptability) which gives a huge contribution in increasing the vulnerability of the sensitive regions which are prone to the events happening due to climate change like extreme precipitation events (flooding). In order to reduce the impact of these events, it is necessary to analyze the data and assess the degree of susceptibility of a region to the event and thereby develop the framework which can help reduce the impact or reduce the intensity of an event.

4.1 Components of Vulnerability

Hazard Exposure:

Exposure means people, assets, and socio-economic groups are subjected to stressors like warming, flooding. They may be repeatedly subjected to such events over a period. Hazard exposure is thereafter referred as exposure (not to be confused with IPCC's definition)

Sensitivity:

Sensitivity refers to the extent to which communities and people are impacted by climate change.

Adaptive Capacity:

Adaptive capacity refers to the extent to which the community and people are capable of coping up with the impact due to climate change. The more is the adaptive capacity, and lesser is the vulnerability

In this research, the analysis of climate data along with the socio-economic factors which contribute to maximizing or minimizing the impact on the region gives a clear idea about where there is a need for planning mitigation strategies at the earliest and where there is the need for implementing effective adaptive measures. A lot of research work has been done on the risk assessment of the different regions, which includes hazard analysis and vulnerability analysis and deal separately with climate and socio-economic parameters. In this research, both the climate and socio-economic parameters are combined to give the single figure called vulnerability index. Vulnerability assessment for different future periods- near term period and midterm period and prior period is done. Future vulnerability is assessed using simulated results of 5 models of precipitation under the RCP 8.5 scenario. According to Mishra et al. (2018), for Indian regions, the RCP 8.5 scenario suits best to study the extreme precipitation events in the future as present emission scenarios are already either following or very close to the RCP 8.5. In 2012, IPCC published the Special Report: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) (IPCC, 2012), in which comprehensive analysis on the frequency of occurrence, the intensity, the vulnerability, and the degree of exposure to extreme events and corresponding disaster risks are presented which helped in forming the framework in the research. This study analyzed the past and future climate data to calculate the exposure index from using volatility ratio and combined with the socio-economic data to conduct a preliminary assessment of future and past vulnerability. This study also accounts for the temperature data analysis by calculating the difference in temperature between the future and past periods. It will provide the reference for developing the mitigation strategies and implementing the adaptive measure wherever needed and help in the efficient management.

4.2 Methodology for vulnerability assessment

This research uses two types of data for analysis - 1) Climate data, 2) Socio-economic data.

4.2.1 Climate data

Observed IMD data for precipitation b) Projected data using the models for precipitation

Observed data is used to calculate the precipitation extremes in the period 1951 to 2015 and projected data is used for future analysis i.e., to project future precipitation extremes in the period 2006-2036 and 2037-2076. Models used - 1) BNUESM 2) CESM 3) MirocESM 4) NorESM and 5) MPI-ESM under the RCP 8.5 Carbon emission scenario. One day, two days, three days, and five days maximum 30-year return level and 100-year return levels are the precipitation extremes taken into account for the calculation. Both past and future analyses are done following a similar procedure. Return levels are calculated by applying the generalized extreme value theory (GEV). Mean return levels are then calculated for each district using the Inverse distance weighted average method. Volatility ratio is calculated by taking 100-year to 30-year return level ratio, and then it is used to calculate the Index using the following formula:

$$\text{Index (I)} = \frac{(V.R.)i - (V.R.)min}{(V.R.)max - (V.R.)min}$$

Where $(V.R.)_i$ = Volatility ratio of district *i* in the state.

$(V.R.)_{min}$ = Minimum volatility ratio among all districts in the state.

(V.R.)max = Maximum volatility ratio among all districts in the state.

After calculating the separate indices for the volatility ratio of each day return level, the exposure index is calculated by summing up these indices with equal weight coefficients assigned to them in such a way that these coefficients add up to 1.

$$\text{Exposure index (E)} = 0.25 \times I_1 + 0.25 \times I_2 + 0.25 \times I_3 + 0.25 \times I_5$$

The reason behind as equal weights is because all the indices are independent of each other as the events occur independently.

c) Temperature data - Simulated data for past and future using models under RCP 8.5 emission scenario. Models used - 1) GFDLESM 2) NorESM 3) MPI-ESM 4) BNUESM. The absolute difference between the temperature in the past (1981-2005, averaged over time) and future(2006-2030) is taken to highlight the changes in temperature from the past, and then the relative temperature index is calculated.

4.2.2 Socio-economic data

Socio-economic data is obtained from the socio-economic caste Census 2011 website as well as India's census website.

The data can be obtained from here for all the states -

(SPM 2014)

http://censusindia.gov.in/2011census/dchb/DCHB.html

https://data.gov.in/

4.2.3 Factors which contribute towards the sensitivity of a region

Population - Total population, tribal population, infants population

Individual population indices are calculated using the established formula the same as that of used in calculating volatility index.

Overall population index is then calculated using the formula as follows:

$$Pindex = \left(\frac{i+1}{T}\right) \times TPI + (0.5 - \frac{t}{T}) \times (\frac{f}{t} \times TRPI + (1-\frac{f}{t}) \times FTRPI) + (0.5 - \frac{i}{T}) \times INFI$$

Where i = Infant population in a district

t = Tribal population in a district

f = Female tribal population

T = Total population in a district

TPI = Total population index

TRPI = Tribal population index

FTRPI = Female tribal population index

INFI = Infant population index

Here, weights are assigned to each subindex such that they satisfy the statement -

Population is more vulnerable if the total tribal and infant population is greater than 50% of the total population.

The population is more vulnerable if the female tribal population exceeds 50% of the total tribal population.

Agricultural parameter - Unirrigated area

Educational parameter - Illiteracy

Sensitivity index is calculated by summing these indices with appropriate weights assigned to them as follows:

$$S = 0.33 \times \text{Pindex} + 0.33 \times \text{Unirrindex} + 0.33 \times \text{Illitindex}$$

4.2.4 Factors which contribute toward the adaptive capacity of a region

Economic factors - Income, employment (workers)

Available data consists of a population of main and marginal workers using which employment index can be calculated as

if the population of main workers is higher than that of marginal workers, then

$$\text{Windex} = \frac{m}{m+mr} \times \text{mworkindex} + \frac{mr}{m+mr} \times \text{mrworkindex}$$

Else,

$$\text{Windex} = \frac{mr}{m+mr} \times \text{mworkindex} + \frac{m}{m+mr} \times \text{mrworkindex}$$

Where m = population of primary workers

mr = population of marginal workers

mworkindex = Index calculated for population of main workers

mrworkindex = Index calculated for population of marginal workers

Here, weights to the subindices are assigned such that they satisfy the following statements:

Main workers work for all the seasons and hence have a continuous source of income, whereas marginal workers work for a particular season, after which their source of income is not defined. Hence, bigger weight should be assigned to main workers if their population is more than marginal workers, and lesser weight should be assigned if their population is less as main workers contribute more towards increasing the adaptive capacity.

Agricultural data - Irrigated land, agriculture workers, agriculture with electricity supply

Agriculture index is calculated as follows:

Agri-index = 0.33agriworkindex + 0.33powerindex + 0.33irrindex

Health facilities - Hospitals and doctors

Available data for doctors consists of population of subsidized and private doctors from which the Index for a total population of doctors is calculated as:

If the population of subsidized doctors is greater than that of private doctors, then

$$drindex = \frac{sdr}{sdr + pdr} \times \text{sdrindex} + \frac{pdr}{sdr + pdr} \times \text{pdrindex}$$

Else,

$$drindex = \frac{pdr}{sdr + pdr} \times \text{sdrindex} + \frac{sdr}{sdr + pdr} \times \text{pdrindex}$$

Where *pdr* = private doctors' population

sdr = Subsidised doctors' population

sdrindex = Index calculated for Subsidised doctors' population

pdrindex = index calculated for private doctors' population

Here, weights are assigned to the subindices such that they satisfy the statement:

Subsidized doctors provide the facility at a lower rate and assured treatment as they are supported by the government. In contrast, private doctors charge enormous fees for the checkup, making it unfavourable for the rural people to visit them. Hence subsidized doctors should be assigned with a higher weight if their population is higher than the private doctors.

Therefore, the health index is calculated by combining both the health facilities with equal weights assigned to them.

$$\text{Hindex} = 0.5 \times \text{drindex} + 0.5 \times \text{hospindex}$$

Educational data - Literacy

Therefore, combining all these factors with equal weights assigned gives adaptive capacity of a region as

$$A = 0.2 \times \text{agriindex} + 0.2 \times \text{Hindex} + 0.2 \times \text{Windex} + 0.2 \times \text{litindex}$$

4.2.5 Vulnerability

The vulnerability, which in this study is considered to be the linear combination of the three components Exposure, Adaptability, and sensitivity, is calculated by combining the three components with equal weights assigned. Linearity is assumed as it is the simplest way to convey the results without any fallacy, according to Occam Razor's principle, although uncertainty exists. Here, adaptability is the component that has a negative effect on the vulnerability i.e., vulnerability decreases as the adaptability increases and vice-versa. Hence it is given (-) sign while combining with the other two components.

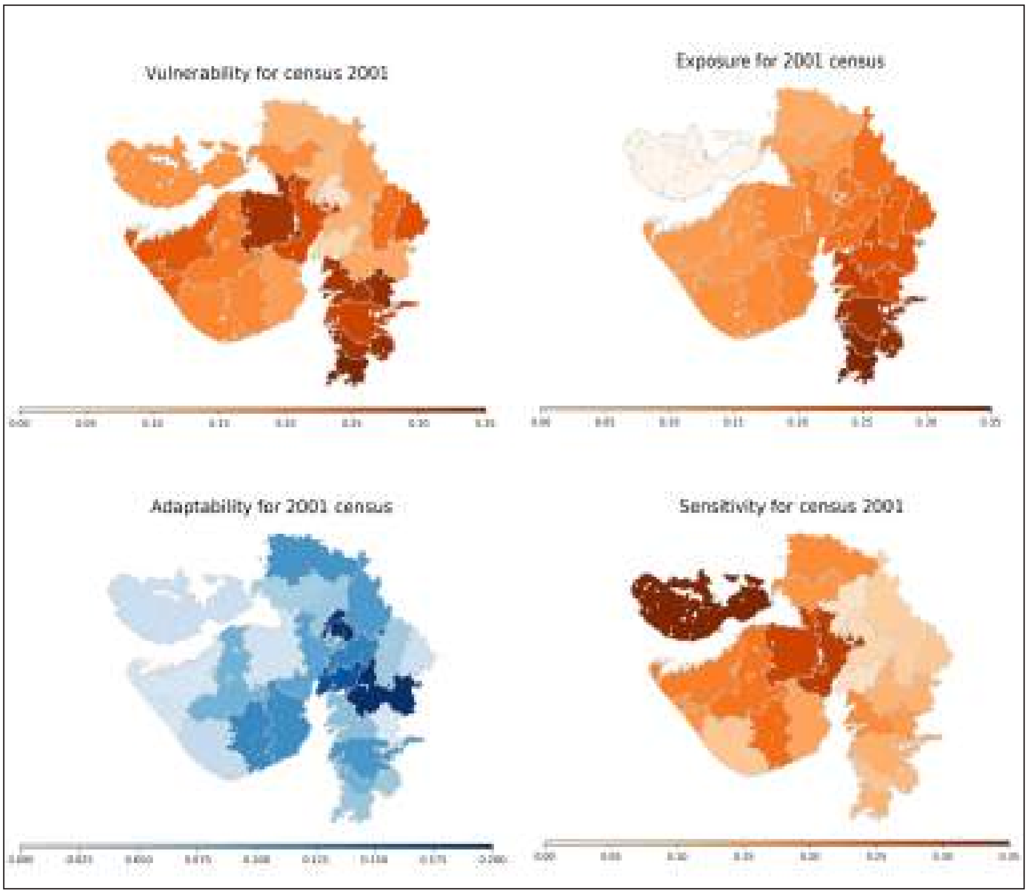
Therefore,

$$V = 0.33 \times E + 0.33 \times S - 0.33 \times A$$

4.3 Assessment of the physical and economic impact of and vulnerability to climate change in the most vulnerable sectors (agriculture, water, forestry and biodiversity, coastal-zone management, health, tourism, urban, etc.)

As can be seen from the above maps, exposure in the Kuchchh area is a minimum of all the districts in Gujrat, whereas its sensitivity is highest and adaptive capacity is considerably low. So, the vulnerability map gives the vulnerability of all the regions after combining the three components. South-east coastal areas are highly vulnerable as the exposure in that region is high and adaptive capacity is low (Figure 4.1).

Figure 4.1: Results for census 2001 socio-economic data analysis and 1970-2001 exposure period



From the analysis of the Figure 4.2, it can be concluded that the volatility ratio is high during this period in Kuchchh as it is having maximum exposure and from the vulnerability map, it can also be concluded that exposure is the major factor in contribution in Kuchchh district as vulnerability is also high there though it has significant adaptability. Hence, the major inference drawn from the analysis in this period is that Kuchchh is the most vulnerable district in Gujarat with highest exposure.

Figure 4.2: Results for census 2011 socio-economic data analysis and 1981-2015 exposure period

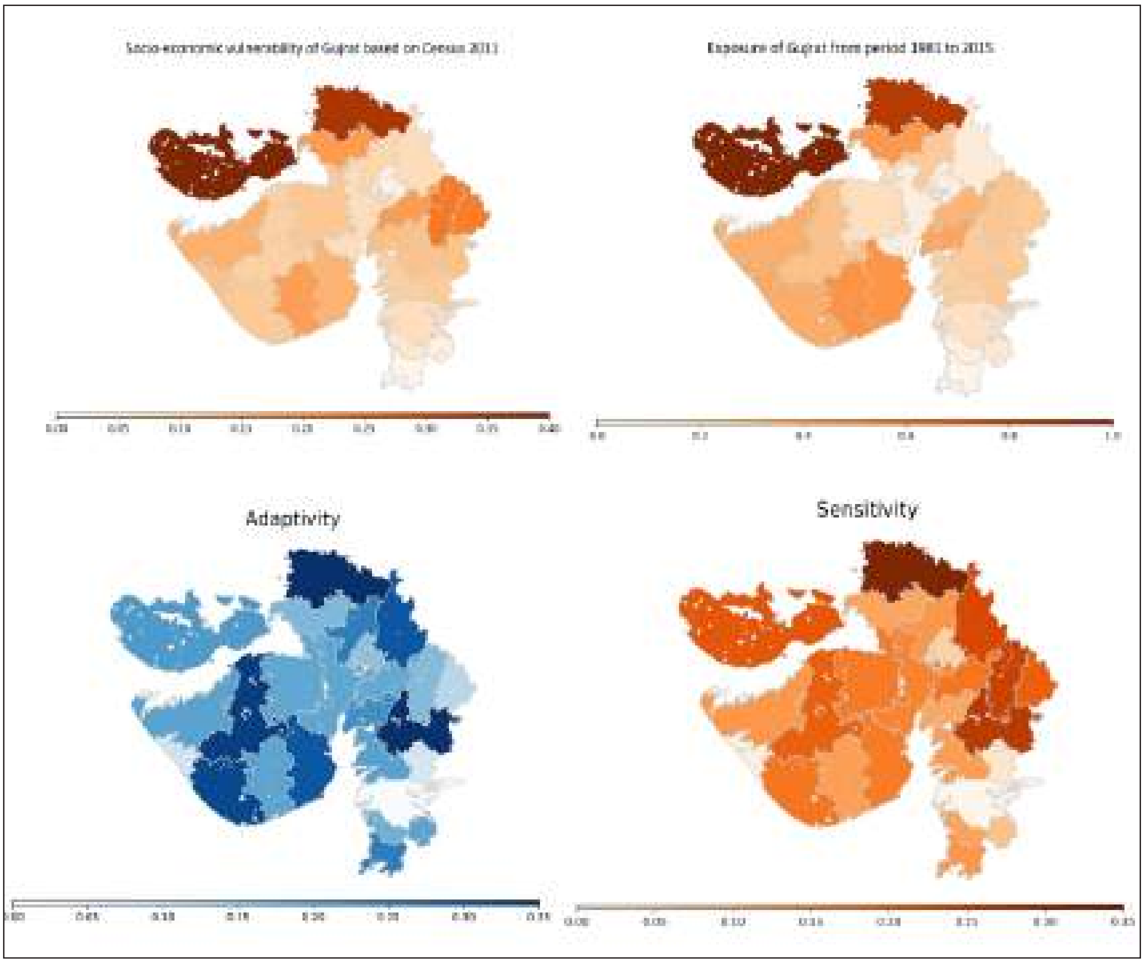
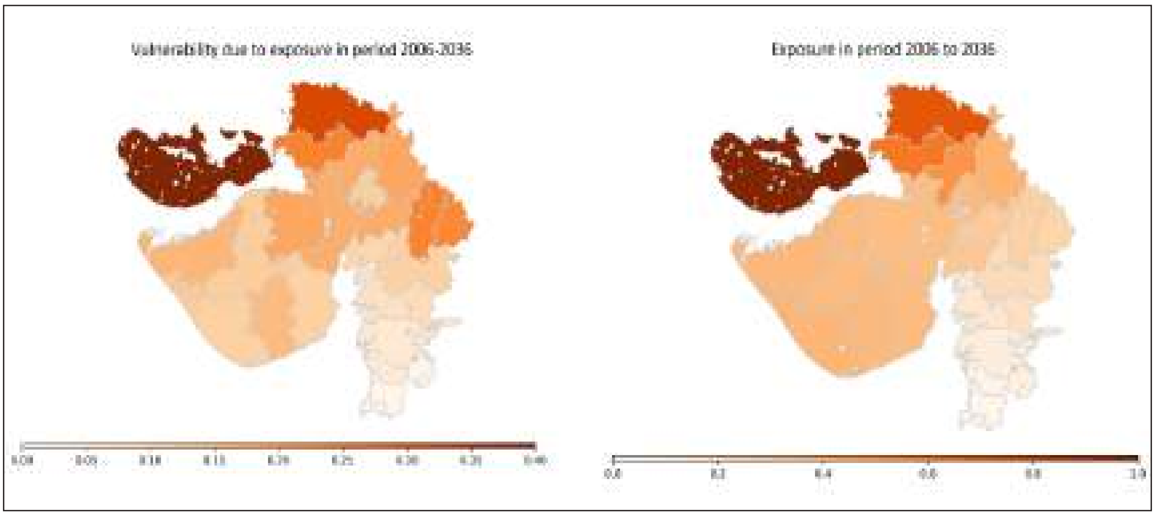
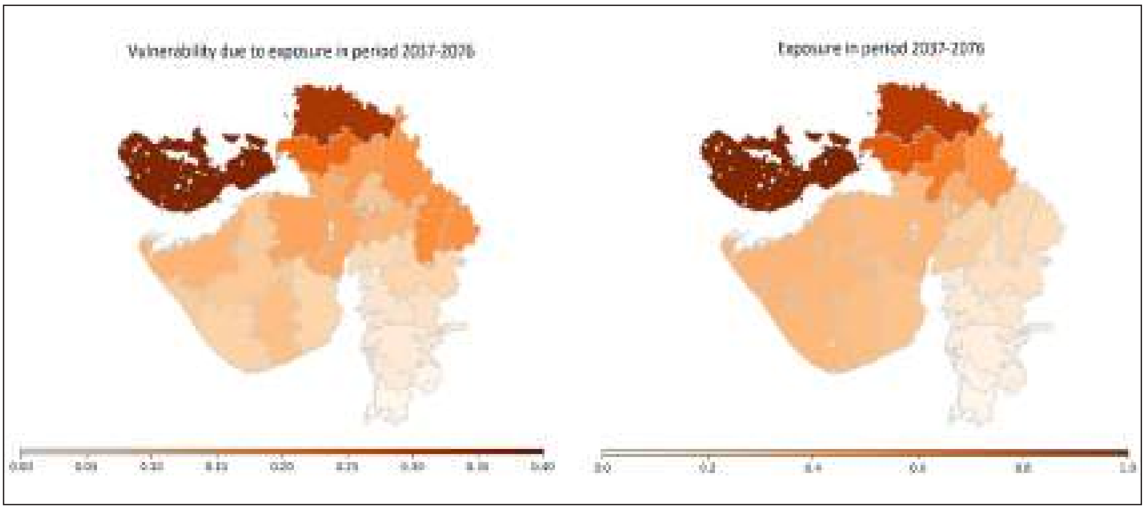


Figure 4.3: Vulnerability in the future period with near term period (2006-2036) precipitation data analysis and constant socio-economic parameters of Census 2011



From the exposure map (Figure 4.3), it can be concluded that the volatility ratio has changed more or less in the same amount for all the districts if compared to past analysis such that exposure of Kuchchh is still high for this particular period. Hence, its vulnerability as socio-economic parameters is not changed.

Figure 4.4: Vulnerability in the future period with near term period (2037-2076) precipitation data analysis and constant socio-economic parameters of Census 2011



From this (Figure 4.4) and previous analysis, it can be concluded that in any period of time the volatility ratio of each region is changing with the same amount for each region keeping Vulnerability of Kuchchh high in any period. Hence there is a serious need of designing the infrastructure in Kuchchh very carefully taking into account the high volatility ratio and increasing magnitudes of the return levels with time to lessen the structural sensitivity of this area and hence ensuring the safety of people living there.

From these four maps (Figure 4.5), it is evident that the precipitation extremes (30-year return levels) have changed most significantly in the northern part of the Gujarat state and the change has the highest magnitude in Kuchchh district which is the evidence for the high exposure in the vulnerability assessment.

Figure 4.5: **Difference in precipitation extremes: Absolute Difference in 30-year return levels between period (2037-2080) and (1981-2015)**

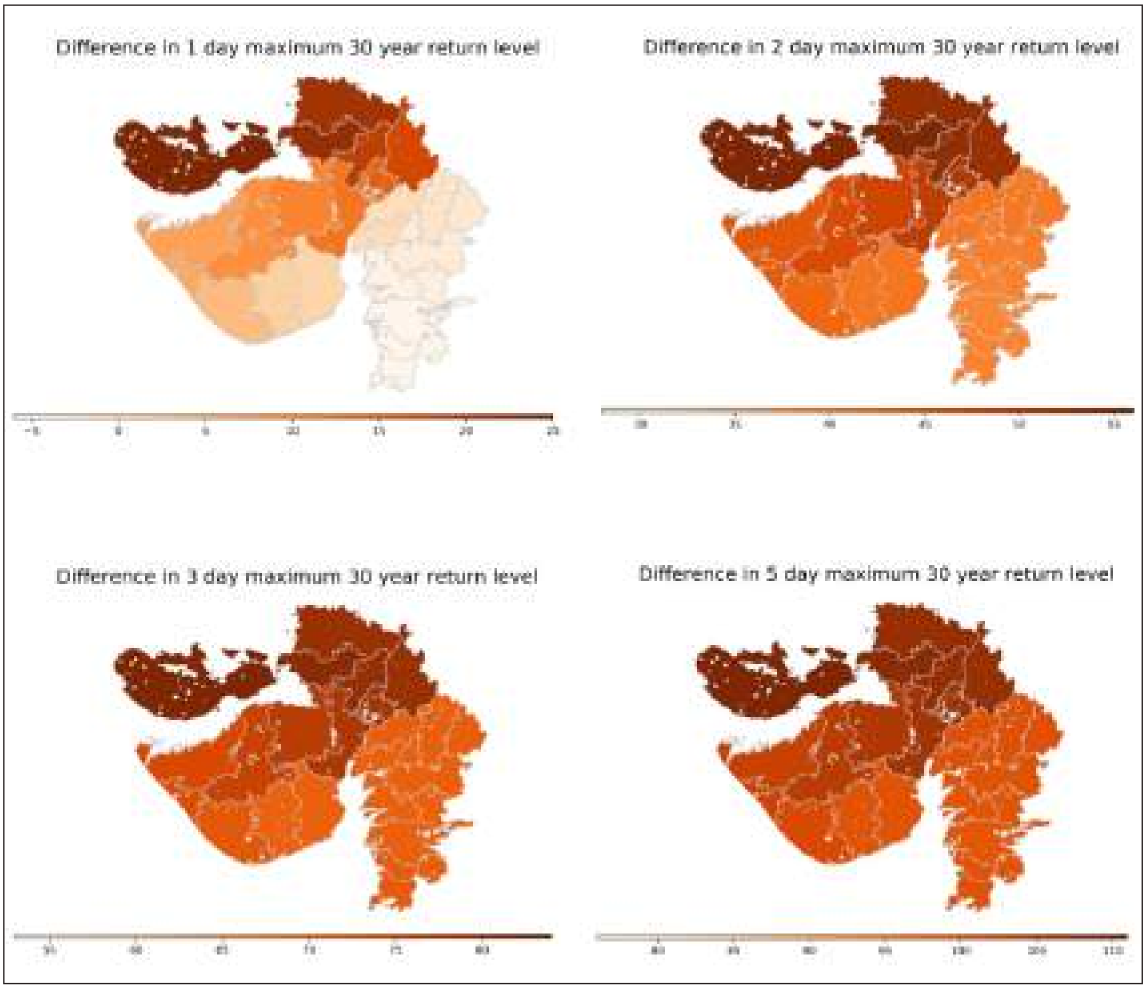
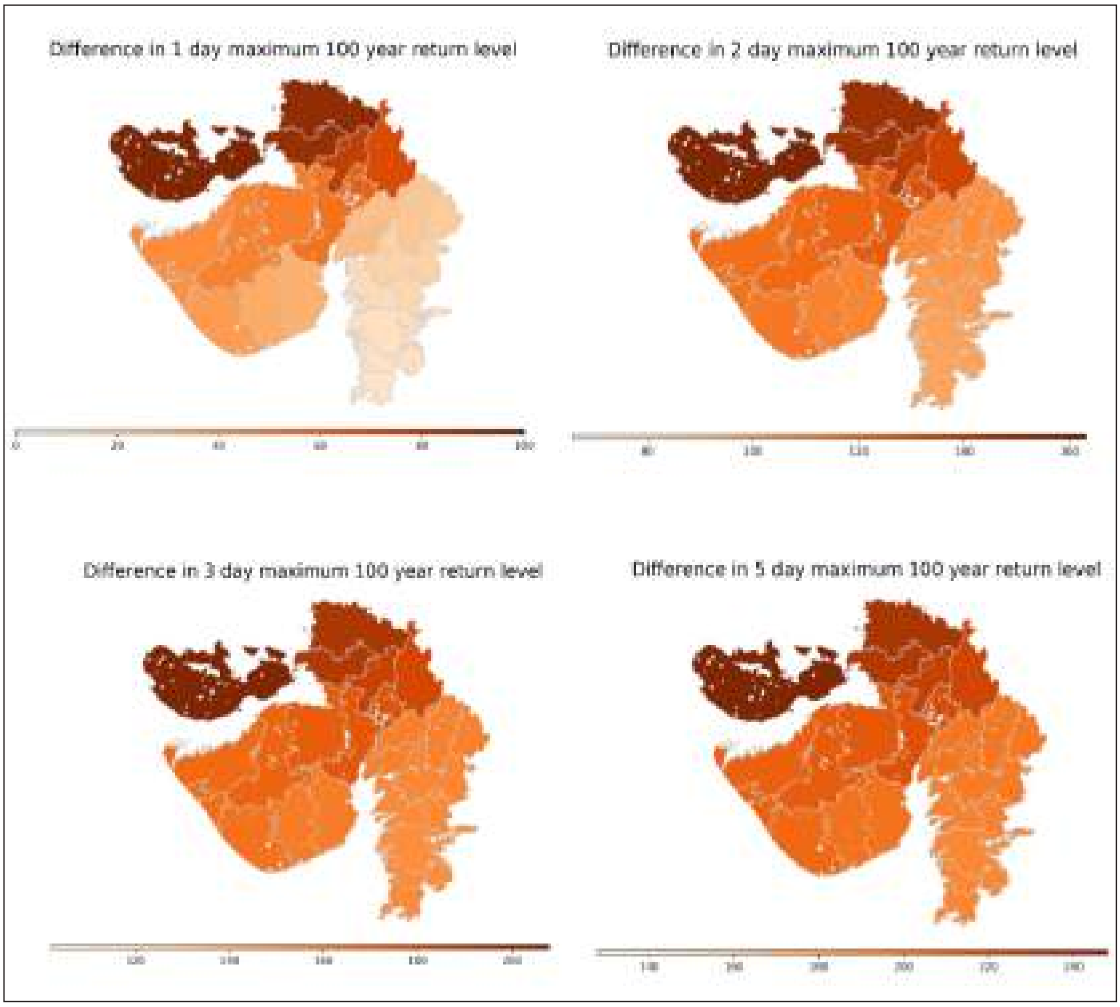
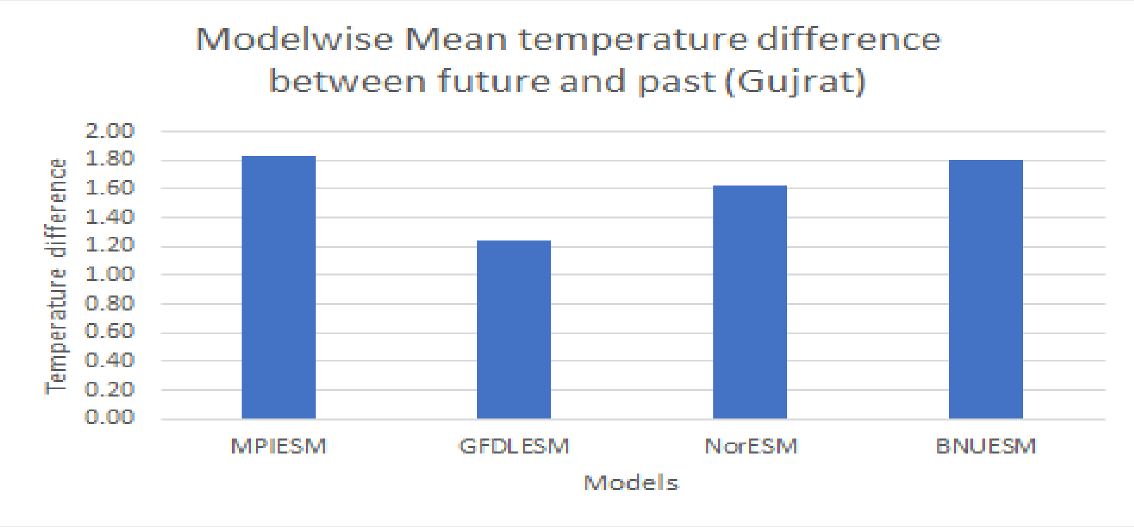


Figure 4.6: Absolute Difference in 100-year return levels between period (2037-2080) and (1981-2015)



Temperature and precipitation can be related by the Clausius Clapeyron's relationship according to which the saturation vapour pressure increases as the temperature increases and hence the moisture holding capacity also increases which can be the reason for increased magnitudes of precipitation extremes. From the above map of temperature difference (Figure 4.6), it is clear that on an average, 2-degree Celsius of temperature increase is projected in the future and hence due to this warming, precipitation extremes can be expected to rise in magnitude though there many uncertainties associated with it like, in the mountainous region, in India, its Himalayan region where the uncertainty is very much in both the projected temperature and precipitation. As in that area, orographic precipitation is dominant which is unpredictable as the weather can change instantly and sudden pour may occur at any time hence, accounting for it is not a trivial task and involves many uncertainties. Figure 4.7 shows the histogram of average temperature difference in Gujarat state according to the 4 models under RCP 8.5 scenario.

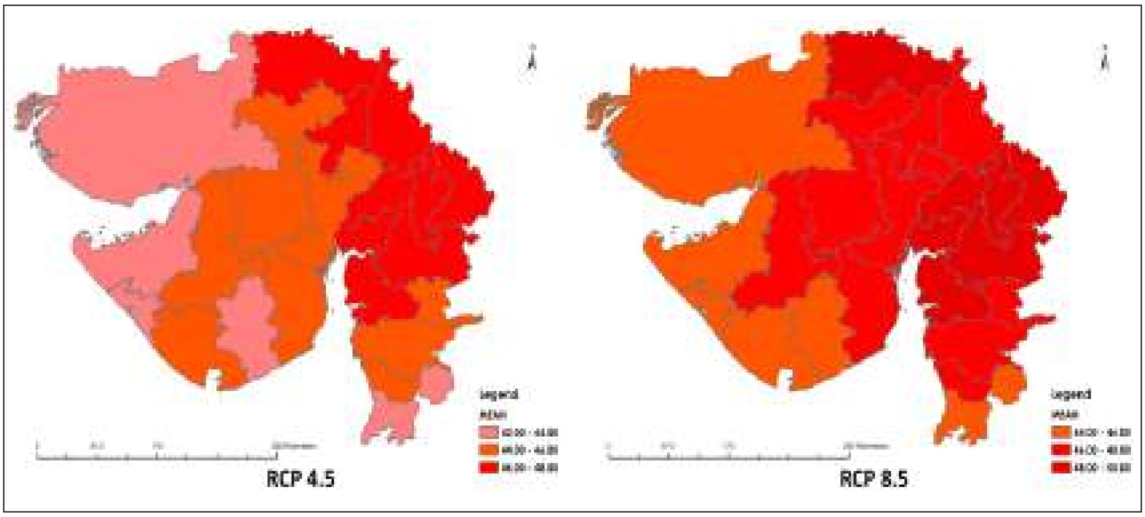
Figure 4.7: **Average temperature difference in Gujarat state according to the 4 models under RCP 8.5 scenario.**



4.3.1 Vulnerability and Temperature Extremes

We apply a similar risk assessment framework to understand the risks from extreme temperature events for various districts of Gujarat. To evaluate the risk, we use returns level estimated from the Extreme Value Theory (Bhatia & Ganguly, 2019). We calculate the magnitude of the 50-year return period of daily maximum surface temperature (tasmax). From a policy perspective, 50-year R.L. can be interpreted as the value of tasmax, which, on an average, have a change of occurrence of once in fifty years. One of the key challenges to adaptation in the context of climate change is the deviation from normal trends. Hence, in addition to absolute values of the return level for historical scenarios, we also compute the relative change in return levels of tasmax averaged for districts of Gujarat (Figure 4.8). We consider two future scenarios: RCP 4.5 and RCP 8.5.

Figure 4.8: **50-year return level for the two scenarios (RCP 4.5, RCP 8.5) for various districts of Gujarat exhibits a consistent upward shift in temperature extreme across districts. Specifically, eastern districts exhibit extreme temperatures as high as 48-50 degrees Celsius, which can be particularly challenging to adapt to - for both urban and natural ecosystems.**



In addition to absolute values of return level, relative changes in the magnitude in future scenarios are more relevant for stakeholders and infrastructure managers for design purposes. Hence, we measure the percentage change in return levels for the two future scenarios for historical levels. Specifically,

$$\Delta RL_{50}^{scenario} = \frac{RL_{50}^{scenario} - RL_{50}^{historical}}{RL_{50}^{historical}} \times 100$$

We notice while south-eastern districts consistently exhibit higher absolute magnitudes of 50-year return levels, north-eastern districts show higher percentage changes. In RCP 8.5 scenarios, these changes are as large as 9%, which could pose severe health challenges in the context of human health and could result in increased fatal and non-fatal health outcomes (Diaz, 2002) & (Azhar et al, 2014). Relative change (in percentage) in the 50-year return level for the two scenarios (RCP 4.5, RCP 8.5) for historical scenarios for various districts of Gujarat exhibits a consistent upward shift in temperature extreme across districts. Specifically, north-eastern districts show more significant relative changes for both scenarios

Figure 4.9: Relative change (in percentage) in the 50-year return level for the two scenarios (RCP 4.5, RCP 8.5)

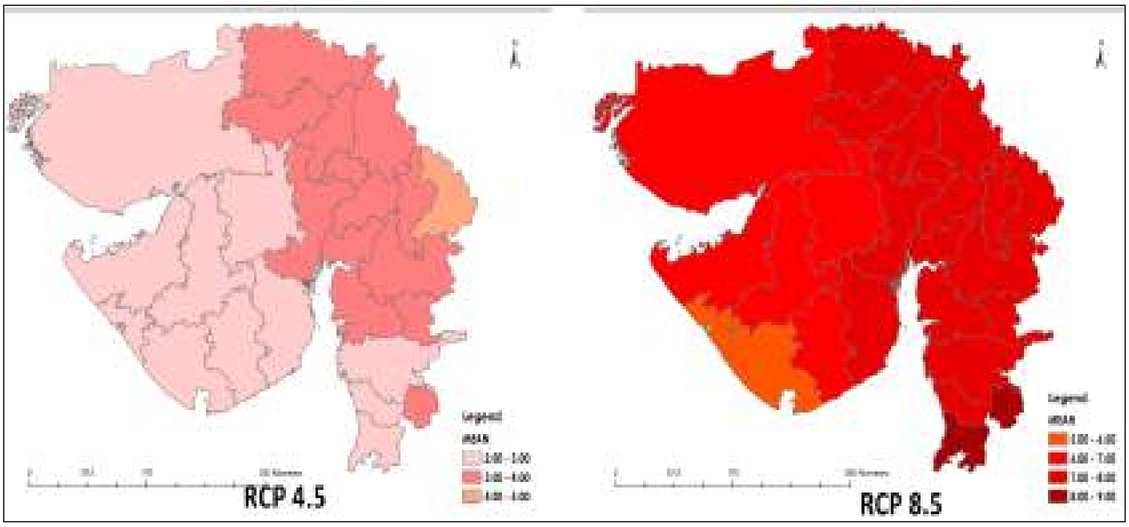
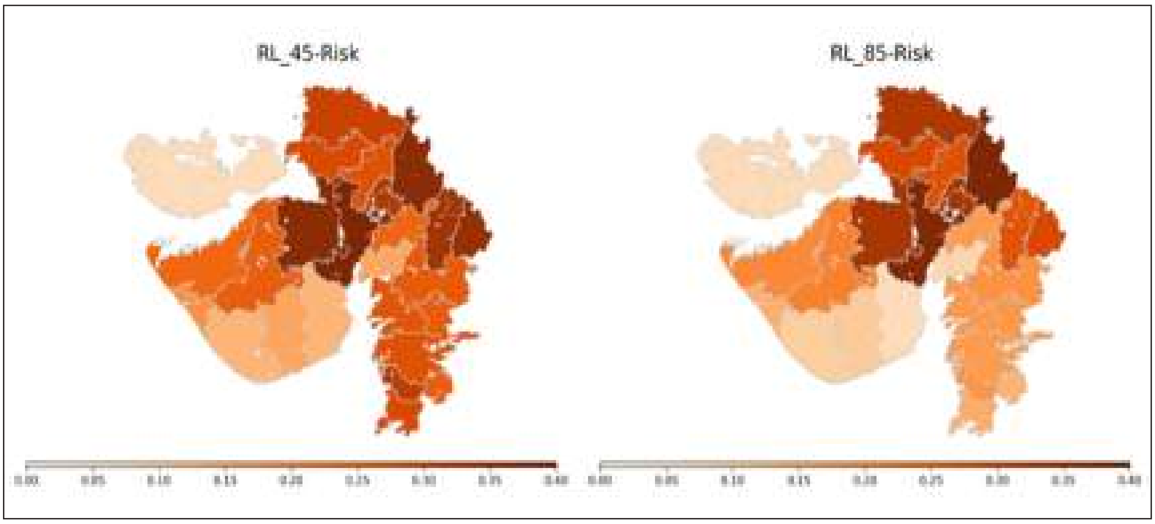


Figure 4.10: Risks to the extreme temperature combined with socio-economic indicators obtained from census data.

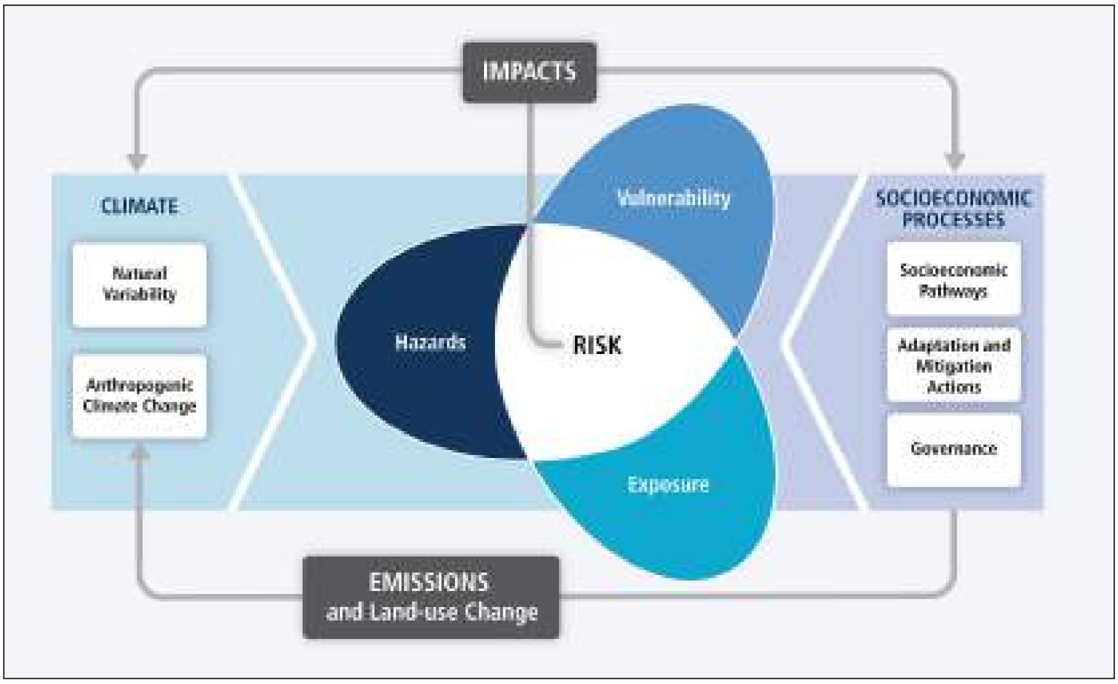


Finally, we combine the socio-economic indicators used in the section on precipitation extremes to compute overall indicators of risk due to extreme temperatures. Analogous to study on precipitation extremes, we use the tasmax return levels to calculate exposure, and various drivers of socioeconomic vulnerability to quantify the vulnerability component of risk. We notice that for both the scenarios, the risk is concentrated in north-eastern and central districts of Gujarat, which can be attributed to higher exposure levels (quantified through relative changes in return levels of heatwaves) as well as a higher population density.

4.3.2 Summary

In this chapter, we develop the methodology of vulnerability assessment that accounts for both precipitation and temperature extremes (hazard), leverage census data to compute various indicators of vulnerability and assimilate the hazard and vulnerability data to give us an overall assessment of overall risk on vulnerable groups in changing climate. In this chapter, we used the definitions and indicators in line with recommendations of Working Group II of Intergovernmental Panel on Climate Change (IPCC) with relevant adaptations in Indian context. We consider two emission scenarios from Climate Model Intercomparison Project 5 (CMIP5) and evaluate the risk levels for both precipitation and temperature extremes for all districts of Gujarat. We note that indicators such as urban factors, health indicators, employment status are integrated into our measures of risk, which are critical drivers of reliable risk indicators or mitigation and adaptation planning.

Figure 4.11: Schematic of the interaction among weather and climate extremes, indicators of vulnerability, and exposure.



Source: IPCC (2014)

The key points summarizing our insights are as follows:

In the context of precipitation extremes, the western districts of Gujarat exhibit higher levels of risk, specifically due to changes in the return level or probability of exceedance of various durations. From policy perspective, this would translate to adaptation challenge for infrastructure managers as north-western Gujarat classified as extremely arid region.

Hence, infrastructures including roadways, water resource structure are designed for the return levels estimated from historical records. However, significant shift in trends and in certain cases trend reversal would require revisiting design standards and engineering practices in these regions.

In addition to intensified exposure, western and central districts also exhibit higher magnitudes of vulnerability which can be attributed to higher fraction of marginalized workers, limited healthcare facilities in the remote areas and sparse transportation networks. Adaption planning and risk management measures in these areas need to account for strengthening of the essential functionalities and generate sustainable employment opportunities and healthcare packages to prepare against unanticipated but no longer surprising extremes.

Various studies on extreme temperature have projected consistently larger increases in the highest percentiles of summer and winter temperature maxima and minima versus the respective lowest percentiles, resulting in a wider range of temperature extremes in the future (Kodra & Ganguly, 2014). In agreement with the literature, we note similar insights even at much finer spatial resolution.

In the context of temperature extremes, north-eastern and eastern districts of Gujarat exhibit higher levels of risk, specifically due to changes in the return level or probability of exceedance of maximum surface temperature. It is noted that these regions also coincide with the regions of high population density and urbanization. While state of Gujarat has grown tremendously in terms of canal density and water resource management projects (including Sardar Sarovar Dam and Narmada Canal network), little to no attention has been paid to heatwaves adaptation. There is ample scope to learn lessons from various cities in the west (including Brookline in Boston), which have designed public facilities to adapt to heatwaves and intensifying temperature extremes.

CHAPTER 5

CLIMATE CHANGE STRATEGY-MITIGATION

Gujarat Tourism Department has developed the National Salt Satyagraha Memorial at Dandi, Gujarat. The operations of this memorial are powered by 41 solar trees
Picture Courtesy: : Arpit, shutterstock.com

Climate Change Strategy-Mitigation

Considering the dire need of GHGs mitigation, Gujarat has adopted a multi-dimensional approach to realize its commitment towards building a climate resilient and sustainable low-carbon future.

The energy sector in Gujarat is a major contributor to GHG emissions. Fossil fuels account for 69% of installed capacity and 81% of power generated in Gujarat. In contrast, nuclear, hydro, and renewables have 31% of installed capacity but account for only 14% of electricity production as of 2018-19 (Buckley & Shah, 2019). According to the GHG emissions inventory (GEER, 2010), 25% of the total emissions in Gujarat are from the power generation industry. On the demand side, industries, agriculture, and domestic consumption account for 43%, 22%, and 16% of the total electricity consumed in the state, respectively (IRADe, 2015). Gujarat is one of India's most industrialized states, and is a leader in the petrochemical, crude oil refining and chemical industries. As of 2017-18, Gujarat had more than 3.3 million micro, small, and medium scale enterprises (MSMEs) employing around 6.1 million people (Ministry of MSME, 2018). Manufacturing, construction and industrial processes, and product use (IPPU) account for 32% of emissions in Gujarat. Agriculture contributes 18% to the total emissions in the state, of which half is due to methane released by livestock.

5.1 India's NDC on mitigation

India's Nationally Determined Contributions (NDCs) outline the mitigation strategies for the country as a part of its commitments towards the Paris Agreement. Three out of the eight NDC goals from India target mitigation activities. Goal 3 aims to reduce the emissions intensity of the GDP by 33 to 35 percent by 2030 from 2005 level. In order to achieve this, the Government of India has identified priority areas that include efficient and cleaner thermal power generation, reducing emissions from transportation, emissions reductions from waste sector, and promoting energy efficiency. Goal 4 pushes the renewable energy capacity in the country. The goal targets 40 percent cumulative electric power installed capacity from non-fossil based sources by 2030. The 5th goal of India's NDC is to create additional carbon sink of 2.5 to 3.0 billion tonnes of CO2e through additional forest cover by 2030. The NDC targets are supplemented by the policies and actions of the state governments.

5.2 State Policies, Measures and Mitigation Actions

5.2.1 Energy Sector

The state envisions "universal access to affordable, adequate, reliable, modern and sustainable energy". In pursuit of this overarching agenda, Gujarat has created several policies to provide clean, sufficient and affordable energy to its citizens.

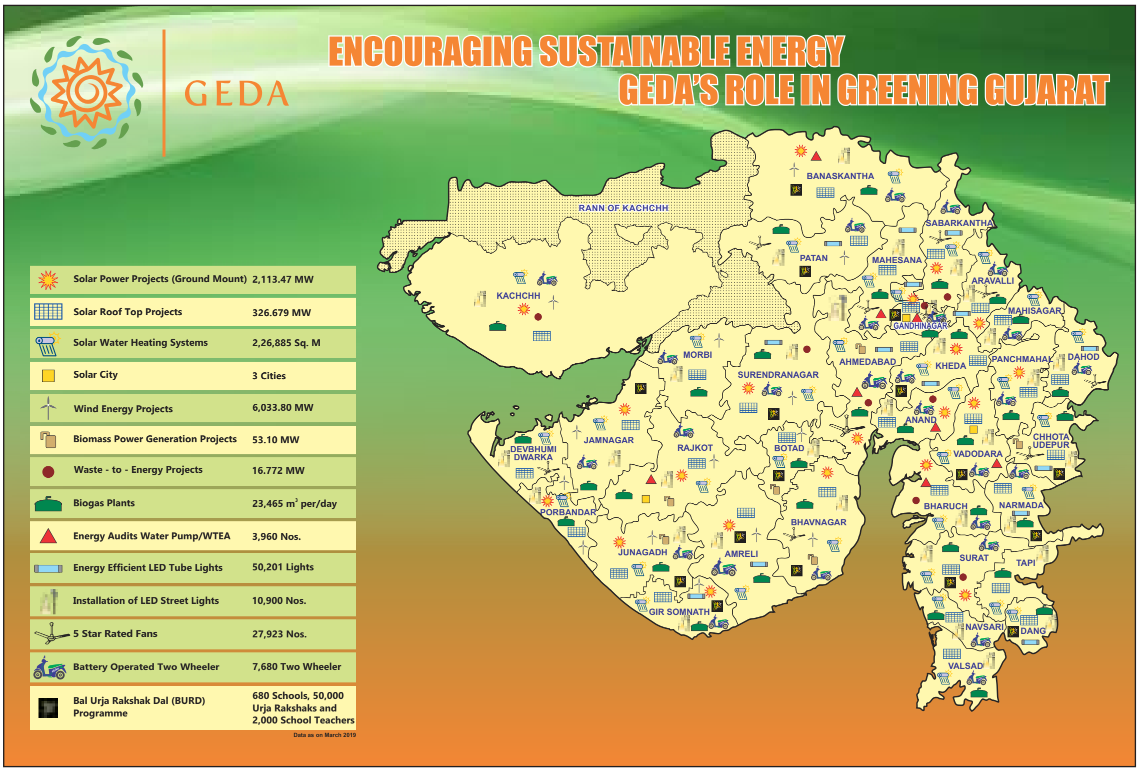
5.2.1.1 Renewable energy

Renewable energy plays an important role in reducing emissions and therapy addressing climate change. Gujarat is rich in renewable energy resources. On one hand it has 300 days of sunshine with relentless sun's heat and on the other hand it has the longest coastline of over 1600 km to capture wind energy. Moreover, the possibility of using vast wastelands for energy plantation along with options like waste to energy make Gujarat a potential hub for renewable energy harnessing.

With this background, Gujarat intends to increase the share of renewable energy in its energy mix. To achieve this, it is following a comprehensive policy driven approach. Furthermore, as part of Gujarat's commitment towards combating threats of climate change and ensuring capacity addition of 30000 MW by December 2022, several conducive policies like Gujarat Solar Power Policy, Gujarat Wind Power Policy, Solar-Wind Hybrid Policy, Waste to Energy, Small Hydel Policy, Tariff for Biomass based power generation and Waste Water Policy have been launched.

Based on current capacity as well as potential generation capacity, Gujarat is one of India's leading states for renewable energy. Figure 5.1 shows the renewable energy map of Gujarat. In order to promote a low cost, low-emission, deflationary, domestic renewable energy driven electricity system in Gujarat, GEDA's challenge has been to make the renewable energy and energy efficient technologies economically and commercially viable. Projects that have involved power generation from wind, solar photovoltaic and biomass have successfully demonstrated that renewables are here to deliver grid-quality power. Experiments in decentralized energy supply models especially for solar cooking, solar water heating systems in the domestic and industrial sectors and decentralized power generation projects are successful case studies that can be replicated from small to large scale levels.

Figure 5.1: Renewable Energy Map of Gujarat



Source: GEDA

5.2.1.1.1 Wind Power Policy

Given the potential of wind power generation in the state, the first demonstration wind farm project was set up by GEDA in 1986 at the Okha coast followed by few more demonstration wind farms with an aggregate capacity of 16.29 MW. The satisfactory performance and operation of these demonstration wind energy generating projects, led to an incentive scheme in 1993, inviting private sector participation in the Wind power generation sector. Private sector investment led to wind farm capacity of 149.55 MW during the period from 1993 to 1998. Subsequently, the state government has launched a succession of policies to encourage private sector participation in wind power generation. The Gujarat Wind Power Policy 2016 will remain in effect until 30th June 2021. Wind projects installed and commissioned during the operative period shall become eligible for the benefits and incentives declared under this policy, for a period of 25 years from their date of commissioning or for the lifespan of the projects, whichever is earlier. The state's total wind capacity by mid- 2019 stood at about 6.5GW. Following a recent bid, Gujarat Urja Vikas Nigam Ltd. GUVNL awarded a total 745GW capacity expansion. Some of India's leaders in renewable energy development like Inox Wind, ReNew Power and Adani Green Energy are among those with wind energy projects in Gujarat.

The vast coastline of state makes for very attractive locations for wind energy production in Gujarat. The estimated potential is 85GW while the installed capacity is 7.5GW.

Picture Courtesy: Hardik Joshi, Unsplash.com

5.2.1.1.2 Solar Power Policy

Gujarat has aggressively promoted solar power generation with a landmark Solar Power Policy 2009. In 2015, the new Solar Power Policy was launched with the following aims:

- To promote green and clean power, and to reduce the State's carbon emission.
- To reduce dependency on fossil fuels in order to achieve energy security and sustainability.
- To help reduce the cost of renewable energy generation.
- To promote investment, employment generation and skill enhancement in the renewable energy sector.
- To promote productive use of barren and uncultivable lands.
- To encourage growth of local manufacturing facilities in line with the 'Make in India' programme.
- To promote research, development and innovation in renewable energy.

The Canal Solar Power Project is a project that aims to use the 19,000 km long network of canals across the state for setting up solar panels to generate energy. Hon'ble Prime Minister of India, Shri. Narendra Modi (Then Chief Minister of Gujarat), launched the project by inaugurating a pilot project on 24 April 2012 on the Narmada branch canal near Chandrasan village of Kadi taluka.

The first solar park – Charanka Solar Park or Gujarat Solar Park-1 developed near Charanka village in Patan district was inaugurated in 2012 over a land plot of 2000 hectares. The Installed capacity is at about expected to grow up to 790 MW. Further, three more solar parks at Dholera SIR (installed capacity of 5 GW), Harshad and Radhanesda are at various stages of implementation.

Another glaring example of the solar energy feat in Gujarat is the Sardar Patel Stadium at Motera. It is one of the world's largest cricket stadium and India's first green-rated stadium. The stadium houses solar power plant for powering its utilities along with 100% of lighting through energy efficient LEDs.

Large institutional consumers have also been encouraged to take up solar power generation for captive use as well as grid feed-in. This picture shows the solar rooftop installations at Indian Institute of Management Ahmedabad. The total installed capacity is currently 365 KW leading to emission savings worth 450 Tonnes-CO2 equivalent annually

Picture Courtesy: IIM Ahmedabad

5.2.1.1.3 Solar rooftop scheme

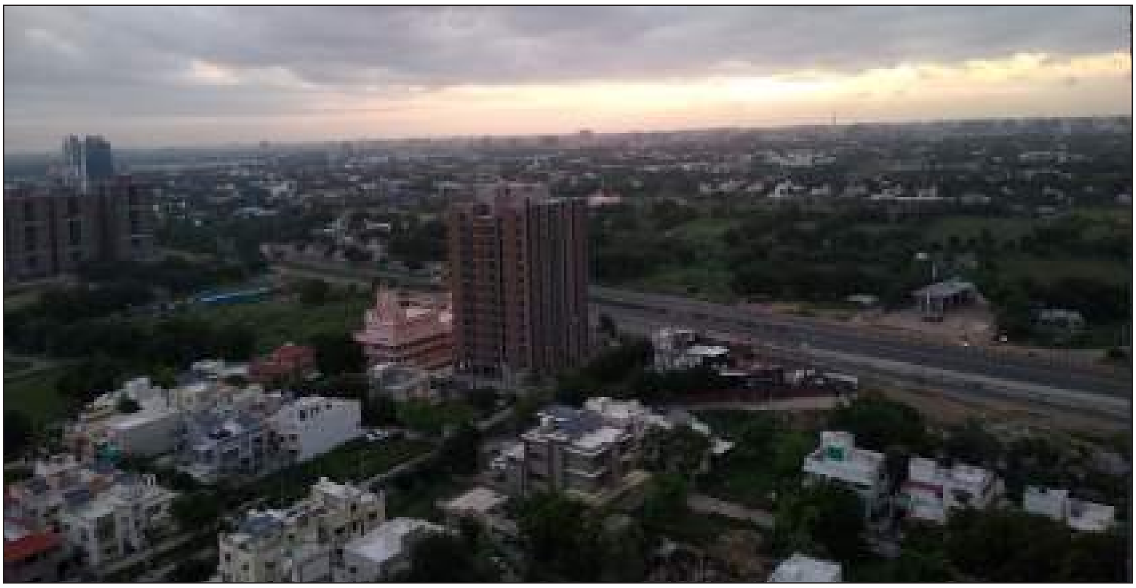
The residential rooftop solar project scheme of the Government of Gujarat is being implemented through Gujarat Energy Development Agency (GEDA). The scheme allows for beneficiaries to install minimum of 1 kW capacity of solar PV systems. 30 per cent subsidy on the cost of the solar PV installation comes from the central government while the state provides a maximum of Rs.20000. The state plans to cover 2 lakh houses under this scheme by March 2020.

Gujarat is leading the on-the-metre rooftop solar capacity in India with about 262 MW installed capacity as in mid-2019. The Government of Gujarat announced a policy for promotion of solar roof tops on 31st March 2016 in residential sector, providing a subsidy of Rs. 10,000/ kW with a maximum ceiling of Rs. 20,000/- for residential category of the consumers of the DISCOM. The Government of India also announced a subsidy for residential and institutional sector at 30% of its derived benchmark cost or discovered price by the states, whichever is less. The Gujarat Government's 2019-2020 budget has the provision for a rooftop solar photovoltaic (PV) program that expects to cover 200,000 families during the year with a subsidy of up to 40% of the capital cost for rooftop solar projects of capacity 3 kW and a subsidy of 20% on the system cost for rooftop solar projects in the range of 3 kW to 10 kW. This will be an added incentive on the subsidy already being provided by the central government and expected to help in faster adoption of rooftop solar PV by the residential customers.

Promoting Solar Irrigation Pumps: The Government of India's KUSUM (Kisan Urja Suraksha evam Uhaan Mahaabhiyan) is a scheme that subsidises solar irrigation pumps (SIPs) for farmers for agricultural uses. Under this scheme, the government will provide a 60% subsidy to a farmer for setting up of pump sets and tube wells on their land.

The following are the list of benefits under Kusum Yojana:

- Farmers will be provided with the option to sell the extra power directly to the government that would help the farmers with additional income
- The government has also taken the initiative to construct plants that would generate solar power. As per the draft, these plants are capable of generating a total of 28,250 MW power
- Apart from the solar power plants, the government work towards the new solar pumps with the diesel pumps that hold the capacity of 720 MW
- This scheme also provides farmers with the opportunity to earn extra money by installing solar pumps. The amount of energy generated extra, can be sold to the government
- Every farmer will be getting a huge subsidy on this new and improved solar powered pump. The farmers will have to raise only 10 per cent of the total cost for this purpose
- The central government will be providing 60% subsidy to the eligible farmers on the total cost of the solar pump, and the remaining 30% of the cost will be provided as credit by the banks
- The increased use of solar power and electricity from solar plants will lower the pollution level in the farm



Gujarat is ranked 1st in India in the implementation of roof-top solar projects with 107055 systems installed to generate 611 MW electricity.

Picture Courtesy: Vidhee Avashia

5.2.1.1.4 SKY Scheme

The Suryashakti Kisan Yojana (SKY) Scheme was launched in June 2018 with an aim to provide solar panels to the farmers with existing electricity connection. The scheme has been structured to provide the farmer with a 35 per cent affordable loan and a total subsidy worth 60 per cent share of the cost from the state and the centre while the farmer takes up the 5 per cent cost. This scheme allows for the farmers to feed-in the surplus solar electricity production. The scheme aims to cover 12,400 farmers across the state's 33 districts as a part of the pilot project that is expected to generate 175 MW at a cost of almost Rs. 870 crore.

5.2.1.1.5 KUSUM scheme

The KUSUM scheme or Kisan Urjas Suraksha evam Uhaan Mahaabhiyan (KUSUM) is a Government of India initiative to subsidize solar powered irrigation pumps for farmer. This increased use of solar power aims to lowering the irrigation related emissions from agriculture sector. Government of Gujarat's SKY scheme will be taken forward under the KUSUM scheme.

The PM-KUSUM scheme succeeds the SKY scheme of Gujarat government that subsides use of solar water pump for agriculture purposes.

Picture Courtesy: Dreamstime.com

5.2.1.1.6 Wind Solar Hybrid Policy

This policy formulated in 2018, aims to facilitate setting up of large grid-connected wind-solar PV hybrid projects that help achieve optimized grid infrastructure and enable grid stability. The operation period for this policy is 5 years while the projects approved under this policy would be eligible for benefits and incentives for 25 years. This policy also encourages the use of emerging technologies in the energy storage domain. Gujarat Energy Development Agency (GEDA) has been nominated as the nodal agency for implementation of this policy. The policy has provisions and modalities for the projects to avail Renewable Purchase Obligations; Renewable Energy Certificates as well as Clean Development Mechanism.

5.2.1.1.7 Gujarat Repowering of Wind Projects Policy

This policy allows for repowering of existing wind turbine generators of 1MW or less capacity that were installed under policies at less capacity at high wind energy potential sites. The policy extends the incentives provided by Government of India's Wind Repowering Policy to the projects located in the state. GEDA is the nodal agency for implementing this policy.

5.2.1.1.8 Gujarat Small Hydel Policy 2016

The policy envisions participation of investors in setting up of micro hydel power projects of up to 100 KW, mini hydel projects between 101 and 2000 KW (unit size up to 1 MW) ad small projects of 2 to 25 MW (unit size of up to 5 MW) across the rivers, streams and canal networks. The policy provisions consider the benefits of Renewable Purchase Obligations; Renewable Energy Certificates as well as Clean Development Mechanism for the hydel projects. A total of 1849 million units of hydroelectricity was consumed in the state in 2019-20. GEDA has been nominated as the nodal agency for implementation of this policy and enabling the project developers in their efforts to setting up clean and green power generation units.

5.2.1.1.9 Grid connected biomass based power projects

In the lines with Ministry of New and Renewable Energy, Government of India's scheme to promote biomass based Cogeneration, the state government also laid out an incentive based scheme for bagasse based co-generation for the captive requirements of sugar mills as well as the option to sell the surplus power to the state electricity board.

5.2.1.1.10 Renewable Energy Certificates (RECs) and Renewable Purchase Obligations (RPOs)

Under the NAPCC, the Government of India envisioned renewable energy generation as a key transition to fight global climate change. The targets under the national strategy were further assigned to each state to form their Renewable Purchase Obligation (RPO). Since all states do not have equal renewable energy generation potential due the varied geography of India, the Renewable Energy Certificate (REC) mechanism was launched by the Government of India in 2010. This mechanism provides for the trading of renewable energy certificate between the renewable energy generators and the obligated entities under the RPO. Gujarat has 42 accredited generators and the minimum quantum purchase by the Gujarat Electricity Regulatory Committee (GERC) has been put at 5 per cent from solar and 8.25 per cent from non-solar sources for 2021-22.

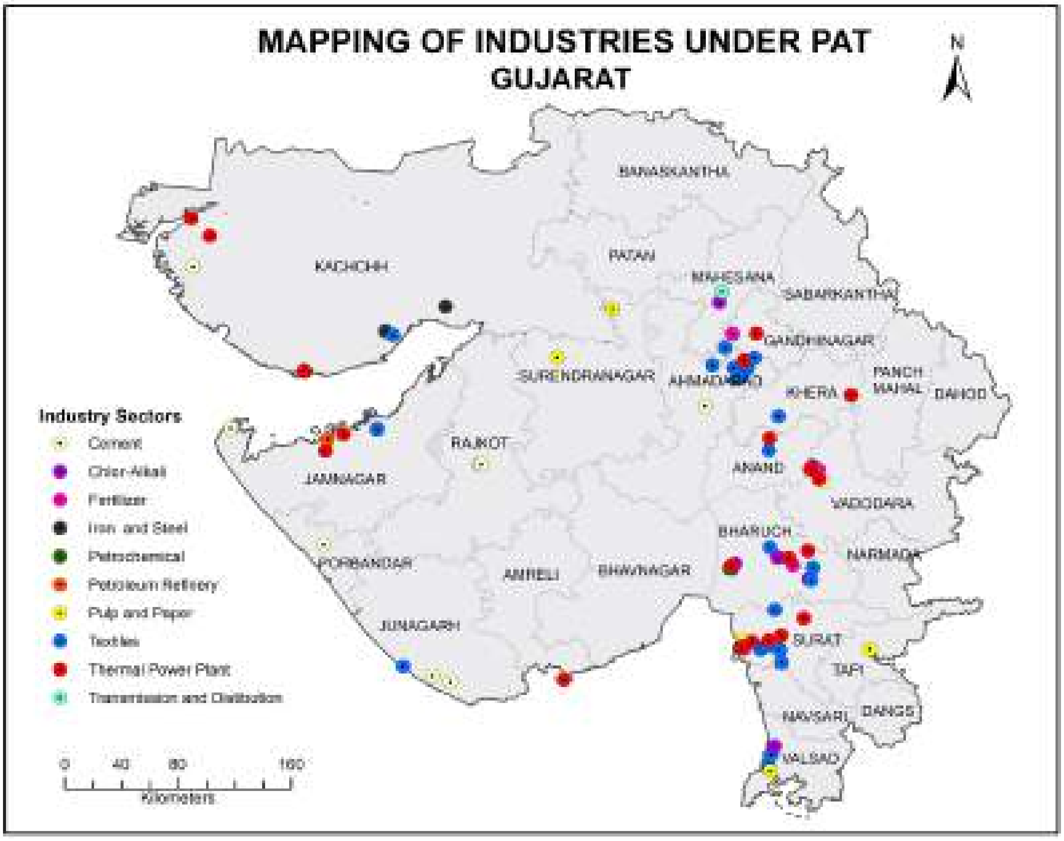
Gujarat has taken up a strategic decision to not build new coal based thermal plants in the state.
Picture Courtesy: shutterstock.com

5.2.1.2 Energy Efficiency

5.2.1.2.1 PAT

Perform, Achieve and Trade (PAT) Scheme is a flagship initiative under the National Mission for Enhanced Energy Efficiency (NMEEE). PAT is a market-based mechanism focused on reducing the specific energy consumption (SEC), in large energy-intensive units. It is a regulatory instrument to reduce SEC in energy intensive industries, with an associated market-based mechanism to enhance cost effectiveness through certification of excess energy savings, which could be traded. Energy Savings Certificate (ESCerts) are issued to the industries which reduce their SEC beyond their target. Those companies which fail to achieve their target are required to purchase ESCerts for compliance else are liable to be penalised. Trading of ESCerts are conducted on existing power exchanges. The Ministry of Power (MoP) has notified industrial units and other establishments consuming energy more than the threshold in 13 sectors namely Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chlor-Alkali, Iron & Steel, Aluminium, Railways, petroleum refinery, Electricity Distribution Company, petrochemicals and Commercial Buildings Sector for this scheme. 537 units in Gujarat have opted for PAT Scheme (Figure 5.2).

Figure 5.2: Map showing the designated entities under PAT scheme from Gujarat



5.2.1.2.2 Domestic Efficient Lighting Programme (DELP)/ UJALA scheme

On 1st May 2015, Unnat Jyoti by Affordable LEDs and Appliances for All (UJALA) was launched, replacing the "Bachat Lamp Yojana". Within 1 year of its launch, 90 million LED bulbs were sold in the country, reducing the electricity bills by ₹55 billion (US$860 million). The scheme was announced as "Domestic Efficient Lighting Programme (DELP)" on 5 January 2015, and urged the people to use LED bulbs in place of incandescent bulbs, tube lights and CFL bulbs as these are more efficient, long-lasting and economical in their life cycle duration. As on October 2018, more than 312 million LED bulbs have been distributed, leading to a reduction of about 33 million tonnes of CO2 per year (MoP, 2018c).The UJALA dashboard numbers suggest 366 million LED bulbs, 7.2 million tube lights and 2.3 million efficient fans have been distributed by October 2020 across India. Gujarat's share in this stood at 41.41 million LED bulbs, 1.27 million tube light and 0.64 million efficient fans.

5.2.1 Industry

Gujarat is one of the industrialized state in India. 16.8 per cent share of India's industrial output comes from Gujarat- largest across states. It is also a leader in exports with 20 per cent share in India's total exports. Gujarat is a global leader in processed diamonds and 3rd largest producer of denim globally. It also hosts the world largest petroleum refining setup. The manufacturing sector in Gujarat covers 7 major categories of Industries- textile and textile machinery, chemical machinery parts, engineering, automobile and auto parts, gems and jewellery, pharmaceutical, ceramics, and Electronic system design and manufacturing. Gujarat is a leader in production of Soda ash, Salt, and Petrochemical downstream products making the share of Gujarat's manufacturing output at 13 per cent of India's total output. Almost 45 per cent of the total main worker population of is involved in non-agricultural activities as per the Census of India, 2011. The industrial power demand in Gujarat has reached almost 200 million units per day and water consumption has been almost 350 million litres per day by 2019. The estimated emissions from the Industrial Processes and Product Use are 24091 Gg CO_2e by 2016.

Gujarat's share in India's pharmaceutical manufacturing market stands at almost 33 per cent. With permissions for 214 new plants to come up in Gujarat, this share is expected to rise to 40-42 per cent in near future. Zydus Cadila one of the prominent organizations based in Gujarat are actively developing a vaccine against COVID-19.

Picture Courtesy: zyduscadila.com

5.2.2.1 Micro, Small and Medium Enterprises

There are several industrial clusters that are being promoted in Gujarat through several initiatives and policies. Currently, there are 83 industrial clusters for different industry groups consisting of small and medium enterprises. The approach of cluster-based development has helped in improving cost competitiveness of the industries by way of creating common facilities, developing market centres and brand names, promotion of skill. Some of these clusters as identified by the Industries Commissinerate are listed here:

- Brass Parts in Jamnagar
- Castings & Forgings in Ahmedabad, Bhavnagar, Jamnagar, Rajkot, Vadodara, Anand
- Ceramics in Morbi, Thangadh, Himatnagar, Ahmedabad
- Chalk Industry in Porbandar
- Dyestuff in Ahmedabad

Gujarat is the leader in textile comprising of 1,560 medium and large textile unit that contribute to more than 25 per cent of India's textile output.

Picture Courtesy: dreamstime.com

- Data Processing in Ahmedabad, Surat
- Diamond Processing in Ahmedabad, Surat
- Fabrication in Ahmedabad, Vadodara
- Fish processing in Veraval
- Jari-Printing in Surat
- Machine Tools in Rajkot
- Oil Engines in Rajkot
- Power driven pumps in Ahmedabad, Mehsana
- Readymade Garments in Ahmedabad
- Re-rolling Mills in Bhavnagar
- Salt in Anjar, Gandhidham, Dasada
- Textiles in Ahmedabad, Dholka, Surat

- Textiles-Ginning in Ahmedabad, Manavadar
- Textiles-Printing in Jetpur
- Textiles-Khadi in Wadhvan
- Textiles-Finishing in Bhuj
- Textiles-Synthetic in Surat, Mangrol
- Textiles-Powerloom in Ahmedabad, Surat
- Testile-Handprinting in Jetpur
- Textile Stores in Ahmedabad, Surat , Wadhvan
- Utensils in Ahmedabad, Vadodara
- Wood based in Nadiad
- Book Publishing in Ahmedabad

Gujarat is the largest milk producer in India contributing almost 8 per cent of India's total milk production. There are 17 Cooperative dairy milk unions & 25 private dairy plants with Anand Milk-producers Union Limited (AMUL) being one of the biggest brand in India, located in Anand. Moreover, around 30,000 food processing units are operating in Gujarat providing employment to over 1 million people.

Picture Courtesy: https://commons.wikimedia.org/wiki/File:Amul_Plant_at_Anand.jpg

5.2.2.2 Start Ups - Innovation Scheme

In Government of Gujarat's new Industrial Policy - 2015, assistance for Start-Ups/ Innovation has been declared. Under this scheme entrepreneur get assistance for their entrepreneurial mindset. The budget provision of Rs. 1900 lakh has been made in the year 2019-20 for this scheme. The scheme focuses on technological development as well as products, processes and services for industrial, cleantech, IT/ITES and Biotech sectors especially encouraging students and women.

5.2.2.3 Petroleum, Chemicals and Petrochemicals Investment Region (PCPIR)

The PCPIR is located at Dahej, South Gujarat, PCPIR is India's first specially delineated investment region of 453 sq. km. for manufacturing of petroleum products, chemicals and petrochemicals. With the coming of DFC, DMIC, Bullet Train and the Express Highway linking Baroda to Mumbai, the prospect in PCPIR is further expected to boost. Three new LNG terminals and a greenfield airport have also been planned in/ around the PCPIR. To meet the increasing demands of land by industries, GIDC has developed a chemical zone in Saykha.

The Hazira transshipment port and industrial hub houses large industrial complexes of Essar, Kribhco, Shell, Larsen & Toubro, NTPC, ONGC, GAIL, GSEG power plant, Gujarat State Petroleum Corporation, UltraTech Cement and Hazira Manufacturing Division (HMD) of Reliance Industries.

Picture Courtesy: https://commons.wikimedia.org/wiki/File:Hazira_Industrial_Area,ONGC.jpg

5.2.2.4 Dholera Special Investment Region (D-SIR)

Dholera SIR in Gujarat is India's largest greenfield industrial investment region, spread over 920 sq. km. DSIR will have smart & sustainable infrastructure spanning transportation, water, power, waste-water, drainage and urban design. Its focus sectors include: Heavy Engineering, Automobiles & Auto ancillary, Defense, Electronics, Hi-tech technologies, Agri & Food processing and Infrastructure. The world's largest solar park of 5 GW is also being developed at Dholera SIR. 6 TP schemes are approved for development of Dholera SIR as smart city. It will be connected with Ahmedabad by a 6-lane access-controlled expressway & Metro Rail Transit System (MRTS) in one common corridor providing seamless connectivity. An international airport is being developed at Dholera SIR giving swift international and domestic connectivity to the region.

5.2.2.5 Mandal Becharaji Special Investment Region (MBSIR)

MBSIR Is emerging as a Auto-Hub. Its become a favoured destination for Japanese automobile and auto component manufacturing industries. Companies such as Suzuki Motor Corp., Honda Motorcycles, Scooter India Pvt. Ltd, and Toyota Tsusho India have already established their units. Located at around 90 kms. from Ahmedabad, the region is well connected to leading ports, airport, railroads and National highway (NH) roads.

5.2.2.6 Diamond Research and Mercantile (DREAM) City

Diamond Research and Mercantile City - A Smart City being developed close to the diamond capital of India – Surat, to promote diamond trading from Gujarat at an estimated project cost of INR 2400 Crore (~USD 350 Million). Spread over 2,000 acres, DREAM City will house an International Diamond Trading Hub and a Diamond Bourse.

5.2.2.7 ZED (Zero Defect in Manufacturing and Zero Effect to Environment)

This initiative was launched to enhance the quality of the manufactured goods. Gujarat's manufacturing sector has imbibed ZED as a core pillar which has supported the Gujarat MSMEs carve a niche for themselves in the global supply chain.

5.2.2.8 Assistance for Environment Protection Measures-MSME units

The Government of Gujarat under this scheme provides assistance for environment management to the MSMEs. This scheme also goes further to encourage green practices and environmental audits to MSMEs through provision of Government assistance.

5.2.2.9 Assistance for Environment Protection Measures and Infrastructure

The objective of this scheme is to provide assistance to industries towards establishing efficient infrastructure for Common Environment Infrastructure Facilities (CEIFs) in PPP mode. It further provides only financial assistance for Non PPP Projects. The scheme aims to bring in clean carbon credits (CERs and VERs) and reducing carbon footprints by providing required support to the industries. Another aim here is also to support in strengthening the regulations and environmental compliance.

5.2.2.10 Industrial Policy 2020

The new policy identifies 15 thrust sectors consisting 9 core and 6 sunrise sectors. The sunrise sectors consist of climate friendly initiatives by Gujarat, namely Green Energy, Electric Vehicle and components, Green and compostable materials and waste management projects.

5.2.3 Transport

5.2.3.1 BRTS

The urban development department of the state government came up with a strategy to develop the Bus Rapid Transit System in the large cities of Ahmedabad, Surat, Vadodara and Rajkot to encourage sustainable public transportation. The first system was inaugurated in Ahmedabad a decade ago and currently covers a network of 88 kms. Surat BRT has been planned for network size of 100 kms, Rajkot has been planned for 29 kms while the Vadodara BRT is still at the design and feasibility check stage.

Ahmedabad Janmarg Limited- the public bus rapid transit system of the city has induced electric buses in their fleet. The Gujarat State Road Transport Corporation is also in process of introducing E-buses for intra-city travels

Picture Courtesy: deshgujarat.com

5.2.3.2 Ahmedabad Metro

Gujarat Metro Rail Corporation (GMRC) Limited is responsible for the development of Metro-Link Express for Gandhinagar And Ahmedabad (MEGA). The total length of the Ahmedabad Metro Rail Project Phase-I is about 40.03 km out of which approximately 6.5 km is underground, and the rest is elevated section. The project will connect 4 corners of the Ahmedabad city with 2 corridors and 32 stations. A section of Phase -1 was operationalized in March 2019. The PHPDT capacity is expected to be 10187 and 12224 on North- South and East-West corridors respectively.

MEGA- Metro-Link Express for Gandhinagar and Ahmedabad has started partial operations on its Phase -1 lines. Such public transport projects help reduce transport emissions from private vehicles

5.2.3.3 Electric Mobility

Gujarat is promoting manufacturing Electric Vehicles (EV) with a number of automobile and battery manufacturers announcing big plans for the state. Moreover, Ahmedabad is the first Municipal Corporation to provide public charging points at public parking spaces. The Government of Gujarat is also working to encourage the use of electricity driven vehicles in Gujarat. The state is in the process of formulating a comprehensive EV policy and would be launching it soon. The Government's upcoming policy proposes to:

- Incentivize the transition the State's transportation sector towards electric mobility in phases with initial aim to have 1 lakh EVs on road by 2022
- Make Gujarat a Manufacturing Hub for EV and ancillary equipment
- Encourage investment in electric mobility
- Work towards Job creation and research in electric vehicles

Gujarat has also extended subsidy on battery operated two wheelers for students, almost 8200, 2 wheelers have been subsidised till date. The Climate Change Department had also introduced a scheme for battery operated three wheelers (E-rickshaws) in 2018-19 for individuals as well as institutes. The government has also announced to install charging stations at multi-level parking lots and public places across the state. The state has also facilitated 15404 E-car penetration.

Under FAME-2 scheme of Government of India, Gujarat plans to develop EV infrastructure in the state. E-bikes for school kids and commercial E-3wheelers are already being promoted and finical support is being provided by Gujarat Government

Picture Courtesy: shutterstock.com

Gujarat State Road Transport Corporation (GSRTC) is in the process of acquiring almost 500 electric buses with the support of Faster Adoption and Manufacturing of (Hybrid) Electric Vehicles, India (FAME)- II scheme of Government of India.

5.2.3.4 CNG Sahbhagi Yojana

Gujarat has promoted the use of Compressed Natural Gas (CNG) as a fuel that can replace many petroleum products, producing fewer undesirable gases than the petrol, diesel or LPG at the time of combustion. CNG has been successfully piped to households, and is also being used in vehicles. Currently, Gujarat accounts for about 31% of India's CNG Stations. CNG Sahbhagi Yojana enables those who want to establish new CNG Pump Stations in Gujarat to apply online. This scheme has been promoted by the Government of Gujarat to increase the use of CNG as a replacement for petroleum products. The Hon'ble Chief Minister Vijay Rupani's cabinet has decided to open 300 more CNG stations in the next couple of years. The Government of Gujarat has also liberalised the norms to setup CNG stations of Gujarat Gas Company Ltd (GGCL) and Sabarmati Gas Ltd (SGL).

CNG infrastructure has developed in the state as a replacement for diesel and petrol for emissions reduction and improved local air quality

Picture Courtesy: GujaratgasCNG

5.2.4 Agriculture and Forestry

5.2.4.1 Irrigation development through Micro Irrigation Systems

The agricultural sector is among the largest consumers of electricity and water in the country. Gujarat has taken a lead in promoting micro-irrigation systems that put less pressure on water resources than traditional methods. Using filters, pipes, valves, and tubing, these systems distribute water slowly in small volumes and target it to plants' root zones with less runoff or overspray than conventional systems. On a macro level, irrigation efficiency has been improved by bringing around 3,57,000 ha of land under Participatory Irrigation Management and micro irrigation leading to an increase in yield increase along with water, fertilizer, labour and energy savings. It has been estimated that around 74.1 million units of energy has been saved in just one year due to adoption of drip irrigation popularized by Gujarat Green Revolution Company (GGRC), an implementing body for the Micro Irrigation, Protected Cultivation and the Solar Water Pump Schemes of Gujarat. This has been achieved through reputed authorized Micro Irrigation System suppliers for kits and related agro services pertaining to Micro Irrigation System.

5.2.4.2 SAUNI Yojana (Saurashtra Narmada Avataran Irrigation Project)

Saurashtra Narmada Avtaran Irrigation (SAUNI) is a project launched by Hon'ble Prime Minister Shri Narendra Modi with the objective of filling 115 major dams by diverting floodwaters overflowing from the Sardar Sarovar Dam to drought prone areas. The 332 K.M. long Sujalam Suphalam Spreading Canal which uses surplus flood water of Sardar Sarovar Dam, Narmada and the Kadana Reservoir, traverses seven districts from Mahi to Banas river taking water to water deficit areas. Nearly 1,200 cusec of surplus rainwater, overflowing the SSP and Kadana dams, is now being released to the 310-km long Sujalam Safalam Spreading Canal, which serves the Gandhinagar, Mehsana, Sabarkantha and Patan districts. These districts are situated at a higher elevation than the Narmada Main Canal Command Area. Similar efforts to divert the surplus rainwater from Narmada Main Canal (NMC) and other dams in the region have helped release total 18,600 cusec of water to recharge the seasonal smaller Heran, Karad, Kun, Sabarmati, Rupen and Banas rivers.

A large part of Gujarat experiences water scarcity and canals and bunds have played a vital role in irrigation and drinking water supply in the state.

Picture Courtesy: Commissionerate of Rural Development, Gujarat

5.2.4.3 Social Forestry Programme

Gujarat has a dedicated social forestry wing. Social forestry involves the management and protection of forest, afforestation of barren and deforested lands, and raising plantations by the people so as to meet the growing demand for forest produce thereby lessening pressure on natural forests. 90 to 100 million seedlings have been supplied annually under this programme. The Social Afforestation Scheme of Gujarat has succeeded in raising green cover at non-forest locations like along roads, river banks, railway tracks, social and institutional places, small tanks and ponds, and earlier fallow land. During an event called Van Mahotsav, saplings and seeds are distributed in order to encourage people to raise plantations. The Social Afforestation Department has provided improved heater for crematoriums which are maintained by the respective panchayats reducing the use of wood for cremation.

5.2.4.4 Mangrove Conservation

Gujarat has one of the largest mangrove densities among Indian states. The mangrove cover in Gujarat has increased from 1,107 sq km in 2019. Mangroves are salt-tolerant trees, adapted to life in harsh coastal conditions with a complex root system and salt filtration system because of which they can resist salt water immersion and wave action. They can also thrive in the low oxygen muddy conditions.

Mangroves and Coral Reefs are among the most important eco-systems, and both exist on the Gujarat coastline. Mangroves protect coastal areas from erosion and storm surge because of their massive aerial root systems. The intricate mesh of mangrove roots make them nurseries of life for many marine species that breed and proliferate in the protection of the rib cage like root zones. Because of their importance, it is not surprising that mangroves are on top of the priority of many conservation and biodiversity plans.

Gujarat has 15 mangrove species, namely Avicennia marina, Avicennia officinalis, Avicennia alba, Acanthus ilicifolius, Aegiceras corniculatum, Bruguiera cylindrica, Bruguiera gymnorrhiza, Ceriops tagal, Ceriops decandra, Excoecaria agallocha, Kandelia candel, Lumnitzera racemosa, Rhizophora mucronata, Rhizophora apiculata and Sonneratia apetala. The main areas of mangrove forests in Gujarat are Kori Creek and the Gulf of Kuchchh, while a high diversity of mangroves has been reported from South Gujarat region.

Recognising the high conservation value of mangroves, Gujarat has taken initiatives to increase the mangrove cover along the state's coastline, specially the southern coast of the Gulf that falls in Jamnagar and Devbhumi Dwarka districts. The mangrove forestation and restoration efforts along the Gulf of Kuchchh, in districts like Jamnagar and Kuchchh, have been successful, and mangrove forestation has also been done in the Gulf of Cambay. The main measures being taken for mangrove conservation in Gujarat include:

- Protection of existing mangrove habitats with patrolling by forest department in protected areas like the Marine National Park and Wildlife Sanctuary, and with local participation in other areas
- Development of new mangrove habitats at suitable inter tidal areas. This is being done with two approaches - the restoration of degraded mangrove habitats and identification of potential mangrove habitats at new sites
- Restoration and development of degraded mangrove habitats by raising mangrove plantations in the open areas of mangrove habitats, thus increasing the forest density of the area
- Gujarat Forest Department has developed three models of mangrove plantation:

- Direct seed sowing at the sheltered inter tidal areas with regular weeding to remove algal deposition
- Raised bed plantations is unique to Gujarat, where the tidal amplitude is very high Fishbone channel plantations in such elevated areas that do not receive regular tidal inundation. Channels are dug similar to fish bone structure

5.2.4.5 State Bamboo Mission

Bamboo are found in 15 Districts of the state and they are spread over in south Gujarat, Central Gujarat, North Gujarat and parts of Western Gujarat Total area under bamboo in the state is of the tune of 5850 Sq. Kms. Which forms about 3% of the total geographical area of the state. To increase the area under bamboo plantation in non-forest Government and private lands to supplement farm income and contribute towards resilience to climate change as well as availability of quality raw material requirement of industries. The bamboo plantations will be promoted predominantly in farmers' fields, homesteads, community lands, arable wastelands, and along irrigation canals, water bodies etc.

- To improve post-harvest management through establishment of innovative primary processing units near the source of production, primary treatment and seasoning plants, preservation technologies and market infrastructure.
- To promote product development keeping in view market demand, by assisting R&D, entrepreneurship & business models at micro, small and medium levels and feed bigger industry.
- To rejuvenate the under developed bamboo industry in India.
- To promote skill development, capacity building, awareness generation for development of bamboo sector from production to ma rket demand.
- To realign efforts so as to reduce dependency on import of bamboo and bamboo products by way of improved productivity and suitability of domestic raw material for industry, so as to enhance income of the primary producers.

5.2.4.6 Urban Forestry

The Forest Department has taken up urban plantation works in 139 municipalities of Gujarat. These cities and towns have also seen an increase in the number of urban gardens. A landmark urban forestry initiative is the creation of an urban forest over an area of about 47 acres around Aji Dam in Rajkot. This initiative was launched in August 2019. The forests will be maintained by the Biodiversity Management Committee of the Rajkot Municipal Corporation. The plantation and maintenance is being done keeping in mind the needs of the fauna of the area.

5.2.5 Waste

5.2.5.1 Urban Waste Management

Gujarat has already taken initiatives for solid waste management and liquid waste management, and projects are being implemented in all Urban Local Bodies (ULBs), which cover around 38% of the State population (as per census 2001) and generate approximately 7000 tons of waste per day. One of the focal areas is converting waste into fuel pallets or compost, which can be reused for industrial or agricultural purposes. Presently at various locations in the State, it is being implementing on PPP (DBOT) mode. This project mainly focuses on the concept of Reuse of Waste. This project has been proposed in such a way that products from recycling of the waste will provide organic fertilizers to the nearby rural farming lands and water for irrigation purpose. By reusing waste for different purposes, it subsequently reduces the burden on ULBs and offsets the water demand. There is also a growing demand of organic food in the market which can be catered to in this manner. By providing organic fertilizers/compost to the farmers, it will reduce the demand of chemical fertilizers.

Gujarat is planning to install water to energy plants for all the Municipal Corporations. Efficient segregation and collection of waste is the first step in achieving success in this initiative

Picture Courtesy: shutterstock.com

5.2.5.1.1 Waste to Energy Policy

Realizing the potential of Municipal Solid Waste (MSW) as a source of clean and renewable energy, the waste to energy policy was framed in 2016 with a vision to support the state action plan on climate change as well as the "Swachh Bharat Abhiyan". This policy was designed to promote the utilization of Municipal Solid Waste for electricity generation. It was estimated that the solid waste generated in the urban areas falling under 8 municipal corporations and 159 municipalities could generate 100 MW of power. The urban local bodies have been directed to provide the land at a token rate of Rs. 1 per annum and the input for the plants – the waste at no cost to the project implementing agency. The policy will remain operational for 5 years. The project financing structure is based on the viability gap funding mode. All the projects are all under implementation and will be operationalized by 2020.

5.2.5.1.1 Liquid Waste Management

With a focus on conserving water, Government of Gujarat worked out a policy for the 'Reuse of Treated Wastewater' which was launched in 2018. As a part of this policy, the state government has planned to build 161 Sewage Treatment Plants (STP) to treat wastewater to the level that it can be utilized by industries, thermal power plants and the construction sector activities, and for other non-drinking uses. To further strengthen the wastewater utilization mandate, the policy makes it compulsory for the thermal power plants, which are located within a radius of 50 km of a STP, to make use of the treated wastewater. This wastewater utilization mandate is expected to to extended to the industries and industrial parks which are consuming more than 1 lakh litres of water per day.

5.2.6 Urban development

5.2.6.1 Street Light National Programme-MEEP

The Hon'ble Prime Minister of India has launched Street Light National Programme (SLNP) to replace conventional street lights with smart and energy efficient LED Street Light under UJALA scheme. Government of India appointed Energy Services Company (ESCO) and Energy Efficiency Services Ltd. (EESL) as the Nodal Agency to implement the Street Light National Programme (SLNP). The State Government nominated M/s EESL as the Nodal Agency for Implementation of Street Light National Programme for eight Municipal Corporations and 162 Municipalities of the State of Gujarat. For the project period of seven years the LED Street Light Management and Maintenance will be taken care by EESL, so the local bodies do not bear the burden. The repayment by the urban local bodies to EESL, will be on a monthly basis. 162 Municipalities and 8 Municipal Corporations in the State have approximately 11.76 lakh streetlights. Till July, 2019, 2.63 lakh street lights are replaced by Municipalities and Municipal Corporation by their own and around 8.70 lakh street lights are replaced by EESL. The installation work has been completed in 5 Municipal Corporation and 160 Municipalities. Till July, 2019 control room had been started in 129 ULBs and Complain Handling System (CHS) is working in 130 ULBs.

Gujarat is planning to install water to energy plants for all the Municipal Corporations. Efficient segregation and collection of waste is the first step in achieving success in this initiative

Picture Courtesy: shutterstock.com

5.2.6.2 Covenants of Mayors of Gujarat for Climate Change and Energy

The urban energy efficiency program covering all municipal corporations and municipalities in Gujarat is envisaged by the State Action Plan on Climate Change to result in energy savings of nearly 30 per cent thereby contributing significantly in the process of ensuring regular energy supply to all urban centres in the State. To reduce energy consumption and wood usage and thereby restrict GHG emissions, crematoriums in several cities are being converted from electric furnace to CNG furnace leading to electricity savings of over 60 per cent. Burning of one pyre by using firewood requires around 240 kg of wood and emits 160 kg of CO_2 in the atmosphere. Replacement of conventional incandescent bulbs with CFLs in commercial and residential buildings and stringent enforcement of the ECBC is being aggressively promoted in the urban areas of the State. The state has also promoted decentralized solar energy technologies/ equipment like roof-tops for heating and cooking purposes are being encouraged. Gandhinagar and Surat are among the urban centres identified for solar cities in Gujarat.

Rajkot's Climate Resilient City Plan: 'Climate Resilient City' in year 2008 with support from the International Council for Local Environmental Initiatives (ICLEI) – Local Governments for Sustainability, South Asia. Rajkot prepared the 'Solar City Master Plan' for 2008 to 2013, as part of the Ministry of New and Renewable Energy's (MNRE's) Solar City Programme, which helped develop a road map for the city to envision and implement renewable energy and energy conservation strategies.

5.3 List of prioritized mitigation activities

5.3.1 Methodology

5.3.1.1 Solar Mission

The data for solar power installed capacity has taken from monthly renewable report of Central Electricity Authority. The CO_2 emission (CO2) factor numbers are the average carbon content of the national power grid and have been obtained from CEA CO_2 baseline database for the Indian power sector. The total CO2 saved during these years have been estimated using the following formula:

Total CO2 saved = solar power generation from total installed capacity of solar power x baseline CO2 emission factor

Example:

In 2019, Solar installed capacity = 2764 MW

Energy generation from solar = 3279500 MWh

Baseline emission factor = 0.82 tCO2/MWh

CO2 saved = 3279500 x 0.82

= 2689190 Tonne

= 2.69 Million Tonne

We have taken assumption of 25 percent efficiency for calculation of solar power generation from the installed capacity. For 2020-2030 period, we have projected the mitigation numbers by applying 13.25% growth rate for solar power installed capacity data. Baseline emission number has been assumed on the basis of expert's judgement.

5.3.1.2 Wind Mission

The data for wind power installed capacity has taken from monthly renewable report of Central Electricity Authority. The CO2 emission (CO2) factor numbers are the average carbon content of the national power grid and have been obtained from CEA CO2 baseline database for the Indian power sector. The total CO2 saved during these years have been estimated using the following formula:

Total CO2 saved = Wind power generation from total installed capacity for wind power x baseline CO_2 emission factor

Example:

In 2019, Wind power capacity = 7492 MW

Energy generation from wind = 12910680 MWh

Baseline emission factor = 0.82 tCO_2 /MWh

CO2 saved = 12910680 x 0.82

= 10586758 Tonne

= 10.59 Million Tonne

For 2019-2030 period, we have projected the mitigation numbers by applying the 6% growth rate for wind power generation data. Baseline emission number has been assumed on the basis of expert's judgement.

5.3.1.3 Other Renewables

The data for Biomass, Bagasse and other power generation and installed capacity are not currently available for Gujarat. The formula to calculate the total CO2 saved during these years have been estimated using below following formula:

Total CO_2 saved = cumulative power generation from other renewable sources × baseline CO2 emission factor

Example:

In 2019, energy generation from other renewable sources = 286000 MW

Baseline emission factor = 0.82 tCO_2 /MWh

CO2 saved = 286000 x 0.82

= 234520 Tonne

= 0.23 Million Tonne

5.3.1.4 Transmission and Distribution Losses

The estimation for CO2 savings from Transmission and Distribution (T&D) losses requires the values for power generation in India. Generation numbers are obtained from Compendium of Selected Indicators published by Directorate of Economics and Statistics. The yearly T&D loss numbers are taken from monthly executive summary reports of CEA. The CO2 emission (CO2) factor have been obtained CEA CO2 baseline database for the Indian power sector.

Total CO2 saved in year (Y_t)= Total electricity generation in present year (Y_t) × (T&D loss in previous year (Y_{t-1})- T&D loss in present year (Y_t))× baseline CO_2 emission factor

Example:

In 2019, gross electricity generation = 123595 GWh

T&D loss in 2018 = 20.88 %

T&D loss in 2019= 20.72 %

Baseline emission factor = 0.82 tCO2/MWh

CO2 saved in 2019 = 123595 x 1000 x ((20.88-20.72)/100) x 0.82

= 159494 Tonne

= 0.16 Million Tonne

For 2020-2030 period, we have projected the mitigation numbers by applying the CAGR number which has been calculated from 2015-2019 gross electricity generation and T&D losses. Baseline emission number has been assumed on the basis of expert's judgement.

5.3.1.5 LED lights distribution

The Honourable Prime Minister Shri Narendra Modi launched UJALA scheme is LED-based Domestic Efficient Lighting Programme (DELP) in 2014 and National Programme to convert conventional street and domestic lights with energy efficient LED lights in 2015. These programs aimed to promote efficient lighting, reducing energy consumption and energy. The primary data for the number of LEDs distributed during these years and the total CO2 emission saved from the scheme have been taken from the UJALA (2019) and SLNP (2019) dashboard of Ministry of Power, Government of India.

We have applied growth rate of 2 percent and 1 percent to UJALA LED and SLNP for the year 2020. Afterwards, we have assumed that the number will remain constant till 2030.

5.3.1.6 PAT scheme

The results for the PAT cycle one have been taken from BEE report. The cumulative CO2 mitigated data have been linearly distributed equally for the years PAT cycle I (2012-2015) and PAT cycle II (2016-2019).

Following set of equations are used in order to calculate the energy savings, using the data for above mentioned DCs. The production data of the baseline year of PAT Cycle II, i.e. 2014-15 has been taken into consideration, in line with PAT rules, and the M&V exercise conducted by BEE.

Step I: Obtain the Specific Energy Consumption (SEC) for the base year = $SEC_{\text{base year}}$

Step II: Obtain the SEC for the latest year = $SEC_{\text{latest year}}$

Step III: $SEC_{\text{base year}} - SEC_{\text{latest year}}$ (Improvement in Energy Efficiency)

Step IV: In order to calculate the Energy Savings (ES) in Mtoe, the results of Step 3 to be

multiplied by the total production of respective DCs for the year base year.

Formula = $ES_{\text{Plant 1}} = (SEC_{\text{base year}} - SEC_{\text{latest year}}) \times Production_{\text{base year}}$

Step V: $\Sigma ES = ES_{\text{Plant 1}} + ES_{\text{Plant 2}} + ES_{\text{Plant 3}} + ES_{\text{Plant 4}}$ +--------------+ $ES_{\text{Plant N}}$

For 2020 onwards we have assumed that the number will remain constant. We will have improvised the numbers in the final report.

5.3.1.7 Metro Rail Transport

Before 2019, there is no metro rail transportation at any cities of Gujarat. The metro rail in Ahmedabad city was launched by Prime Minister Narendra Modi on March 4. It has started for 6.5 km stretch in Ahmedabad city between Vastral Gam and Apparel Park. Nearly, 76,000 people availed the free rides on the Metro between March 6-14 in 2019[3] . The total ridership of these metro rail system has been estimated using the draft report and we have assuming that

[3]https://www.dnaindia.com/ahmedabad/report-ahmedabad-metro-gains-traction-with-over-1k-passengers-daily-2746415

the ridership has stabilized after 2020. The average emission reduction (tCO2 per passenger) has been arrived at after factoring in baseline emissions (trip length, ridership, etc.), project emissions and leakages (nil). The total CO2 saved have been estimated using the following formula:

Total CO_2 saved = Total passengers travelling in metro rail × Average emission reduced per passenger

5.3.1.8 Bus Rapid Transit System

During the period of 2011-2014, the Bus Rapid Transit System (BRTS) was operational only in 3 Gujarat cities, viz. Ahmedabad, Surat and Rajkot. The data for average daily ridership and total length of the corridor for these cities have been obtained from newspaper articles and city municipal reports. Total operational lengths for BRTS are 114 kms in Surat city, 101 kms in Ahmedabad city, and 10.5 kms for Rajkot city as of October 31, 2020. The CO_2 emissions saved from the BRTS is estimated using the following formula:

Total CO_2 saved = $\sum_{City}$ Total passengers travelling in BRTS × Average emission reduced per passenger

The following are the assumptions taken for the calculations:

1. The ridership will increase by 5 percent annually over period of 2020-2030 due to BRTS operation.
2. The value for average emission reduction (tCO2e/passenger) is assumed to be less in case of BRT. An average trip length in case of BRT is assumed to be 7 km. Hence, we assume emissions / passenger would reduce by half to that of Delhi metro.

6.3.1.9 Future mitigation potential of current key policies

We have identified about 128 number of state's key policies and programmes which have direct impact on climate change mitigation, adaptation and vulnerability. Table 5.1 represents the list of 128 key policies or programmes and their respective sector or department.

Table 5.1: State's identified key policies and programmes having direct impact on climate change mitigation, adaptation and vulnerability

Sr. No.	Name of policy /programme	Sector/Department
1	Micro Irrigation Scheme (MIS)	Agriculture
2	Saurashtra Narmada Avataran Irrigation Project (SAUNI) Yojana	Agriculture
3	Agro Industry- MOFPI schemes	Agriculture
4	Horticulture Mission	Agriculture
5	Biogas subsidy scheme - National Horticulture Board, Government of India(NHB)	Agriculture
6	NHB scheme on cold storage development	Agriculture
7	Agri-implements Subsidies	Agriculture
8	Soil Health Improvement through use of Biofertilizers	Agriculture
9	National City Compost Policy, 2016	Agriculture
10	Climate Change Implications on Crop Growth in Gujarat	Agriculture
11	Animal Hostels in various districts of Gujarat	Agriculture
12	Cattle Breading farms (including sheep)	Agriculture
13	National programme for bovine breeding	Agriculture

Sr. No.	Name of policy /programme	Sector/Department
14	Gokul Gram Yojana	Agriculture
15	AGR-2/3/4 Scheme	Agriculture
16	Sagar Khedu Survangi Vikas Yojana	Fisheries
17	Crop Insurance Scheme	Agriculture
18	Rashtriya Krishi Vikas Yojana	Agriculture
19	Mukhya Mantri Pak Sangrah Yojana	Agriculture
20	Avail crop-loan at zero percent interest	Agriculture
21	National Food Security Mission	Agriculture
22	Cow Based Natural Farming	Agriculture
23	New agricultural power connections	Agriculture
24	Vadi Project for providing saplings of fruit trees and fertilizer for tribal farmers of South Gujarat	Welfare of Farmers/Tribal development
25	Pradhan Mantri Krushi Sinchai Yojana in villages and rural area	Agriculture/Rural development
26	Mukhya Mantri Pashudan Sahay Yojana	Animal Husbandry
27	Subvention to livestock owners under various schemes like dairy farm, animal unit and goat unit etc.	Animal Husbandry
28	Songadh – Uchchhal - Nizar lift irrigation scheme based on Ukai reservoir in Tribal area	Water Resources
29	Vagharej Recharge Scheme	Water Resources
30	Bhadbhoot Bharrage under Kalpasar Yojana	Water Resources
31	Narmada Yojana for completion of Kuchchh branch canal work and undertaking Dudhai sub-branch canal and its distributaries work	Water Resources
32	Compensatory Afforestation Fund Management and Planning Authority (CAMPA) for undertaking forestation, conservation of forests, land and soil conservation, management of wild animals and biological resources management	Forest and Wetlands
33	Joint Forest Management	Forest and Wetlands
34	Soil and Moisture Conservation works	Forest and Wetlands
35	Social Forestry Programme (Gramvan, strip plantation, Hariyalu gram Yojana, farm forestry)	Forest and Wetlands
36	National Agroforestry Policy, 2014/Agro forestry	Forest and Wetlands
37	Mangrove Conservation	Forest and Wetlands
38	State Bamboo Mission	Forest and Wetlands
39	Border Area Development Project (BADP)	Forest and Wetlands
40	MGNEGA	Forest and Wetlands
41	Horticulture	Forest and Wetlands
42	Fodder development scheme Binni Project (non-tribal)	Forest and Wetlands
43	Action Plan for Creation of Eco-Task Force and Mangrove Plantation (non-tribal)	Forest and Wetlands
44	Forest Management & Development (Tribal & Non- tribal area)	Forest and Wetlands
45	Dang Forest Management & Development (Special area program scheme)	Forest and Wetlands
46	Mangrove Coral Reef project	Forest and Wetlands
47	Vruks Kheti	Forest and Wetlands

Sr. No.	Name of policy /programme	Sector/Department
48	Forest Right Act for providing sapling of mango trees, cashew tress and Manvel bamboos in the land allotted to beneficiaries	Forest and Wetlands
49	Create Holy Forest in the districts of tribal areas by growing trees which have significance in terms of religious beliefs	Forest and Wetlands
50	Creating single-use plastic bag free nursery using specially prepared reusable tray for raising saplings	Forest and Wetlands
51	Wind Power Policy 2007, 2009, 2013, 2016	Renewable Energy
52	Solar Power Policy 2009, 2015	Renewable Energy
53	Solar Roof Top Scheme, 2016	Renewable Energy
54	5 MW Gandhinagar Rooftop Programme	Renewable Energy
55	Green Solar Projects, 2010-11	Renewable Energy
56	Gandhinagar as Solar and Carbon Neutral City, 2010-11	Renewable Energy
57	Rooftop solar for 5 cities, 2012-2014	Renewable Energy
58	Suryashakti Kisan Yojana (SKY) Scheme, 2018	Renewable Energy
59	Gujarat Solar Park (Under solar power policy)	Renewable Energy
60	Installation of Solar Photovoltaic Power Pack for Anganwadis, 2013-14	Renewable Energy
61	Installation of solar pumps for small farmers in Gujarat	Renewable Energy
62	Solar Photovoltaic Power Plant at Gandhinagar Thermal Power Station	Renewable Energy
63	Solar plant on the premises of GNFC	Renewable Energy
64	Wind Solar Hybrid Policy, 2018	Renewable Energy
65	Wind Repowering Policy, 2018	Renewable Energy
66	Waste to Energy Policy, 2016	Renewable Energy
67	Mini Hydel Power Policy, 2016	Renewable Energy
68	Grid connected biomass based power projects in the state	Renewable Energy
69	Renewable Purchase Obligation (RPO)	Renewable Energy
70	Renewable Energy Certificate (REC)	Renewable Energy
71	Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) 2018	Renewable Energy
72	Small Scale Distributed Solar Projects-2019	Renewable Energy
73	Surya Gujarat Scheme, 2019-2022	Renewable Energy
74	Solar PV project to produce 250 MW power by GSECL on the govt. land located near GETCO substation.	Renewable Energy
75	Assistance to farmers for purchasing mini solar powered tractors	Renewable Energy
76	Solar-energy based hot water system to be installed at government schools, Eklavya schools, government circuit houses and pilgrim places	Renewable Energy
77	Subsidy to purchase solar pump for salt production to salt pan workers	Renewable Energy
78	LED lamps in APMCs spread in Gujarat	Energy Efficiency
79	Perform Achieve and Trade (PAT)	Energy Efficiency
80	Domestic Efficient Lighting Programme (DELP)/ UJALA scheme	Energy Efficiency
81	Establish new sub-stations for 140 new sub-stations next year	Energy Efficiency

Sr. No.	Name of policy /programme	Sector/Department
82	Changing the old and dilapidated electricity wires, shifting the obstructive power structures, division of long agriculture feeders, implementation of Kisan Hit Urja Shakti Yojna and providing three phase power supply to Sim Shalas	Energy Efficiency/ Agriculture
83	Dinkar Yojana for strengthening transmission network and install new sub-station in 3 years	Energy Efficiency
84	Modernization and retrofitting of power generation units of GSECL	Energy Efficiency
85	22,500 LED tube lights and 23,000 star rated fans will be installed at Government schools of the state	Energy Efficiency
86	Financial assistance of Rs. 40000 per rickshaw will be given for 800 E-Rickshaws	Electric Vehicle/ Energy Efficiency
87	Financial assistance of Rs. 10000 per vehicle will be given for 1000 battery operated two wheelers	Electric Vehicle/Energy Efficiency
88	Installing charging points in cities for EVs	Electric Vehicle /Energy Efficiency
89	Industrial Policy, 2015	Industry
90	Industrial Policy, 2020	Industry
91	Greenhouse gas (GHG) reduction by implementing energy efficient plough share mixer (PSM) technology in soap manufacturing at Hindustan Lever Limited (HLL), India	Industry
92	Amine Circulation Pumps Energy Efficiency at Hazira works of ONGC	Industry
93	Demand side energy conservation &reduction measures at IPCL – Gandhar Complex	Industry
94	Efficient utilisation of waste heat and natural gas at Dahej complex of GACL	Industry
95	Energy efficiency and fuel switch project at Welspun India Limited	Industry
96	Energy efficiency improvement in power generation at Sajjan India Limited, Ankhleshwar, Gujarat	Industry
97	Energy efficiency through steam optimisation projects at RIL, Hazira,	Industry
98	Flare Gas Recovery and Utilization of Recovered Flare Gas for process furnace and other heating applications	Industry
99	Fuel Switch, process improvement and energy efficiency initiatives at brick manufacturing plant in Golan, Gujarat, India	Industry
100	GHG emission reduction by thermal oxidation of HFC 23 at Navin Fluorine International Limited (NFIL), Surat, Gujarat, India	Industry
101	GHG emission reduction by thermal oxidation of HFC 23 in Gujarat	Industry
102	GHG emission reduction through the installation of energy efficient vacuum creating system in the vacuum distillation column of petroleum refinery	Industry
103	Gujarat Narmada Valley Fertilizer Company (GNFC) Nitrous Oxide Abatement Project	Industry
104	Optimisation of steam generation and distribution systems through various energy efficiency measures at Anil Products Limited, Ahmedabad	Industry

Sr. No.	Name of policy /programme	Sector/Department
105	Reduction in steam consumption in stripper reboilers through process modifications	Industry
106	Up-gradation of Gas Turbine 1 (GT 1) and Gas Turbine 2 (GT 2) at co-generation plant of Hazira Gas Processing Complex (HGPC) of Oil and Natural Gas Corporation Limited (ONGC)	Industry
107	Waste heat recovery project based on technology up-gradation at Apollo Tyres, Vadodara, India	Industry
108	GACL Blended Cement Projects in India	Industry
109	Reduction in Steam Consumption through Revamping of Ammonia Plant of Indian Farmers Fertiliser Cooperative Ltd (IFFCO) plants	Industry
110	Urban Transport (BRTS)	Urban Development
111	Street Light National Programme-MEEP	Urban Development
112	Indian Green Building Council (IGBC) (10 million sq.ft. of green building footprint in the next three years)	Urban Development
113	Swarnim Jayanti Mukhya Mantri Shaheri Vikas Yojana (SJMMSVY)	Urban Development
114	Metro Rail Project	Urban Development
115	Smart Cities	Urban Development
116	AMRUT Yojana (for facilities like water supply, sewage, rain water disposal, transport etc.)	Urban Development
117	Mukhya Mantri Sadak Yojana	Urban Development
118	Two/Four/Six laning of roads, New bridge or overbridge construction	Urban & Rural Development/Road & Buildings Dept
119	Resurfacing of plan and non-plan rural roads of the length of 9500 kms	Rural Development/ Road & Buildings Dept
120	Strengthen or rebuilt the bridges which found weaker or dilapidated during survey	Road & Buildings Dept
121	Waste Water Recycling in Rural Areas	Rural Waste Management
122	Waste to compost scheme for 162 ULBs	Urban Waste Management
123	Liquid waste management - collection and treatment	Urban Waste Management
124	Shifting of dung-hills under Nirmal Gujarat	Urban Waste Management
125	Reuse of Treated Waste Water Policy in cities other than Vadodara, Jamnagar, Gandhinagar and Bhavnagar	Urban Waste Management
126	Management of solid and liquid waste in gram panchayats	Waste Management in Gram Panchayats
127	Monthly grant for door to door collection of solid waste in gram panchayats	Waste Management in Gram Panchayats
128	Inducting 895 new buses of BS-6 model environment friendly buses	Ports and Transportation

Further, few key policies have been assessed to estimate their potential of emissions reductions or mitigation up to 2030. Figure 5.3 shows the mitigation potential due to implementation of some of the key policies between 2005-2030. The chart represents the mitigation due to Solar power policy, wind power policy, Other renewables, Super critical power generation, T & D losses reductions, PAT scheme, Micro Irrigation system, SLNP, UJALA programme and urban transport (Metro & BRTS). While figure 5.4 shows the mitigation potential due to increase in forest cover in Gujarat between 2005-2030.

Figure 5.3: **Mitigation due to some of the key policies (2005-2030)**

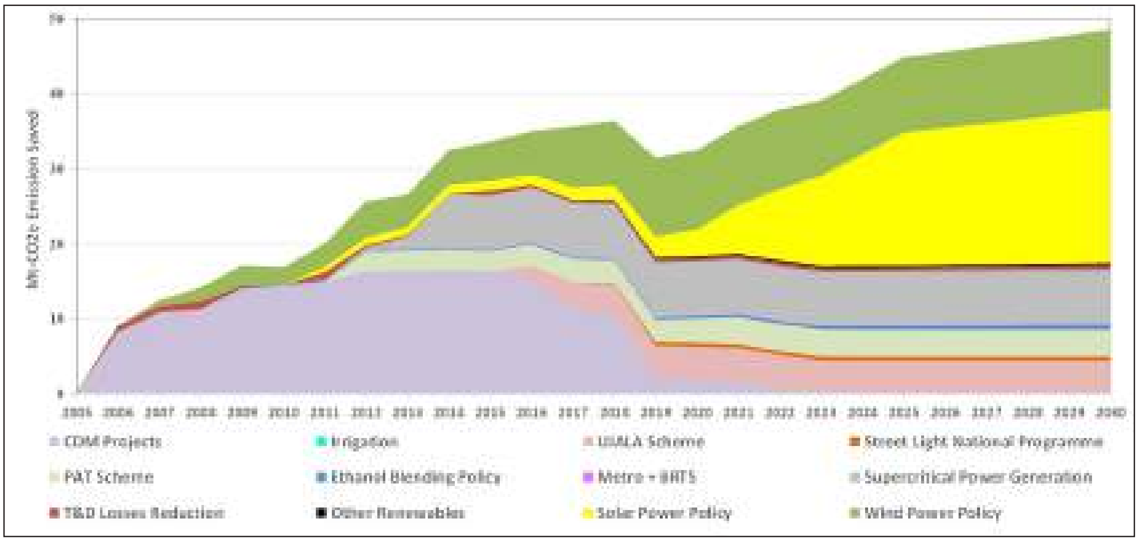


Figure 5.4: **Mitigation due to increase in forest cover (2005-2030)**

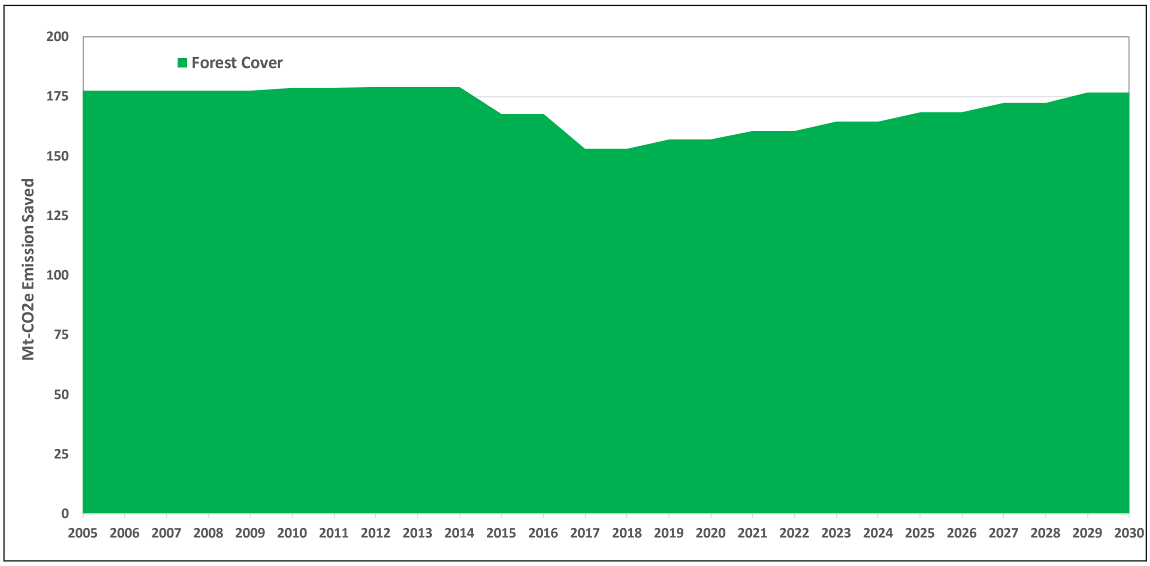


Table 5.2: CO2 Emission Mitigated (Mt-CO2e) due to some of key policies

Year	Solar Power Policy	Wind Power Policy	Other Renewables	T&D losses reduction	Super critical Power Generation	UJALA	SLNP	PAT	Irrigation	Metro + BRTS	Total
2005	0	0	0		0	0	0	0	0.00000	0.000	0.00
2006	0	0	0	1.31	0	0	0	0	0.00001	0.000	1.31
2007	0	0.74	0	1.49	0	0	0	0	0.00002	0.000	2.23
2008	0	1.87	0	-0.14	0	0	0	0	0.00003	0.000	1.74
2009	0	2.69	0	-0.14	0	0	0	0	0.00004	0.001	2.55
2010	0.01	2.27	0	1.80	0	0	0	0	0.00005	0.008	4.08
2011	0.65	3.12	0	1.97	0.00	0.00	0.00	0.00	0.00007	0.008	5.74
2012	0.95	4.86	0	0.02	0.28	0.00	0.00	2.63	0.00011	0.008	8.75
2013	1.12	4.31	0	0.02	1.68	0.00	0.00	2.63	0.00014	0.010	9.77
2014	1.21	4.64	0	0.02	7.23	0.00	0.00	2.63	0.00018	0.011	15.75
2015	1.23	5.29	0.05	0.02	7.23	0.00	0.00	2.63	0.00021	0.012	16.47
2016	1.29	5.84	0.03	-0.91	7.23	1.83	0.05	2.96	0.00024	0.025	18.34
2017	1.64	8.08	0.08	0.35	7.23	3.56	0.09	2.96	0.00026	0.034	24.03
2018	1.84	8.61	0.11	0.16	7.23	3.93	0.19	2.96	0.00028	0.037	25.07
2019	2.69	10.59	0.23	0.16	7.23	4.29	0.53	2.96	0.00030	0.040	28.73
2020	3.82	11.22	0.24	0.17	7.23	4.40	0.53	3.29	0.00034	0.042	30.95
2021	4.33	11.90	0.25	0.17	7.23	4.40	0.53	3.62	0.00039	0.044	32.48
2022	4.90	12.61	0.26	0.18	7.23	4.40	0.53	3.62	0.00045	0.046	33.78
2023	5.28	12.71	0.25	0.18	7.23	4.40	0.53	3.62	0.00049	0.049	34.26
2024	5.98	13.48	0.26	0.18	7.23	4.40	0.53	3.62	0.00055	0.052	35.74
2025	6.77	14.28	0.27	0.19	7.23	4.40	0.53	3.62	0.00063	0.054	37.36
2026	7.67	15.14	0.27	0.20	7.23	4.40	0.53	3.62	0.00072	0.057	39.13
2027	8.69	16.05	0.28	0.21	7.23	4.40	0.53	3.62	0.00082	0.060	41.08
2028	9.84	17.01	0.29	0.21	7.23	4.40	0.53	3.62	0.00094	0.063	43.21
2029	11.14	18.03	0.30	0.22	7.23	4.40	0.53	3.62	0.00107	0.067	45.56
2030	12.62	19.12	0.31	0.23	7.23	4.40	0.53	3.62	0.00122	0.070	48.14

5.4 Barriers and gaps in implementation of mitigation actions

Development of an action plan to tackle the concerns arising due to climate change is a first step in the policy process. Efficient implementation of the mitigation actions is an equally crucial task. The challenges faced in efficient implementation may be due to the barriers and gaps faced in a policy process. Barriers in this context are any obstacle that prevents achievement of the full potential of a policy, programme or plan. Barriers and gaps are context-specific and have the tendency to switch over time and space. The barriers can be broadly classified into the following five themes:

Financial barriers:

The financial barriers manifest in terms of availability of appropriate funding mechanisms and structures, lack of access to funds, a possible lack of market structures, and budget limitations. Some of the mitigation actions towards reducing the GHG emission requires large financial resource since the entire system of production needs to be modified.

Political, social and cultural barriers:

The political, social, behavioural and cultural barriers pose a large share of the barriers towards implementation of mitigation actions. Lack of political will and public acceptance of policy instruments impact the efficient outcomes from a well-designed policy. Cultural and behavioural approaches towards policy enforcement also influences efficient policy outcomes. A few more practical and political concerns e.g. land acquisition impact the policy process in a detrimental manner.

Knowledge and Capacity Barriers:

The knowledge and capacity required for implementation of climate change mitigation or adaptation policies is highly specific and contextual. It can vary according to a variety of factors, especially spatial scale of the policy intervention (local, regional, national), specific geographical locations, substantive topics or sectors (water, health, agriculture, fisheries, etc.) (Ryan & Bustos, 2019). Thus, policy implementation may be highly impacted by the lack of key skills and expertise.

Legal and institutional barriers:

The legal and institutional barriers comprise of limitations on the legal powers to implement a particular policy instrument, and the roles and responsibility divided between various departments and agencies- bringing in the complications to co-ordinate as well as competing policy designs. This could affect the ability of efficient implementation.

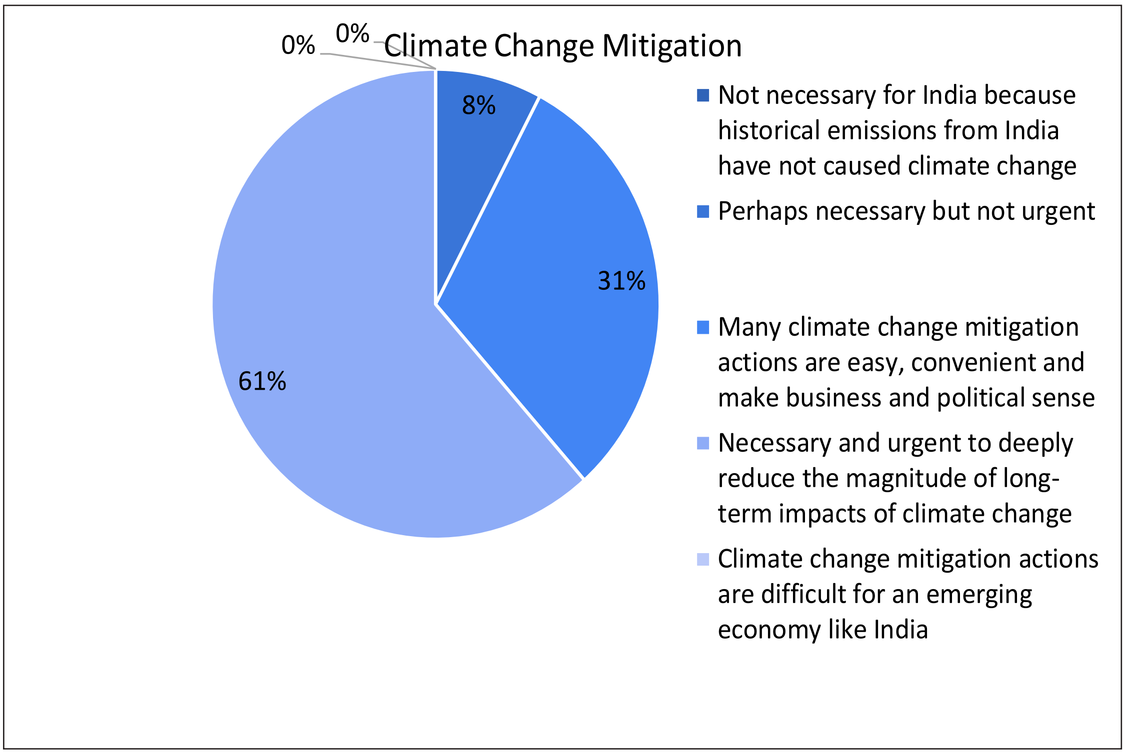
Technological barriers:

Some policies and programs face practical limitations. Technological constraint like access to efficient and best available technology, technology costs and pricing, technology management and know-how and similar concerns play a huge role here.

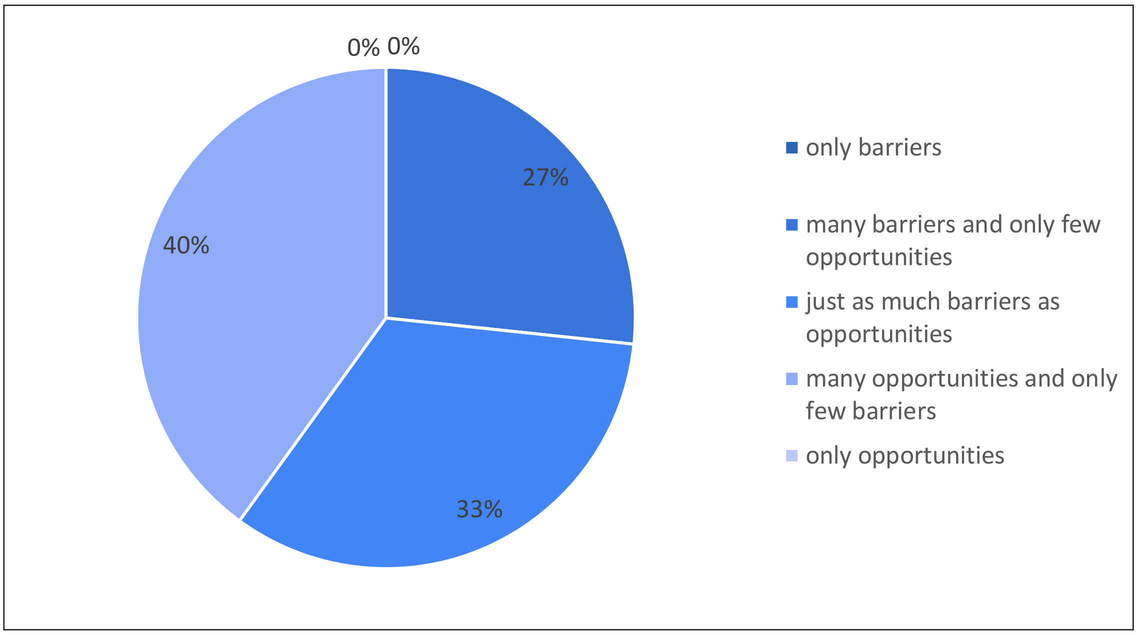
Based on these themes we tried to access the barriers and gaps faced by mitigation policy implementation. This exercise was conducted through a survey of policy-makers. The survey questions tried to assess the opinion on need for mitigation. The survey further tried to gauge the viewpoint on the obstacles and challenges versus opportunities (Figure 5.4). Further the survey presented statements describing the technological, financial, institutional and legal, knowledge as well as socio-political barriers. The results are discussed here.

Figure 5.5: Opinion of Policy-makers on Climate Change Mitigation

(a) Need and Urgency for Climate Change Mitigation



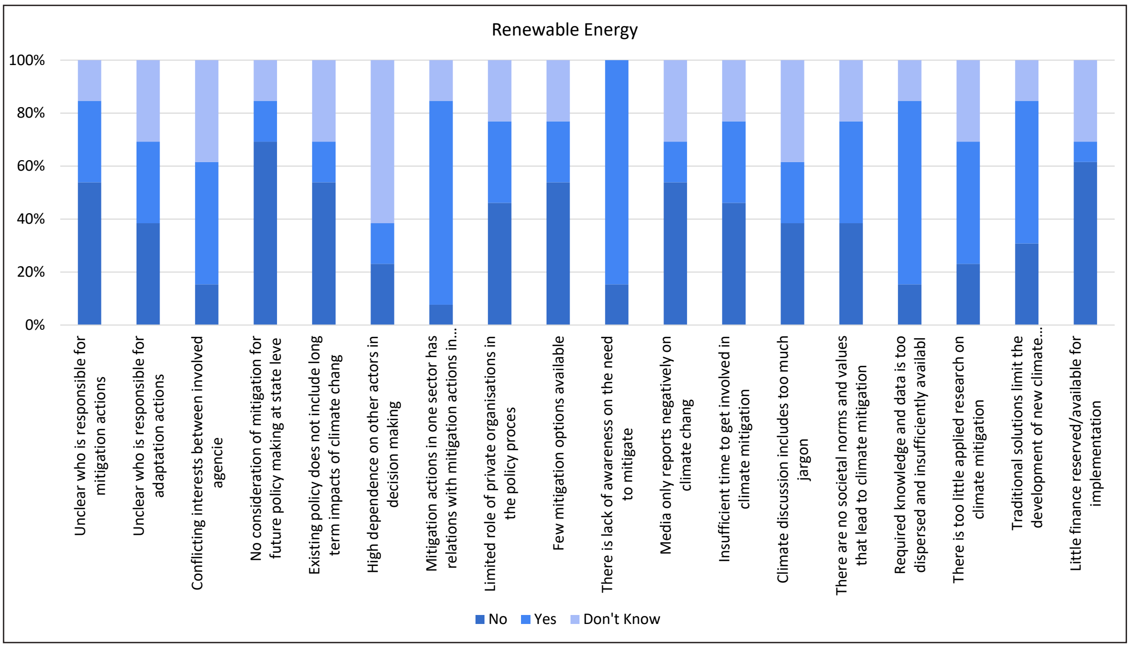
(b) Opportunities versus Barriers Perception



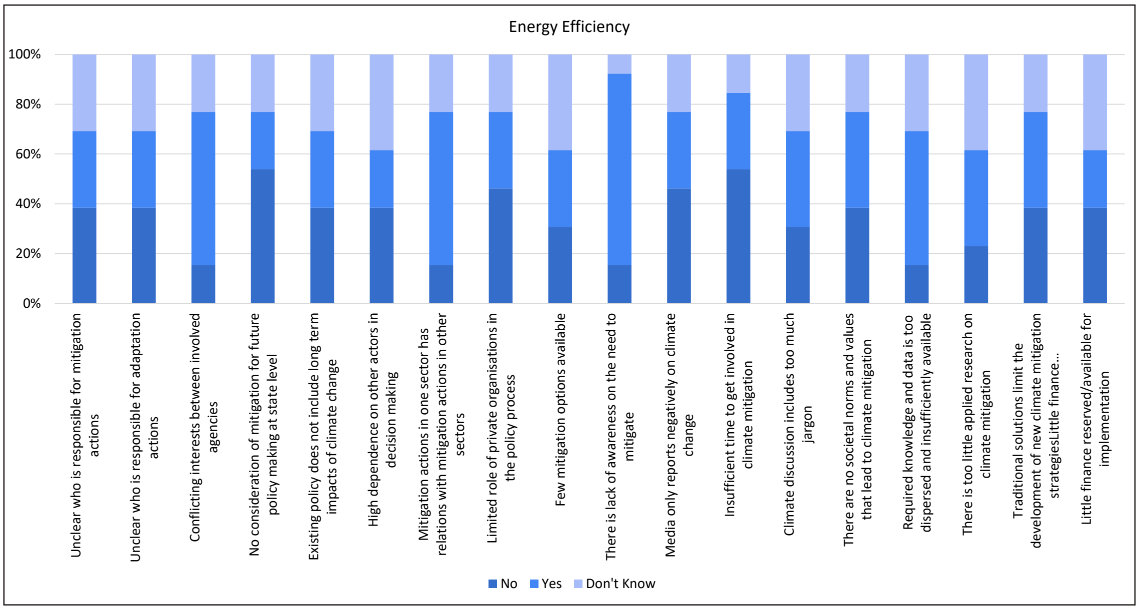
The responses on the renewable energy policies and their implementation indicated that institutional arrangements are clear and smooth functioning with not may hurdles. Also, the policy makers understand that there is consideration for mitigation of climate change in the policymaking process- which has a significant impact on the future policies while acknowledge the interdependency of various sectors, actors and opportunities. The results also indicate that knowledge is available, however, they also indicate a lack of awareness towards the need to mitigate (Figure 5.5).

Figure 5.6: **Responses on Barriers & Gaps in Mitigation Policies**

(a) Renewable Energy Policies



(b) Energy Efficiency Policies



5.5 Implementation plan including the agencies responsible for implementation, required policy and budget

Table 5.3 below shows the key mitigation policies for Gujarat and the institutions responsible for the success of these policies. While, Table 5.3 lists the key geographies for the successful implementations of these policies.

Table 5.3: List of Key Policies and the Key Institutions for Mitigation Actions

Sr. No.	Key Policy	Department Responsible*
1	Wind Power Policy 2007, 2009, 2013, 2016	GEDA/ GUVNL
2	Solar Power Policy 2009, 2015	GEDA/ GUVNL
3	Solar Roof Top Scheme, 2016	GEDA/ GUVNL
4	5 MW Gandhinagar Rooftop Programme	GEDA/ GUVNL/ Gandhinagar Municipal Corporation
5	Green Solar Projects, 2010-11	GEDA/ GUVNL
6	Solar and Carbon Neutral City (Gandhinagar), 2010-11	GEDA/ GUVNL/GUDC
7	Rooftop solar for 5 cities, 2012-2014	GEDA/ GUVNL
8	SKY Scheme, 2018	GEDA/GUVNL, Agriculture and Co-operation
9	Gujarat Solar Park (Under solar power policy)	GEDA/ GUVNL
10	Installation of Solar Photovoltaic Power Pack for Anganwadis, 2013-14	GEDA
11	Installation of Solar Pumps for small farmers in Gujarat (KUSUM)	GEDA/GUVNL, Agriculture and Co-operation
12	Solar Photovoltaic Power Plant at Gandhinagar Thermal Power Station	GEDA, GSECL
13	Solar plant on the premises of GNFC	GEDA/GUVNL / GNFC
14	Wind Solar Hybrid Policy, 2018	GEDA/GUVNL
15	Wind Repowering Policy, 2018	GEDA/GUVNL
16	Waste to Energy Policy, 2016	GEDA/GUVNL/GUDC
17	Mini Hydel Power Policy, 2016	GEDA/GUVNL
18	Grid connected biomass-based power projects in the state	GEDA/GUVNL
19	RPO	GEDA
20	REC	GEDA
21	Industrial Policy, 2015, 2020	Industries and Mines
22	Greenhouse gas (GHG) reduction by implementing energy efficient plough share mixer (PSM) technology in soap manufacturing at Hindustan Lever Limited (HLL), India	Industries and Mines
23	Amine Circulation Pumps Energy Efficiency at Hazira works of ONGC	Industries and Mines
24	Demand side energy conservation &reduction measures at IPCL – Gandhar Complex	Industries and Mines

Sr. No.	Key Policy	Department Responsible*
25	Urban Transport	Urban Development & Urban Housing/ GUDC
26	Urban Waste Management	Urban Development & Urban Housing/ GUDC/ GPCB
27	Street Light National Programme-MEEP	G Urban Development & Urban Housing/GUDC
28	SJMMSVY	Urban Development & Urban Housing/ GUDC
29	Smart Cities	Urban Development & Urban Housing/ GUDC
30	AMRUT Cities	Urban Development & Urban Housing/ GUDC
31	Wastewater Recycling in Rural Areas	Rural Development & Panchayati Raj
32	Irrigation development through Micro Irrigation Systems	Agriculture and Co-operation/ Narmada, Water Resources, Water Supply and Kalpsar
33	SAUNI Yojana (Saurashtra Narmada Avataran Irrigation Project)	Narmada, Water Resources, Water Supply and Kalpsar
34	Agro Industry- MOFPI schemes	Agriculture and Co-operation /GAIC
35	Horticulture Mission	Agriculture and Co-operation
36	Biogas subsidy scheme - National Horticulture Board, Government of India (NHB)	Agriculture and Co-operation
37	NHB scheme on cold storage development	Agriculture and Co-operation
38	Agri-implements Subsidies	Agriculture and Co-operation
39	Soil Health Improvement through use of Biofertilizers	Agriculture and Co-operation
40	National City Compost Policy, 2016	Agriculture and Co-operation
41	Climate Change Implications on Crop Growth in Gujarat	Agriculture and Co-operation
42	Animal Hostels in various districts of Gujarat	Agriculture and Co-operation/ Livestock board
43	Cattle Breading farms (including sheep)	Agriculture and Co-operation/ Livestock board
44	National programme for bovine breeding	Agriculture and Co-operation/ Livestock board
45	Gokul Gram Yojana	Agriculture and Co-operation/ Livestock board
46	AGR-2/3/4 Scheme	Agriculture and Co-operation/ Livestock board
47	Joint Forest Management	Forest and Environment
48	Soil and Moisture Conservation	Forest and Environment
49	Social Forestry Programme	Forest and Environment
50	National Agroforestry Policy, 2014	Forest and Environment
51	Mangrove Conservation	Forest and Environment
52	State Bamboo Mission	Forest and Environment

*GEDA- Gujarat Energy Development Agency, GUVNL- Gujarat Urja Vikas Nigam Limited, GUDA- Gujarat Urban Development Company Limited, GPCB- Gujarat Pollution Control Board, GAIC- Gujarat Agro Industries Corporation Limited.

Table 5.4: List of Key Geographies for Mitigation Actions

Sr. No.	Key Policy	Key Districts and Cities
1	Wind Power Policy 2007, 2009, 2013, 2016	Kuchchh, Jamnagar, Morbi, Devbhumi Dwarka, Porbandar, Junagadh, Gir Somnath and Amreli
2	Solar Power Policy 2009, 2015	Kachchh, Jamnagar, Morbi, Devbhumi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Rajkot, Banaskantha, Sabarkantha, Mehsana, Aravalli, Mahisagar, Dahod, Panchmahal and Gandhinagar
3	Solar Roof Top Scheme, 2016	Cities: Gandhinagar, Ahmedabad, Rajkot, Jamnagar, Junagadh, Towns: Bhuj, Morbi, Porbandar, Veraval, Keshod, Mangrol, Amreli, Palanpur, Himmatnagar, Mehsana, Dahod, Godhra
4	5 MW Gandhinagar Rooftop Programme	Gandhinagar
5	SKY Scheme, 2018	Valsad, Surat, Tapi, Navsari, Narmada, Bharuch, Amreli, Bhavnagar, Rajkot, Junagadh, Jamnagar
6	Gujarat Solar Park (Under solar power policy)	Banaskantha, Sabarkantha, Mehsana, Kuchchh
7	Installation of Solar Photovoltaic Power Pack for Anganwadis, 2013-14	Across state
8	Installation of Solar Pumps for small farmers in Gujarat (KUSUM)	Valsad, Surat, Tapi, Navsari, Narmada, Bharuch, Amreli, Bhavnagar, Rajkot, Junagadh, Jamnagar
9	Wind Solar Hybrid Policy, 2018	Kuchchh, Jamnagar, Morbi, Devbhumi Dwarka, Porbandar, Junagadh, Gir Somnath and Amreli
10	Wind Repowering Policy, 2018	Kuchchh, Jamnagar, Morbi, Devbumi Dwarka, Porbandar, Junagadh, Gir Somnath and Amreli
11	Waste to Energy Policy, 2016	Cities: Gandhinagar, Ahmedabad, Rajkot, Jamnagar, Junagadh, Surat, Vadodara, Bhavnagar
12	Grid connected biomass-based power projects in the state	Across state
13	Urban Transport	Cities: Gandhinagar, Ahmedabad, Rajkot, Jamnagar, Junagadh, Surat, Vadodara, Bhavnagar
14	Urban Waste Management	Cities: Gandhinagar, Ahmedabad, Rajkot, Jamnagar, Junagadh, Surat, Vadodara, Bhavnagar + 159 towns
15	Street Light National Programme-MEEP	Cities: Gandhinagar, Ahmedabad, Rajkot, Jamnagar, Junagadh, Surat, Vadodara, Bhavnagar

Sr. No.	Key Policy	Key Districts and Cities
16	SJMMSVY	Cities: Gandhinagar, Ahmedabad, Rajkot, Jamnagar, Junagadh, Surat, Vadodara, and Bhavnagar
17	Smart Cities	Surat, Ahmedabad, Vadodara, Rajkot, and Dahod
18	AMRUT Cities	31 cities
19	National City Compost Policy, 2016	159 towns
20	Gokul Gram Yojana	Across state
21	Joint Forest Management	Junagadh, Gir Somnath, Amreli, Bhavnagar, Valsad, Dang, Tapi, Narmada, Chota Udaipur, Dahod, Panchmahal
22	Soil and Moisture Conservation	Across state except parts of Kuchchh, Bhavnagar, Surat and Anand districts
23	Social Forestry Programme	Junagadh, Gir Somnath, Amreli, Bhavnagar, Valsad, Dang, Tapi, Narmada, Chota Udaipur, Dahod, Panchmahal
24	National Agroforestry Policy, 2014	Junagadh, Gir Somnath, Amreli, Bhavnagar, Valsad, Dang, Tapi, Narmada, Chota Udaipur, Dahod, Panchmahal
25	Mangrove Conservation	Jamnagar, Kuchchh, Morbi, Devbhumi Dwarka, Gir Somnath, Amreli, Bhavnagar
26	State Bamboo Mission	Narmada, Dangs, and parts of Tapi, Surat and Valsad

5.5.1 Electric vehicle charging infrastructure

GEDA is the designated nodal agency for development of EV charging infrastructure in Gujarat under the guideline of Department of Heavy Industries and Ministry of Power, Government of India. Ministry of Heavy Industries and Public Enterprises has approved the construction of 2636 charging stations in 62 cities across 24 states and union territories under Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME-II). Gujarat is planning to develop 227 charging stations under this project. Ahmedabad Municipal Corporation (AMC) is planning to install EV Charging points in multi-level parking in which each lot will be housing charging points for about 400 cars and 600 two wheelers.

5.5.2 Harnessing Renewable Energy Potential to the Fullest

Gujarat's efforts on promoting renewable energy are among the top in the country. Further, the state has committed to a voluntary target of 30000 MW renewable energy production by 2022 to harness the high potential of solar and wind energy including offshore wind energy. The state is also looking for opportunities in the areas of energy storage technologies, geothermal energy, hydrogen energy, fuel cells, tidal energy and bio-gas.

5.5.3 Value Addition in Agriculture through Solar Energy

The state is planning the following initiatives for the following:

Solar Cold Storage:

A large quantity of fresh produce deteriorates by the time it reaches the consumer. This is due to the need of cold supply chain to ensure the quality and extend the shelf life of the perishables. A solar cold storage system with a capacity of 5 to 10 metric tonnes for fresh horticulture, fruits and floriculture products may prove to be sufficient for the 24 hours need of a farmer.

Solar powered tractor:

The total tractor population in Gujarat is almost 7.75 lacs. Huge amount of diesel gets consumed to run these for agricultural operations leading to increased GHG emissions as well as operations costs to the farmer. In order to ensure sustainable agricultural operations, introduction of solar powered tractors is being explored in Gujarat. A mere 1% replacement of tractors are expected to reduce 19000 kilo litres of diesel consumption annually.

5.5.4 Carbon Capture and Storage

Carbon Capture and Storage (CCS) is an important for climate change mitigation. However, it is not binding for India as a compulsory climate action. There is an opportunity of CCS for Enhanced Oil Recovery (EOR) in existing oil fields. Gujarat is exploring opportunities for CCS-EOR in oil field assets of Public Sector units like Oil and Natural Gas Corporation (ONGC) and Gujarat State Petroleum Corporation (GSPC) located in Gujarat.

5.5.5 Energy Conservation Building Code

Gujarat in near future shall adopt the Energy Conservation Building Code (ECBC) – a powerful regulation to encourage the transition of buildings to efficient use of energy. The Code shall help set provisions for achieving energy neutrality in buildings that stipulates minimum energy performance levels for building. Buildings consume significant amount of energy resources and ECBC is an essential tool to curb the energy footprint. The ECBC are hinged on the climate responsive buildings that use local natural resources and climatic conditions to their advantages. Passive design strategies are one of the most effective methods to ensure that building designs and technologies are sensitive to the surroundings. ECBC shall be applicable to buildings or building complexes to have connected load of 100kW or greater or a contract demand of 120kVA or greater and are intended to be used for commercial purposes. ECBC shall support many of the Government's objectives for achieving energy security, economic growth and environmental sustainability.

5.5.6 Solar Banking and Power Storage

Gujarat is leading in Renewable Energy Generation and now looking to explore various options for promoting its viability including Solar Banking and Battery Storage. For example, if a solar generator produces during the day and wants to sell to a consumer that needs electricity at night, banking service allows the generator to put all of its generation on the grid during the day and then use banked grid-supplied energy to serve the customer's needs to night.

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CHAPTER 6

CLIMATE CHANGE STRATEGY – ADAPTATION

Picture Courtesy: Dreamstime.com

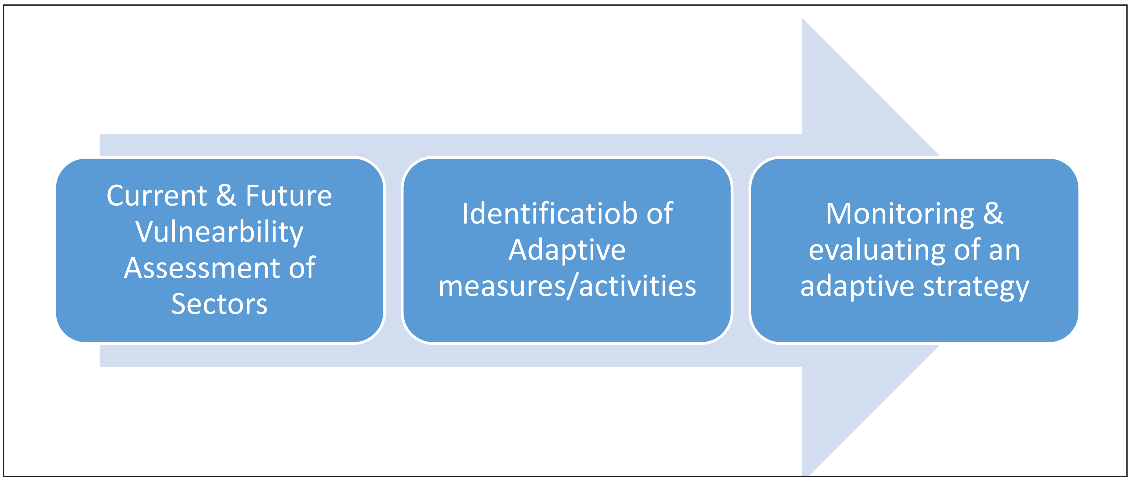
Climate Change Strategy – Adaptation

Climate change is a global phenomenon. Although it has far-reaching implications at a local scale. Climate change poses tremendous pressure on society and infrastructure. Over the last few decades, human emissions (greenhouse gases) and activities (burning fossil fuels, deforestation, and farming livestock) have accelerated climate change (IPCC, 2014). IPCC assessments have found that human activities were responsible for observed 1951-2010 warming. Based on the severity and future threat of climate change, the global scientific community declared a climate emergency. Hence, it is essential to understand the historical and projected change in climatic variables at a local scale to prepare an adaption and resilience strategy to minimize the worse impact.

In previous chapter (Chapter 3) results showed a significant change in the climatic variables across the Gujarat state. We find that the precipitation and air temperature patterns have been changed from 1951-2019 over Gujarat with the increased precipitation and temperature extremes. Moreover, Gujarat has witnessed frequent flood, drought, and cyclone events in recent years. These recent natural disasters were more destructive and devastating than before. We also studied climate projections and found an overall increase in precipitation in Gujarat. However, an increase in precipitation over south Gujarat is more than north Gujarat. In the future climate, the air temperature is projected to increase by 4-5 ºC under the RCP 8.5 scenario. The increased temperature results in high frequency of heatwave in the warming climate over Gujarat. Overall, our results based on the observed and future climate data suggest that the hydroclimatic extreme events (extreme precipitation, temperature, heatwave, drought, and flood) are projected to increase over the state. Moreover, Gujarat exhibits higher levels of climate risk in the future.

These historical and future results indicate an alarming signal for the changing climate scenario within Gujarat. Hence, adaptation strategies to climate change are inevitable to minimize the adverse impacts on the community. The adaptation strategies aim to reduce climate risk to an acceptable level by providing an alternative solution. It also helps in capacity building at the local community level. The vast majority of the adaptation strategies for managing resources and mitigating adverse impacts of a changing climate are generally grouped into three basic types of strategies: those promoting resistance, resilience, and change (Hoffmann and Sgró, 2011; Intergovernmental Panel on Climate Change, 2014; Smit and Wandel, 2006) by adopting grey (technical), green (nature), and soft (policy, legal, and financial) measures. Effective strategies should be planned and adopted in different sectors with a vision of not only adapting to climate change but also making those changes sustainable. Figure 6.1 shows the methodology to prepare a climate adaptation strategy. The first step is to identify the priority sectors by assessing current and future sector vulnerability to climate change. Then prepare a list of current and possible adaptive measures/activities to build climate-resilient sectors. The last step is monitoring and evaluating an adaptive strategy.

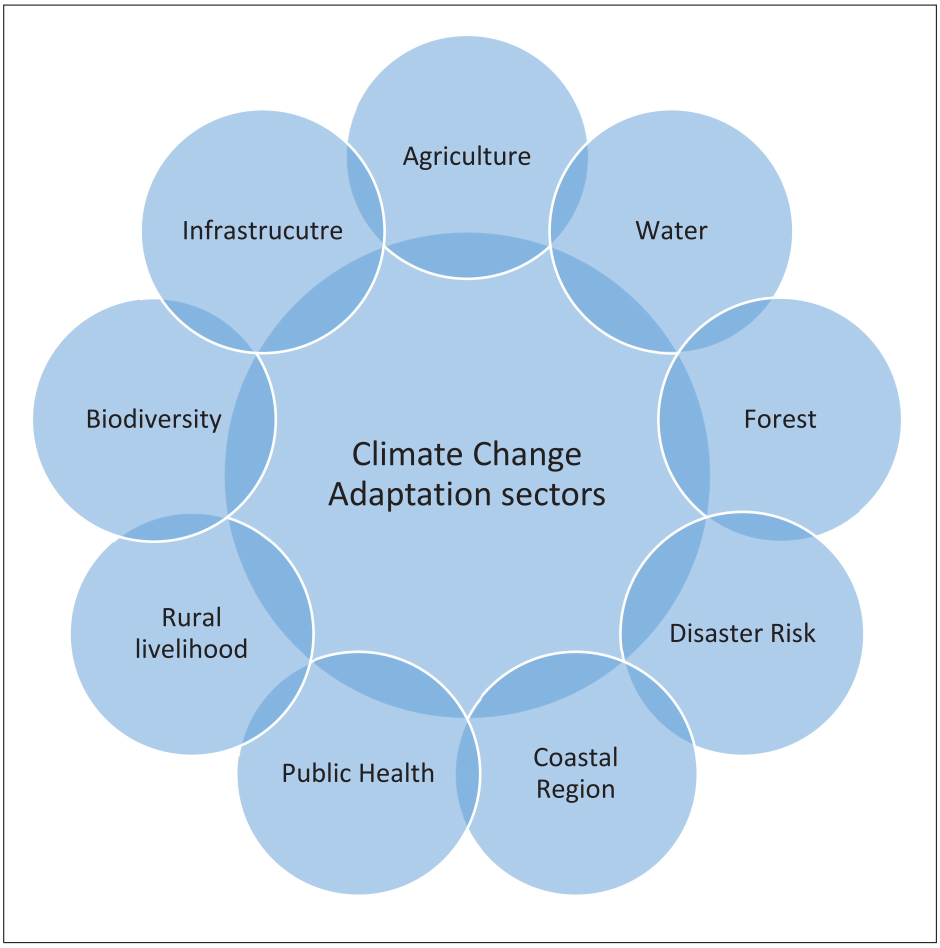
Figure 6.1: Flowchart of climate change adaptation methodology



6.1 Identification of priority sectors for adaptation (ex. Agriculture; Forests; Biodiversity; Water; Health; Coastal Regions; Disaster Management; Rural Livelihood; Infrastructure)

We identified nine priority sectors for climate change adaptation strategies over the Gujarat state (Figure 6.2). The selection of sectors is based on the extent of climate change impact on them.

Figure 6.2: Climate change adaptation sectors



6.1.1 Water Resources

Gujarat has only 2% of the country's water resources. The total water availability in the state is 50 Billion Cubic Meter (BCM), of which surface water accounts for 38 BCM and groundwater accounts for 12 BCM. The major portion of water is being used for irrigation purposes and limited supply for drinking and industrial uses. The major source of the state's surface and sub-surface water resources is rainfall. The state receives an average of 875 mm annual rainfall during the monsoon season (June-September) with large spatial variability, where southern regions of Gujarat receive about 1500 mm rainfall while the northwest regions receive less than 500 mm. Due to the climate warming, the change in magnitude and intensity of rainfall has direct implications on water availability and impact the environment. Gujarat has faced severe water-related problems like depletion of groundwater over North Gujarat, groundwater pollution over South Gujarat, drought in Kuchchh and Central Gujarat, and flood in Saurashtra and South Gujarat.

Moreover, water demand across different sectors might increase with global warming. The erratic rainfall or shift in monsoon rainfall could result into drought and famine conditions. Hence, low discharge in rivers could create serious consequences like decreased hydropower generation, inadequate irrigation, and environmental problem. On the other side, extreme precipitation events cause floods that lead to increased runoff and sediment flow. It also reduces water quality and disrupts water supply. The contamination of water resources causes widespread waterborne diseases. Also, sea-level rise disturbs the water ecosystem and biodiversity. Moreover, small islands and atolls are submerged, and freshwater resources are contaminated with salinity due to the sea-level rise. Overall, climate change impact on the water sector also drives other (health, biodiversity, infrastructure) sectors. Therefore, understanding the water availability in observed and future changes can be helpful in the adaptation strategy to mitigate the impact of climate change.

Shah and Mishra (2016)a majority of the river basins experienced increased monsoon season precipitation, evapotranspiration, and surface water availability (as defined by total runoff found that mean monsoon season precipitation increased by 4.0% in the Sabarmati and Tapi River basins. In contrast, the Narmada river basin experienced a decline of 4% in mean monsoon season precipitation during the 1948-2012 period. Moreover, our current study reveals that annual streamflow is projected to increase in Sabarmati, Mahi, and Tapi River basins. However, annual streamflow is projected to decrease in North Gujarat and Narmada basin (Figure 6.3). We simulated daily streamflow at 34 Central Water Commission (CWC) gauge locations over Sabarmati, Mahi, Narmada, and Tapi river basins (Table 6.1) from 1951 to 2100. The streamflow simulations were performed using the calibrated hydrological model [VIC, Variable Infiltration Capacity (Liang et al., 1994)] and Routing model (Lohmann et al., 1996)] for bias-corrected General Circulation Models data (Table 6.2) for different scenarios (RCP 2.6, RCP 4.5, and RCP 8.5).

Sardar Sarovar Dam is the largest structure built over river Narmada with six 200 MW turbines, it provides hydro-electricity to four states in India, while irrigating 17,920 km2 of land across 12 drought prone districts of Gujarat and parts of 2 arid districts of Rajasthan

Picture Courtesy: Dreamstime.com

Figure 6.3: Projected change in mean annual streamflow at different CWC gauge locations during the Near (2011-2040), Mid (2041-2070), and End (2071-2100) period against the base period (1971-2000).

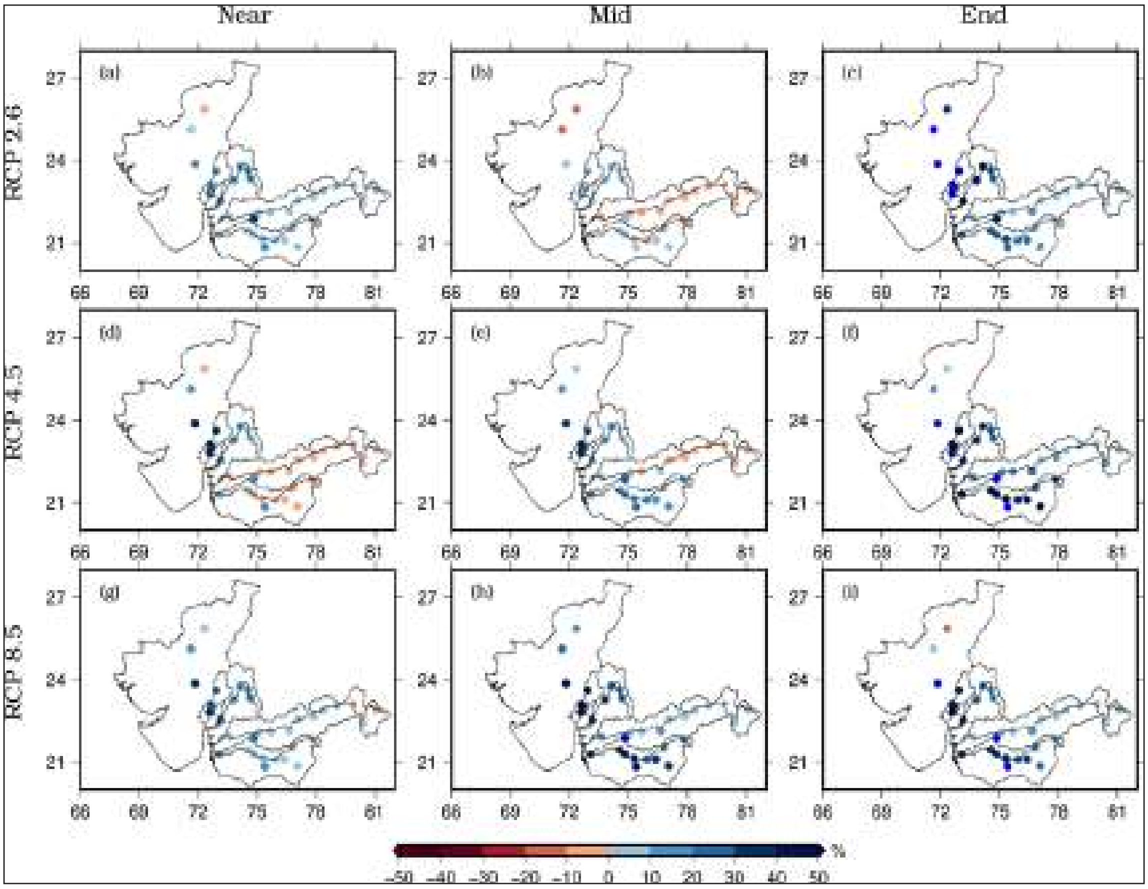


Table 6.1: List of river basins and gauge locations

Basin	Station	Basin	Station	Basin	Station	Basin	Station
Narmada	Bamni Banjar	Tapi	Dahigaon	Sabarmati	Hathmati Weir	Mahi	Kadana
	Barmanat Narmada		Dedtalai		Subhash Bridge		Kadana Dam
	Dindori		Ghala		Vautha		Khanpur
	Garudeshwar		Gidhade		Balotra		Mahi Dam
	Ginnore		Gopalkheda		Gandhav		Mataji
	Handia		Hathnur		Kamalpur		Paderdibadi
	Jamtara		Sarangkheda				
	Mandleshwar		Savkheda				
	Manegaon		Teska				
	Pati		Yerli				
	Rajghat						
	Sandia						

Table 6.2: Information about the CMIP5 climate models used for study

GCM Model	Country
BNU-ESM	China
CESM1-CAM5	USA
GFDL-ESM2M	USA
MPI-ESM-LR	Germany
NorESM1-M	Norway

We also estimated the change in high flow (95th percentile flow) and low flow (10th percentile flow). We find that the high flow frequency and magnitude are projected to increase in the majority of river basins in Gujarat except Narmada River basin (Figure 6.4 and Figure 6.5). A large increase in high flow frequency and magnitude is observed in the End period. The increase in high flow is attributed to increased extreme rainfall events under future warming climate scenarios (Ali et al., 2019; Mukherjee et al., 2018; Shah and Mishra, 2018).

Figure 6.4: Basin-wise change in number of high flow frequency estimated for RCP 2.6, RCP4.5 and RCP8.5 scenarios for Near, Mid and End period

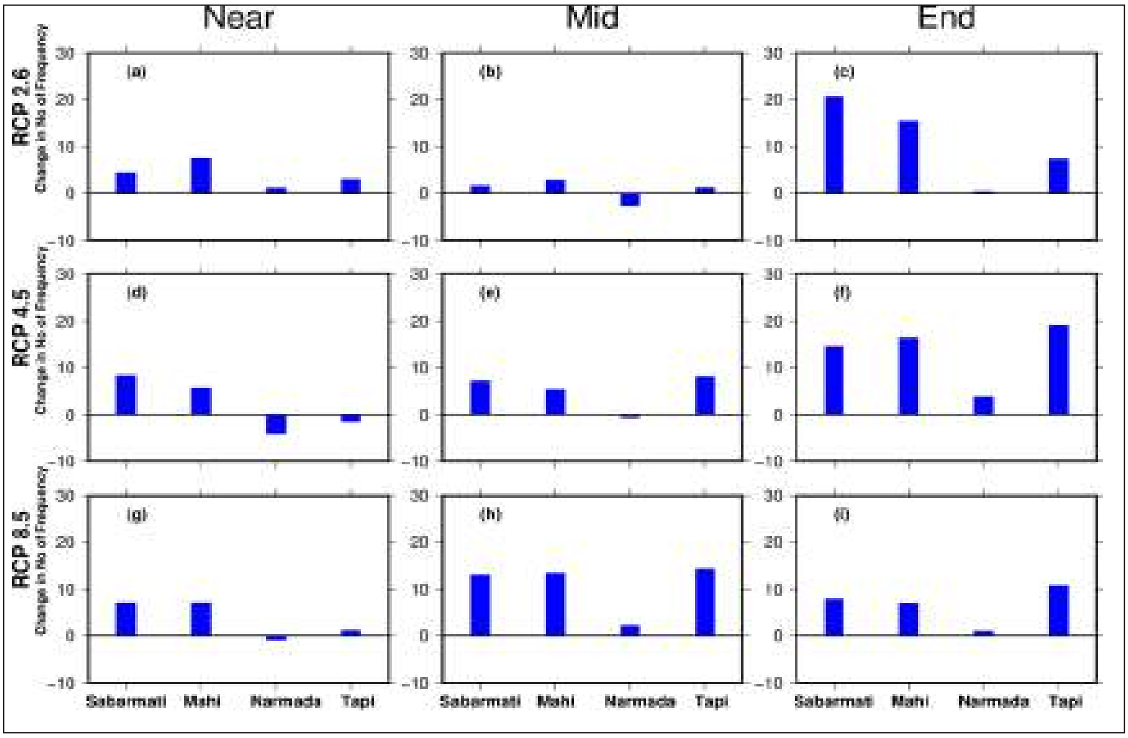
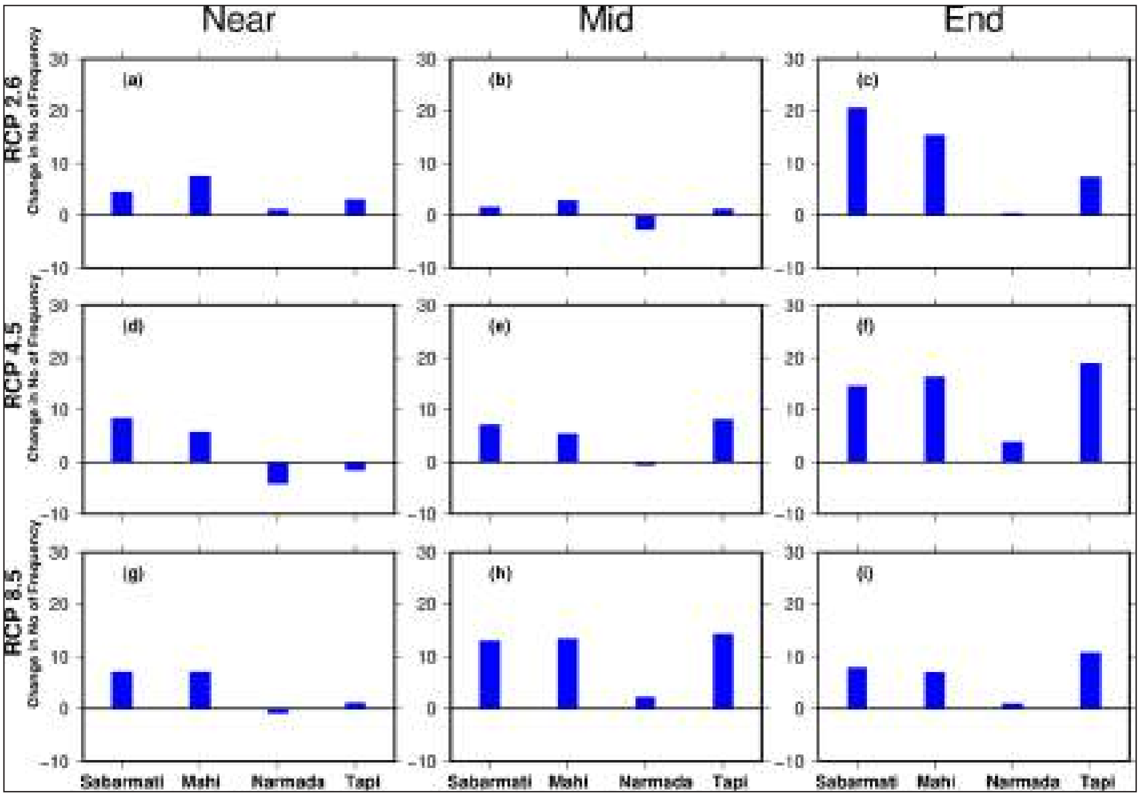
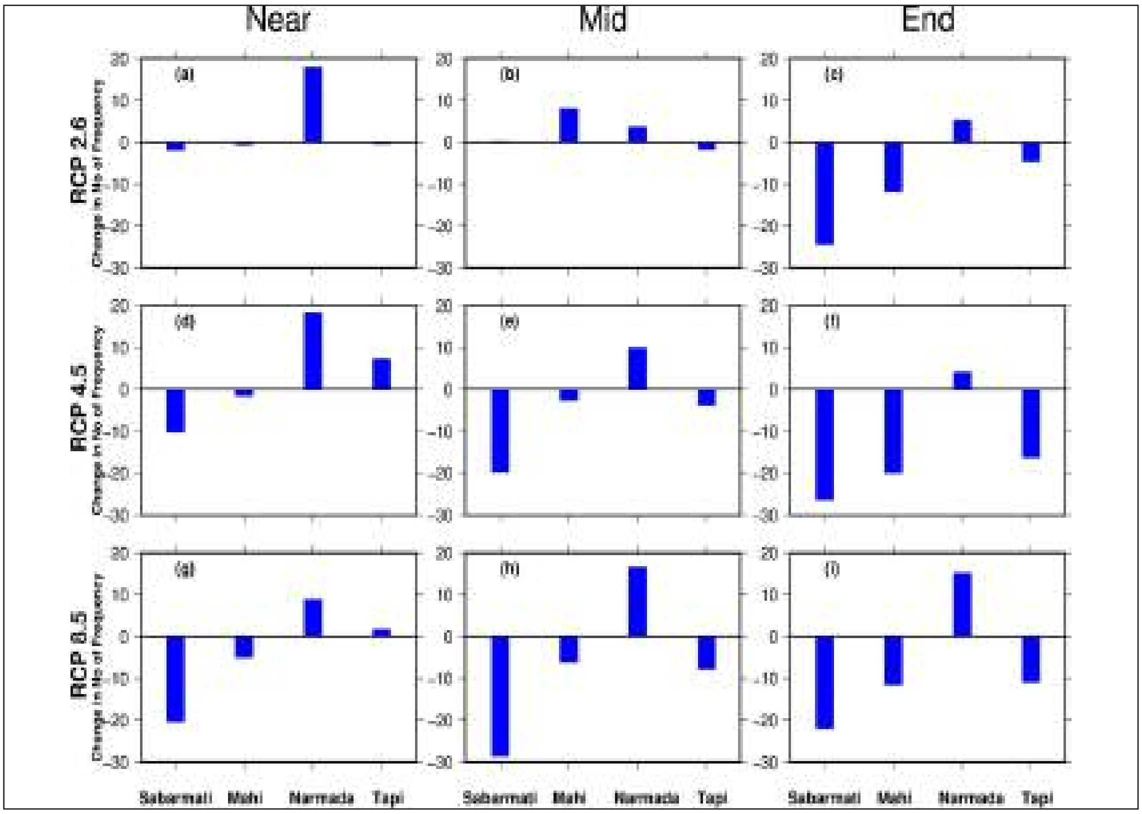


Figure 6.5: Basin-wise change (%) in high flow magnitude estimated for RCP 2.6, RCP4.5, and RCP8.5 scenarios for Near, Mid, and End period



Moreover, we find that low flow frequencies are projected to decrease in the warming climate over Gujarat (Figure 6.6). The results show that the decline in low flow frequency is more under RCP8.5 in all basins (except Narmada basins). Overall, our results show that the water sector of Gujarat is most likely to be affected by floods and droughts in the future climate.

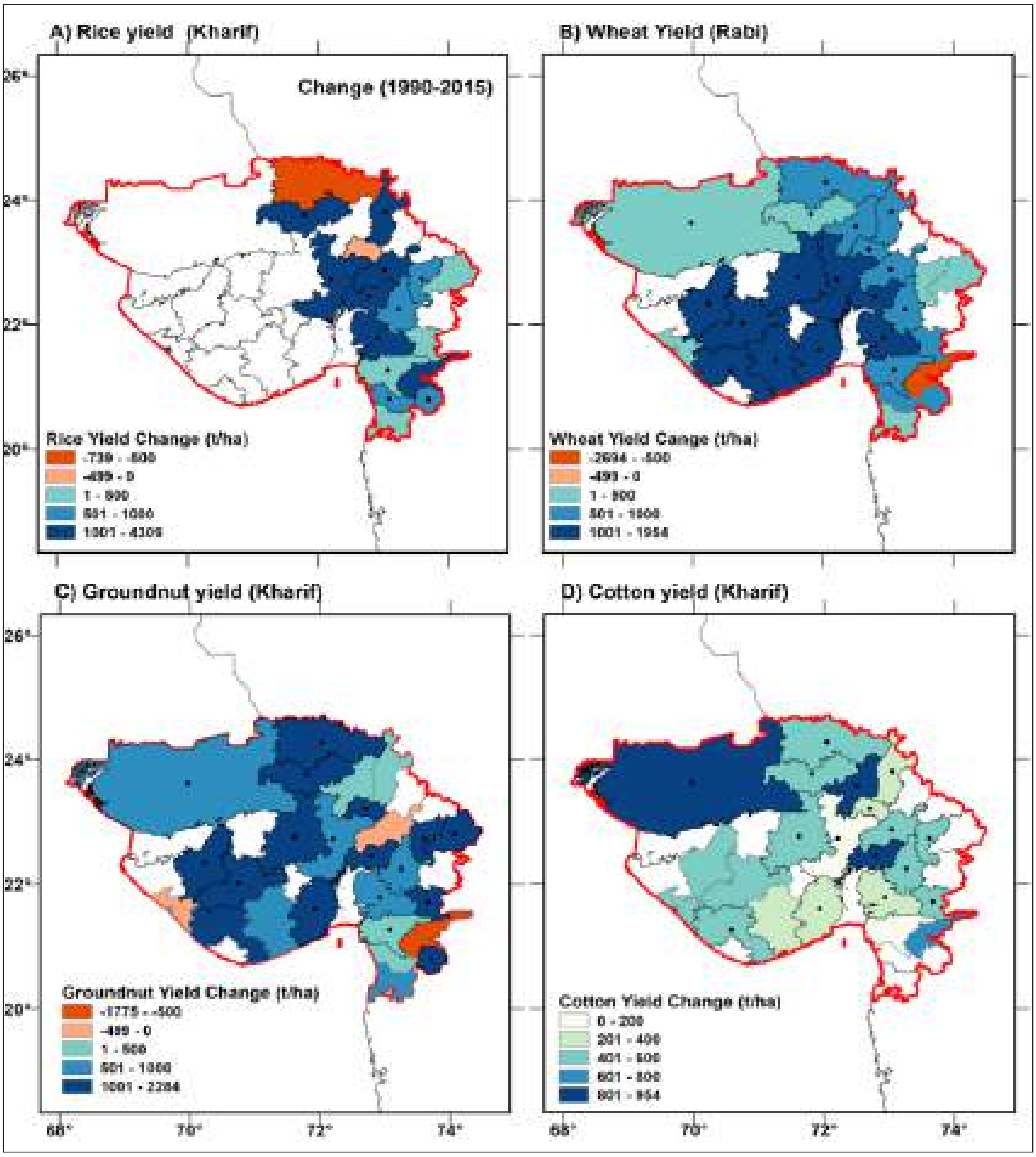
Figure 6.6: Basin-wise change in number of low flow frequency estimated for RCP 2.6, RCP4.5 and RCP8.5 scenarios for Near, Mid and End period



6.1.2 Agriculture Sector

The agriculture sector plays a significant role in the process of economic development of the state. In Gujarat, it is the primary source of rural livelihood. More than five million farmers are associated with agriculture activity in the state. The cultivated area is almost half of the geographic area in Gujarat. Moreover, the total number of operational farm holdings, according to the 2015-16 Agriculture Census, is increased by 8.90 percent over the previous Agriculture Census 2010-11 in Gujarat. The major crops of the state include rice, wheat, cotton, and groundnut. The state produces 1/3 of India's cotton. Our crop yield analysis shows an increase in crop yield (production per area) across Gujarat for the period of 1990-2015. We find highest decline in rice yield in the Banaskantha district by 700 ton/ha (Figure 6.7 (a)). However, Patan, Sabarkantha, Ahmedabad, Kheda, Anand, Vadodara, Panchmahal, Dahod, Bharuch, Narmada, Surat, Dang, Tapi, Navsari, and Valsad districts show an increase in rice yield. The wheat yield was increased by 2000 ton/ha in all districts except the Tapi district (Figure 6.7 b) during 1990-2015. Moreover, we find a decline in groundnut yield in Porbandar, Tapi, and Kheda districts. Overall, groundnut yield has increased. The cotton yield shows a positive trend across Gujarat.

Figure 6.7: **The change in A) rice B) wheat C) groundnut and D) cotton during 1990-2015**

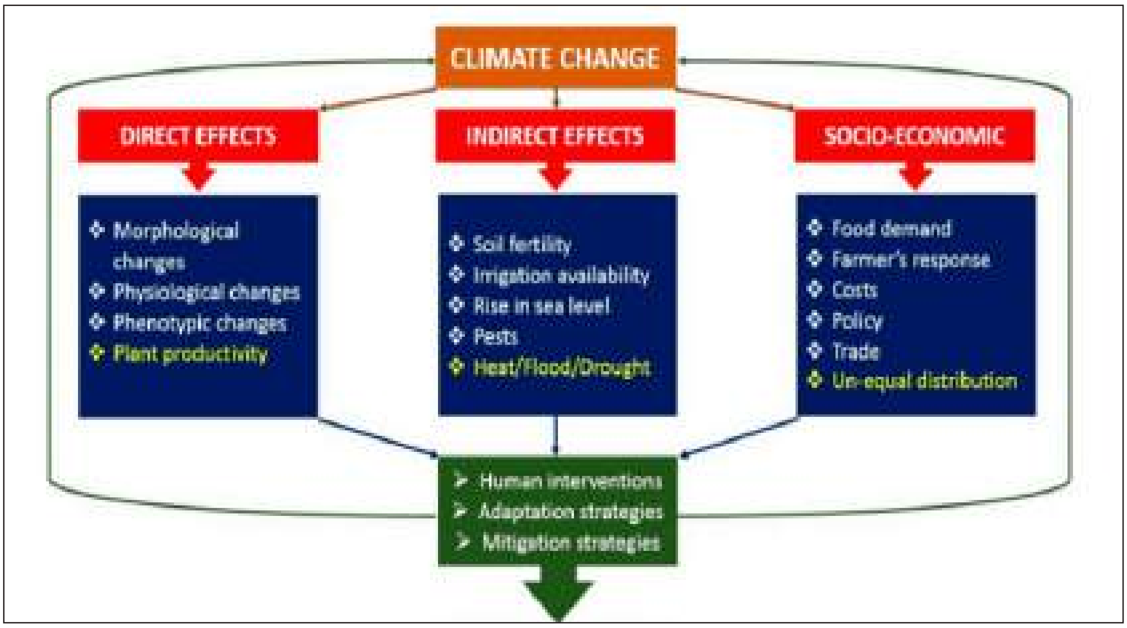


The negative impacts of climate change are the major concern of the agriculture sector in Gujarat. The significant precipitation deficit and extreme high temperature cause drought that can lead to crop damage, crop yield reduction, and ecosystem degradation by reducing the soil moisture and create hydrological water scarcity in the region at later stages. For instance, every year, at least 15% of rice and maize crops get affected due to drought and flash drought in India in the monsoon season (Mahto and Mishra 2020). On the other hand, floods due to high intensity & low duration rainfall cause massive destruction of crops under the climate change scenario, which is also a serious concern (Iizumi et al., 2015).

The Gujarat state has witnessed severe drought and flood events that adversely affect livestock and the economy. A recent study shows 4 to 9% of crop loss due to extreme rainfall and temperature in India. Moreover, an increase in sea surface temperature results in a further increase in the frequency of cyclones and associated storm surges, causing widespread damage to crops and livelihood. The erratic rainfall also increases insect attacks in the region. Recently, a locust attack results in severe crop loss of more than 33 percent in Gujarat. Our climate projections show warm and wet climatic conditions by the end of 21st century, which may result a decline in crop yield in the future. Auffhammer et al. (2012)thus increasing the risk of drought and flood damage to the country's wet-season (kharif found that the rice yield is expected to decrease with climate change in India.

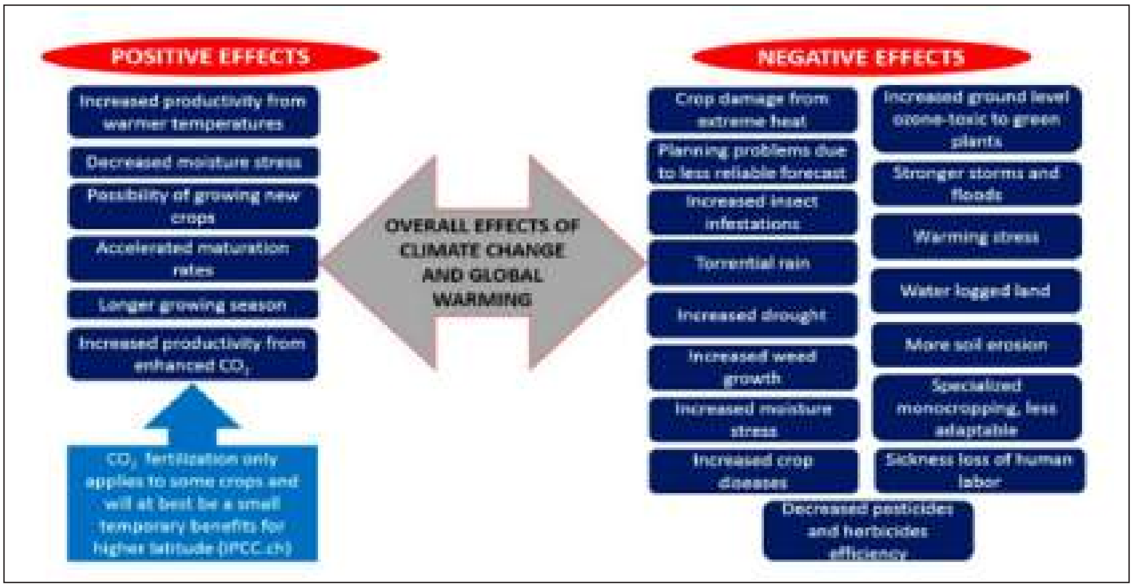
Moreover, the extreme rainfall extremes are projected to increase in the future, which could result in water logging in an area for days resulting in crop damage. Floods and variations in rainfall availability are also a great threat to the agriculture sector as it directly affects the crops sown, soil fertility, and nutrient cycle. Climate change not only impacts crop health and yield but also impacts soil productivity. Due to global warming, sea-level rise causes saltwater intrusion into the groundwater of coastal areas and affects the soil salinity. Hence, the agriculture sector will most likely be affected by the increase in extreme precipitation events and the increase in mean temperatures across Gujarat. The typical direct, indirect, and socio-economic effects of climate change on crop production are described in Figure 6.8, which can be further categorized into positive and negative effects in Figure 6.9 (Raza et al, 2019).

Figure 6.8: Direct, indirect and socio-economic effects of climate change on agricultural production



Source: Raza et al, 2019

Figure 6.9: **Overall positive and negative effects of climate change and global warming on crops and humans**



Source: Raza et al, 2019

To understand climate and crop yield relation, we estimated the correlation between crop yield and climate variables (precipitation, maximum temperature, and minimum temperature). We find that precipitation is positively correlated with rice yield over the majority of districts in the state (Figure 6.10). However, the maximum and minimum temperature in the rabi season (October-February) shows a negative correlation with wheat yield (Figure 6.11). Moreover, we find that the precipitation during the monsoon season (Kharif, June-September) is positively correlated with groundnut and cotton yield. The maximum temperature shows a significant negative correlation with crop yield in the majority of the districts (Figure 6.12 and Figure 6.13). Our results indicate that crop yield is highly sensitive to climatic conditions. Table 6.3 describes the climate change impacts on the agriculture sector.

Although Gujarat is highly industrialized, agriculture and animal husbandry from the mainstay of the economy of its villages (where more than half of the state's population resides)

Picture Courtesy: Dreamstime.com

Figure 6.10: **The correlation between rice yield and A) precipitation B) maximum temperature and C) minimum temperature. The stippling represents correlation values significant at 90% confidence level.**

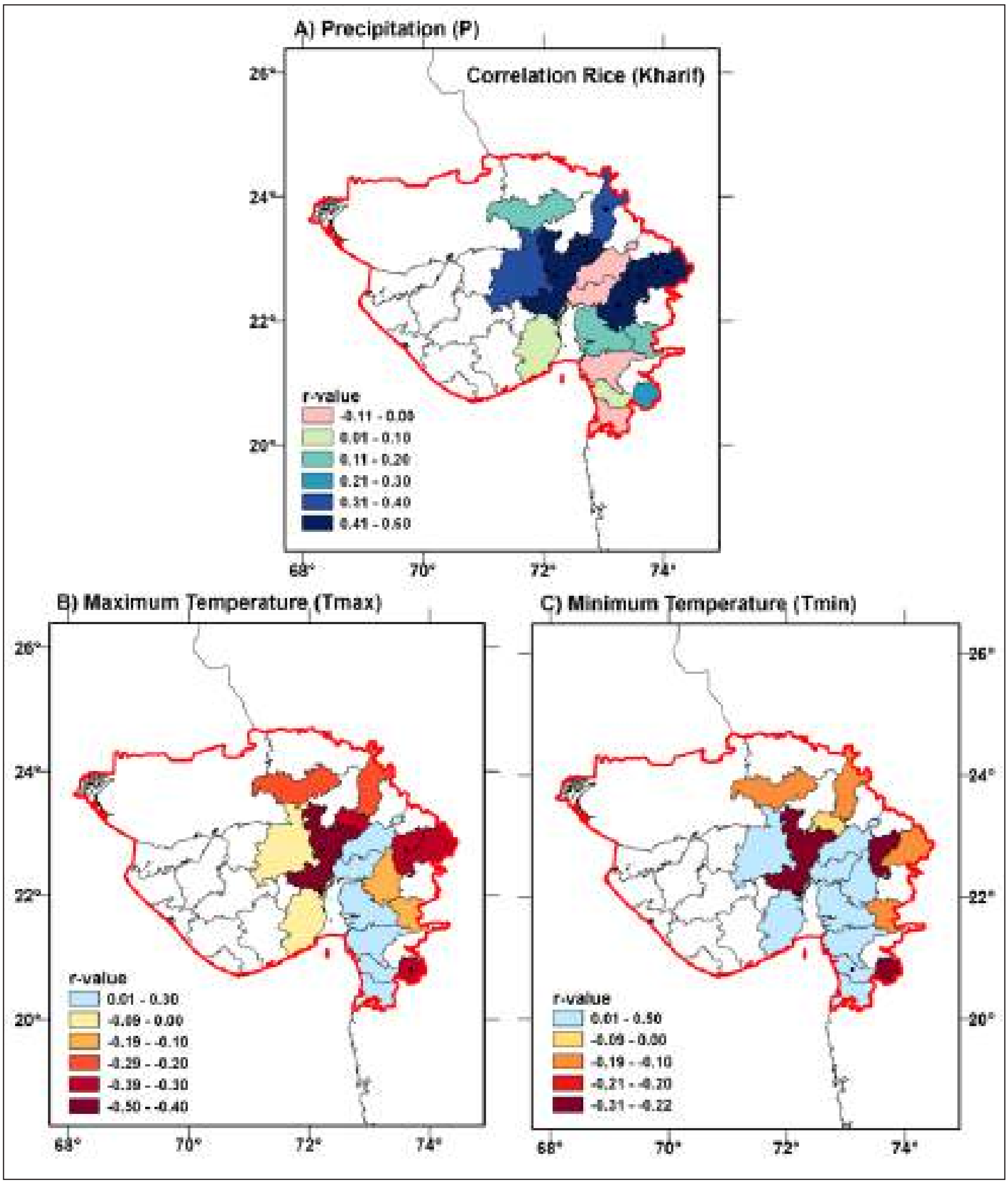


Figure 6.11: The correlation between wheat yield and A) precipitation B) maximum temperature and C) minimum temperature. The stippling represents correlation values significant at 90% confidence level

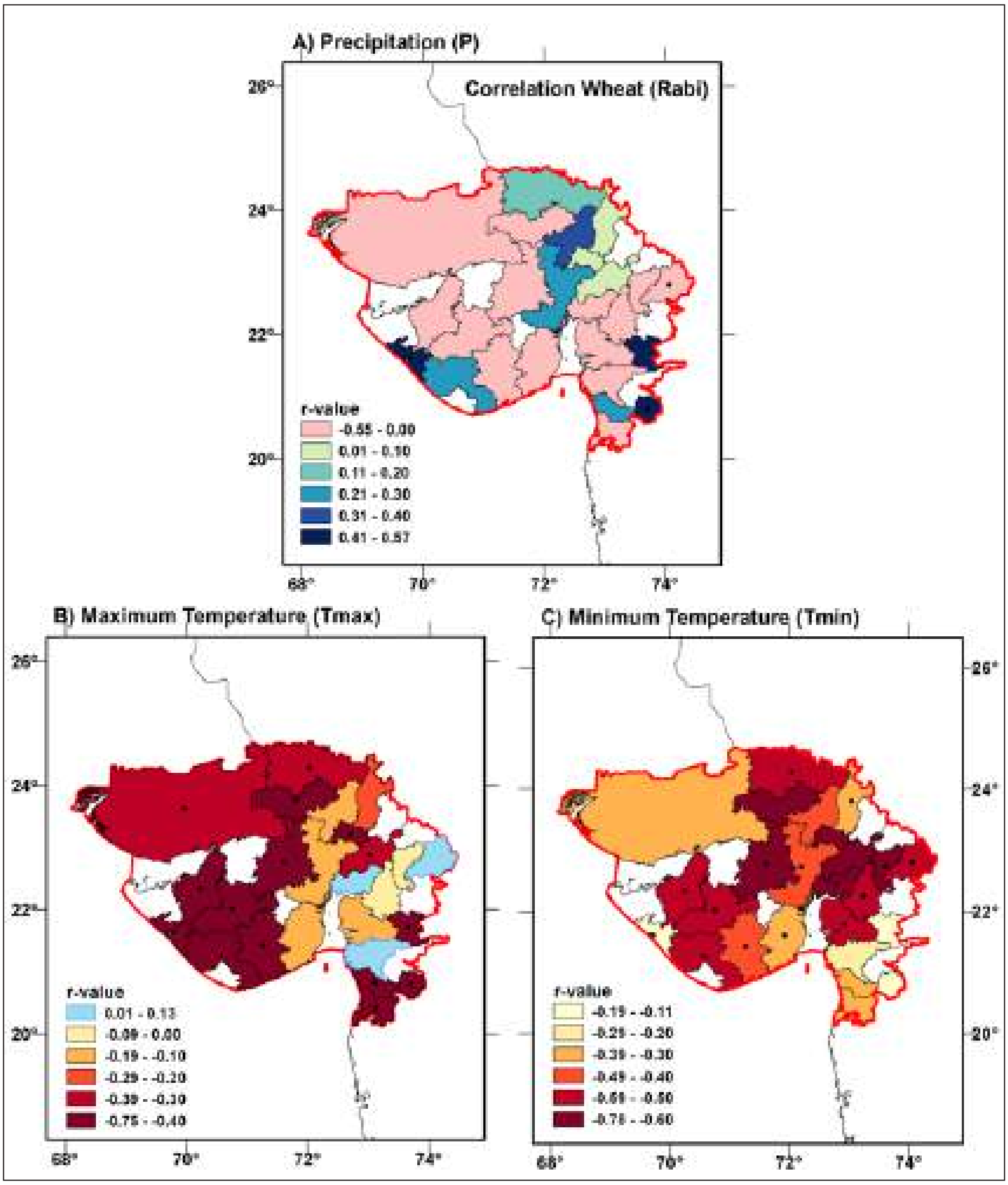


Figure 6.12: **The correlation between groundnut yield and A) precipitation B) maximum temperature and C) minimum temperature. The stippling represents correlation values significant at 90% confidence level**

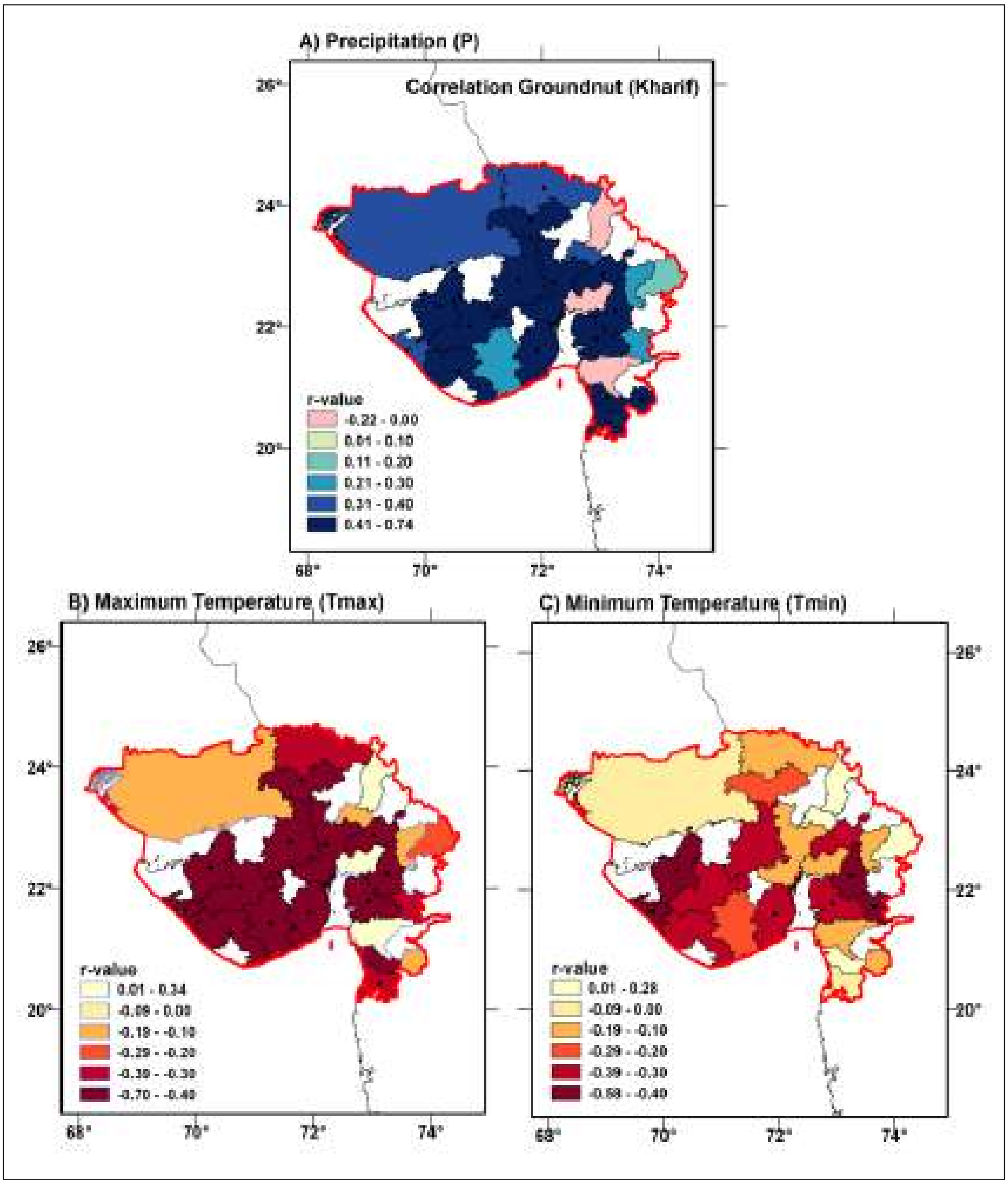


Figure 6.13: **The correlation between cotton yield and A) precipitation B) maximum temperature, and C) minimum temperature. The stippling represents correlation values significant at 90% confidence level**

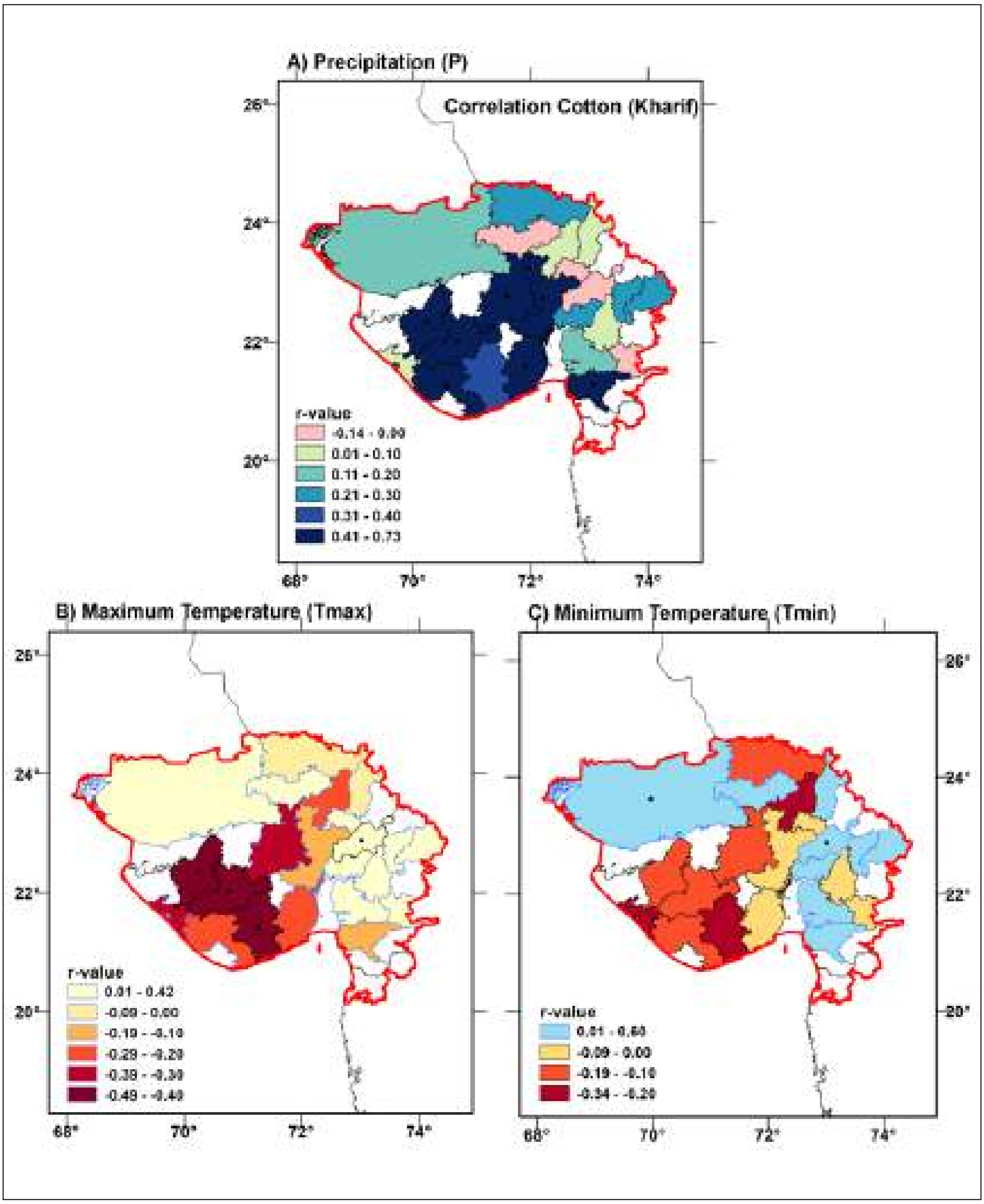


Table 6.3: Climate Impacts on the Agriculture Sector

S. No	Climate Factors	Climate Impacts
1	Temperature (Heatwave/ coldwave)	• Mean Temperatures are projected to increase due to an increase in GHG concentrations
		• Increased photosynthesis, but a reduction in quality of crops such as cotton
		• Crop yield has shown a declining trend with climate change
		• Increased susceptibility to pest attacks due to rising temperature
		• Increased temperatures reduce fodder quality, increases heat stress on livestock
		• Non-availability of freshwater reduces output from livestock
		• changes in sea temperatures and salinity cause coral bleaching
		• Increased Sea temperature and its salinity change will affect fish breeding grounds
2	Rainfall (extreme rainfall/flood/drought)	• Rainfall variability is projected to increase
		• More extreme rainfall events in both excess and deficit cause substantial crop losses
		• Erratic timings of rainfall negatively impact rainfall dependant agriculture
		• Both drought and flood frequency are expected to increase with climate change
		• Droughts and floods cause massive damage to crops
3	Rising sea level	• Increased sea level associated with increased ingress of salinity at coastlines reduction in crop output in coastal regions

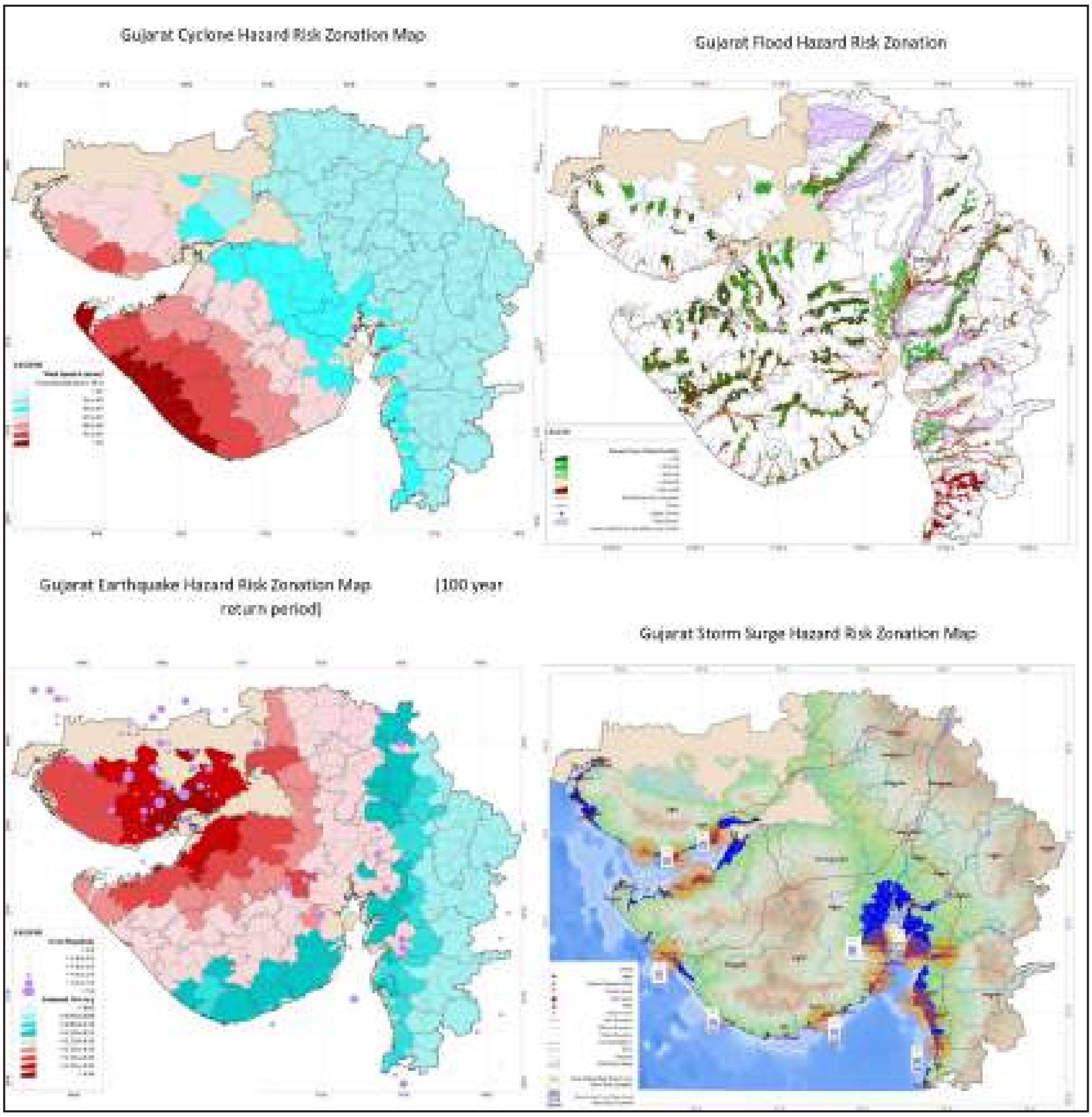
6.1.3 Disaster Management

As per National Disaster Management Act, 2005 (NDM Act 2005), disaster means a catastrophe, mishap, calamity, or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to and destruction of property or damage to or degradation of the environment and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area. Disasters always lead to huge losses of lives and the economy.

Gujarat falls in the region of a tropical cyclone with a semi-arid climate. It has a 1600 km long coastline, which is connected to the Arabian Sea and highly vulnerable to the cyclone (Figure 6.14 (a)). Gujarat has witnessed all major climate governed natural hazards like cyclones, droughts, floods, tsunamis, heatwaves, and lightning in the past due to its geo-climatic and geological features.

More than 120 cyclones had passed through Gujarat in the last century. Saurashtra districts were affected a lot during past cyclone events (Nilofar 2014, Vayu and Maha 2019, Nisarga 2020). Gujarat is a drought-prone state. Kuchchh, North Gujarat, and Saurashtra region had faced famines. Lack of surface water availability leads to groundwater exploitation. Due to deficit and delays in monsoon, Gujarat had suffered severe droughts in 2002 and 2016. Whereas, extreme and unprecedented rainfall events cause flooding in the past (Surat 2006 and Morbi 1979). The coastal region is prone to a tsunami and the Kandla coast was hit by a tsunami in 1945. The maximum temperature reaches 40-45 ºC in April-May which results in the severe heat wave. The community like construction workers, homeless, etc are most vulnerable. In 2019, two people died, and 300 people were affected by the heat wave. Lightning occurs during the monsoon season and it is a weather-related natural disaster. The lightning causes several deaths and loss of property across Gujarat.

Figure 6.14: Risk zone of Gujarat state for different disaster events



Source: GSDM – 2016-17

Our future projections show that precipitation and temperature are projected to increase over Gujarat. We find the temperature is projected to increase by 1.5-5 ºC and precipitation is projected to change by -15 to 25% across Gujarat by the end of the 21st century. We find that the high flow event is projected to increase in Sabarmati, Mahi, and Tapi River basins. These climatic and hydrological analyses support that the natural hazards are expected to increase in the coming decades. Moreover, the Sendai Framework for Disaster Risk Reduction 2015-

30 (SFDRR), Sustainable Development Goals (SDG), and Paris Agreement (CoP21) suggest for future global action on Disaster Risk Reduction (DRR), sustainable development, and climate change.

Due to the location of Gujarat, it is very vulnerable to many disasters like cyclone, earthquake, flood, storm surge and many more. Drought is the very impactful climatic event that affects the millions of the people in India. Gujarat has primarily sub humid, arid and semi-arid region over the state. Due to changing precipitation and temperature, may it will impact over the state. Gujarat is highly vulnerable to cyclones, that is because of the longest coastal area and climatic condition. Cyclones are more vulnerable in the coastal region of Saurashtra region and Kuchchh. In other hand storm is also impactful disaster for the state. Whereas in case of earthquakes earlier Gujarat faced a heavy earthquake in Bhuj, it created huge loss of economy and life. The Gulf of Kuchchh and the Saurashtra region is very vulnerable to earthquakes. Parts of Surat, Vadodara and many more regions get affected most of the year due to flood events (Figure 6.14 (b))

High flow event is projected to increase in Sabarmati, Mahi, and Tapi River basins under climate change scenarios, leaving a large population and infrastructure in Gujarat vulnerable to the vagaries of nature

Picture Courtesy: https://upload.wikimedia.org/wikipedia/commons/thumb/4/40/Flood_Affected_Areas_of_Amreli_District_Gujarat_India_on_24_June_2015_5.jpg/4096px-Flood_Affected_Areas_of_Amreli_District_Gujarat_India_on_24_June_2015_5.jpg

6.1.4 Coastal Regions

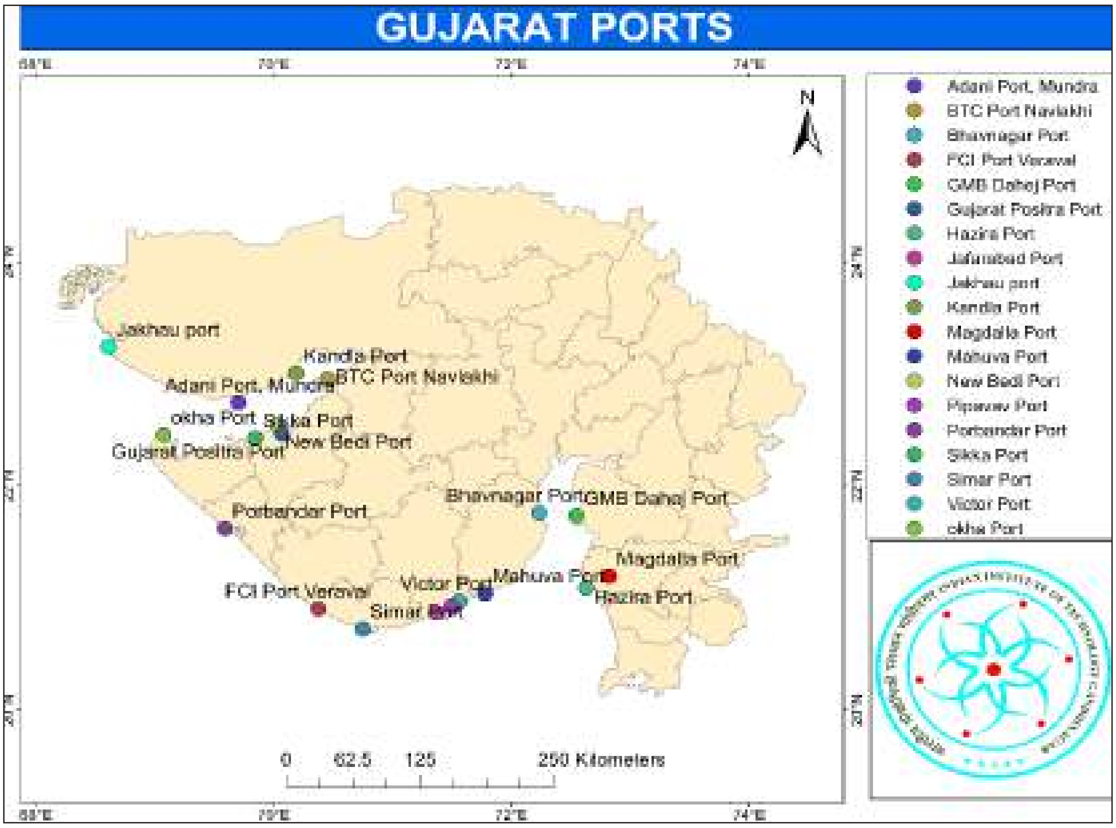
Gujarat has a coastline of approximately 1,663 km, which is the longest and is approximately 22 percent of the total coastline of India (GEC, 2008). The coastal area is another vulnerable sector prone to the adverse effects of climate change by different climate factors like temperature, precipitation, and severe storms. The projections of mean annual daily maximum temperature suggest that there is an overall tendency of increase in temperature. The mean annual daily maximum temperature increase is estimated to increase of 4.4 °C by the end of 2099. Considering the frequency of hot nights and hot days, an increase in frequency is also observed for the future projections. Similar pattern of increase is observed for heatwave projection is observed for the regions of Gujarat. Rising sea surface temperature is alarming as warmer water affects marine life and increases the frequency of occurrences of cyclones. Rising temperature is the major cause of rising sea levels. The migration of species from a warmer environment to a much colder habitat adversely affects change in habitat and marine species distribution in that area. Increased temperature causes drought conditions in the area which severely affects the freshwater mixing with tidal water leading to an increase of saline conditions in estuaries. Increased temperature triggers coral bleaching among coral reefs. Rising levels of carbon dioxide in seawater cause increased acidity in ocean water due to a decrease in oxygen levels affecting marine ecosystems and also escalates coral bleaching leading to declining of coral reefs.

Gujarat has a coastline of approximately 1,663 km. Climate change projections suggest rising sea surface temperatures that will impact marine ecosystems and declining of coral reefs

Picture Courtesy: Mukesh Acharya

Rising sea levels due to the melting of glaciers can result in flooding and submerging of low lying islands and wetlands resulting in migration of coastal people to the safer regions to cities in response to the alarming sea-level rise. It accelerates shoreline erosion, as the sediments carried to the coastal region are changed. As the sea level rises saltwater intrusion into the freshwater increases in the coastal region affecting the life of people and coastal ecosystems. Population growth and development along the coastal regions like ports and other constructions further increase the vulnerability of coastal ecosystems to sea-level rise. The studies show that 45.67 % of the Gujarat coast is under high to the very high risk category and 54.33 % of the Gujarat coast is under Moderate to Low risk category due to an anticipated rise in sea level. The coastal regions under very high risk category are along with northwestern parts of the Gulf of Khambhat, the northernmost parts of the Gulf of Kachchh and western parts of the Kachchh coast (Mahapatra et al. 2015). The figure 6.15 shows the different ports including Major and minor ports along the Gujarat coastline, Ports are highly at risk towards rising sea levels.

Figure 6.15: Major and minor ports of Gujarat



The long coastline of Gujarat houses several major and minor ports. By its sheer nature and location, the port infrastructure is vulnerable to the impacts of climate change like sea level rise, storm surge and cyclonic winds

Picture Courtesy: shutterstock.com

In the future climate projection scenario for Gujarat, extreme precipitation events seem to increase in all the three emission pathways like RCP 2.6, 4.5, and 8.5. Precipitation extremes and severe storms events make the coastal region vulnerable to flooding especially low lying areas, this further increases the chance of shoreline erosion along the coastal regions. Flood-like situations destroy habitats that poses a threat to the life of both flora and fauna. Coastal flooding of wetlands and marshlands affects the species that are exclusive for these vulnerable areas due to inundation as mangrove forests are very sensitive ecosystems. Flood water from land may carry nutrients and fertilizers washed away with it which can trigger the algal and phytoplankton growth on the marine surface. This algal and phytoplankton growth causes difficulties for other marine and aquatic organisms by depleting oxygen levels of the water. In some cases, severe storms like cyclones result in a threat to human life also. Increasing temperature leads to increased sea surface temperature ultimately increasing the intensity of cyclonic events in the future. The studies show a substantial increase (by 46 %) in Tropical Cyclone frequency over the Arabian Sea and a decrease (by 31 %) in the Bay of Bengal (Murakami et al. 2013)they commonly show a substantial increase (by 46 %. Cyclones are always associated with heavy rainfall doubling the adverse effects in the coastal region including damages to infrastructures, properties, disruption to transportation networks, water pollution, a threat to life, etc. Table 6.4 describes the indicative risks of climate change impacts on the coastal areas of Gujarat.

Table 6.4: Indicative risk on coastal regions due to climate change

Climate Variable	Indicative Risk
Temperature increase & Heatwaves	• Rising sea surface temperature • CO_2 rising causes acidity to sea water affecting marine ecosystems and decrease in oxygen levels • Drought decreases the freshwater mixing with tidal water increasing salinity of estuaries • Warmer water affects marine life • Migration of species from warmer to much colder habitat Increased Coral Bleaching
Precipitation	• Vulnerable to coastal flooding • Shoreline Erosion • Flood water from inland may carry nutrients and fertilizers which trigger growth of alga and phytoplankton
Severe Storm/ Cyclones	• Flooding of low lying areas • Destroy habitats and threat to human life
Rising Sea Levels	• Increased risk of flooding of inhabited islands and tidal wetlands • Vulnerability of coastal ecosystems • Development can block the inland migration of wetlands in response of sea level rise, • Change in amount of sediment delivered to coastal area • Accelerated shoreline erosion • Salinity of ground water • Destruction of marsh lands

Gujarat's coastline is a source of income for a large population from port operators to fisherman to the salt pan workers. The vulnerable coasts will impact the livelihoods of all these dependent communities

Picture Courtesy: pixabay.com

6.1.5 Rural Livelihood

Rural livelihood is interconnected with their environment and its resources, hence any disturbances related to the environment affect their life tremendously. The projections of mean annual daily maximum temperature suggest that there is an overall tendency of increase in temperature. The mean annual daily maximum temperature increase is showing a heightened temperature of 4.4 °C. In the case of hot nights and hot days, an increase in frequency is also observed. In the future heat wave projection, an increase in the frequency of heatwave is observed for the regions of Gujarat. Rising temperature puts high stress on farmers as they are outside workers getting heat strokes. Drought like situation arises due to increasing temperature induce scarcity of water which affects crop production, crop harvesting, and livestock management. Drought results in drinking water scarcity for both rural people and livestock and it also adversely affects rural industries (small scale) on which the livelihood of rural people depend on. Drought also causes loss of grazing land affecting livestock management because of less precipitation resulting in inadequate soil moisture for plants to survive. High temperature also triggers wildfire in the forest area, drying up of wetlands and water supply intensifying damages further. Wildfire damages their dwellings, threat to the life of people and livestock, forest products like timber, etc. Disappearing forests are putting great stress on the lives of rural people. Sometimes climate change impacts on rural areas indirectly impact cities too through a shortage of food and water supply but during the hazards, rural areas are suffering more in resource management and other service disruptions where urban areas get more privilege.

Adaptation of rural communities through sustainable livelihood options has a major role ensuring climate resilient Gujarat
Picture Courtesy: Dreamstime.com

Floods affect their lives completely, increase or decrease of rainfall affect farming and water sources on which is their primary source of income. In the future climate projection scenario for Gujarat, extreme precipitation events seem to indicate a net positive trend in all the three emission pathways (RCP 2.6, 4.5, and 8.5). Rainfall variation affects the farming and fisheries sector and other small scale rural industries like handicrafts. This may lead to a hike in poverty among rural people. Heavy rainfall can cause water logging that may go for many days, resulting in the decaying of crops. Persistent waterlogging also causes problems to the rural infrastructure and damages the grazing land of their livestock. Livestock management is greatly affected due to the deficiency of fodder. Severe storms result in loss of homes and damage to forest outputs like fruits, firewood, honey, and similar products. Damage to firewood either due to wildfire or severe storms severely affects cooking as they are primarily dependent on firewood for cooking purposes. The selling of forest outputs is a source of their income which is getting disturbed due to various calamities. Various natural hazards affect transportation from the rural area to the cities for their food supply and handicrafts to the market are disrupted. This will lead to a financial crisis and starvation among the rural community. Loss of marginal land and water contamination due to salinity as a result of sea-level rise is also expected. Greater dependence on agriculture and other natural resources makes them highly vulnerable to extreme climate events, and climate change. Existing vulnerabilities among rural communities caused by poverty, lack of education, isolation from cities, and negligence by policymakers can all elevate climate change impacts in different ways.

Cottage industries, self-help groups and training skilled artisans in different trades would strengthen the socio-economic situation of Gujarat

Picture Courtesy: Commiserate of Rural Development, Gujarat

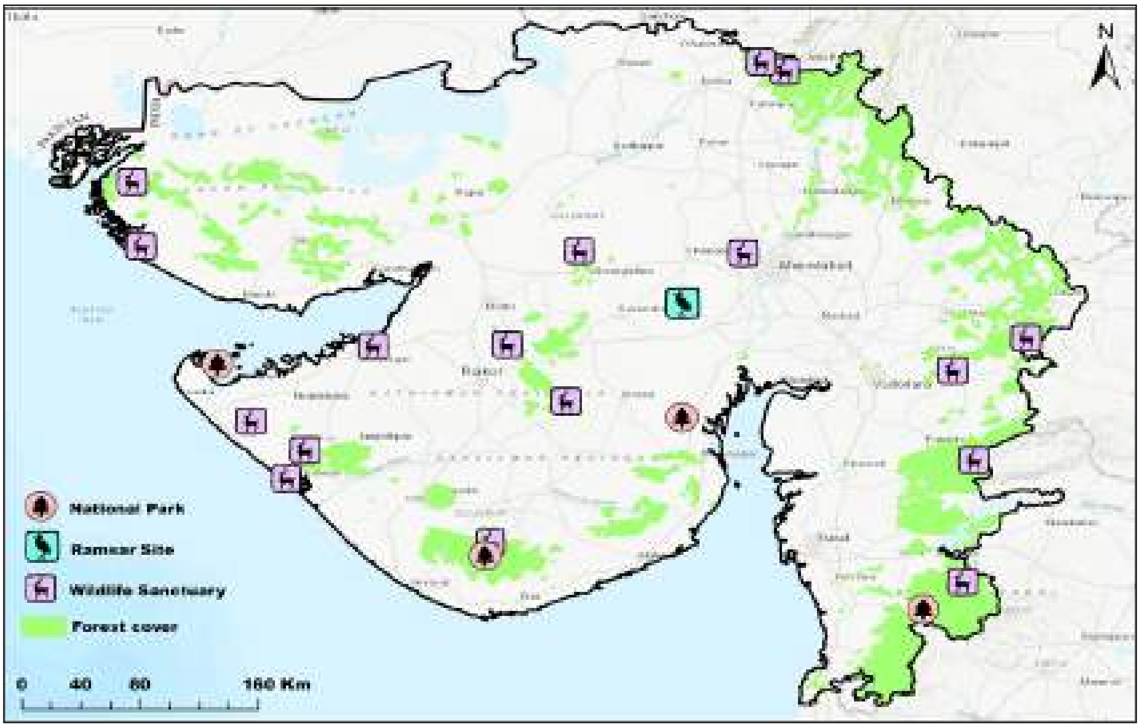
Table 6.5: Indicative risk on rural livelihood due to climate change

Climate Variable	Indicative Risk
Increased Temperature & Heatwaves	• High heat affects outdoor workers like farmers • High heat affects crop production and harvest • Scarcity of water for drinking and for other rural industries • Loss of gazing land affect livestock • Trigger wildfire
Increased Rainfall intensity	• Affect fisheries sector • Increase or decrease of rainfall affect farming and water sources • Floods affect their lives completely and hike in poverty • Transportation of their supply to city area is affected
Severe Storm/ Cyclones	• Forest outputs like fruits and honey are damaged • Loss of homes • Loss of Firewood
Rising Sea Levels	• Loss of Marginal land • Water quality of drinking water decreases

6.1.6 Biodiversity

Biodiversity plays an important role in creating a balanced ecosystem. A healthy composition of biodiversity includes all types of living plants and animals which co-evolve within a closed ecosystem. Because of climate change the stability of ecosystems can be affected as change in precipitation and temperature will influence the existence, development and distribution of species. Most important compositions that provide support to the other genetically different species are mangroves, corals reefs, wetlands, and forest and wildlife populations. Locations rich in biodiversity in Gujarat state such as wildlife sanctuaries, national park and Ramsar sites are shown in Figure 6.16.

Figure 6.16: Locations rich in biodiversity (wildlife sanctuaries, national park and Ramsar sites) in Gujarat State

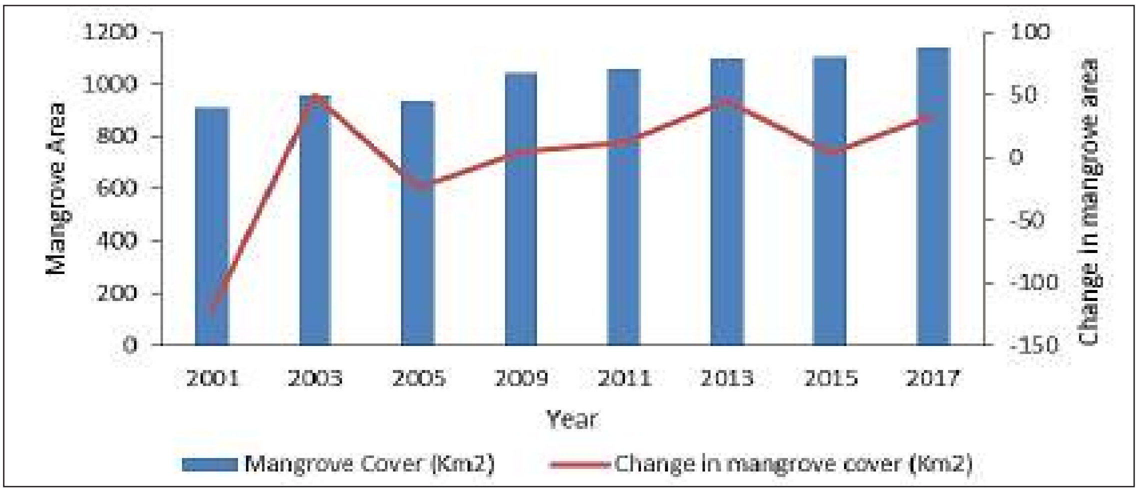


In Gujarat, mangroves are one of the vulnerable and ecologically important species that regulates the coastal climate and the ecosystem. Gujarat has 23.66% of the total mangrove cover of Indian region, which is the second largest mangrove reserves after West Bengal. It shares the longest coastline in Indian states, with 1650 km constituting over 21% of the Indian Coastline. A narrow range of climatic factors precipitation, humidity and sea surface temperature along with other important factors such as fresh water inflow to the ocean are the key components for growth and development of mangrove. Mangroves play an important role in maintaining the balance between atmosphere and aquatic ecosystem; preventing salinity and sea water intrusion, reducing the impact of wave action, reducing coastal erosion, reducing impact of cyclones over the coastline etc. Due to climate change sea level rise is a very severe concern which creates the impact over the mangroves. So proper monitoring of mangroves is very essential. As per Forest Survey of India, Gujarat mangroves covers the area 1140 km2 (in year 2017). Mangroves of Gujarat are distributed in five major regions as shown in Table 6.6. In Gujarat state mangroves cover is increased mainly due to conservation and larger mangroves plantation in Jamnagar, Kuchchh, Junagadh and Bhavnagar (Figure 6.17) FSI report, 2017.

Table 6.6: Region wise distribution of mangrove cover in Gujarat State in 2017 (FSI, 2017)

S.N.	Region	Region wise Total mangrove cover (Km2)	Percentage of State's mangrove cover
1	South Gujarat	17	1.49
2	Gulf of Khambhat	131	11.49
3	Gulf of Kachchh	188	16.49
4	Saurashtra region	6	0.53
5	Kuchchh region (including Kori creek)	798	70
	Total	1140	100

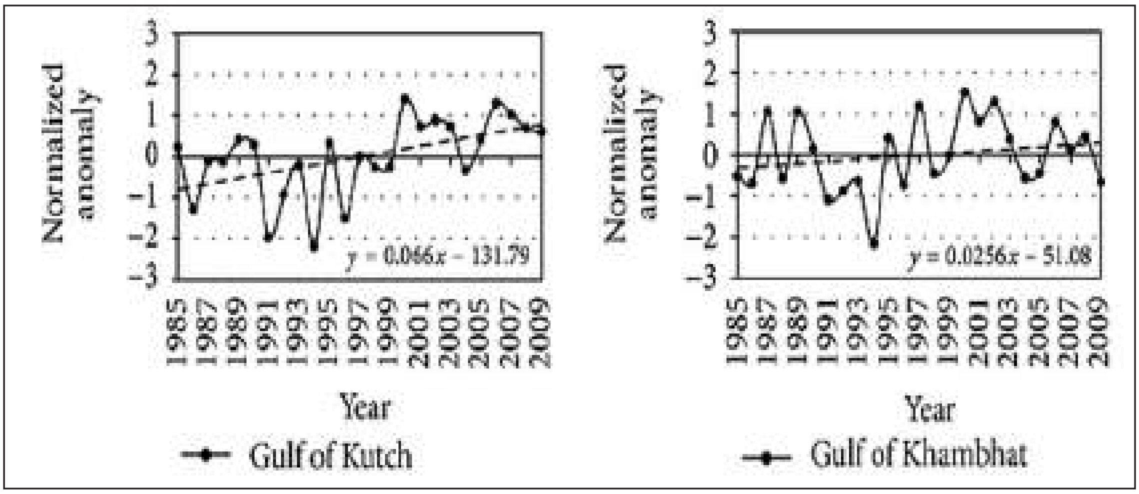
Figure 6.17: Status of mangrove cover in Gujarat from 1978 to 2017



Wetlands are the land area that are either temporarily or permanently covered by water. Gujarat is also rich in wetland biodiversity. It consists of both types of wetlands, i.e. inland and coastal wetlands (NWIA- SAC, 2010). Wetlands cover approximately seven percent of the earth surface and it provides forty-five percent of natural productivity and ecosystem. Wetland plays an essential role in many ecosystem services like replenishing groundwater and sub-soil aquifers, reducing sea water intrusion, providing habitat to flora and fauna in order to maintain the biological and genomic diversity of aquatic animals, micro-organisms, and inland water animals. Gujarat state covers the 34749.5 km2 area of wetland (aquatic: 28070.51 km2, Inland: 6581.91, other: 97.08). Due to climate change wetlands are directly or indirectly affected by sea level rise, increase in sea surface temperature (SST), temperature, precipitation. Increasing temperatures have direct impact on sea level rise due to melting glaciers that cause threat to coastal wetland, shoreline infrastructure and lowland inundation (Dwivedi et al, 2005). A rise in sea level by 0.1, 0.2, 0.3, 0.4, 0.5 m will affect 2508.3, 5016.6, 7524.9, 10033.2 and 12541.5 km2 of wetland area in the state of Gujarat, respectively. Moreover, decrease in precipitation and continuous increase in temperature may deplete the existing wetlands and lead to unsuitable conditions for migratory birds. In effect, the Nal-sarovar (a Ramsar site) will be in danger under the future projected climate.

Coral reefs provide benefits to the environment and people in numerous ways like; protects the sea shores from storms, fisheries, medicine, provide economic benefit as tourism and recreation. In the Gulf of Kuchchh in Gujarat, 352.50 km2 area is covered with Coral (Bhatt et al, 2012). Studies showed that corals bleaching is a serious concern for biodiversity conservation in Gujarat state resulting from rise in sea surface temperature and UV-B radiation, delay in the onset of the southwest monsoon associated with climate change (Figure 6.18) (Ali, R. 2014; Arora et al, 2019). Evidence of coral bleaching due to increasing SST has been provided in Nandkeolyar et al. (2013) which showed an increasing SST trend (Figure 6.19). Therefore, a continuous increase in SST is a major concern which should be taken into account to protect the coastal biodiversity of Gujarat region. Though most of the coral reefs located in the Gulf of Kuchchh Marine National Park are protected (corals are also protected under the Wildlife Protection Act, 1972), however, there is a need to design and maintain networks of protected areas to increase resilience of the entire reef system.

Figure 6.18: Annual normalised SST anomaly from 1985 to 2009



Source: Nandkeolyar et al. 2013

Figure 6.19: Healthy and bleached corals at Laku Point reef (July 2016).

(a) Healthy coral: Turbinaria sp. (b) Bleached coral: Turbinaria sp. (c) Bleached coral: Goniopora sp. (d) Partially bleached coral: Favia sp. (e) Partially bleached coral:Porites sp. (f) Bleached sea anemone: Heteractis sp

Source: Arora et al, 2019

Wildlife species and their food chain mainly sustain within the forest resources; therefore, the climate change effect of forest will directly affect the lifestyle of wildlife species. For example, Pride of Gujarat, the Asiatic Lions are increasing in numbers and migrating outside the Gir sanctuary in search of new territory. Climate change can adversely affect the growth and productivity of forests that will pose a condition of extreme survival for the species because of limited resources. Fortunately, Gujarat forest department is actively working on the protection and management of forests and as a result of it, forests in Gujarat states are increasing (FSI, 2017).

Mangroves are the first line of defence towards the impacts of climate change in coastal areas. Gujarat hosts the 2nd largest mangrove cover in India and 15 diverse species of mangroves found in the state

Picture Courtesy: Mukesh Acharya

6.1.7 Forest Sector

Since ages, forests (a precious natural resource) provide us with tons of valuable resources and goods for the wellbeing of human and other living beings. From the Oxygen (O2) that we breadth to the goods and services (timber, fruits, rubber, shelter, food) we use in our day-to-day life, all comes from the forests. Most importantly, forests provide living and breeding habitat for other wildlife species who have equal contribution to maintain the balance of the Earth's ecosystem. However, under climate change (mostly by human activities) scenario, forests can have various direct and indirect impacts. Climate change effects mainly include the effects of changing temperature, precipitation and CO2 concentration in the periphery of local to regional forest environments. Droughts and heatwaves associated with low precipitation and high temperature directly influence the growth and productivity of forests. When plants and trees get stressed during drought, it results in a lower than average carbon sequestration from the atmosphere. Hence, the Net Primary Productivity [NPP= Total amount of carbon uptake from the atmosphere during photosynthesis - amount of carbon release during respiration (metabolization of sugars and starches to convert it into energy)] get reduced. A persistence of long hot and dry conditions during frequent and heatwaves, forest fire can be one of the common but serious threats resulted by climate change. A forest fire can occur due to both man-made and natural causes. For instance, the 2019-2020 forest fire in East Australia and North India caused a huge loss of forest biodiversity, taking the life of more than a million species whereas many more get affected (Yu et al., 2020).

The forest cover in Gujarat is spread over an area of around 21647km2 (11% of total area). The Gir forest in Saurashtra region boasts of being the only natural habitat of the mighty Asiatic Lions

Picture Courtesy: Vijay Kumar Gaba, Unsplash.com

The forest cover in Gujarat is spread over an area of around 21647km2 which is 11% of the total geographical area in 2011-2012 (GoG, 2013). Recent report published by the forest department, Gujarat (GFS, 2019) showed that forest area has increased around 215km2 since 2012 (i.e. 21860km2 forest area in 2019). The State has 23 wildlife sanctuaries and 4 national parks, one natural history museum, one zoological park, one botanical garden and one Ramsar site covering about 10% of the total geographical area of the State (GFS, 2019). There has been a tree density (trees above 30cm girth) of 127 trees/ha reported in the forest areas.

It is for sure that increase in temperature occurs due to global carbon emission that causes warming. However, on the contrary, many studies have actually shown that increasing CO2 concentration increases forest productivity through a process called 'carbon fertilization effect'. Long-term free-air CO2 enrichment (FACE) experiments demonstrated that an increase in CO2 concentration leads to tree growth. It was surprising to see that an increase of 23% in the average NPP in response to doubling of CO2 concentration (Kirilenko and Sedjo, 2007; Norby et al., 2005; Korner et al., 2005). Apart from these, human activities also significantly affect the forests under the pressure of climate change. For instance, deforestation for land development or mining activities directly destroys the forest ecosystem. This may cause further negative impact to existing forest due to forcefully altering the natural land cover. Such activities can pose serious impacts on wildlife species and lead to biodiversity loss. Therefore, forest cover change has direct and adverse implications on biodiversity of that area. Also, many a time a pest/insect attack can be a threat to plant and forest cover which can be recognized as an indirect effect of climate change.

The long term changes in precipitation pattern and increase in temperature due to the combined effect of climate change and anthropogenic CO2 increase can influence the net primary productivity (NPP) of forest. Here, we showed the combined effect of precipitation and temperature change on forest growth and productivity (NPP) of Gujarat forest region by analyzing the change in annual NPP for the dry and wet years. Over the forest area, by considering the percentage change in total annual precipitation (mm) and average of daily maximum temperature over an year, we find that NPP from the forests over Gujarat has a strong positive correlation with precipitation and negative correlation with temperature with coefficient of correlation (r) = 0.8 and -0.57 for precipitation and temperature, respectively (Figure 6.20 and 6.21). The change in NPP is more sensitive to the change in precipitation then temperature, and therefore, precipitation is the driving factor for forest growth and productivity (NPP) in Gujarat. The reason can be attributed to the arid and semi-arid climate of Gujarat where vegetation is highly sensitive to the small change in precipitation. Furthermore, though over the forested area, there is no significant increasing/decreasing trend in precipitation, but the NPP response to extremely dry (year 2018; reference) and wet (year 2017; ref) is clearly noticeable (Figure 6.22). On the other hand, we also find that both the precipitation and temperature has a considerable increasing trend (and so extreme) over the south west districts of Gir Somnath, Devbhumi Dwarka, Surendranagar (reference period: 1951-2019), where a dense patches of forest are present in the Geer national park and century. Since, high temperature (insolation) and precipitation is the perfect ingredient for any plant to grow, the combined increase in precipitation and temperature can be attributed to the increase in the forest cover in the South-west districts of Gujarat (GFS, 2019). Other reasons for the increasing forest cover in the State are plantation, conservation activities and awareness programs by the forest department.

Figure 6.20: Correlation between percentage change in annual precipitation and net primary productivity (NPP) during 2003-2019

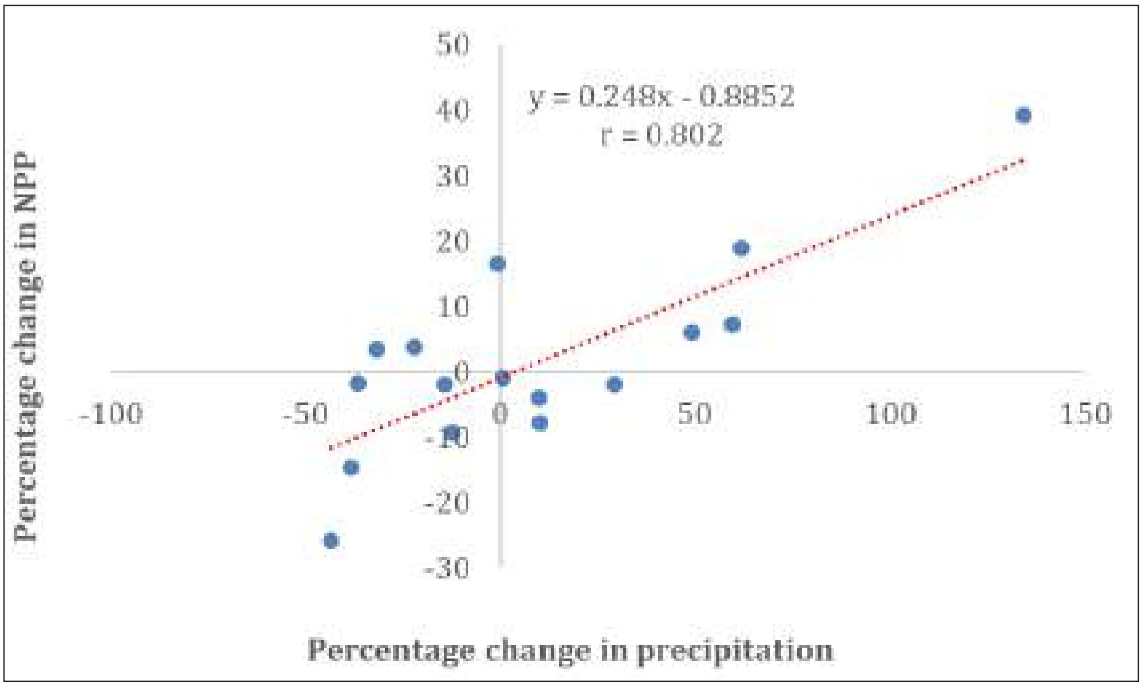


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Figure 6.21: Correlation between percentage change in average daily maximum temperature and net primary productivity (NPP) during 2003-2019

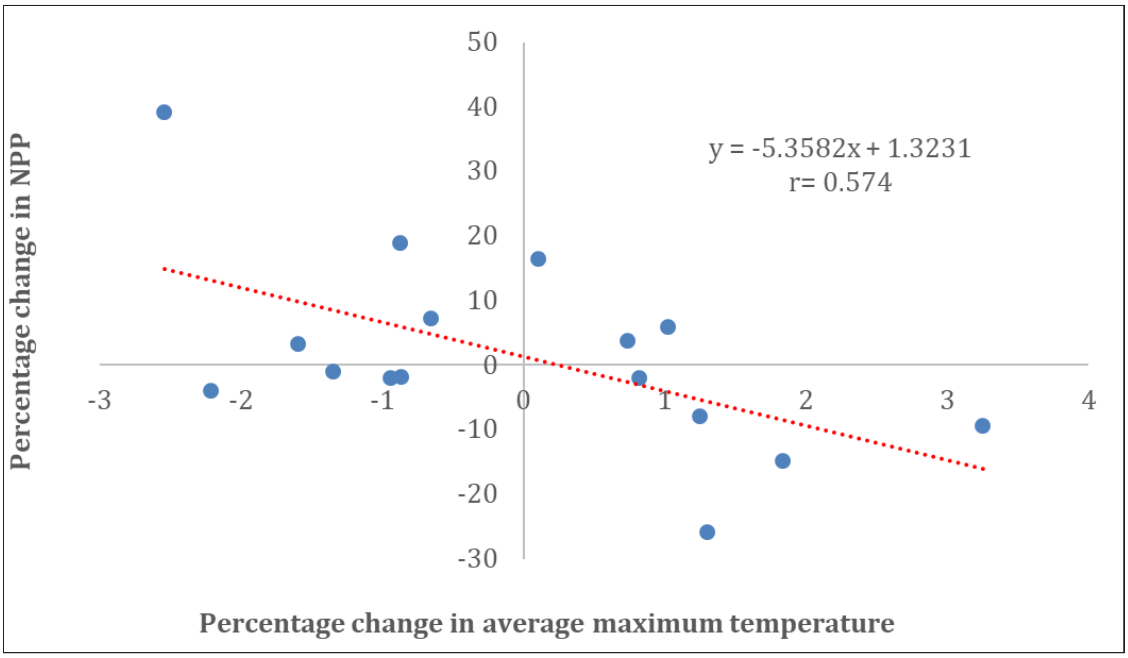


Figure 6.22: Year to year variation in total precipitation and NPP over the forested region in Gujarat. Year 2017 and 2018 had reported severe floods and drought in the state

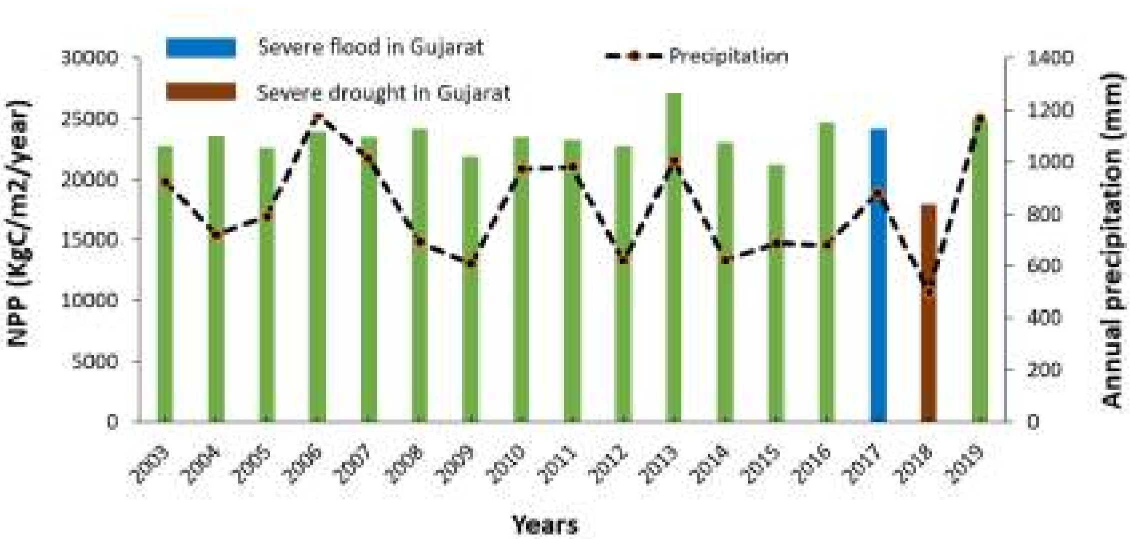
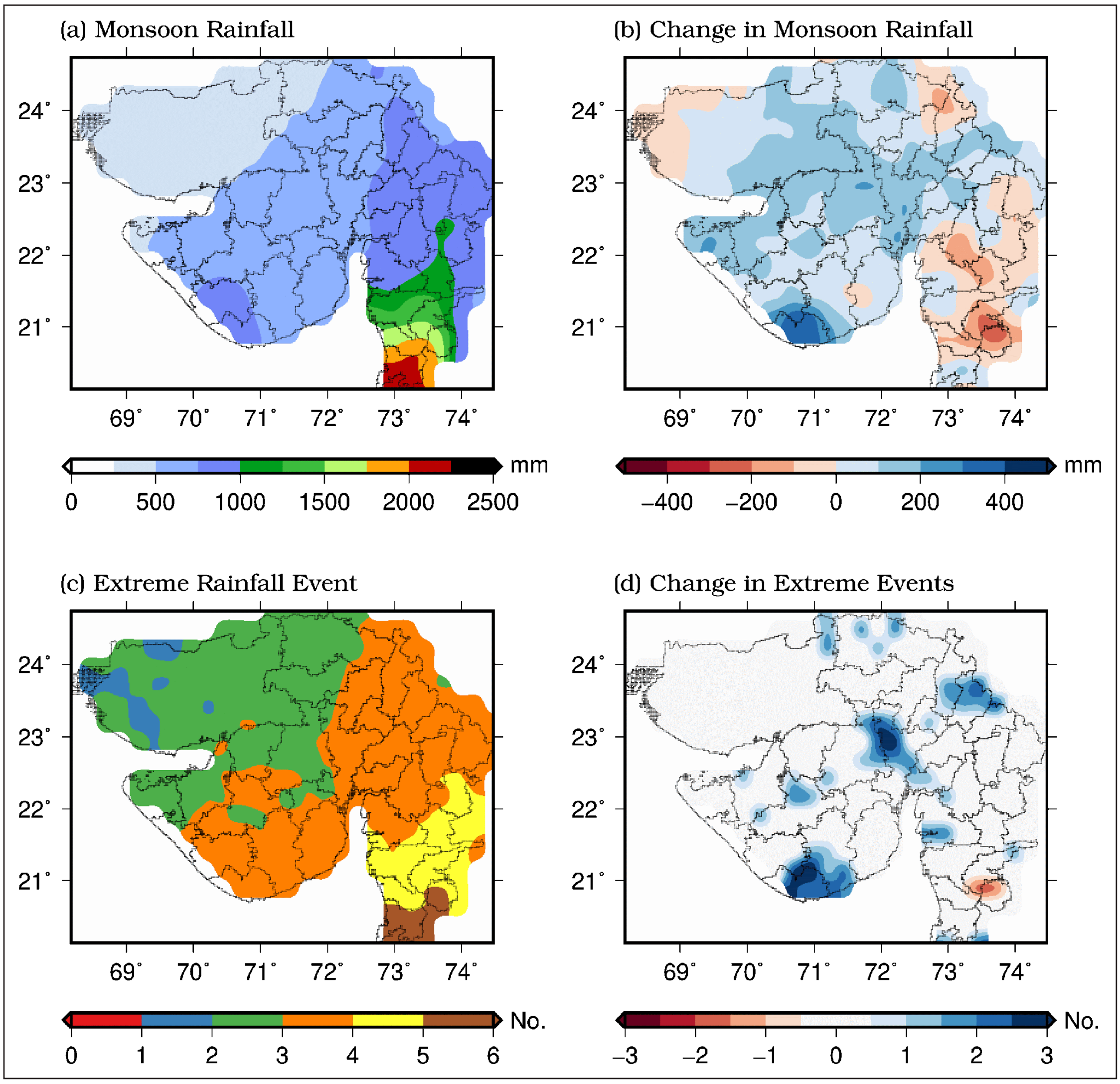


Figure 6.23: (a) Observed mean monsoon season precipitation, (b) Change in monsoon season precipitation during the period of 1951 – 2019



Forest fire due to climate change is one of the serious threats to the forest resources in Gujarat. We find a positive trend in the observed temperature in most of the state which accounts for the temperature to rise by 0.1 to 1.5°C (Figure 6.24 (b), (d), and (f)). The presence of dry and woody vegetation can act as a fuel that may trigger forest fire in the pre-monsoon season, which is dominated by extremely dry temperature and low precipitation. According to Forest Survey of India (FSI) report, around 15% of the forest cover are under moderate to extremely high risk of forest fire in the Gujarat state (FSI report, 2019). The extremely high risk of forest fire is present over the regions of south-east Gujarat where forest density is comparatively higher. Due to climate change, the decrease in the precipitation (Figure 6.23 and Figure. 6.25) and average increase in the temperature in that region can be one of the potential drivers for triggering the forest fire.

Figure 6.24: (a), (c) and (e) Observed annual mean of daily max, mean and min temperatures. (b), (d) and (f) change in observed annual mean of daily max, mean and min temperatures

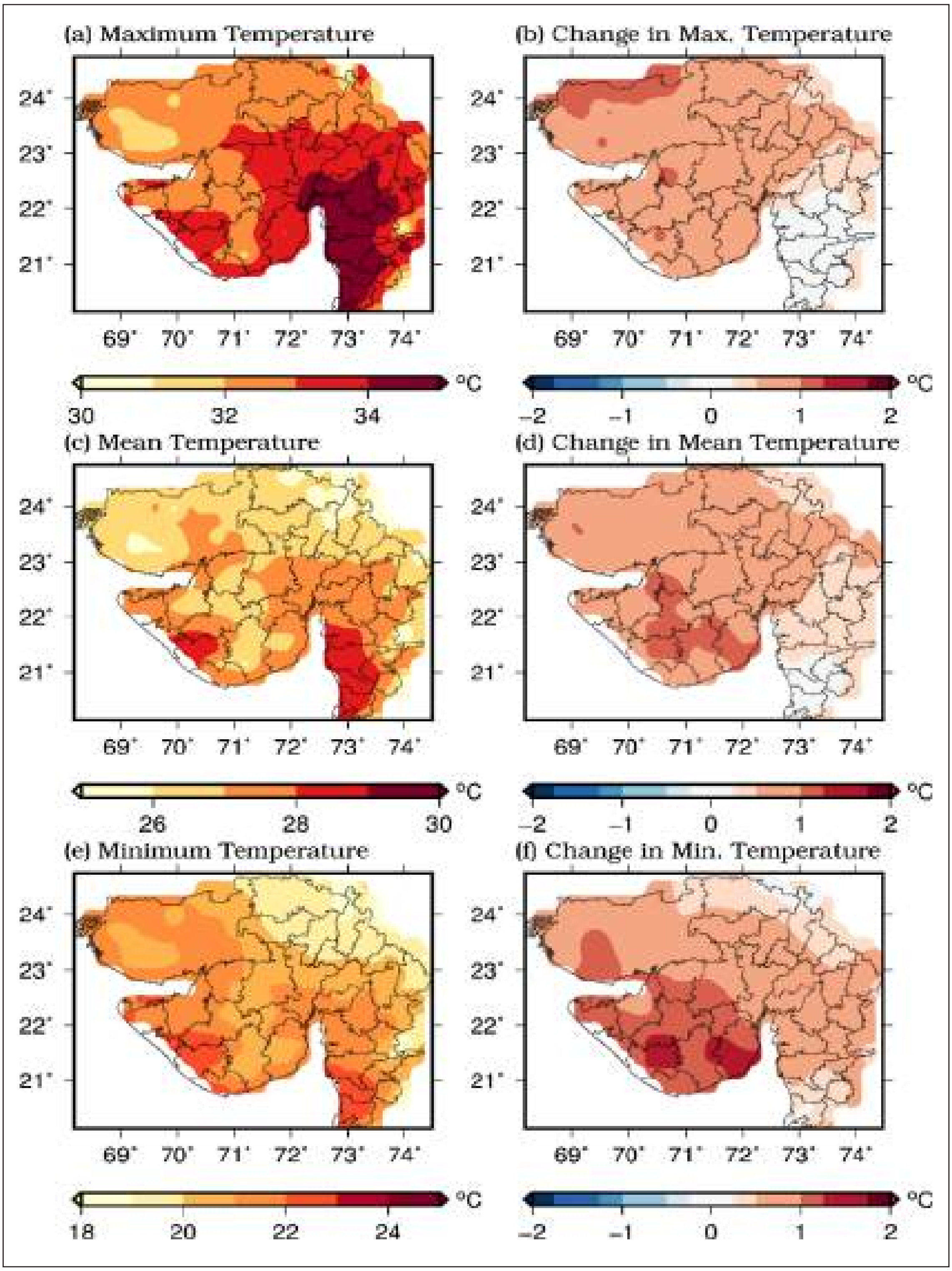
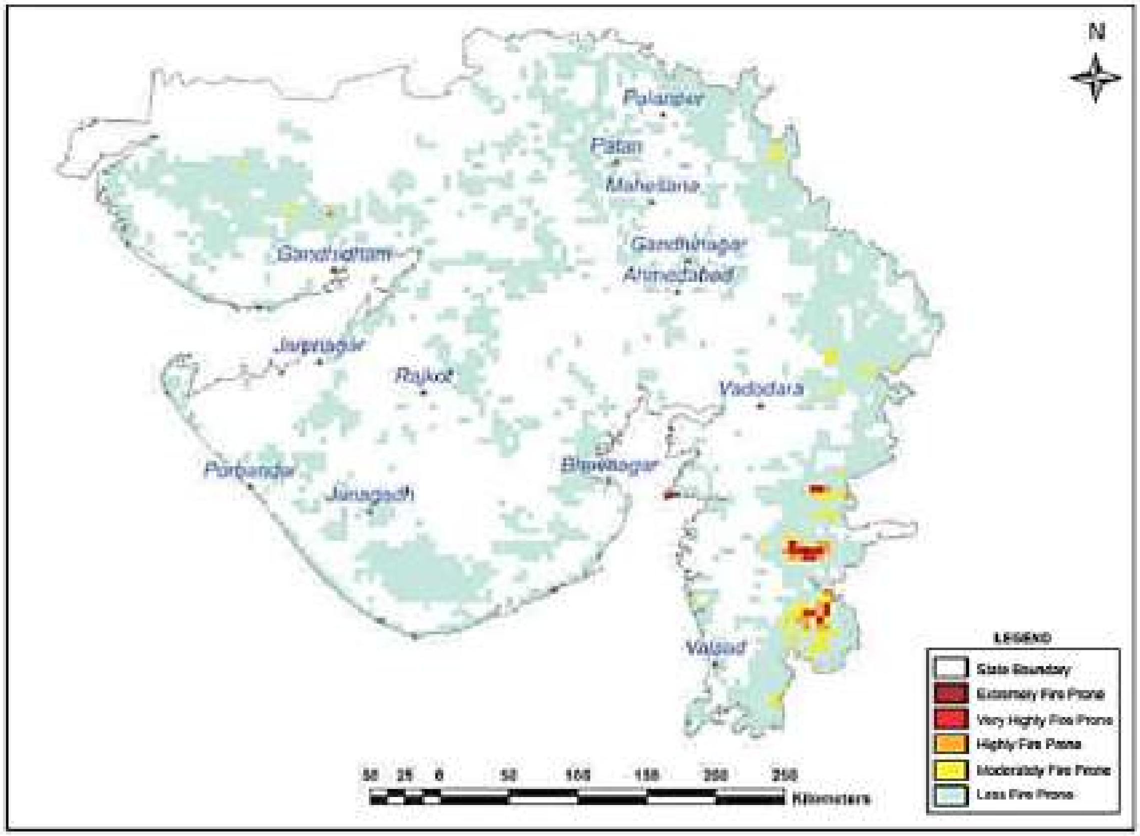


Figure 6.25: **Fire prone forest areas under different fire prone classes**



Source: FSI report, 2019

A warming climate with change in precipitation pattern and higher CO2 concentration can lead to changes in the patterns and behaviour of pests and insects in the forest area. These changes can play an important role in establishing forest cover. Insects and pathogens have been noted to respond to warming in terms of changes in phenology and distribution to influencing forests (Menéndez, 2007). Most of the time impact-attack are quite hazardous to forest health (Ayres and Lombardero, 2000). The reproduction, growth, survival and spread of insects, pests and pathogens are very much sensitive to small changes in precipitation and temperature (climate) because of their cold-blooded nature. In a short life span, insects respond more quickly to climate change than long-lived organisms (Menéndez, 2007). Climate influence on insects can be direct, as the birth and mortality rate of the insects and pests in a particular region can be directly influenced by climate change which overall affect the forest growth and development. Moreover, change in the phenology of plants and animals such as flowering or breeding can also occur due to changing precipitation and temperature patterns which may attract more pests and pathogens to accommodate in the limited forest resource. Gordo and Sanz, (2006) suggested that it is one of the easiest impacts of climate change to monitor. Nevertheless, the relationships between pests, forest and other species is expected to get altered by climate change, resulting in creating an imbalance in the natural food chain in the set ecosystem.

6.1.8 Infrastructure

Gujarat is one of the leading industrialized states in India. With 5% of India's population and 6% of India's landmass, Gujarat accounts for 7.5% of India's GDP. Gujarat's average GDP growth per year is close to 10%, which is higher than the national average GDP growth. To achieve this growth, infrastructure sectors (road, railway, airport, metro, and port etc) are playing an important role. Gujarat's infrastructure sector is large and diverse. There are various transport infrastructure modes available in Gujarat for passenger as well as freight transport like roads, civil aviation, railways, coastal shipping, and inland waterways. However, roads and railways are the most widely used modes. Gujarat has about 111,560 km of roads and is considered to have one of the best road networks in the country. The rail network in Gujarat is about 5,259 km (Figure 6.26). Moreover, Gujarat has a long coastline which has an energy potential of 80000 MW (Govt. of Gujarat G.R. No.: SLR/11/2017/141/B1). In the changing climate, this infrastructure sector is expected to be a major hurdle in the growth story of Gujarat. Economic activities and their nature play a significant role in the translation of GDP to transport demand. With such a large reliance on the transport network currently, it becomes a very important and strategic asset.

Figure 6.26: Rail and road network of Gujarat

Source: https://www.mapsofindia.com/

The Infrastructure sector has covered almost the entire state and is projected to expand further in the future. The infrastructure is generally immobile and made up of large and lumpy physical assets such as flyovers, bridges, buildings, roads, power plants, and transmission lines. It is vulnerable to climate-induced natural calamities as it is exposed to natural weather situations (Naswa and Garg 2011). The infrastructure sector faces the challenges posed by the weather and climate. Koetse and Rietveld (2009) note that the performance of transport systems deteriorates under adverse and extreme weather conditions.

Gujarat is projected to experience adverse impacts of global climate change. The population, economic development plans, and natural ecosystems in the country are facing a threat from climate change in the future (Table 6.7). Moreover, considerable changes in mean and extreme climate have been observed over Gujarat between 1951-2019 (Chapter 3, Fig 3.8). For instance, the risk of extreme rainfall events has increased in Gujarat and likely to increase further under the projected future climate (end of 21st century) in all three (RCP 2.6, 4.5, and 8.5) scenarios. In addition, the frequency of floods (High flow) is projected to increase significantly under the projected future climate in all four (Sabarmati, Tapi, Mahi, and Narmada) rivers (chapter 3, Fig 3.7). In the last 60 years, Gujarat has experienced significant warming (more than 1°C), which can lead to increased heatwaves, hot summers, and associated mortality (Mishra et al 2017, JA et al 2020)the implication for population exposure to severe heatwaves remains unexplored. Here, we characterize maximum potential human exposure (without passive/active reduction measures. These changes in mean and extreme climate will pose long lasting impacts on infrastructure.

Table 6.7: Climate modeling reveal projected climate trends over Gujarat (based on Chapter 3 in this report).

Climate Driver	Current (1951-2019)	Future (2021-2100)
Mean Temperature	Increase	Increase
Extreme Heat (hot day and night)	Increase	Increase
Extreme cold (cold day and night)	Decrease	Decrease
Mean Rainfall	Increase	Increase
Extreme Rainfall	Increase	Increase
Extreme River Discharge	Increase	Increase

Infrastructures are heavily prone to damage due to extreme temperature and precipitation events, severe storms, and rising sea levels. Increased temperature causes the buckling of roads and rail lines, causing damages to them and also resulting in the formation of potholes on roads. These damages increase the chances of road and railway accidents and also add to the maintenance cost and effort. Moreover, temperature and humidity change results in the speedy degradation of infrastructures (Stewart et al 2012). On the other hand, increased precipitation extremes increase the chances of landslides causing damages to buildings, roads, rails, tunnels, etc. Due to urbanization and increased extreme precipitation, the occurrence of flood events is also increased in the observed climate and projected to increase in the future. The floods result the deterioration of roads, buildings, tunnels, escalating erosion due to soil runoff particularly affecting railways and water infrastructures and also flooding causes disturbances in waste disposals and drainage systems. For instance, the 2017 flood caused the cut off of 753 villages, damaged six national highways, 153 state highways, and 674 panchayat roads and results loss of INR 10 Crore for national and INR 26 Crore for state highways. Also, 11 out of 20 trains were cancelled due to damage to tracks near Palanpur in the 2017 flood.

Due to climate change, an increase in Sea-Surface temperature results frequent and intense storms. Severe storms like cyclones and extreme rainfall events affect airports severely, damages water/sewerage/gas pipeline networks, damages electricity, telephone, and other communication networks, damages railway overhead line, and uproots trees causing damage and disruption in many ways. Recently, the 'Vayu' storm occurred over Gujarat in 2019, which suspended the cargo operations at Chhara, Pipavav, Swan Energy's Floating LNG units, Reliance Sikka Jetties, Salaya, Okha, Porbandar, Deen Dayal port (at Kandla) and workers were shifted to a safe place. During the 'Vayu' storm, the western railway was terminated or cancelled, and educational institutes were shut down. On the other side, sea level rise causes the intrusion of saltwater into groundwater, which affects its quality and distribution. In particular, infrastructures at a lower elevation are at higher risk as saltwater increases the risk of corrosion of these infrastructure. These indicative risks are described in Table 6.8.

Table 6.8: **Indicative risk on infrastructure due to climate change**

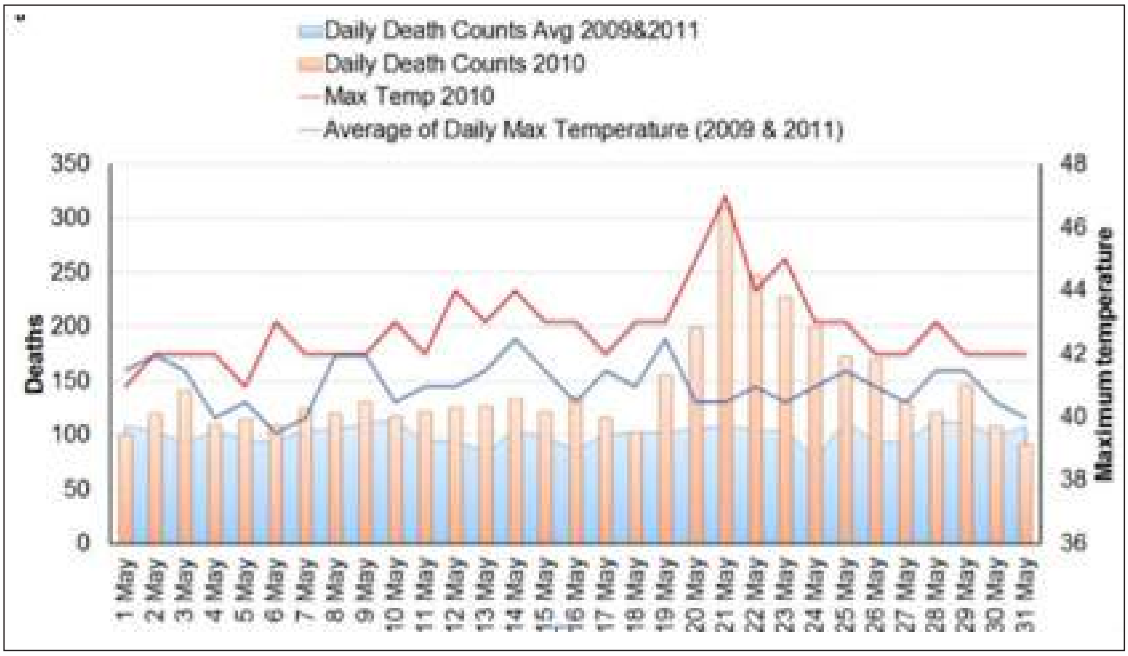
Climate Variable	Indicative Risk
Increased rainfall intensity	Extreme rainfall could lead to flooding Capacity overload for drainage systems may lead to flooding that may cause erosion of roads Damage to roads, bridges, and culverts due to flooding Landslides and subsidence
Heatwaves	Higher risk of road damage due to high temperature (melting Asphalt) Higher deterioration rates of pavements and roadways Thermal expansion of bridge joints and paved surface Damage of bridge structure material
Increased storm and wind intensity	Closure of linked mode of road transport Damage from wind-blown debris
Increased storm surge intensity	Increased wave action at waterfront structures and consequent increase in overtopping rates leading to flooding of berthing facilities Closure of coastal highways
Sea Level Rise	Damage to coastal road High salt water concentration Affect distribution of goods

Thus, the infrastructure needs to be protected from climate-induced risks. The costs of such climate-induced natural disasters may be insignificant compared to the benefits achieved through economic development in the case of a country like India. It thus becomes important for an economy like Gujarat to protect its infrastructure against different types of risks comprising the ones that accompany climate change (Naswa and Garg 2011). The new infrastructure investment needs to climate-proof, indicating its higher resilience capacity to reduce the impacts of the climate-induced risks as well as systems in place for a speedy recovery in case of damages.

6.1.9 Health Sector

The Gujarat state has widespread health infrastructure (about 7274 sub-centres, 1072 primary health centres, 253 community health centres, 106 Urban Family Welfare Centres) that serve the primary, secondary, and tertiary needs of the rural and urban population in the state. Moreover, these health centres help to combat the climate change impact on the health. The climate change, including climate variability, has multiple influences on human health. The climate change results rising temperatures, more intense heat waves, extreme precipitation, drought, and floods in the Gujarat. These events are often very dramatic and result deaths and severe impact on the human health. For instance, 2019 summer heat wave affects more than 300 by dehydration and 2 people died in Rajkot and Sabarkabtha districts in Gujarat (The Hindu, 2019). Moreover, heatwave in India during 1998 and 2003 caused more than 2000 deaths (Mishra et al 2017)the implication for population exposure to severe heatwaves remains unexplored. Here, we characterize maximum potential human exposure (without passive/active reduction measures. Based on observations, the majority districts of Gujarat have reported the high rise in the daily maximum temperature (Based on Chapter 3), which results a positive trend in the mortality due to increase in heatwaves (Figure 6.27).

Figure 6.27: Temperature and all-cause mortality correlation during the 2010 heat wave in Ahmedabad as compared to 2009 and 2011

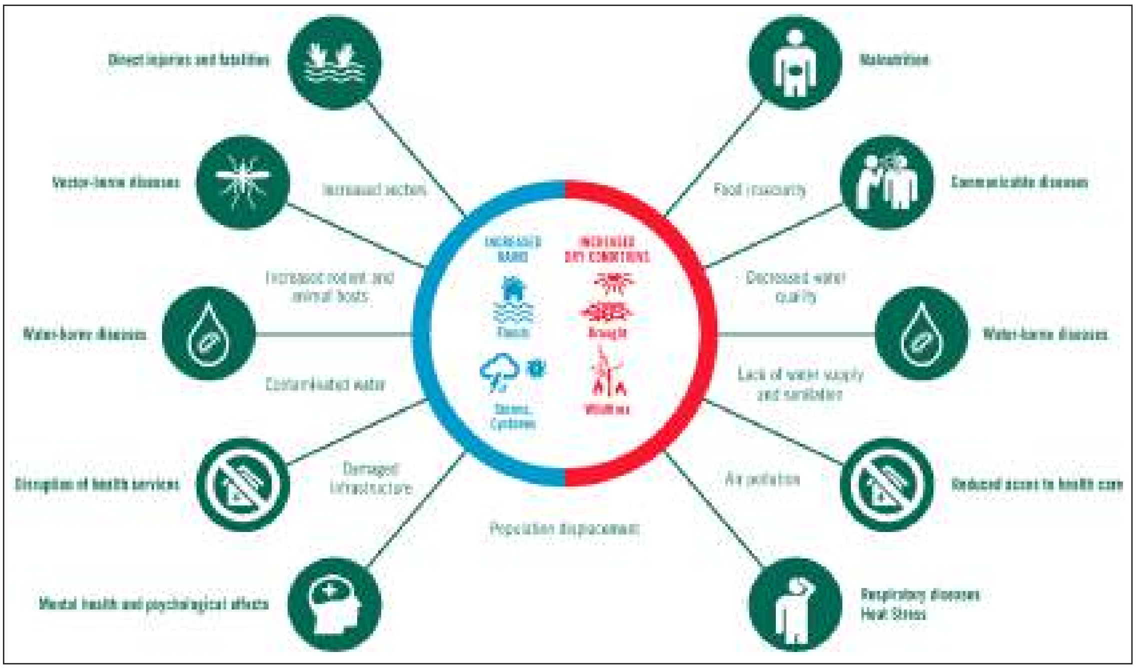


Ahmedabad Municipal Corporation, 2016

Other than the direct impact of climate change on human health, the potential large impact on human health may also arise from the indirect mechanisms. For instance, the increased temperature and drought can affect availability food (Mishra et al 2020), clean water, and sanitation, which results the increased transmission of vector and water-borne diseases. According to the World Health Organization (WHO), climate change caused over 150,000 deaths per year in the observed climate and are projected to increase in the future (WHO 2012).

Health diseases are largely concentrated in the poorest regions of the Gujarat and affect the basic supply of health protection in the region. Unless adaptation mechanisms are implemented, climate change is likely to result in further demands on health services, and an increasing burden of disease control (WHO, 2012) (Figure 6.28). Moreover, due to the increase burden on health facilities, little attention will be paid to the patients in the vulnerable and resource-poor regions during climate change. Gujarat is one of the most affected states due to the climate changes. The mean temperature is projected to increase, and the frequency and duration of heat waves are also projected to intensify in the future climate over Gujarat. Using climate model datasets, we observed that the maximum temperature is projected to increase in the range of 0.9 to 1.2 °C, 1.2 to 1.6 °C, and 1.1 to 1.4 °C in the near (2011-2040), mid (2041-2070), and far (2071-2100) future period over Gujarat in RCP 2.6 scenario. Moreover, if the rise in global mean temperature is increased by 2°C (fail to limit by 1.5°C), the frequency of severe heatwave events will rise by 30 times the current climate in India (Mishra et al., 2017). The increased temperature under the climate change scenario will be a challenge for the Gujarat state. Moreover, the climate change also leads to drought, disease, floods, famine, extreme heat, and humidity.

Figure 6.28: **Climate change related health impacts**



Source: World Health Organisation

http://www.who.int/hac/crises/el nino/who_el_nino_and_health_global_report_21jan2016.pdf

Increased heat waves due to climate change impacts the health sector by increasing the instances and intensity of heat stroke, sunburns, and dehydration. Increased temperature and drought result widespread forest fires resulting in loss of life, burns, and respiratory issues. Climate change impacts both the physical and mental health of people in a society. The urban area is found to be much warmer than the surrounding area (rural area) worsening the impacts, especially for outdoor workers and slum dwellers. Warmer temperatures can provide a suitable breeding ground for of insects, parasites, and algal growth. Cold related issues arise among people if there is a sudden temperature drop. Extreme precipitation leads to flood events that contaminate drinking water sources and disturbs transportation which may delay emergency health assistance. Severe storm and storm surges may result in interrupted communication services resulting in a delay of emergency health assistance. Severe storms like cyclones can result in chemical/gas leakage from distribution networks that could affect an entire population in an area. Pollutants like increased levels of ground ozone cause respiratory issues, and particulate matter emitted as a result of wildfire, and dust storms also affect the health of people to a wider area. Increased carbon monoxide emission, aerosol particles also cause health issues. Climate change may trigger allergies (like pollen allergies) and other conditions like asthma in some people. Table 6.9 describes the indicative risks on human health due to impacts of climate change.

Table 6.9: Indicative risk on health sector due to climate change

S. No.	Climate Factors	Climate Impacts
1	Temperature	• Heatwaves can cause Heat strokes/burns and dehydration • Increased temperatures increase risk of wildfires • Outdoor workers are highly affected • Urban area warmer than surrounding area • Climate Impacts Physical and mental health of people • Warmer water can brood insects, parasites and algal growth • Cold related issues if temperature drops
2	Extreme precipitation / Flood	• Flood events contaminate drinking water • Disturbances in transportation may delay necessary health assistance for emergency cases • Interrupting communication, utility, and health care services. • Increased mosquito abundance
3	Drought/dry spells	• Changes in vector abundance (ex. vector breeds in dried up river beds) • Food shortage, illness, malnutrition (increases risk of infection) • Increased risk of disease associated with lack of water for hygiene • Health impacts associated with population displacement
4	Severe Storm/ Cyclones	• Chemical leakage from distribution networks • Storms along with severe storms also contaminate drinking water
5	Particulate Matter/ Air pollution	• Increased level of ground ozone causes respiratory issues • Particulate matter as a result of wildfire also affect health • Aerosol particles also causes health issue • Climate change may trigger allergies • Dust storms also increases respiratory issues • Increased carbon monoxide poisoning

6.2 List of prioritized sector-wise adaptation activities

As discussed earlier climate change has its impact on various sectors differently, hence the strategies adapted are customized to each sector and are adopted for each sector based on the extent of impact by climate change. The various sector-wise adaptation activities that can substantially decrease the effects of climate change are discussed below.

6.2.1 Water Resources

Gujarat had been hit by frequent droughts and water scarcity till late 90's. The drinking water was supplied through tankers in most parts of the state. However, the water resource scenario in Gujarat has been significantly improved in early 21st century. The changes in rainfall pattern, augmentation of surface water and ground water recharge, and distribution management through reduction of dependence on the scarce ground water resources. The government has implemented several schemes to make water surplus Gujarat (Table 6.10).

Table 6.10: Policies and Schemes for Enhanced Water Security

Scheme	Objective
Sardar Sarovar	To secure power, irrigation and drinking water for drought prone area of Gujarat
Narmada Canal	To transfer Sardar Sarovar water to North Gujarat
Sujlam Suflam Yojna	To divert surplus water to the water deficit areas
SAUNI Yojana	To distribute excess Narmada river water to Saurashtra though link pipeline
Water Conservation	To conserve water by constructing check dams and rain water harvesting structures
Coastal Area Protection	To reduce damages due to coastal erosion by constructing protection wall
Salinity Ingress Prevention	To recharge the fresh water,increase the quality of underground water and prevent salinity of surface water and underground water due to spreading of tidal water.
Sagar Khedu	To prevent salinity ingress, conserve and provide water over coastal region
Interlinking of rivers	To integrate water resources with equitable distribution of available Water Resources
Atal Bhujal	To improve ground water management through community
Sujalam Sufalam Jal Sanchay Abhiyan	To deepen water bodies in the state to increase storage of rainwater to be used during times of scarcity

Water harvesting and groundwater recharge structures, improved of soil moisture retention capacity, wetland restoration, dam construction and improved reservoir capacity, integrated water resources management, irrigation system, and water supply to agricultural lands, adequate planning of drainage systems, water transfer and protection against soil erosion and loss of soil fertility can be adopted to cope up against climate change impacts on water resources. Adopting low-cost water quality management systems and installation of desalination systems are also useful to stop salinity ingress. Table 6.11 describes the adaptation strategies for water resource management under changing climate. Additional efforts are required to make water sector climate change resilient, which are:

1. Watershed management
2. Limit the groundwater use for domestic and agriculture purpose
3. Accountability of water quality and quantity at local scale
4. Forecasting system to monitor drought and flood

Table 6.11: **Adaptation Strategies for Water Resources**

Climate Impacts	Adaptation Strategies for Water Resources	Key Districts and Cities
Drought and famine	• Wetland restoration • Change irrigation patterns from flood irrigation to drip or sprinkle irrigation • Change in Crop pattern to conserve water-related • Early warning system • Village level awareness about new strategies to conserve water • Proper drinking water supply	• Kuchchh, Jamnagar, Mehsana, Vadodara, Ahmedabad, Surendranagar, Anand and Navsari • Banaskantha, Patan, Mehsana, Ahmedabad, Gandhinagar, Kachchh, Sabarkantha, Aravali, Rajkot, Morbi, Surendranagar, Junagadh and Porbandar • Across State • Across state • Across state
Ground water depletion	• Water shed management • construction of check dams, bunds • construction of ponds at village level • Mandating water harvesting and artificial recharge in rural as well as urban areas • Ground water regulation/ governance • Incentivising to promote recharging of ground water • Preserve and protect aquifers • Optimizing water use efficiency • Conjunctive management	Banaskantha, Patan, Mehsana, Ahmedabad, Gandhinagar, Kachchh, Sabarkantha, Aravali, Rajkot, Morbi, Junagadh, Surendranagar, and Porbandar
Ground water contamination & water pollution	• It is possible through sea water intrusion, in this case we have to do more plantation in coast area like, mangroves etc • Desalination systems installation • Industries water purification • Wastewater treatment • Enforce proper guideline for dump waste etc	• Banaskantha, Patan, Mehsana, Ahmedabad, Gandhinagar, Kachchh, Sabarkantha, Aravali, Rajkot, Morbi, Junagadh, Surendranagar and Porbandar • Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Bharuch, Surat, Navsari and Valsad • Ahmedabad, Vadodara, Surat, and Rajkot cities, Bharuch and Navsari • Across state
Flood, Extreme precipitation & water logging	• Proper flood warning and management systems • Proper planning of drainage systems • Dam construction and improved reservoir capacity • River linking to supply water from wet region to dry region • Conserve, maintain, or rehabilitate wetland ecosystems	• Across state • 31 cities, 159 ULBs • Across state • Across state • Kuchchh, Jamnagar, Mehsana, Vadodara, Ahmedabad, Surendranagar, Anand and Navsari

Sources: UN-Water Policy ,2019, Turral et al., 2011, Crimmins et al. 2016

6.2.1.1 Gujarat State Water Policy 2015

The objectives of this policy is to ensure the comprehensive multisectoral planning, development and management of the State's water resources, and effective, efficient, equitable and sustainable service deliveries for various water uses. The policy looks into evolving a State Framework Law in the line of National Framework Law, uses of water, Priorities for Water allocation, Demand Management and Water Use Efficiency, Enhancing Water Available for Use, Adaptation for Climate Change, Planning and Management of Water Resources and Groundwater Development.

6.2.1.2 Water Security

Gujarat has significantly addressed its water problems by using the strategies of rainwater harvesting, check dams and inter-basin transfers. Twenty rivers have been interlinked and the challenge of uneven water distribution met through inter-basin transfers. These projects have substantially raised the water table across the state and consequent availability of water for irrigation; this is expected to bring about stable growth of the agriculture sector across the state. The Sardar Sarovar project and the Sujalam Sufalam projects, being implemented by the Government of Gujarat, amongst India's largest irrigation and water supply projects, will further improve Gujarat's water security. Nal Se Jal scheme of Government of Gujarat , which aims to supply potable water 24/7.

6.2.1.3 Sujalam Sufalam Yojana (SSY)

The scheme looks into lift Irrigation schemes from Narmada Main Canal to various reservoirs of North Gujarat region, ground water recharge and prevent salinity ingress. The scheme has completed works of 332 km long Sujalam Suphalam Spreading Canal from Mahi to Banas river for diversion of surplus flood water of Kadana Reservoir and Narmada to the water deficit areas, about 15,000 ha area under command of Dantiwada, Watrak, Mazam and Meshwo reservoir will be benefited North Gujarat region, 50 Bandharas are constructed in Kachchh region for utilization of 1 MAFT excess flood water of Narmada under SSY and to prevent salinity ingress in the region, works of Panam High Level Canal under SSY is under progress which will benefit 18,000 ha area in Shahera, Godhara and Lunavada Taluka of Panchmahal District, and works of Kadana Left Bank High Level Canal under SSY is towards completion which will benefit 5,000 ha area in Kadana, Santrampur and Lunavada Taluka of Panchmahal District.

6.2.1.4 Water Conservation Schemes

The efforts under this scheme include water harvesting by deepening of tanks and through Check dam construction. About 25697 tanks in 25 districts of Gujarat have been deepened for water harvesting under this scheme. Further, the work of rain water harvesting system is completed in 24,103 SM up to the year 2012-13 out of total area of 366204 and construction of total 93092 check dams covering 33 districts of the state have been completed till March 31, 2018.

6.2.1.5 Participatory Irrigation Management (PIM) (for water use efficiency)

The scheme aims to cover maximum possible command area under PIM to ensure that irrigation water is distributed efficiently and equitably in the command area and used efficiently. Almost 1721 Water Users' Association (WUA) have been established in the command area of various irrigation projects and about 5.19 lac hectare area has been served by WUAs under PIM.

6.2.1.6 Flood Protection Scheme

The scheme is designed to reduce damages created due to Flood. Flood Protection work is completed at 13 different locations in the districts of Surat, Ahmedabad, Navsari, Kheda, Bharuch, Sabarkantha, Panchmahal, while it is in progress at 5 different locations of the districts of Ahmedabad, Vadodara, and Sabarkantha.

6.2.1.7 Interlinking the Rivers of the State

The project is aimed to making water available to water deficit area by transfer from other areas having surplus water. Currently, planning of inter basin transfer of water from Narmada main canal to en-route 11 rivers, and planning to fill about 700 nos. of small/large village Tanks/Ponds by water of Narmada have been completed. Sabarmati- Saraswati link from Branch Canal No.1 of Right Bank Main Canal of Dharoi Project to Saraswati river is under planning stage.

6.2.1.8 Hydrology Project

The project is to assist the Central Government and the participating State Water resources agencies in the development of valid, comprehensive, interactive, easily accessed and user-friendly data base covering aspects of the Hydrology. Establishment / Up-gradation of Water Monitoring Networks, Infrastructure facilities, Established Hydrology Data Users Group, HYMOS Software is made available, and, Training, R&D studies are being carried out.

6.2.1.9 Water Resources Project for Major Dams of State

The project is designed to develop a data bank for major dams of the state. Uptill now, detailed data bank for 18 major dams/canals of the state have been developed through water resources project.

6.2.1.10 Holiyu Project

The project empowers the marginal, small and medium farmers to create own water resource for irrigation by technique of storing and retaining rainwater underground in the areas where aquifer is of saline water and soil is affected with salinity of Patan District.

Gujarat has a long tradition of water harvesting and conservation. One example of such water conservation structure is the famous step-well of Adalaj

Picture Courtesy: pixabay.com

6.2.1.11 State-wide Drinking Water Grid

In 2020, the Government of Gujarat has implemented a master plan for the creation of State-Wide Water Supply Grid. The Grid is a far-sighted, comprehensive and ambitious water strategy to sustainably supply adequate and safe drinking water to its rural and urban population. Overall, the state-wide water grid has helped immensely in achieving water security, improving the quantity and quality of water supply services, extending water provision to uncovered habitations, strengthening and recharging local resources as well as promoting 24X7 water supply services. The project aims to:

- Creation of state-wide 120769 km long drinking water grid includes 1987 kms of bulk pipelines and 115058 kms of distribution pipelines.
- 2250 MLD of drinking water supply is expected through 10871 hydraulic structures, 10683 storage pumps and 151 water filtration and treatment plants
- Creation of 4 lakh micro water harvesting structures

The state wide drinking water grid not only provides clean and safe drinking water to the villages of Gujarat but also plays a vital role in gender balance and women empowerment – savings countless hours of water fetching activities for the women of the households-allowing them to attend schools or take up some vocational employment.

Picture Courtesy: shutterstock.com

6.2.2 Agriculture Sector

The Government of Gujarat (GoG) has prepared contingency crop planning to mitigate worst impact of erratic monsoon and climate resilient agriculture sector. The contingency crop planning helps farmer to select appropriate crop, its variety and other necessary relevant farm practices. The GoG also provides weather based agriculture advisory in local language to the farmer community. The automatic weather stations have been installed across Gujarat to monitor weather variables in real-time. Anand, Dantiwada and Junagadh Agriculture University closely work with farmers. The government organizes Krushi Mahotsave every year to provide knowledge about organic farming, scientific farming, farm mechanization and micro irrigation to the farmers. The National Agricultural Insurance Scheme along with Pradhan Mantri Fasal Bima Yojna has been introduced to stabilize farmers' income, during disaster period by providing insurance coverage. The government also purchase crop at minimum support price. The soil testing laboratories were established to provide free of charge soil testing facilities to the farmers under soil health card program. For online governmental scheme application, the government has developed I-khedut portal. A category wise climate change adaptation strategies for crop and agriculture sector has been provided in Table 6.12.

Crop planning and management with inclusion of modern irrigation techniques, cold chain and warehousing, fostering peri-urban agriculture would be some of the most important adaptation strategies for Gujarat

Picture Courtesy: Dreamstime.com

Table 6.12: Category wise climate change adaptation strategies for crop and agriculture

Category	Adaptation strategies	Outcomes/Objective
Cultural Methodologies	• as altering planting and harvesting time • collection of crops with short life cycles • crop rotation & cultivation of new crops • modern irrigation techniques • variation in cropping schemes	• To lessen the climatic variability danger and provide better adaptability to crop plants for assuring food safety and security (Duku et al 2018)
	• Crop-management techniques such as: • choice of sowing time • planting density • optimum irrigation practices	• To enhance crop development under various environmental stresses (Battisti et al 2018)
Conventional Techniques	• Genetics and Genomics Strategies: • Genome Wide Association Studies (GWAS) • Genome Selection (GS) • Genetic Engineered Plants	• Help plants escape from various stresses by developing stress resistant cultivars (i.e. Stress Tolerance, Crop Improvement) (Stinchcombe & Hoekstra, 2008; Manolio 2010; Kumar et al 2018)
Genome Editing Strategies	• CRISPR/Cas9 System for Crop Advancement	• To manipulate the plant genome by means of sequence-specific nucleases (Abdelrahman et al 2018)

Sources: Raza et al., 2019

Apart from government schemes additional efforts are required for climate change adaptations are:

1. Reduce greenhouse gas emissions through crop residue burning,
2. Encourage research to incorporate climate resilient genes in crops (Aggarwal, 2008),
3. Develop crop health and pest monitoring systems (Mall et al., 2006),
4. Prevent waterlogging, erosion, and nutrient leaching by soil moisture conservation techniques (Maharjan and Joshi, 2013),
5. High resolution drought and flood warning systems helps to prepare action plan (Shah and Mishra, 2014),
6. Watershed management and water conservation practices to raise groundwater levels.

Other strategies include the development of improved forecasts for crop heath and climatic variables and shifting to saline resilient cash crops to tackle salinity intrusion.

Gujarat contributes to 20% of India's marine production from its coastlines. There are also traditional fresh water fishing activities that happen in the tribal belt of the state. Encouraging such activities and dissemination of the indigenous knowledge supports the march to resilient Gujarat

Picture Courtesy: https://commons.wikimedia.org/wiki/File:Traditional_bamboo_mat_fishing_Dang_Gujarat_India.jpg

6.2.3 Disaster Management

The NDM Act 2005 was formed to effective disaster management at the national to the local level. The government of Gujarat has also formed the Gujarat State Disaster Management Act 2003 (GSDM 2003) and established the Gujarat State Disaster Management Authority (GSDMA) immediately after the 2001 Gujarat earthquake. Gujarat State Disaster Management Authority (GSDM) developed Gujarat Hazard risk and vulnerability atlas for different calamities. The GSDM suggested structural and non-structural measures to cope up with climate-induced hazards (Table 6.11).

The disaster management sector must work on enhancing early warning systems (Shaw et al., 2010). It helps to improve community preparedness for disasters beforehand. Mercer (2010) suggested that capacity building and spreading awareness at the community-level, which includes mapping, and environmental trend analysis, and develop a digital database. However, with the involvement of more funds and skilled people, adopting new cost-effective techniques at local community levels helps for climate adaptation (Forino et al., 2015). Whereas Ghazali et al. (2018) advised to prepare hazard vulnerability maps and adopt new cost-effective techniques at local community levels. Zimmerman and Faris (2010) emphasized the use of renewable energy sources to reduce green gas emission and hence global warming could control.

After the vulnerability, adaptation strategies help us to work on the lack of problems to reduce impact. Extreme events like flood, droughts are common in India, also in Gujarat state. Due to the aid climate some of the districts are facing problems of drought and on other hand due to changing climatic patterns some regions experience heavy rainfall that is the cause of flood. First of all, we have to establish an advanced disaster early warning facility so people can save their life first. We have to aware people on community level as per previous disaster. Due to disasters like cyclone etc, electricity etc will get affected, so we have to work more on renewable energy sources. Establish proper communication during disaster. Grant funds for mapping and assessment of disaster risk, environmental assessment etc so we can prepare a concrete plan for future from the previous events. Arrange mock drills related to disaster on village level so every people know how to save life and survive at the time of disaster. Here (Table 6.13) we have listed the impacts and adaptation measures

Table 6.13: Disaster Sector impact, adaptation and recommendations

Disaster	Adaptation	Recommendations	Key Districts and Cities
Cyclone & Tsunami	• Provide cyclone shelters • Strengthening/ Repair infrastructure • Forecasting and warning • Construct missing roads and bridges • Repair existing saline embankment	• Mangrove Plantation and conservation • Construct cyclone shelters in prone area • Strengthen dams and canals • Early warning System • Also, setup warning system in crowded area (ports, beach, market), warn to fisherman etc • Construct new saline embankment	• Kuchchh, Jamnagar, Devbhoomi and Dwarka • Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Rajkot, Morbi, Bhavnagar • Across state • Across state • Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Rajkot, Morbi, Bhavnagar • Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, and Bhavnagar
Drought	• Construct water infrastructure • Forecasting and warning • Supply Water • Construct warehouses and cold storages for preservation/storage of food grains • Construct percolation tanks, check dams, farm ponds, etc	• Adaptation of new technology for effective use of water • Change in Crop pattern • Change in irrigation pattern • Supply less water consumptions crops seeds to farmers • Prepared strategy plan for future	Banaskantha, Patan, Mehsana, Ahmedabad, Gandhinagar, Kachchh, Sabarkantha, Aravali, Rajkot, Morbi, Surendranagar, Junagadh and Porbandar

Disaster	Adaptation	Recommendations	Key Districts and Cities
	• Repairs, up-gradation and strengthening of dams, reservoirs, lift irrigation and canals for surface irrigation • Apply advanced agro-Science technology and agro-engineering inputs to improve agriculture production	• Construct check dams, ponds, bunds, percolation tanks etc to store water • Interlinking of rivers from wet to dry regions. • Drought early warning system	
Flood	• Development of catchment area • Floodproofing • Distribute food and necessary things to survive • Strengthen dams and canals • Strengthen /repair of existing roads, bridges as well as critical infrastructure in flood plains. • Forecasting and warning	• Improve design for flood protective structures like bunds, dams etc • Construct flood diverting channels, stone walls to reduce erosion, dams, flood protection walls, etc. • Develop catchment area of the floodplain: Forestation, Land sloping, small reservoirs/ Check dams/ponds etc. • Strengthen and upgrade existing flood forecasting system • Enact and enforce laws strictly for developmental activities in flood plain	• Across state • Across state • Catchments for rivers Narmada, Tapi, Mahi, Sabarmati, Banas, Bhadar, Shetrunji, Ozat, Ambica, Machuchhu and Rupen • Across state • Across state
Earthquake	• Provide first aid • Strengthening/ Repair infrastructure • Forecasting and warning	• Improve design for infrastructure with regulation of earthquake • Provide or make available seismic micro zonation map • Provide vulnerability and risk assessment map • Develop earthquake resistant design features for the construction of public utility structures • Develop earthquake resistant design features for the construction of residential structures • Provide earthquake resistant design for incorporating in different types of structures of the line departments • Prepare a scheme/ programme for retrofitting • Identification and removal of unsafe buildings/structure	Kuchchh, Jamnagar, Devbhoomi Dwarka, Rajkot, Morbi, Surendranagar, Patan, Banaskantha

Disaster	Adaptation	Recommendations	Key Districts and Cities
Common in case of disaster	• preparedness of disasters beforehand • Community level awareness for local level activities based on previous experience and local knowledge • Greater collaboration could also make more efficient use of limited human, material and financial resources • Mapping and environmental trend analysis in community level with a digital database • Switching to renewable energy sources • Vulnerability reduction, resilience increase, Risk assessment • Design of alternate routes during flood, cyclones or landslides • Wastewater treatment, water harvesting for rescue operations • Adopting new cost effective techniques at local community levels • Adopting mock drills for experience beforehand • Establishing proper communication during a disaster • Establishing recent hazard vulnerability map • Involvement of more funds and skilled people • Enhancing Early warning system		Across state

Source: GSDM – 2016-17

Gujarat's disaster management plan reflects a paradigm shift in Disaster Management from relief-centric approach to the current one which is Disaster Risk Resilience encompassing all facets of Disaster Management

Picture Courtesy: Indian Express

6.2.3.1 Climate-induced Disaster Preparedness

As per Gujarat State Disaster Management Act, 2003, a State Disaster Management Plan (SDMP) has been developed by keeping in mind the vulnerability of the State to various hazards. Gujarat State Disaster Management Plan, 2020-21 (GSDMP) provides further clarity about the actions, roles and responsibilities necessary to adequately prepare for and respond to various disasters situations in a coordinated manner. Gujarat Institute of Disaster Management (GIDM) is in the process of developing heat action plans for several locations across the state. Considering the expanse of the coastline and the vulnerability to cyclones, GSDMA has also prepared a Cyclone Preparedness and Response Plan to mitigate the effects of cyclone, associated floods and storm surge hazards. These measures reflect a paradigm shift in Disaster Management from relief-centric approach to the current one which is Disaster Risk Resilience encompassing all facets of Disaster Management. The plan provides a frame-work and a well-defined Standard Operating Procedure (SOP) for various Government Departments in respect of all phases of Disaster Management. It enhances resilience, inter alia, through reduction, better preparedness and a systematic understanding of hazards.

6.2.4 Coastal Regions

Coastal regions of Gujarat can be heavily affected by climate change especially sea-level rise is a potential threat to coastal ecosystems and biodiversity. Effective adaptive strategies suggested by (Sinay & Carter, 2020) are the identification of vulnerable areas and adopting protective measures according to the nature of vulnerable areas like conservation of mangrove forests, protection of marsh, dune forests, and wetlands by incorporating wetland protection steps into the new infrastructure planning and maintaining the water quality of wetlands and marshlands. Conservation of natural resources and restoration of coastal ecosystems can enhance ecological resilience towards climate change. Mangroves can easily adapt to salinity and water level changes, and grow in a higher concentration of Carbon dioxide, hence serving as a natural adaption against the alarming climate change. Ecosystem diversification also contributes to ecosystem resilience as some organisms have better adaptive traits than others.

Preservation of habitats from habitat fragmentation of marine organisms is very significant as the species migration can affect the ecosystem adversely. Controlling invasive species during the species migration should be incorporated to reduce the declining number of indigenous species in the area on which these new invasive species prey on. Invasive species have a higher tolerance and tend to colonialize rapidly in their new habitat imposing a new potential threat. Avoid overfishing and harvesting should be implemented to reduce the decline of various marine species, as the fisheries sector is an important sector for a west coast state like Gujarat. Improve the species diversification within the ecosystem to enhance the adaptation of the pressure of climate change.

Gujarat has taken up several hard and soft adaptation actions for reducing impacts of climate change on coastal areas due to soil and beach erosion

Picture Courtesy: shutterstock.com

Reducing greenhouse gas emissions can reduce the absorption of CO_2 by the ocean water from the atmosphere thus decreasing the acidity of marine water, this can reduce coral bleaching to a great extent. Enhance efforts to restore dead coral reefs by the incorporation of artificial reefs as coral reefs play a critical role in coastal protection. Protection of existing coral reefs is crucial as they are many other organisms that are in a symbiotic relationship with them. As species are dependent on each other, the decline of one may affect the existence of the other. Carbon sequestration within these marine ecosystems can improve their distress from climate change. Reduce marine pollution due to ships, waste dumping by industries by maintaining a proper waste management system. Marine pollution is a great threat to aquatic organisms and invites many health hazards for humans. Protect shoreline from erosion by maintaining sediment transport, prohibit or control the removal of beach sediment or add sand for beach nourishment, and by managing coastal land and its development. Construction of storm surge barriers also protects the coastal area to a great extent from the underlying damages caused by severe storm events. Construction of structures like dykes, elevated canal walls, and seawalls reduces the water flow and prevent inundation. Table 6.14 lists the adaptation strategies for the coastal areas of Gujarat.

As the sea level rises saltwater intrusion rate also goes up disrupting the daily life and health of coastal people. Higher saline water cannot be used for drinking purposes without desalination processes. Therefore, the necessary steps should be undertaken to improve the water quality to avoid salinity related health issues like waste and water treatment capacities especially desalinization technologies, installation of devices to prevent seawater from back flowing into storm drains and installation of rainwater harvesting tanks for the supply of water.

Table 6.14: Adaptation strategies for coastal regions

Climate Drivers	Affected Asset	Adaptation Strategies	Key Districts and Cities
Extreme Heat/ Heatwaves	• Species distribution • Health of Coral Reefs • Ocean Acidity • Sea Surface Temperature	• Identification of vulnerable area • Reducing greenhouse gas emissions • Proper monitoring of the changes happening • Preservation of habitats • Control of invasive species • Avoid overfishing to protect symbiosis of species • Enhance efforts to restore dead coral reefs	Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Bharuch, Surat, Navsari and Valsad
Extreme Precipitation/ Flooding	• Shoreline • Sediment Transport • Nutrient Transport	• Maintain sediment transport • Control algal and phytoplankton growth	Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Bharuch, Surat, Navsari and Valsad
Severe Storm/ Cyclones	• Flooding • Habitat • Life	• Early warning system • Conservation of mangrove forests	Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Bharuch, Surat, Navsari and Valsad
Rising Sea Levels	• Flooding • Coastal ecosystems • Development Activities • Salinity • Marsh lands	• Maintaining water quality of wetlands and marshlands • Incorporating wetland protection into the planning of new infrastructure • Reduce marine pollution (due to ships) • Prohibit or control the removal of beach sediment • Protection of marsh and wetlands	Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Bharuch, Surat, Navsari and Valsad

Salinity in the groundwater affects the agricultural sector in the coastal areas as they tend to shift the crop patterns more towards salt-tolerant ones along the coastal regions, hence the introduction of salt-tolerant crops should be introduced in the fields adjacent to coastal areas and proper irrigation systems to ensure hydration of vegetation.

Accumulated nutrients and fertilizers trigger the growth of algal and phytoplankton growth on the surface of the marine water. Hence proper monitoring of the changes happening on the water surface is mandatory to control algal and phytoplankton growth. Sea grass and other aquatic communities suffer through this bloom on the surface as it hinders the sunlight from penetrating and depleting oxygen levels in the water. Water quality should be maintained where freshwater mixing with tidal water in the estuaries.

The introduction of the early warning system is mandatory for the early warning of natural disasters to the local people and to attain this proper communication network should be established. During the planning stage communication and transportation networks should be given proper attention as these two basic facilities can create hurdles during the later stages. For the proper preparedness, we have to assess climate change vulnerabilities in regular intervals and integrate hazard mitigation adaptions during the planning and policy-making steps. During the policymaking stage, the efforts should be taken from the local level communities, as the vulnerable communities suffer more. Strategies to be adopted should be planned for consistent and long term adaptations like spatial planning for the developments of new infrastructure and other projects. In such cases, the proper planning will help to retreat from the most vulnerable areas prone to shoreline erosion and sea level rise. Climate change awareness among people should also start from the local level communities by conducting workshops and training sessions with the help of disaster management experts. Participation of NGOs and other similar organizations for the rise of awareness among people of all sections in the society is required by sharing strategic and technical knowledge with more emphasis on youth. Such organizations can provide better professional assistance as well as financial incentives for awareness-raising and planning. Adaptive Strategies for coastal regions focus on reducing anthropogenic stress to these vulnerable systems. The Government of India adopted many policies for coast line protection in India are tabulated in the Table 6.15. The governing bodies for decision making include the Department of Ocean Development, Ministry of Environment and Forests, Ministry of Agriculture, Ministry of Water Resources, Ministry of Defence (Indian Coast Guard), etc.

Table 6.15: Polices for Coastline Protection

Year	Government Policies	Objectives
1987	Indian Fisheries Act	Protection against using explosives during fishing
1908	Indian Ports Act in 1908	Relating to port charges and conservation
1950	Coast Guard Act of 1950 for	Combatting marine pollution
1958	Merchant Shipping Act	Control of pollution from ships and offshore platforms
1978	Marine fishing Regulation Act	Control on fishing
1982	Coastal Pollution Control Series (COPOCS programme)	Assessing the pollution status of coastal waters
1991	Coastal regulation zone (CRZ) was issued in 1991	Restriction on various activities to protect the coastline
1991	Coastal Ocean Monitoring and Prediction systems (COMAPS Project)	Assesses the health of coastal waters and facilitates management of pollution-related issues
1995	Land Ocean Interaction in the Coastal Zone (LOICZ Project)	Integrated management of coastal environments
1998	Integrated Coastal and Marine Area Management (ICMAM Project)	Integrated management of coastal and marine areas. Model plans for Chennai, Goa and Gulf of Kuchchh being prepared

6.2.4.1 Sagar Khedu Sarvangi Vikas Yojana for Coastal Communities

Sensing the important fact, of large coastline and hence a large vulnerable coastal population, Gujarat has devised a new integrated development programme for coastal communities known as 'Sagar Khedu Sarvangi Vikas Yojana' (Multi-Dimensional Development Packages for coastal Communities). Catering to the needs of the coastal communities for climate resilience and sustainable livelihood promotion the State has promoted a multi-dimensional development package for coastal communities at a cost of INR 110 billion. The programme goes beyond livelihood issues taking into consideration a holistic ecosystem approach to coastal areas development. It proposes specific and time bound action plan for improving Wage and Self Employment, Capacity Building and Skill up-gradation , , Educational Facilities Health infrastructure, Drinking Water, Salinity Ingress and Water conservation, Electrification, Development of salt pan workers and National Security. The move towards alleviation of the fishing community has been taken under the Gujarat government's Sagarkhedu Sarvangi Vikas Yojana and is supported by United Nations Conference of Trade and Development (UNCTAD).

- Sea Fisheries Schemes
- Brackish Water Aquaculture
- Inland Fisheries
- Welfare Schemes

6.2.4.2 Coastal Area Protection Scheme

The scheme is aimed at providing gabion/ big stones wall to protect the damages due to coastal erosion in coastal area. Coastal protection works have been completed in various talukas of three districts i.e. Surat, Navsari, Valsad.

6.2.4.3 Salinity Ingress Prevention Scheme

This scheme is targets to reduce deterioration of underground water due to salinity Ingress and recharge of reservoir/ponds. Works of construction of 13 Tidal Regulators, 29 Bandhara, 15 Recharge Reservoirs, 661 Check Dams, 28 Recharge Tanks, 4487 nala plugs and afforestation in 5867 hectors of land have been completed, along with 141 kms length of extension canal project completed which have benefitted total 19569 hector area. Presently, 33 Salinity ingress projects worth Rs. 107.70 crore are under progress in the 6 districts of coastal regions of Saurashtra.

6.2.5 Rural Livelihood

Climate change has adverse impacts on natural resources which in turn have huge control over rural livelihood, hence effective adaptation strategies are highly linked with conservation of environmental resources to a great extent. Introducing drought-tolerant crop varieties, mixed cropping practices, new farming adaptations, risk management, and crop insurance (Maharjan & Joshi, 2013) relieve the stress caused by increased temperature on agriculture in the rural areas. Better storage of seeds, fodder, and food materials, adopting alternative cash crops are some other strategies that can be adopted. Water management in rural areas is very critical as they depend on natural resources mostly, rainwater harvesting is a beneficial strategy that can be adopted along with more efficient irrigation methods to maintain soil quality. Increasing the trading activities of agricultural, forest products, and their handicraft products to more cities gain more exposure for their products, hence strengthening their financial conditions. For the proper livestock management, the strategies suggested are the use of new varieties of fodder crops suited to the changing conditions, changing herd size and composition (diversified farms), grazing, and feeding patterns. Frequent and proper health check-up for livestock is a necessary step for healthy livestock management.

The UJJWALA scheme has inspired the PNG Sahayg Yojana in Gujarat. The state government through this scheme will be providing pipe-gas to rural households. This scheme will have larger socio-economic impacts alongwith the health benefits to women and children

Picture Courtesy: shutterstock.com

Since agriculture is the major source of livelihood the adaptation strategies must include livelihood diversification to increase the non-agricultural activities among rural communities, so the diversification of their income also happens which in turn reduces the risk associated with the impacts of climate change. Nonfarm industries that are independent of agriculture like the supply of raw materials to the urban industries should be given more emphasis on rural economic growth. Increased employability in non-farming sectors encourages migration to an urban area which is crucial when relocation from marginal lands is unavoidable under the critical conditions of recurring landslides, loss of land due to sea-level rise, etc. Affordable housing should be adapted in these areas and modifying infrastructure to adapt the climate change can also be implemented.

Efficient water treatment methods have to be adopted to battle contamination either due to saltwater intrusion or due to flooding. Maintaining water quality reduces the chances of occurrences of an epidemic among the community. Local-level health centres should be provided to raise awareness of hygiene, the importance of rehydration among people. Rural people are mostly outdoor workers prone to situations like heat stroke. Malnutrition among children is common among rural communities, local health centres can play a major role in reducing this.

Proper awareness about climate change and its impacts should be given to these communities as they lack basic education. Integrating new technology and advanced skills with traditional knowledge should be introduced among rural people. Identification of vulnerable areas and the associated population is determined for providing specific need-based assistance among local communities. Self-employment among rural people should be encouraged by the authorities encouraging the women population equally. Local climate change impact studies and understanding of climate risk should be done as a part of preparedness and mitigation. Early warning systems and early forecasting should reach these communities so they can plan the harvesting and sowing time. Authorities can provide better communication and transportation networks between rural and urban areas facilitating trading. Table 6.16 describes the adaptation strategies for rural livelihood.

Table 6.16: Adaptation strategies for rural livelihood

Climate Drivers	Affected Asset	Adaptation Strategies	Key Districts
Extreme Heat/ Heatwaves	• Heath facility • Agriculture • Water Supply • Livestock management	• Proper awareness and preparedness • Drought tolerant crop varieties • Water Harvesting • Mixed Cropping practice • New farming adaptations • Use new varieties of fodder crops	Across state
Extreme Precipitation/ Flooding	• Fisheries sector • Water Supply • Agriculture • Rural Infrastructures • Financial Condition • Transportation Network	• Introduction of small Community organisations by NGO • Introduction of new technology and advanced skills • Early warning system • Specific need based assessments • Changing herd size and composition, grazing and feeding patterns, • Diversifying their livelihoods	Kuchchh, Devbhoomi Dwarka, Amreli, Jamnagar, Bhavnagar, Junagadh, Rajkot, Surendranagar, Patan, Banaskatha, Morbi, Anand, Vadodara, Chotta Udaipur, Panchmalas, Valsad, Dang, Navsari, Bharuch
Severe Storm/ Cyclones	• Forest outputs • Rural Infrastructure • Transportation Network • Health facility	• Increase in non-agricultural activities • Identification of vulnerable areas and population • Livelihood diversification • Risk management and crop insurance	Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Bharuch, Surat, Navsari and Valsad
Rising Sea Levels	• Water Quality • Property loss	• Water treatment • Relocation from marginal lands	Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Bharuch, Surat, Navsari and Valsad

The introduction of small community organizations by NGO in these vulnerable areas increases better implementation of policy driven adaptation strategies (Example of Mask Production- Figure 6.29). Participation of Stakeholders from various government sectors, non-government organizations, private sectors partnership, and community-based organizations is advised for better decision and policy making. Training sessions should be from local communities with people trained in climate change adaptation measures. Provide training in risk assessment and vulnerability mapping to the community volunteers to assist in the decision-making process. Climate change risk reduction adaptation practices as well as post-disaster activities should be included addressing the high priority areas. The government needs to ensure technical and extended financial support for climate change adaptation. The Indian Government implemented several programs aiming at rural development, and rural livelihoods are tabulated in Table 6.17. These programs aim at poverty alleviation, and rural development with key policies like land policy, price policy, technology policy, agriculture policy, employment policy, and rural institutions policy.

Figure 6.29: Mask Production activities by SHG Women in COVID-19, available for online purchase through GLPC website

Source: http://glpc.co.in/downloads/Doc1.pdf

Gujarat Livelihood Promotion Company (GLPC) is the executive arm of Mission Mangalam, the implementation agency for National Rural Livelihood Mission (NRLM)

(Source: http://glpc.co.in/showpage.aspx?contentid=3).

Main objectives of GLPC are:

- Empowering the Poor by organizing them into SHGs/Federations/other Collectives.
- Empower the poor through ensuring access to Financial Services.
- Augmenting existing livelihoods and enhancing incomes
- Explore livelihood opportunities through newer ventures in rural service sector
- Developing Inclusive Value Chains

Table 6.17: Government schemes and policies on rural development

Year	Government Policies	Salient Features
1978	Integrated Rural Development Programmes (IRDP)	Employment Programme
1999	Swarna Jayanti Gram Swarozgar Yojana (SGSY)	Self-Employment Programme
2001	Sampoorna Grameen Rozgar Yojana (SGRY)	Employment Programme
2005	National Rural Employment Rural Guarantee Act (NREGA)	Employment Programme
1992	Integrated Wastelands Development Programme (IWDP)	improving the productivity of waste & degraded lands
1999	Development of Women and Children in Rural Areas (DWCRA)	Employment Programme
1979	Training of Rural Youth for Self-Employment (TRYSEM)	Employment Programme

6.2.5.1 Empowering Vulnerable Communities

Tribal groups, coastal communities, small farmers, pastoral groups and women are extremely sensitive to climate change and climate-induced disasters given their lack of access to alternative livelihood, information, finance and land. By assisting such vulnerable groups with education, awareness, livelihoods and knowledge not only can they become more resilient to disasters, but they can also use their capacities, skills and resources for climate action and sustainable development. The initiatives undertaken by the State aim to:

- Offer supplemental or alternative livelihoods to communities whose present source of income could be impacted by climate change and related disasters.
- Encourage women and marginalized groups to participate in the decision-making processes.
- Improve responsiveness of vulnerable communities in climate and disaster risk reduction.
- Encourage women to use renewable energy as economic resources.
- Promote self-help groups and collectives among women and vulnerable groups to promote savings, better understanding of schemes and resilient livelihoods.skills and resources for climate action and sustainable development.

6.2.5.2 Initiatives for Tribal Communities

The Government of Gujarat has launched a number of schemes and initiatives with the aim of enhancing the adaptive capacities of the tribal communities. Some of the schemes are:

- Vanbandhu Kalyan Yojana (VKY)
- Mission Mangalam
- Samras Yojana
- Janani Shishu Suraksha Karyakram
- Sarva Shiksha Abhiyan-Pragna: an Activity Based Learning Approach
- Kasturba Gandhi Batik Vidhalaya (KGBV)
- Tribal Area Sub Plan Scheme

Tribal welfare schemes not only promote the local artisans and crafts of Gujarat but also deliver economic empowerment and social justice along with climate justice

Picture Courtesy: Commissionerate of Rural Development, Gujarat

6.2.5.3 Climate Change Adaptation for Natural Resource-Dependent Communities-- Vanbandhu Kalyan Yojana

This programme was launched in 43 taluka of 12 District for economic, social and overall development of tribal people of the State. Total 402636 ha of area has been benefitted due to construction of check dams, deepening of tanks, lift irrigation schemes, water recharge through creating watershed, PIM, Canal water, etc.

A project aiming to enhance the adaptive capacity of natural resource dependent communities (Agriculture, Coastal Fishing and Pastoral communities) to climate change in targeted villages of Kachchh district, Gujarat has been funded by Government of India under the National Adaptation Fund on Climate Change

Picture Courtesy: Darpak Joshi, GEER Foundation

6.2.5.4 Integrated Planning in Tribal Belt from Ambaji to Umargam

This project is designed for irrigation purpose through Narmada canal. Total 144219 ha of area has been benefitted for irrigation due to Canal water, and 40821 ha area of completed work for participatory irrigation.

6.2.6 Biodiversity

Tables 6.18 and 6.19 sum up the adaptation strategies for biodiversity preservation towards the impacts of climate change.

Every year millions of birds from the Northern hemisphere take a trip to Gujarat during winters to avoid the cold harsh weather in in higher latitudes. The large variations in the flora, fauna and wetlands make Gujarat their prime destination

Picture Courtesy: Dreamstime.com

Table 6.18: **Some key adaptation strategies biodiversity (wetlands, coral reefs, mangroves, wildlife)**

Climate impacts	Adaptation strategies	Key Districts
Extinction of several species of flora and fauna due to rising temperature	Relocation of less adaptive species to favourable habitat regions	Kuchchh, Jamnagar, Devbhoomi Dwarka, Banaskantha, Panchmahal, Narmada, Dang, Rajkot, Morbi, Porbandar, Junagadh, Gir Somnath, and Amreli
Wildfire imposes great threat to millions of species	Fast and effective rescue schemes	Kuchchh, Jamnagar, Devbhoomi Dwarka, Banaskantha, Panchmahal, Narmada, Dang, Rajkot, Morbi, Porbandar, Junagadh, Gir Somnath, and Amreli
Changes in population and distribution of species	Ensuring adequate space and resources for migrating species, more data accumulation and learning	Kuchchh, Jamnagar, Devbhoomi Dwarka, Banaskantha, Panchmahal, Narmada, Dang, Rajkot, Morbi, Porbandar, Junagadh, Gir Somnath, and Amreli
Alteration in phenology (natural migration & breeding cycles)	Providing possible assistance in various phases	Kuchchh, Jamnagar, Devbhoomi Dwarka, Banaskantha, Panchmahal, Narmada, Dang, Rajkot, Morbi, Porbandar, Junagadh, Gir Somnath, and Amreli
Ocean warming affects marine ecosystem (e.g. Coral bleaching)	Protect critical habitats for threatened species	Kuchchh, Jamnagar, and Devbhoomi Dwarka
Rise of invasive species due to extended growing season	Artificial implantation of indigenous species and artificial insemination	Kuchchh, Jamnagar, Devbhoomi Dwarka, Banaskantha, Panchmahal, Narmada, Dang, Rajkot, Morbi, Porbandar, Junagadh, Gir Somnath, and Amreli
Declining precipitation in tropical regions affect the diversity	Preservation and protection of vulnerable species in artificial environments	Kuchchh, Jamnagar, Devbhoomi Dwarka, Banaskantha, Panchmahal, Narmada, Dang, Rajkot, Morbi, Porbandar, Junagadh, Gir Somnath, and Amreli
Flooding conditions due to heavy precipitation leads to loss of animals and plants	Introducing timely relocation measures of species (rapid shift)	Kuchchh, Jamnagar, Devbhoomi Dwarka, Banaskantha, Panchmahal, Narmada, Dang, Rajkot, Morbi, Porbandar, Junagadh, Gir Somnath, and Amreli
Cyclonic winds damage several big and old trees.	characterizing cyclone-prone areas; Mangrove rehabilitation in cyclone prone areas	Kuchchh, Jamnagar, Devbhoomi Dwarka, Rajkot, Morbi, Porbandar, Junagadh, Gir Somnath, and Amreli
Disappearing wetlands due to inundation of rising sea level	Protection and reconstruction of wetlands	Kuchchh, Jamnagar, and Devbhoomi Dwarka

Sinay & Carter, 2020; Watson et al, 2012; Sintayehu 2018

Table 6.19: Overall climate change adaptation strategies for wildlife and biodiversity conservation

Category	Adaptation strategy	Benefits/Outcomes
Related to Land and Water Protection and Management	Increase extent of protected area	Increase in the extent of terrestrial and aquatic habitat
	Improve representation and replication within Protected-area networks	To build a more comprehensive portfolio of protected areas
	Restoration of existing Protected areas to facilitate resilience	Minimizing small-scale effects of climate change in protected areas through direct management activities
	Design new natural areas and restoration sites to maximize resilience	Resilience enhancement of natural systems to climate-change effects (example: saltmarsh restoration sites adjacent to steep shorelines)
	Manage and restore ecosystem function rather than focusing on specific components	Maintenance of aspects of ecosystem function (such as nutrient uptake by riparian forest buffers or wetland filtration of nutrients and sediments) in conservation areas
	Improve the matrix by increasing landscape permeability to species movement	Increasing broader landscape connectivity and permeability to species movement
Strategies Related to Direct Species Management	Focus conservation resources on species that might become extinct (wildass, corals, mangroves, great Indian bustard)	Maintenance and continued survival of those species most likely to become extinct as a result of global climate change
	Translocate species at risk of extinction	To create a favourable condition for their continued existence
	Establish captive populations of species that would otherwise go extinct	initiate captive maintenance programs for species that may extinct due to climate change
	Reduce pressures on species from sources other than climate change	To give wildlife species the maximum flexibility to evolve responses to climate change
Strategies Related to Monitoring and Planning	Evaluate and enhance monitoring programs for wildlife and ecosystems	Provide information that managers can use to adjust or modify their activities
	Incorporate predicted climate-change impacts Into species and land-management plans, programs, and activities	Incorporating climate-change information into existing and future natural resource planning activities

Category	Adaptation strategy	Benefits/Outcomes
	Develop dynamic landscape conservation plans	Include information on fixed and dynamic spatial elements, along with management guidelines for target species and ecosystems
	Ensure wildlife and biodiversity needs are considered as part of the broader societal adaptation process	Overall societal adaptation for wildlife and biodiversity to value the ecosystem services in an ecosystem.
Strategy Related to Law and Policy	Review and modify existing laws, regulations, and policies regarding wildlife and natural resource management	Includes efforts to reform or enhance public policies regarding wildlife management and biodiversity conservation.

Mawdsley et al, 2009

6.2.6.1 Bio-diversity Conservation

To manage the rich biodiversity, Government of Gujarat has established Gujarat Biodiversity Board. It's purpose of promoting conservation, sustainable use and documentation of biological diversity including preservation of habitats, conservation of land races, folk varieties and cultivars, like the Asiatic bon and Indian wild ass domesticated stocks and breeds of animals, micro-organisms and that are not seen elsewhere chronicling of knowledge relating to biological diversity.

6.2.7 Forest Sector

To mitigate the impact of climate change, control over the release of greenhouse gases due to burning of fossil fuels is extremely necessary. Gujarat government took initiative to promote the forest awareness about its importance and need. Afforestation and plantation of various tree species is being carried out as an adaptive measure to mitigate climate change impact on forest. The detection of vulnerable areas to climate change can be useful for an early preparedness. Linking to this, an early drought warning system and accurate weather forecasting system will be very useful for systematic planning for designing the future forest conservation policies and strategies. In terms of conserving coastal forest and biodiversity, coastal area management and development plans should be ready in hand to tackle the rapid impacts of climate change. In addition to that, special forest conservation acts and laws should be included and implemented to ensure the protection and conservation of limited forest resources and its surrounding biodiversity. Nevertheless, the development of watershed management practices can be a logical step as well as a powerful adaptation mechanism towards protecting and preserving the forest species (flora and fauna) in the arid and semi-arid regions of Gujarat, to tackle the impacts of climate change. Tables 6.20 and 6.21 list the adaptation strategies towards impacts of climate change on forests of Gujarat.

Table 6.20: **Disaster sector impact, adaptation and recommendations**

Climate vulnerability and impacts	Adaptation	Recommendation
• Reduction in carbon sequestration	• Less use of woody materials • Afforestation or reforestation • Enhanced natural regeneration • Re-vegetation of degraded lands	• Reduce pollution near to forest region • Stop mining in the forest region • reduced soil tillage and other agricultural practices which increase soil carbon
• Reduced growth and productivity of forest	• Less forest resource utilization during drought years	• Forest management
• Deforestation (land development, timber production)	• Less use of woody materials. • Afforestation	• Restriction in unnecessary land development • Government protection
• Forest fire and pollution	• Plantation in forest region to recover • Identify the point and non-point sources of forest fire • Monitor the dry biomass to reduce the forest fire • Restrict burning materials in forest region	• Reduce recreational activity in forest region • Obey local laws regarding open fires, including campfires • Carefully extinguish smoking materials
• Forest pests and insects	• Monitor endangered species • Use some medicines are technology to divert pests from forest region	• Prepare the management and strategic plan to reduce the pest attack
• Wildlife habitat & Biodiversity loss	• Extinction of particular species • Forest management and monitoring • Monitor wetland and coastal area • Restoring grasslands	• Wetland and mangrove protection • Coastal areas management • Use renewable energy

Table 6.21: **Some key adaptation strategies for forest**

Climate Impacts	Adaptation Strategies	Key Districts
Increasing temperature due to increasing GHG's may increase forest growth	Reducing the GHG emission by fossil fuels	
Change in forest patterns, may threaten availability of forest resources	Detecting areas as climate vulnerable, enacting laws for protection	Junagadh, Gir-Somnath, Amreli, Bhavnagar, Valsad, Dang, Tapi, Narmada, Chota Udaipur, Dahod, Panchmahal
Increased susceptibility to forest fires	Monitoring of forest health, dryness to prevent forest fires	Junagadh, Gir-Somnath, Amreli, Bhavnagar, Valsad, Dang, Tapi, Narmada, Chota Udaipur, Dahod, Panchmahal

Climate Impacts	Adaptation Strategies	Key Districts
Increased rainfall extremes, leading to droughts and floods	afforestation, drought monitoring to prevent forest fires	Junagadh, Gir-Somnath, Amreli, Bhavnagar, Valsad, Dang, Tapi, Narmada, Chota Udaipur, Dahod, Panchmahal
Increased dryness may lead to replacement of Sal trees with dry teak dominated trees	watershed management, and protection to preserve forests	Junagadh, Gir-Somnath, Amreli, Bhavnagar, Valsad, Dang, Tapi, Narmada, Chota Udaipur, Dahod, Panchmahal
May cause submergence of wetlands and mangroves, critically endangered these ecosystems	coastal areas management	Kuchchh, Jamnagar, and Devbhoomi Dwarka
Critically endangered coral reefs which serve as hotspots of biodiversity and breeding grounds for fishes	Incorporation of Artificial reefs	Kuchchh, Jamnagar, and Devbhoomi Dwarka

Sintayehu 2018, D. Mukhopadhyay, 2009, Sinay & Carter, 2020

6.2.8 Infrastructure

Adaptation strategies help to reduce the adverse effects of climate change on the infrastructure sector. For instance, designing and development of climate-resilient buildings, which include promoting green urban designs (introduction of green roofs and green spaces) are helpful to reduce the stress from heat waves within the urban area (Zimmerman and Faris 2010). Moreover, the various adaptation plans have adopted in various cities to combat with climate change, like incorporating green buildings into the climate change adaptation plans and policies, the adaption of energy-efficient buildings, change of design specifications of the building designs as a part of the introduction of climate-resilient buildings and adaptation of land-use policies (Table 6.20 to 6.23). However, the selection of an adaptation solution is dependent on a number of factors, including location, temporal scale, and the specific impacts faced (USAID; United States Agency for International Development). The USAID suggested the four accepted types of adaptation strategy options that can be implemented and considered in the infrastructure sector. The four adaptation strategies are:

1) Accommodate and maintain;

2) Harden and protect;

3) Relocate; and

4) Accept or abandon.

Table 6.22 provides an overview on each strategy, which helps to prompt thinking and idea generation for the development of adaptation options for new and existing infrastructure (AECOM 2015).

Table 6.22: Approach to adaptation strategies

Strategic Approach		Adaptation Strategy	
Existing Structure		New Structure	
1	Accommodate and Maintain	• Extend, strengthen, repair or rehabilitate over time • Adjust operation and maintenance	• Design and build to allow for future upgrades, extensions or regular repairs
2	Harden and Protect	• Rehabilitate and reinforce • Add supportive or protective features • Incorporate redundancy	• Use more resilient materials, construction methods, or design standards • Design for greater capacity or service
3	Relocate	• Relocate sensitive facilities or resources from direct risk	• Site in area with no, or lower, risk from climate change
4	Accept or Abandon	• Keep as is, accepting diminished level of service or performance	• Construct based on current climate, accepting possibly diminished level of service or performance

Source: AECOM 2015

Based on the available range of possible adaptation strategy options, the most appropriate option for the implementation should be selected. The common approach to select a best option is to include the use of a Multi-Criteria Analysis (MCA) and applying an economic analysis, such as Cost-Benefit Analysis (CBA). Moreover, each adaptation strategies have unique advantages and disadvantages, as listed in Table 6.23.

Table 6.23: Advantages and disadvantages of adaptation approaches

Strategic Approach		Advantages	Disadvantages
1	Accommodate and Maintain	• Less costly • More pragmatic and flexible, allows adjustment over time as more climate change data becomes available	• Requires monitoring, possibly frequent repairs, adjustments, or more rigorous operations • Necessitates design for more flexible or upgradeable structure
2	Harden and Protect	• Proactive • Straightforward to implement and justify	• Increased costs • Assumes reasonably accurate climate forecasts
3	Relocate	• Proactive	• Increased costs • Sub-optimal location may decrease period of performance or service
4	Accept or Abandon	• No extra up-front cost	• Proper communications needed to inform decision-makers and beneficiaries to expect lower performance or service

Source: AECOM 2015

The education campuses in Gujarat are turning green and sustainable. IIT Gandhinagar (shown below) is a GRIHA rate green campus houses large water harvesting structures, solar energy generation and passive cooling systems to list a few

Picture Courtesy: https://commons.wikimedia.org/wiki/File:Academic_Area,_Indian_Institute_of_Technology_Gandhinagar.jpg

Out of four adaptation strategies, select the appropriate approach to reduce the impact of climate change on the infrastructure sector. These approaches include elevating low-lying infrastructures including roads to cope up with the sea-level rise and flood events, steps to increase water quality and tackle contamination, impact assessment on various infrastructure facilities, proper spatial planning during the decision making phase, construction of drains and similar structures to collect water during storm surges and flood events, designing alternate transportation services (Picketts et al 2016), construction of storm surge barriers (Esteban et al 2014)potentially in excess of 100 trillion yen, with the indirect costs likely to be even greater. As a result it is likely that sea defences will have to be strengthened around Tokyo Bay in the future, which could cost in the order of 370bn yen to defend against a 1 in 100 year storm by the year 2100. Alternatively, a storm surge barrier could be built, which would be more expensive (possibly in the range of 700-800bn yen, and corrosion-resistant buildings for the coastal area (Stewart et al 2012). Based on the appropriate adaptation strategies, we list the adaptation strategies to combat with different climate change drivers and reduce the effect of climate change risk (Tables 6.24 and 6.25).

The large-scale industrialization and high economic growth of Gujarat is underpinned by its infrastructure development. By sheer nature of being lumpy, infrastructure assets are highly vulnerable to impacts of climate change and extreme events. Thus, enhanced designing and monitoring need to be taken up as resilience strategies for infrastructure

Picture Courtesy: Tejas Patel, Unsplash.com

Table 6.24: Illustrative adaptation strategies

Climate Drivers	Affected Asset and Risk	Engineering Design Adaptation Strategies
Extreme Heat/ Heatwaves	• Health facility • Loss of power and air conditioning to manage excessive heat increases health risk to patients	• Harden: Enhance design to enable additional cooling and ventilation capacity • Accommodate: Install emergency back-up generators
Drying Trend/ Drought	• Trunk sewer system • Reduced flow in pipelines causes increased blockages, and potential for environmental pollution	• Harden: Redesign sewer for low flow conditions (e.g., install smaller pipes) • Accommodate: Facilitate and increase maintenance
Extreme Precipitation/ Flooding	• River embankment • More frequent submersion, lesser level of protection, and possible breach / failure of embankment	• Harden: Heighten or buttress embankment based on long-term projected floods • Accommodate: Slightly heighten embankment • Relocate: Build behind a new embankment (maybe only to protect sensitive or urban areas) • Accept: Inform residents and farmers to expect lesser protection and increased flooding (possibly dismantle embankment to avoid disastrous failure)

Climate Drivers	Affected Asset and Risk	Engineering Design Adaptation Strategies
Storm Surge	• Seawall • Structural damage and submersion leading to property or asset damage and potential loss of life	• Harden: Heighten and reinforce seawall, or build offshore breakwaters • Accommodate: Monitor and repair as needed • Relocate: Build new seawall further away from the coast • Abandon: Relocate properties and condemn area for future development (possibly dismantle seawall to avoid disastrous failure)
Sea Level Rise	• Coastal road • Often submerged at high tide, preventing traffic and distribution of goods	• Relocate: Move road inland • Harden: Elevate road or build sea wall • Accommodate: Monitor and close road at high tide • Abandon: Close road and redirect traffic permanently to more inland routes
Damaging Storms (wind, lightning)	• Coastal wind turbines • Damage from windblown debris	• Harden: Enhance wind resistance design • Accommodate: Stop operation during storms • Abandon: Dismantle and build other energy production system (e.g., solar) as a substitute
Wildfire	• Potable water supply • Burned catchment causes ash and sediments to impact water quality of water sources	• Harden: Install additional filtration • Accommodate: Reforest, stabilize slopes, build sedimentation traps • Relocate: Build raw water intake and conveyance from another nearby catchment

Source: AECOM 2015

Table 6.25: **Adaptation measures can be taken for Climate Resilient Design**

Climate Drivers	Adaptation Measures
Extreme Precipitation Events, Flooding	**For energy infrastructure:** • Allocate sufficient budget for repair and recovery after extreme events (often more cost effective than relocation, especially for large facilities) • Cyclone proof wind turbine in cyclone prone areas (existing system where the turbine can be easily removed from the axis and secured to the ground) • Reinforce overhead transmission lines and apply hydrophobic coating or install lines and equipment underground • Relocate or protect energy substations **For flood management infrastructure:** • Consider future climate in design of asset to manage larger peak water flows • Combine open space and storm water storage to manage peak flows • Provide training on the use of temporary flood barriers to protect critical infrastructure • Flood education, awareness and emergency management training for at risk communities • Revegetation of catchments • For information and communication technology infrastructure • Install temporary, or permanent flood barriers to key facilities • Consider future climate in design of asset to manage increased risk of flooding **For solid waste infrastructure** • Relocate landfills or construct levee or other protective barrier **For Transportation Infrastructure:** • Alter maintenance regimes to target vulnerable sections of transport systems • Size drain and storm water systems with a consideration of climate change projections. If no projections are available, include a precautionary overestimation in the design to provide a safety buffer • Harden or stabilize slopes subject to increased run off from extreme weather events • Seal ventilation grates of below ground facilities • Elevate mechanical and electrical equipment in operations or maintenance facilities • Use waterproof materials • Review capacity of pump equipment

<table>
<tr><th>Climate Drivers</th><th>Adaptation Measures</th></tr>
<tr><td></td><td>For wastewater and sanitation infrastructure
• Design sewage system with inclusion of changing precipitation projections
• Size drain and storm water systems with a consideration of climate change projections. If no projections are available, include a precautionary overestimation in the design to provide a safety buffer
• Planning of retention and safety basins to avoid overflow to the drainage network and pollution spills downstream
• Integrate flood management procedures (forecasting and early warning systems) in sewer and landfill operational planning
• Elevate mechanical and electrical equipment in operations or maintenance facilities
• Use waterproof materials
• Review capacity of pump equipment
For water supply infrastructure
• Use mesh and specific filters to minimize the potential of stationary water becoming a breeding area for mosquitoes
• Design efficient irrigation systems with inclusion of precipitation projections
• Size drain and storm water systems with a consideration of climate change projections
• Relocation of raw water intake</td></tr>
<tr><td>Sea Level Rise and Storm Surge</td><td>For energy infrastructure:
• Consider multiple combinations of waves' direction and height in the design to maximize the potential for energy generation
For flood management infrastructure:
• Consider future climate in design of coastal protection assets
• Beach nourishment and dune construction
• Revegetation of coastal areas
• Storm surge barriers, barrier islands, and tide gates
For Transportation Infrastructure:
• Raise elevation of track, roadway, or bridge touchdown, on embankments or levees
• Construct causeway
• Elevate mechanical and electrical equipment in operations or maintenance facilities
• Increase capacity of storm water drainage system and increase drainage maintenance at flooding hotspots
• Use corrosion-resistant or waterproof materials
• Construct low-water crossings
For wastewater and sanitation infrastructure
• Review location of outfall pipes (in relation to potential backflow)</td></tr>
</table>

Climate Drivers	Adaptation Measures
	For water supply infrastructure • Raise elevation of storage infrastructure to protect from saltwater intrusion • Elevate mechanical and electrical equipment in operations or maintenance facilities • Increase capacity of storm water drainage system and increase drainage maintenance • Use corrosion-resistant or waterproof materials • Reduce pumping from freshwater lenses to inhibit saline intrusion
Extreme Heat	**For energy infrastructure:** • Improve energy efficiency and reduce the demand on the network • Increase peak generation capacity (e.g. gas peaking plant or hydro reserve) • Diversify fuel sources **For solid waste infrastructure** • Reassess management and covering of landfill to control decomposition and potential odors • Reassess management of dry matter in landfill to protect against fire **For Transportation Infrastructure:** • Confirm capability of current heat-resistant road and track materials and if necessary, use more heat tolerant binders and materials **For wastewater and sanitation infrastructure** • Equip the sewage system with independent power generation backup to ensure pump power supply during electricity blackout
Drought; Reduced Average Precipitation	**For energy infrastructure:** • Assess the proportion of water flows that is dependent on glacier or snow fed rivers and integrate this • component in the design and exploitation of the facility (hydro) • Manage water in an integrated framework to avoid use conflict (hydro) • Give priority to drought resistant species where possible (biofuels) **For water supply infrastructure** • Consider alternative water supply options (e.g. recycled water systems) and conservation measures (e.g. restrictions on water use) • Increase the individual capacity and the number of rainwater tanks • Relocation of raw water intake • Diversify water sources such as new water storages or expanding their existing capacity, tapping deeper groundwater aquifers, inter-basin water transfer, capturing unharnessed resources such as rainwater harvesting, desalination, or employing water reuse technologies **Increase reservoir capacity** • On-site recycling of used water or decentralized treatment (industrial reuse and small local use) • Increase water efficiency by using drip feed systems
Damaging Storms	**For information and communication technology infrastructure** • Maintain vegetation management practices that minimize the chance of contact being made that may damage infrastructure • Allocate sufficient budget for repair and recovery after extreme events (often more cost effective than relocation, especially for large facilities) • Install communication lines underground • Consider future climate in design of asset to manage increased risk of flooding and storm damage

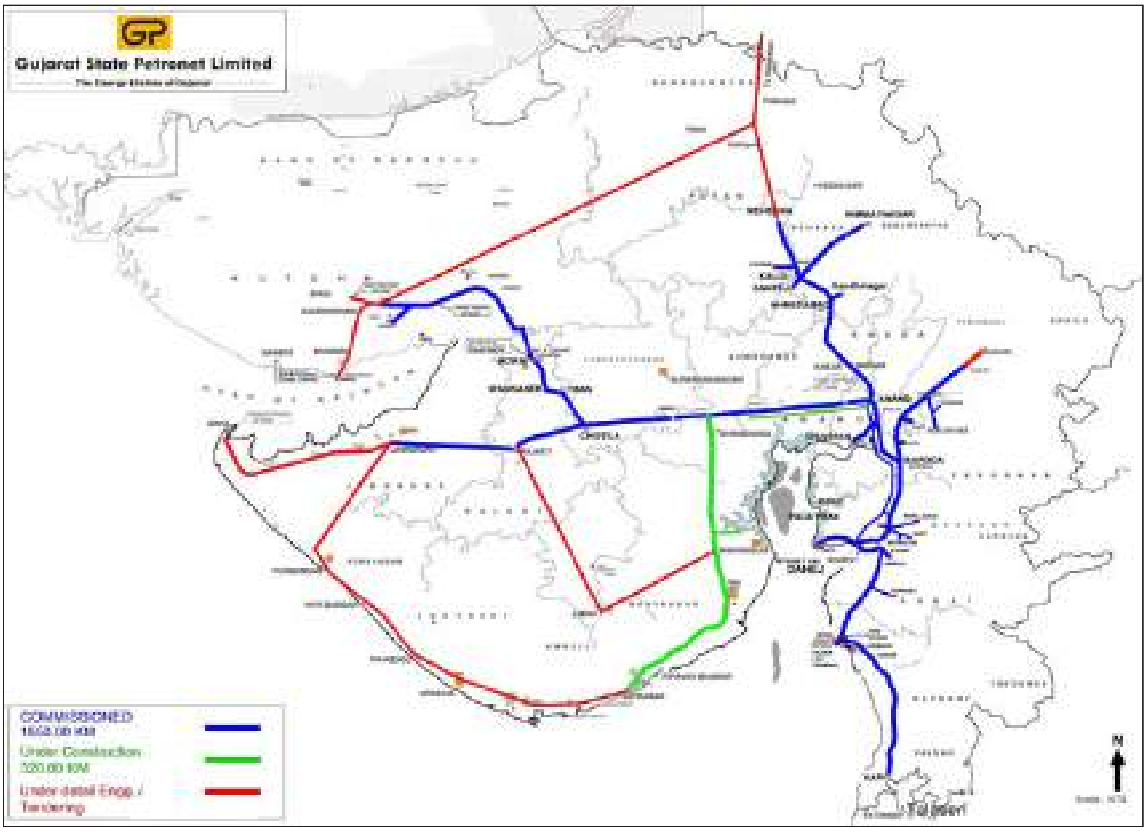
Source: AECOM 2015

6.2.8.1 The Gas Grid

The Gujarat State Petroleum Corporation Limited (GSPC) has planned a 'State-wide Gas Grid' (Figure 6.30) to provide clean fuel to remote areas of the State. A 1,500 km long high-pressure gas pipeline passing through 15 districts of the State (to cater to power, fertilizer, chemicals and SME units like glass and ceramic etc.) has been laid and commissioned and an 800 km stretch is under construction. The power generating units of the State are also exploring fuel switching options from Naphtha to gas (for both captive use and grid supply) to reduce GHG emissions. The State's new Power Generation Policy encourages setting up of super-critical and ultra-super-critical technology-based generation projects. 1st Indian State to have gas grid network of 2696 km operational pipeline passing through 25 districts with 25 MMSCMD capacity. The gas grid supports:

- An increasing share of natural gas in the energy mix of Gujarat
- City Gas Distribution (CGD) in Gujarat
- Natural Gas Vehicles
- Use of natural gas in industry replacing conventional fuels
- Cooking gas availability to replace firewood and conventional fuels.

Figure 6.30: Gas Grid Map of Gujarat



6.2.9 Health Sector

In order to reduce the climate change impact on the health sector, it is essential to consider adaptation. The adaptation is considered both the assessment of impacts and vulnerabilities of climate change on human health. The climate change assessment can be done using the following steps (Source: WHO 2012):

- Assessment of current health status in Gujarat
- Identification of populations most vulnerable to climate change over Gujarat
- Identification of mechanisms by which projected climate changes may affect health
- Estimates of current burden of climate-sensitive diseases using scenario based modelling
- Studies that address early health effects of climate change
- Assessment of strategies that may reduce potential impacts on health
- Identification of knowledge gaps.

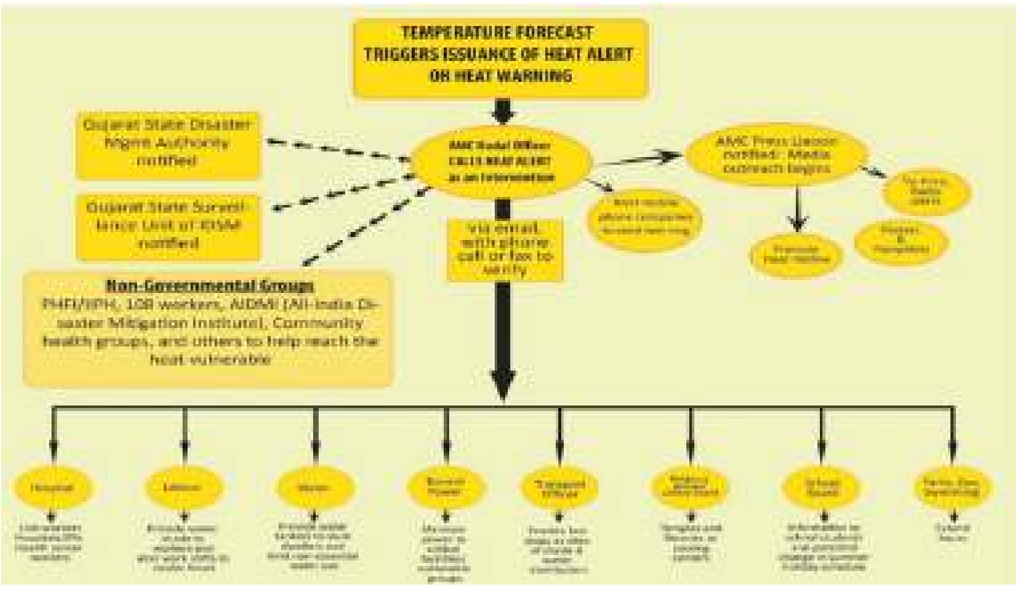
For instance, increased temperature will lead to frequent heat waves in most of Gujarat in the future climate. The proper predictive modeling or monitoring and communication of climate driver will reduce the damage on the health of residents. Recently, the Health Action Plan (HAP) in Ahmedabad have shown some success (Ahmedabad Municipal Corporation 2016) in heat wave monitoring. The HAP in Ahmedabad coordinates among the different stakeholders such as government departments, health care professionals including emergency medical personnel, health centre staff, hospital staff, and community groups and provides proper heatwave warning. The Health Action Plan has shown positive outcomes in reducing mortality during the hot months (May-June) of the year in Ahmedabad. The Ahmedabad Municipal Corporation issues heat alerts based on temperature thresholds (Table 6.26):

Table 6.26: Showing heat alerts issued by AMC based on temperature thresholds

Alert	Advisory	Temperature
Yellow Alert	Hot Day Advisory	41.1°C- 43°C
Orange Alert	Heat Alert Day	43.1°C- 44.9°C
Red Alert	Extreme Heat Alert Day	>=45°C

These alerts are communicated through a systematic communication plan as shown below in Figure 6.31.

Figure 6.31: The communication plan for activating Heat Alert in Ahmedabad



Source: Ahmedabad Municipal Corporation, 2016

Similar strategies can be used in the other heat wave vulnerable districts of Gujarat (like Banaskantha, Sabarkantha, Aravalli, Dahod, Patan, Mehsana, Gandhinagar, Kheda, Panchmahals, Anand, Kuchchh, and Surendranagar). Since maximum temperature (hot days and nights) and heatwaves are projected to increase in the future climate. Therefore, prediction and monitoring system like HAP is needed in the state to reduce impact of climate change on health. Table 6.27 lists the adaptation strategies for health sector.

Ahmedabad was the first city in Asia to develop a heat action plan. The plan is not only an early warning system but also provides for concrete steps like measures to cooling the tin roof in the slum areas and drinking water kiosks across the city to prevent the events of heat stroke in heatwave durations

Picture Courtesy: Ahmedabad Municipal Corporation

Table 6.27: Adaptation strategies for health sector

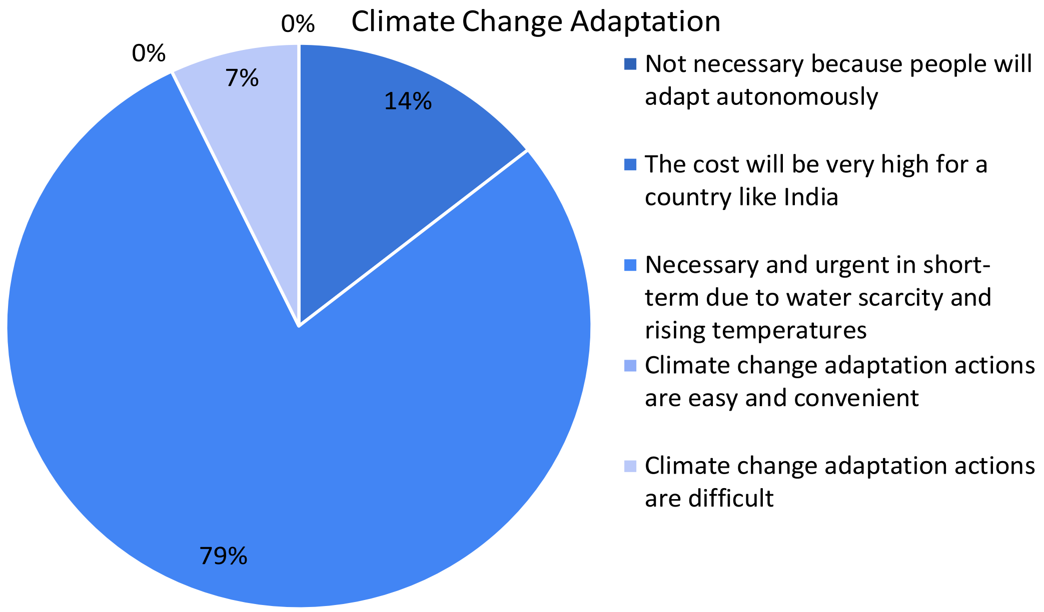
Sr No	Climate Factors	Adaptation Strategies	Key Districts and Cities
1	Temperature	• Air Conditionings and energy efficiency to the buildings • Identification of vulnerable population • Provision for rehydration • Increase community resilience • Proper awareness • Proper monitoring and their counter measures or climate warning	Across state
		• Timely health services • Weather relationship to influenza and other causes of winter mortality	

Sr No	Climate Factors	Adaptation Strategies	Key Districts and Cities
2	Precipitation (flood, extremes precipitation, and drought)	• Water treatment measures • Restoration of communication facilities as early as possible • Reservoir Control and improved operation • Improved prediction, Epidemic/climate warning	Kuchchh, Devbhoomi Dwarka, Amreli, Jamnagar, Bhavnagar, Junagadh, Rajkot, Surendranagar, Patan, Banaskatha, Morbi, Anand, Vadodara, Chotta Udaipur, Panchmalas, Valsad, Dang, Navsari, Bharuch
3	Severe Storm/ Cyclones	• Proper alerting system • Tracking of outbreaks of diseases and mapping	Kuchchh, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Rajkot, Morbi, Bhavnagar
4	Particulate Matter/ Pollution	• Air quality improvement measures (promote use of environmentally friendly fuels and healthy transportation system, promotion of healthy environment housing,) • Temporary relocation • Use of face masks to avoid triggering of asthma and other allergy issues • Chemical Control (near river or water table) • Integrated pest management systems	Ahmedabad, Vadodara, Surat, Rajkot cities, Kuchchh, Jamnagar, Rajkot, Bhavnagar, Amreli, Junagadh, Ahmedabad, Bharuch, Vadodara, Surat, Navsari, Valsad, Anand
5	Others (for all factors)	• Sanitary Education and awareness • Training and equipment • Legislation • Multidisciplinary approach and collaboration with other agencies—such as, agricultural, meteorological, environmental and planning • Database and information system to be established for accurate monitoring and data collation • Climate resilient health Infrastructure development	Across state

6.3 Barriers and gaps in implementation of adaptation actions

A survey similar to the survey conducted for assessing the barriers and gaps faced by mitigation policy implementation, was conducted for the understanding the challenges in implementation of adaptation policies. The survey questions tried to assess the opinion on need for adaptation. The survey further tried to gauge the viewpoint on the obstacles and challenges versus opportunities (Figure 6.32). Further the survey presented statements describing the technological, financial, institutional and legal, knowledge as well as socio-political barriers. The results are discussed here.

Figure 6.32: Opinion of Policy-makers on Climate Change Adaptation



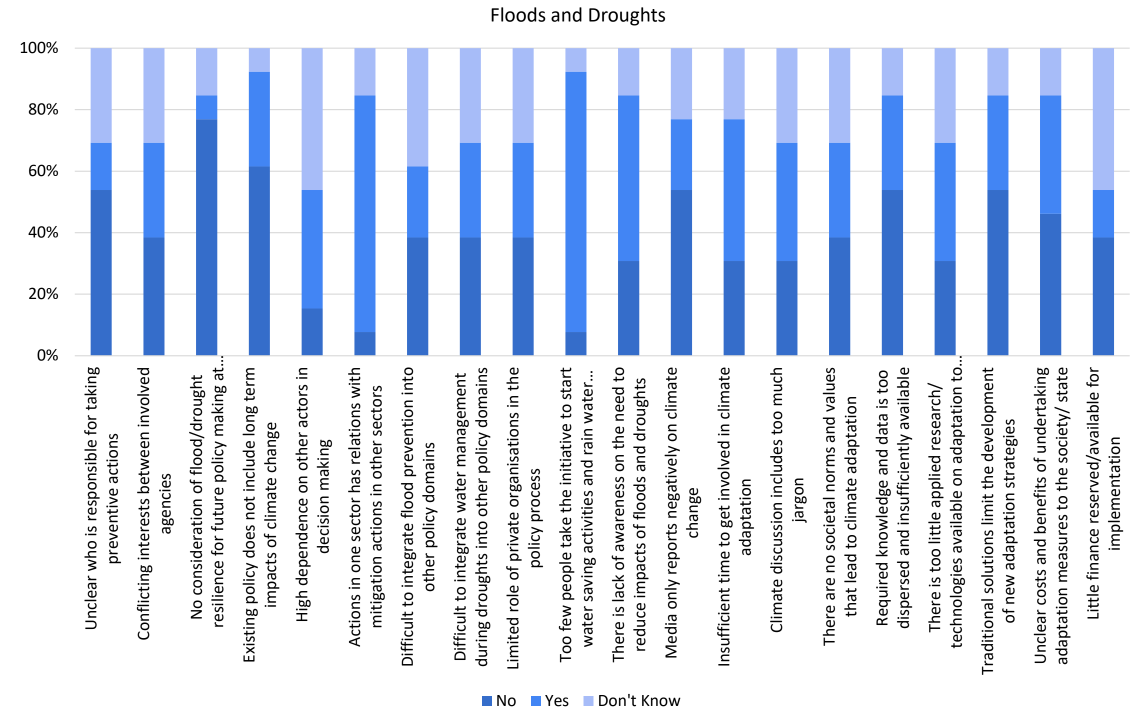
The responses on the policies to manage extreme perception situation and their implementation indicated that institutional arrangements are clear and smooth functioning with not may hurdles (Figure 6.33 (a)). Also, the policy makers understand that there is consideration for adaptation towards climate change in the policymaking process- which has a significant impact on the future policies while acknowledge the interdependency of various sectors, actors and opportunities. A third of the policymakers do feel that it is difficult to integrate some of the aspects of flood and drought management in policy making. They also point towards lack of time and initiatives from individuals towards water savings and rainwater harvesting actions. The results also indicate that knowledge is available, however, they also indicate a lack of awareness towards the need to adapt.

A similar opinion comes for the actions to manage extreme temperatures (Figure 6.33 (b)). The opinions that knowledge and data being sparsely available is prominent. However, the feeling that traditional solutions limit the development of new adaptation strategies is also high. Policymakers also don't see very clear cost to benefits of the implementation extreme temperature related action plans.

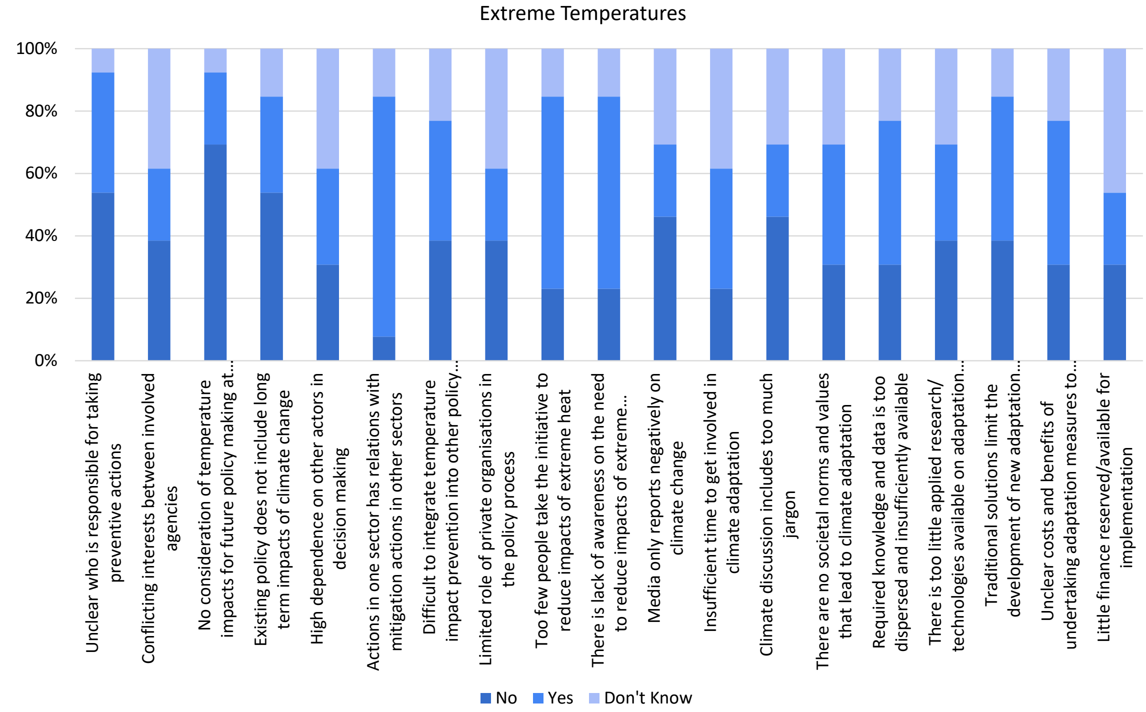
As far as the policies on afforestation and reduced deforestation and pollution management are considered, there is very high clarity on the roles and responsibilities of each of the agencies (Figure 6.33 (c)).

Figure 6.33: Responses on Barriers & Gaps in Adaptation Policies

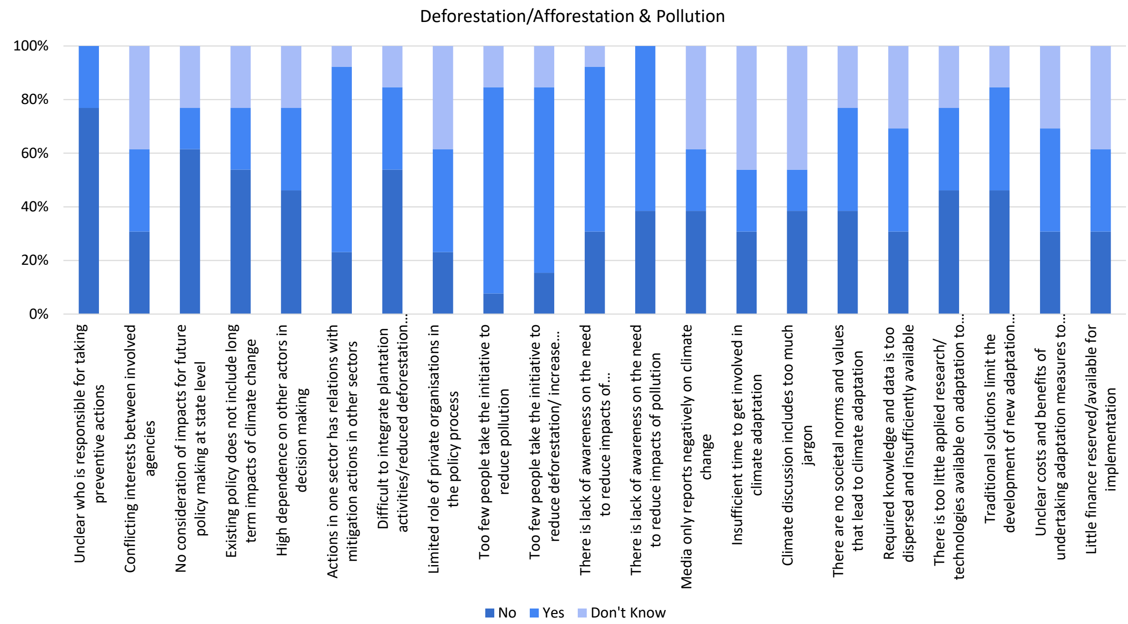
(a) Extreme Precipitation



(b) Extreme Temperatures



(c) Afforestation/Deforestation and Pollution



6.4 Implementation plan including the agencies responsible for implementation, required policy and budget

Table 6.28 below shows the key adaptation policies for Gujarat and the institutions responsible for the success of these policies.

Table 6.28: List of Key Policies and the Key Institutions for Adaptation Actions

Sr. No.	Adaptation Strategies	Department Responsible*
1	Wetland restoration	Forests and Environment
2	Change irrigation patterns from flood irrigation to drip or sprinkle irrigation	Agriculture
3	Change in Crop pattern to conserve water-related	Agriculture
4	Early warning system	Revenue
5	Village level awareness about new strategies to conserve water	Panchayat, Rural Housing and Rural Development/Information
6	Proper drinking water supply	Narmada and Water Resources, Water Supply and Kalpsar
7	Water shed management	Panchayat, Rural Housing and Rural Development/ Narmada and Water Resources, Water Supply and Kalpsar
8	Mandating water harvesting and artificial recharge in rural as well as urban areas	Panchayat, Rural Housing and Rural Development/ Urban Development and Urban Housing
9	Optimizing water use efficiency	Panchayat, Rural Housing and Rural Development/ Urban Development and Urban Housing/Agriculture/Industries and Mines

Sr. No.	Adaptation Strategies	Department Responsible*
10	Plantation in coast area like, mangroves	Forests and Environment
11	Wastewater treatment	Forests and Environment
12	Proper flood warning and management systems	Revenue
13	Proper planning of drainage systems	Urban Development and Urban Housing/ Municipalities/ Municipal Corporations
14	Dam construction and improved reservoir capacity	Narmada and Water Resources, Water Supply and Kalpsar
15	River linking to supply water from wet region to dry region	Narmada and Water Resources, Water Supply and Kalpsar
16	Altering planting and harvesting time	Agriculture
17	Collection of crops with short life cycles	Agriculture
18	Crop rotation & cultivation of new crops	Agriculture
19	Modern irrigation techniques	Agriculture
20	Preparedness of disasters beforehand	Revenue
21	Community level awareness for local level activities based on previous experience and local knowledge	Revenue/ Information/ Panchayat, Rural Housing and Rural Development/ Urban Development and Urban Housing
22	Mapping and environmental trend analysis in community level with a digital database	Revenue/ Information/ Panchayat, Rural Housing and Rural Development/ Urban Development and Urban Housing/ Narmada and Water Resources, Water Supply and Kalpsar/ Agriculture/ Forests and Environment
23	Maintaining water quality of wetlands and marshlands	Forests & Environment
24	Incorporating wetland protection into the planning of new infrastructure	Forests & Environment/ Gujarat Infrastructure Board
25	Reduce marine pollution (due to ships)	Forests & Environment/ Ports and Transport
26	Protection of marsh and wetlands	Forests & Environment
27	Enhance efforts to restore dead coral reefs	Forests & Environment
28	Monitoring of forest health, dryness to prevent forest fires	Forests & Environment
29	Joint Forest Management	Forest and Environment
30	Soil and Moisture Conservation	Forest and Environment
31	Social Forestry Programme	Forest and Environment
32	National Agroforestry Policy, 2014	Forest and Environment

Sr. No.	Adaptation Strategies	Department Responsible*
33	Mangrove Conservation	Forest and Environment
34	State Bamboo Mission	Forest and Environment
35	Extend, strengthen, repair or rehabilitate infrastructure over time	Roads & Building/ Ports & Transport
36	Adjust operation and maintenance of infrastructure assets	Roads & Building/ Ports & Transport
37	Use more resilient materials, construction methods, or design standards	Roads & Building/ Ports & Transport
38	Design and build to allow for future upgrades, extensions or regular repairs	Roads & Building/ Ports & Transport
39	Relocate sensitive facilities or resources from direct risk	Roads & Building/ Ports & Transport
40	Timely provision of health services	Health
41	Climate resilient health Infrastructure development	Roads & Building/ Health
42	Sanitary Education and awareness	Health/Information

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CHAPTER 7

Financing the SAPCC

Picture Courtesy: Mukesh Acharya

Financing the SAPCC

7.1 Financing roadmap including sectoral activity budget

One of the major resources required for efficient policy implementation are the finances. Thus, assessments need to be undertaken for financial resources required and the sources from where these will be made available. Currently, public spending is the mainstay of climate change finance in India (Garg, Mishra, & Dholakia, 2015). The international funding for adaptation (for India) is about a third of the domestic commitments (Garg, Mishra, & Dholakia, 2015). Therefore, the is a need for the state and central government to their share of financing climate change actions in the years to come.

Gujarat state has provided safe drinking water facilities, village level quality health care services, 24-hour power supply, productivity in agriculture and animal husbandry, expansion of irrigation facilities, schools, collages, and universities since last 25 years. Also, it has placed vast network of roads, enhanced residential amenities in rural and urban area and created large scale infrastructure facilities. **Gujarat has become a role model** and has earned recognition for being the leading Indian state in the world.

- Keeping framers' welfare at the center, **Hon. Prime minister has introduced the Pradhan Mantri Kisan Sanman Nidhi Yojana** since last year under which assistance of INR 6000 is provided to every farmer family. Under this scheme, 48 lakh farmers of Gujarat have directly received INR 3186 crore into their bank accounts.
- Gujarat Government has announced the biggest ever agricultural package of INR 3795 crore in 2020-21 for millions of farmers keeping in view the crop-loss to the farmers owing to unseasonal and excessive rainfall and the compensation is being paid to the beneficiary farmers in their bank accounts.
- **Sujalam Sufalam Scheme, SAUNI Scheme and lift irrigation schemes** has also been implemented towards powerful water management.
- State has facilitated **Ease of Doing Business** under **Business Reform Action Plan** which has provided extraordinary momentum to industrial growth. It has recorded memorandum for investment of INR 344000 crore out of the total investment of INR 679000 crore announced by GoI.
- State has implemented a policy of **"First Production, then Permission"** to encourage and facilitate MSME industries. This policy allows an entrepreneur to set up an industry first and obtain the necessary permission to do so within three years. As a result, approximately 16000 MSME are registered every month.
- The schemes include setting up of the bullion exchange in the Gift City, redevelopment of Dholavira site, establishment of Maritime Museum in Lothal, establishment of National Forensic University and National Police University.
- Government of Gujarat (GoG) budget for 2020-21 works untiringly keeping in focus the motto of **Sauno Sath, Sauno Vikas, Sauno Visvas.** The size of the budget 2020-21 is INR 217287 crore. State has placed special thrust on Education, Health, Agriculture, Animal

Husbandry, Water Management, Rural and Urban Development, Social Development in the budget for FY21.

On analysing the budget for various departments as well as the overall state budget for years 2017-18, 2018-19, 2019-20 and 2020-21, we find that there has been considerable spending on implementation of various key policies. Departments assessed here include Energy & Petrochemical, Climate Change, Food and Civil Supplies & Consumer Affairs, Urban Development and Urban Housing, Forest & Environment, Industry & Mines, Labour & Employment, Education, Agriculture & Co-operation, Health and Family Welfare, Roads and Buildings, Panchayat and Rural Development, Law and Order (Home), Narmada, Water Resources, Water Supply and Kalpsar, Revenue, Social Justice and Empowerment, Women and Child Development, Tribal Development, General Administration, Legal, Labour Welfare and Employment, Ports and Transports, Sports, Youth and Cultural Activities, Science and Technology, and Information and Broadcasting (Table 7.1). We further looked into the trends of Gujarat Government's Capital and Revenue spending for years 2017-18, 2018-19, 2019-20 and 2020-21. Further, the 12th Five year plan (2012-17) volume 1, paragraph 7.99 (pp. 260), suggests that adaptation costs may be in the range of "3-10 per cent" additional to the total costs (Planning Commission, 2013). We then project the budgets for each of the above listed departments based on this trend as well as, additional 3-10 per cent costs based on the criticality of the department and their mandates towards climate change action.

7.1.1 Climate Finance

The options for financing the actions for climate change at local, national and transnational levels from public, private and other alternative sources qualifies as climate finance. Thus, as described through various UNFCCC agreements, financial mechanisms have been put in place. The Global Environment Facility (GEF) has served as an operating entity of the financial mechanism since the inception of the Kyoto Protocol. Green Climate Fund (GCF) has been assigned as the operating entity since 2011. The Government of Gujarat is looking forward to set up an entity looking into Green/Climate Finance at the Gujarat International Finance Tec-City.

7.1.1.1 Climate Change Fund of Gujarat

The Climate Change Fund of Gujarat (CCFG) is aiming to channelize the investments from the developed countries and other donor agencies as well as national policies that promote low carbon development in the state of Gujarat. The fund will be utilized to implement Climate Change Mitigation and Adaptation projects in order to reduce the state's vulnerability to climate change. This would be a first-of-its-kind fund dedicated for effective implementation of the State Action Plan on Climate Change and other climate change initiatives at state level. The CCFG intends to promote clean technologies, research and development in the field of Climate Change and utilizing the fund for state's sustainable development across sectors. The CCFG is tasked to pool international donor resources and private resources and managing their use within the scope of the climate programmes and strategies so that local governments are able to access funding via CCFG in order to finance their mitigation and adaptation activities.

Table 7.1: Department-wise budget provision for 2018-19, 2019-20, 2020-21 and projections for 2021-22

	Budget Estimates						Projected Budget Estimates		Percentage increase/ Percentage Growth				Ratios Revenue: Capital		
Department	2018 -19	2018 -19	2019 -20	2019 -20	2020 -21	2020 -21	2021-22	2021-22	2018-19 to 2019-20	2018-19 to 2019-20	2019 -20 to 2020-21	2019-20 to 2020-21	2018 -19	2019 -20	2020 -21
	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue	Capital	Revenue	Capital	R:C	R:C	R:C
Agriculture & Co-operation	544544.86	54552.55	592643.01	51537.55	637309.03	34871.03	701039.93	37312.00	8.83	-5.53	7.54	-32.34	9.98	11.50	18.28
Climate Change	10210.70	0.00	104725.70	0.00	95307.87	0.00	106744.81	0.00	925.65		-8.99				
Education	2443066.08	83903.22	2716070.65	62597.81	2900352.03	59878.23	3248394.27	64069.71	11.17	-25.39	6.78	-4.34	29.12	43.39	48.44
Energy & Petro-Chemicals	552049.76	280582.04	906569.10	322904.21	919563.31	420551.09	1048302.17	471017.22	64.22	15.08	1.43	30.24	1.97	2.81	2.19
Finance	3938768.51	1543462.02	4148235.05	1659129.35	4473115.64	1788504.21	4920427.20	2021009.76	5.32	7.49	7.83	7.80	2.55	0.37	2.50
Food, Civil Supplies & Consumer Affairs	82874.04	10744.79	75026.17	8899.46	97172.98	7482.02	109805.47	8230.22	-9.47	-17.17	29.52	-15.93	7.71	8.43	12.99
Forest and Environment	49112.24	45773.22	64814.68	45235.44	86952.40	55526.03	99995.26	61633.86	31.97	-1.17	34.16	22.75	1.07	1.43	1.57
General Administration	38233.22	118801.60	71804.01	106480.01	45144.53	106936.01	49658.98	114421.53	87.81	-10.37	-37.13	0.43	0.32	0.67	0.42
Gujarat Legislature Secretariat	3636.52	29.00	4695.05	29.00	5137.56	29.00	5651.32	31.03	29.11	0.00	9.43	0.00	125.40	161.90	177.16
Health & Family Welfare	640789.32	176448.59	785563.73	115204.99	862843.01	86083.80	949127.31	92109.67	22.59	-34.71	9.84	-25.28	3.63	6.82	10.02
Home	472692.77	61111.23	569041.70	89937.30	654736.95	83208.99	733305.38	89033.62	20.38	47.17	15.06	-7.48	7.73	6.33	7.87
Industries and Mine	340844.29	73591.20	454456.66	142927.45	533518.01	138262.18	608210.53	147940.53	33.33	94.22	17.40	-3.26	4.63	3.18	3.86
Information & Broadcasting	14422.56	30.00	14375.75	15.00	14135.99	10.00	15549.59	10.70	-0.32	-50.00	-1.67	-33.33	480.75	958.38	1413.60
Labour and Employment	122960.91	3109.40	105170.78	2556.70	102181.57	7201.70	112399.73	8281.96	-14.47	-17.78	-2.84	181.68	39.54	41.14	14.19
Legal	125865.62	177.00	118323.02	52.00	126255.84	45.00	138881.42	48.15	-5.99	-70.62	6.70	-13.46	711.11	2275.44	2805.69
Legislative & Parliamentary Affairs	744.84	0.02	808.98	0.02	852.83	0.02	938.11	0.02	8.61	0.00	5.42	0.00	37242.00	40449.00	42641.50
Narmada, Water Resources, Water Supply & Kalpsar	146405.50	1083555.83	170284.24	1142519.08	177717.66	1220740.61	199043.78	1330607.26	16.31	5.44	4.37	6.85	0.14	0.15	0.15

Department	Budget Estimates						Projected Budget Estimates		Percentage increase/ Percentage Growth				Ratios Revenue: Capital		
	2018 -19	2018 -19	2019 -20	2019 -20	2020 -21	2020 -21	2021-22	2021-22	2018-19 to 2019-20	2018-19 to 2019-20	2019 -20 to 2020-21	2019-20 to 2020-21	2018 -19	2019 -20	2020 -21
	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue	Capital	Revenue	Capital	R:C	R:C	R:C
Panchayat, Rural Housing & Rural Development	538395.25	325.00	685345.54	463.72	737570.97	402.11	833455.20	442.32	27.29	42.68	7.62	-13.29	1656.60	1477.93	1834.25
Ports & Transport	56013.50	67945.02	58865.17	63181.22	70410.12	54426.52	80971.64	58236.38	5.09	-7.01	19.61	-13.86	0.82	0.93	1.29
Revenue	287747.82	8056.50	311462.26	7556.10	407984.39	16329.62	469182.05	17962.58	8.24	-6.21	30.99	116.11	35.72	41.22	24.98
Roads & Buildings - Part-I	425059.55	476183.61	437957.72	533964.22	459081.02	539393.98	504989.12	598727.32	3.03	12.13	4.82	1.02	0.89	0.82	0.85
Science & Technology	51984.97	115.03	50383.95	16.05	49707.93	26.04	54678.72	29.95	-3.08	-86.05	-1.34	62.24	451.93	3139.19	1908.91
Social Justice & Empowerment - Part-I	169594.83	62227.40	202844.12	62047.40	217737.56	60770.90	239511.32	65024.86	19.61	-0.29	7.34	-2.06	2.73	3.27	3.58
Social Justice & Empowerment-Part-II	389253.33	99351.38	440713.47	87051.50	451703.28	87609.06	496873.61	93741.69	13.22	-12.38	2.49	0.64	3.92	5.06	5.16
Sports, Youth & Cultural Activities	40980.30	7122.07	42782.54	4599.26	41835.81	4703.53	46019.39	5032.78	4.40	-35.42	-2.21	2.27	5.75	9.30	8.89
Tribal Development - (Part-1) Volume-III	46388.31	2342.29	54193.39	3897.68	55339.21	6181.61	61979.92	7108.85	16.83	66.40	2.11	58.60	19.80	13.90	8.95
Tribal Development - (Part-4) Volume-IV	829884.61	449171.38	868015.65	530629.70	911545.85	437575.49	1002700.44	481333.04	4.59	18.14	5.01	-17.54	1.85	1.64	2.08
Urban Dev & Urban Housing	1022671.88	62206.00	1071600.65	51502.00	1081601.36	60521.75	1189761.50	67179.14	4.78	-17.21	0.93	17.51	16.44	20.81	17.87
Women and Child	223607.03	11344.00	230879.15	4487.09	225332.13	9306.19	247865.34	10702.12	3.25	-60.45	-2.40	107.40	19.71	1.00	24.21

7.2 Measures for mainstreaming climate actions in the State budget

Government of Gujarat under the aegis of the climate change department have already undertaken special efforts to mainstreaming climate actions in the state budget as well as the budgets of various line departments. The Government of Gujarat has allotted a special budget for Climate Change Mitigation and Adaptation Schemes. The budget estimates for 2017-18 for the department of Climate Change was Rs. 97.96 crores, while the same for year 2018-19 was Rs. 102.1 crores. Gujarat has also undertaken initiative to compile schemes of various line-departments related to Climate Change adaptation and mitigation actions and published this as Climate Change Scheme as a part of climate change department's budget. The budget for 2020-21 is described in Table 3.2.

Table 7.2: **Government of Gujarat's department-wise budget provision for 2020-21 and projected for 2021-22**

Sr. No	Department	Budget provision for 2020-21 (INR Crore)	Budget Projection for 2021-22 (INR Crore)
1	Agriculture & Co-operation	6721.80	7383.52
2	Climate Change	953.08	1067.45
3	Education	29602.30	33124.64
4	Energy & Petro-Chemicals	13401.14	15193.19
5	Finance	62616.20	69414.37
6	Food, Civil Supplies & Consumer Affairs	1046.55	1180.36
7	Forest and Environment	1424.78	1616.29
8	General Administration	1520.81	1640.81
9	Gujarat Legislature Secretariat	51.67	56.82
10	Health & Family Welfare	9489.27	10412.37
11	Home	7379.46	8223.39
12	Industries and Mine	6717.80	7561.51
13	Information & Broadcasting	141.46	155.60
14	Labour and Employment	1093.83	1206.82
15	Legal	1263.01	1389.30
16	Legislative & Parliamentary Affairs	8.53	9.38
17	Narmada, Water Resources, Water Supply & Kalpsar	13984.58	15296.51
18	Panchayat, Rural Housing & Rural Development	7379.73	8338.98
19	Ports & Transport	1248.37	1392.08
20	Revenue	4243.14	4871.45
21	Roads & Buildings - Part-I	9984.75	11037.16
22	Science & Technology	497.34	547.09
23	Social Justice & Empowerment - Part-I	2785.08	3045.36
24	Social Justice & Empowerment-Part-II	5393.12	5906.15
25	Sports, Youth & Cultural Activities	465.39	510.52
26	Tribal Development - (Part-1) Volume-III	615.21	690.89
27	Tribal Development - (Part-4) Volume-IV	13491.21	14840.33
28	Urban Dev & Urban Housing	11421.23	12569.41
29	Women and Child	2346.38	2585.67

Source: Speech of Shree Nitinbhai Patel Deputy Chief Minister on Budget Estimates 2020-2021 (Part A) <https://financedepartment.gujarat.gov.in/Documents/Bud-Eng_1010_2020-2-26_475.pdf>

***The following programmes which are budgeted above INR 200 crores by Government of Gujarat in FY21, have* direct linkages to climate change mitigation and adaptation.**

- Avail crop-loan at zero percent interest
- Crop Insurance Scheme
- Rashtriya Krishi Vikas Yojana
- Mukhya Mantri Pak Sangrah Yojana
- Mukhya Mantri Pashudan Sahay Yojana
- Saurashtra Narmada Avtaran Irrigation (SAUNI) Yojana
- Water conservation works
- Bhadbhoot Bharrage under Kalpasar Yojana
- Micro irrigation scheme
- Pradhan Mantri Krushi Sinchai Yojana
- Mukhya Mantri Sadak Yojana
- Amrut Yojana for facilities like water supply, sewage, rain water disposal, transport etc.
- Har Ghar Jal under Jal Jivan Mission
- Construct over bridge and under bridge over railway crossings
- Commencement of metro rail project in Surat and for progress of the metro work of Ahmedabad-Gandhinagar
- Resurfacing of plan and non-plan rural roads of the length of 9500 kms
- Mukhya Mantri Gram Sadak Yojana
- Two-laning, four-laning, six-laning of roads
- Widening of roads
- Works of new bridges and new construction of over bridges
- World Bank aided project for widening, strengthening and renovating the roads are under progress
- 895 new BS-6 model based environment friendly buses to be inducted
- Dinkar Yojana to strengthen transmission network and install new sub-station in 3 years
- New agricultural power connections and various scheme
- Surya Gujarat Yojana for providing solar rooftop subsidy
- Establish 140 new sub-stations
- Solar PV project on the govt. land located near GETCO substation
- Various agriculture schemes for changing the old and dilapidated electricity wires, shifting the obstructive power structures, division of long agriculture feeders, implementation of Kisan Hit Urja Shakti Yojna and providing three phase power supply to Sim Shalas
- Green Budget schemes to various departments
- Compensatory Afforestation Fund Management and Planning Authority (CAMPA)
- Preservation and conservation of forests
- Social Forestation Scheme

The following programmes, budgeted above INR 200 crores by Government of Gujarat in FY21, have indirect linkages to climate change impacts.

- Atal Bhujal Yojana
- Pipeline to be laid from Tharad to Sipu Dam in Banaskantha district
- Songadh – Uchchhal - Nizar lift irrigation scheme based on Ukai reservoir in tribal area
- Completion of the remaining works of Kuchchh branch canal and undertaking the works of Dudhai sub-branch canal and its distributaries
- School of Excellence Scheme to ensure education of excellent quality
- Construction of 7000 class rooms of primary schools
- Mid-Day-Meal and Anna Sangam Yojana
- Subvention to approx. 4,22,000 students getting enrolled in private schools under Right to Education Act
- To distribute tablets under Tablet Scheme
- Construction of government universities and construction of buildings of government colleges
- Sarvagrahi Mukhyamantri Yuva Swavalamban Yojana
- Purak Poshan Yojana, Pradhan Mantri Matru Vandana Yojana, Bal Sakha Yojana, Kasturba Poshan Sahay Yojana, Poorna Yojana
- Mukhya Mantri Amrutam-MA and MA Vatsalya scheme
- Ayushman Bharat Pradhan Mantri Jan Arogya Yojana
- Ganga Swarupa Arthik Sahay Yojana
- To cater to the future requirement of water for Saurashtra and Kuchchh bulk pipeline works
- Water supply works under tribal area sub-plan
- Works to supply water for 24 hours in Gandhinagar
- Setting up desalination plants of 27 crore liter capacity in next 2 years
- Nal Se Jal Abhiyan
- Paying scholarship and uniform subsidy for students belonging to developing castes and scheduled castes and studying in primary school
- Rashtriya Vrudhdha Pension Yojana
- Gujarat Bin-Anamat Shaikshanik and Aarthik Vikas Nigam for education and employment oriented schemes
- Providing lodging, boarding and educational facilities to almost 1.35 lakh tribal students
- For providing post-metric scholarship to approx. 2 lakh tribal students
- Maintenance grant to grant-in-aid hostels and Ashrams shalas in tribal area
- Madre Vatan Yojana for developing various facilities in the village
- Mukhya Mantri Mahilla Utkarsh Yojana
- “Saune Awas” by 2022 to build 85,000 new houses
- Swachchh Bharat Mission Gramin
- Gandhi Rashtriya Gramin Rojgar Yojna
- Shyamaprasad Mukharjee Rurban Mission
- Swarnim Jayanti Mukhya Mantri Shaheri Vikas Yojana

- For creating facilities of underground drainage system and water supply in urban area
- To assist the municipalities to develop necessary facilities where there is adequate stock of water but the distribution system is inadequate
- To develop necessary infrastructural facilities in areas where the villages are in the close vicinity of the cities
- Smart City Mission
- Swachchh Bharat Mission in urban area
- Pradhan Mantri Awas Yojana
- Share capital subscription to Gift City
- Providing facillities such as ITI, new buildings, workshop, theory room, construction of staff quarter, etc. (for Youth Employment Department)
- Works for Seva Sadans, Rest houses or Guest houses
- Construction of quarters for government employees
- Modernization of Alang ship recycling yard
- Providing subsidy for supplying power at concessional rate to reduce the cost of farming
- Providing free electricity to water works at gram panchayats
- Share capital subscription to GSECL and GETCO
- Industrial Policy 2015
- Schemes for incentive to industries, plastic industries, mega innovative project and aerospace and defence sector
- Assistance to various infrastructural projects and deep-sea pipeline
- Vajpayee Bankable Yojana in three fields- Industry, Service and Trade
- To accelerate development of tourism & hospitality sector
- Integrated Kevadia Development Project at Statue of Unity
- Development of four lane Signature Bridge on Arabian sea at Krishna Nagari Bet Dwaraka
- Construction of total 13851 houses for accommodation of police personnel
- National Food Security Act and Public Distribution System
- Distribution of 12 kg. turdal at concessional rate to 66 lakh beneficiaries
- Decentralized District Planning Programme, ATVT and other schemes (General Administration department)

590141/2022/CC

Picture Courtesy: Commissionerate of Rural Development, Gujarat

CHAPTER 8

INSTITUTIONAL MECHANISM

Institutional Mechanism

On 17th September 2009, the then Chief Minister of Gujarat Shri Narendra Modi declared the formation of a new department in the state to address the concerns of Climate Change. This department was the first of its kind in Asia to hold charge of activities on mitigation and adaptation to climate change. With the creation of this department, Gujarat sowed the seeds of a new green revolution of sorts. The conceptualization included its role as a bridge department between various other line-departments and the Society at large in order to address the issues arising out of climate change. The core objectives of this department are related to creating core competencies in the Government and facilitates capacity building of various Government Departments to integrate Climate Change perspectives in their planning, generating strategic knowledge for informed decision making for sustainable and climate resilient future for the people of Gujarat, enabling a low carbon pathway for Gujarat's economic growth that would meet people's aspirations with equity and inclusiveness, mitigation of Green House Gases emissions, empowering communities for participatory and decentralized action on Climate Change, and creating public awareness, education and capacity building on Climate Change.

With these broad objectives, the department was specifically mandated to look into:

- To co-ordinate with various departments such as Energy and Petrochemicals Department, Forests and Environment Department, Industries and Mines Department, Narmada, Water Resources, Water Supply and Kalpasar Department, Urban Development and Urban Housing Department, Panchayat, Rural Housing and Rural Development Department, Ports and Transport Department, Education Department, Health and Family Welfare Department et al. and provide advice and guidance to them in the context of Climate Change and prepare a holistic Climate Change policy for the Government of Gujarat with the support of these departments.
- To co-ordinate with the Government of India, National Clean Development Mechanism (CDM) Authority, United Nations Framework Convention on Climate Change and other national and international agencies on the issues related to Climate Change.
- To work on issues related to promulgated policies for non-conventional alternative sources of energy like Solar energy and Wind energy along with necessary research and developmental work and publicity to encourage the use of such sources.
- To study the impacts of Climate Change in terms of the rising of the sea level, agricultural productivity, problems of coastal population and coastal infrastructural facilities and assets and to impart guidance on its mitigation.
- To act as nodal department for the purpose of maximum utilization of Green Technology and to create new employment opportunities so as to convert green technology into a new vehicle to boost economy.
- To promote dealing with policy issues related to Green technology and Clean technology to generate revolving fund for the purpose and to administer the same.

- To promote availing of benefits of CDM by earning CERs (Certified Emission Reduction/ carbon credit) through public and private sectors.
- To suggest measures to promote wide acceptance of CNG or other alternative fuel resources for transportation so as to control air pollution.
- To make suggestions and provide guidance on disposal of solid waste, sewage waste and medical waste in the context of Climate Change.
- To evolve new strategies for environmental conservation with regard to air, water and land.
- To suggest measures to ward off expansion of desert and to increase forest cover.
- To provide guidance on developing various courses and curricula for educational purpose in the context of Climate Change and encourage Research and Development on Climate Change in the universities, organize training for professors and planning thereof.
- To establish new "Gujarat Institute of Research and Climate Change (GIRCC)" affiliated with Pandit Deendayal Petroleum University and other ancillary work related thereto.
- To develop new technology and suggest measures for mitigation of Green House Gases (Carbon dioxide and Methane etc.) in the atmosphere.
- To keep the city and rural areas clean, to associate Sakhi-Mandal with activities such as awareness development among people, to remove filth and create hygienic environment.
- To produce biogas from cow dung, agriculture and biological waste as an alternative source of energy and adopt a new international technology for the purpose.

8.1 Institutional Structure for SAPCC Implementation

Over the past decade, the department has co-ordinated the efforts to take the state and the country forward on the subject of climate change mitigation and adaptation through action. has been it has been involved in various activities that confer to its objectives and mandates and beyond. Be it the solar parks or the canal rooftop solar power projects; be it the issue of enhancing water conservation efforts to mitigate drought or taking the lead with state drinking water grid; or be it even the bus corridors to augment public transportation in Ahmedabad and Rajkot – the state has shown how a path of sustainable development can be pursued that is in harmony with nature.

The Climate Change Department has also played a vital role in planning of the initial State Action Plan on Climate Change (SAPCC) around 2014 and its and implementation thereafter. For the current revision of the SAPCC as well, the Climate Change Department has played a vital role as a nodal agency representing Government of Gujarat. Thus, the Climate Change Department will continue to perform its nodal role as the coordination and implementation of this revision of the SAPCC.

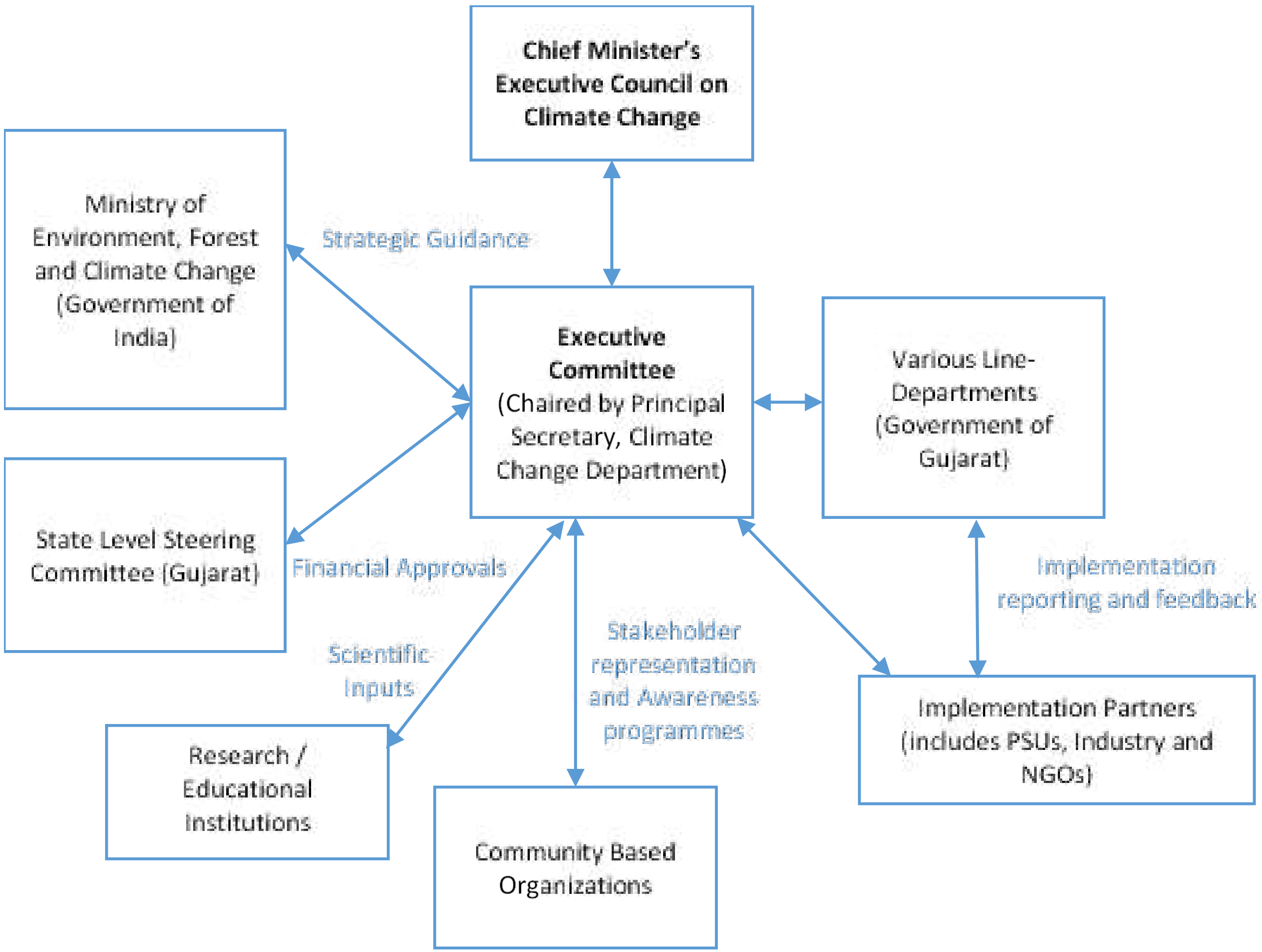
A State Level Steering Committee was constituted by the Government of Gujarat to oversee and approve the planning and implementation of the 1st State Action Plan. The committee is composed of the following representatives across various line departments of the state:

1. Chief Secretary of Gujarat (Chairman)
2. Additional Chief Secretary (planning) GAD (Member)
3. Additional Chief Secretary/Port & Transport (Member)
4. Additional Chief Secretary/Urban development & Urban Housing – Additional Charge (Member)

5. Principal Secretary/Agriculture & Co-operation (Member)
6. Principal Secretary/Forest & Environment (Member)
7. Principal Secretary/Health & Family Welfare (Member)
8. Principal Secretary/Industries & Mines (Member)
9. Principal Secretary (Water Supply) N.W.R. & Kalpsar Department (Member)
10. Principal Secretary Narmada, Water Resources/Water Supply & Kalpsar Department (Member)
11. Commissioner Rural Development & Principal Secretary/Rural Development & Housing (Member)
12. Principal Secretary/Energy & Petro-Chemicals (Member)
13. Principal Secretary/Tribal Development (Member)
14. Secretary/Department of Climate Change (Member Secretary)
15. Secretary (Narmada) N.W.R. & Kalpsar Department (Member)
16. Secretary/(Kalpsar) N.W.R. & Kalpsar Department (Member)
17. Secretary/Women & Child Development (Member)
18. Chief Executive Officer/GSDMA (Member)

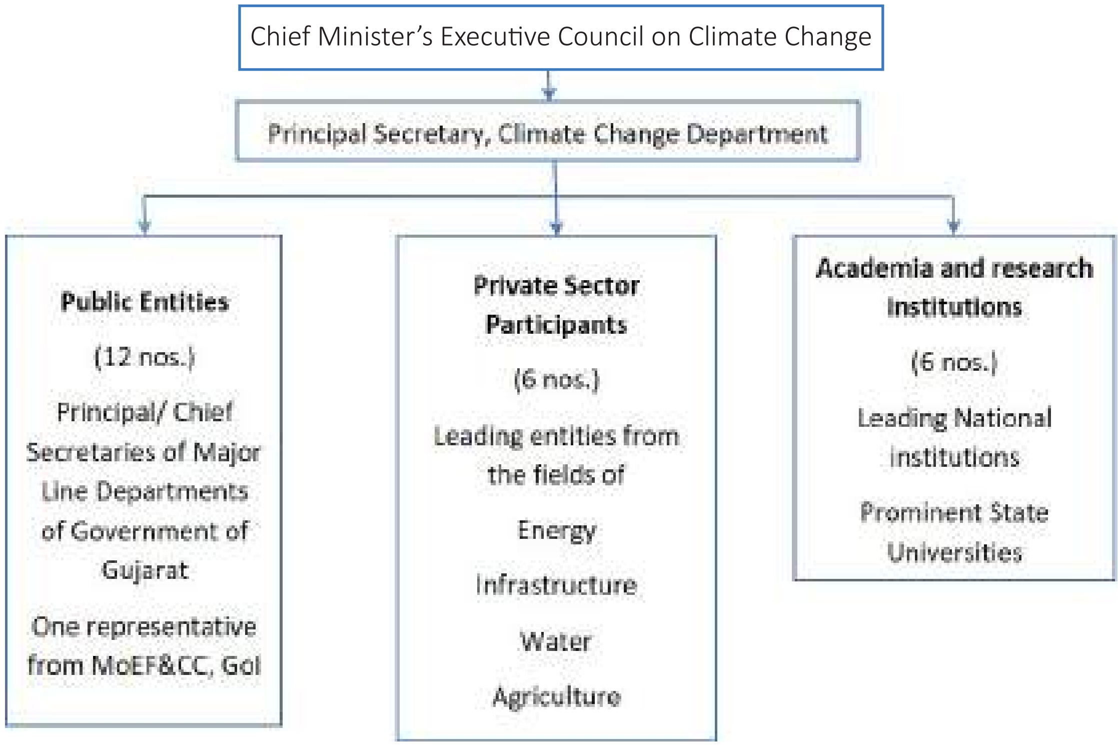
The committee will continue to play its guiding role in the formulation/approval and implementation of this revision of the State Action Plan as well that would be accordance to the state's vision, priorities and the expectations put forth through the NAPCC guidelines and Ministry of Environment, Forest and Climate Change, Government of India. This document in Section 7 has outlined the financial needs and its roadmap for implementation of this action plan. The recommendations on the budgetary provisions and allocations to various departments and implementation agencies for mitigation as well as adaptation actions will come from the State Level Steering Committee. Figure 8.1 describes the institutional mechanism for the SAPCC.

Figure 8.1: **Institutional Co-ordination Mechanism for State Action Plan on Climate Change**



Gujarat proposes to establish Chief Minister's Council on Climate Change (CMCCC) in alignment with the Prime Minister's Council on Climate Change. CCD will be nodal department for coordinating the activities of CMCCC as described in Figure 8.2

Figure 8.2: Structure of the CM's Executive Council on Climate Change



8.2 Role of various State Government Departments

8.2.1 Agriculture and Co-operation

- Assist in rolling out mitigation policies related to solar pumps, farm waste management, livestock and manure management, organic fertilizer applications, livestock feed and fodder management practices
- Adaptation and resilience building by identifying hazard prone areas, crop vulnerability, altering planting and harvesting time, resilient crops and seed research, modern irrigation techniques, farmer support during disasters and crop insurance schemes, and similar initiatives
- Awareness creation and capacity building among farmers regarding disaster risk reduction, crop disease management, water conservation and management, pesticide and fertilizer applications, and sustainable land management practices.
- Emergency preparedness and early warning system for disaster preparedness
- Inclusive and equity-based actions towards developing long term resilience to climate change in agriculture sector through gender prioritization.

8.2.2 Climate Change

- Nodal agency for implementation of the State Action Plan on Climate Change

8.2.3 Education

- Awareness/Education and Communication regarding climate change mitigation and adaptation at primary, secondary and higher levels of education by roping into the curriculum.

- Inclusion of vulnerability, disaster preparation, capacity assessment on disaster risk reduction at school level.
- School level energy efficiency and renewable energy efforts e.g. use of LEDs and efficient equipments'.
- Encourage water and energy saving behaviors at schools through inters school competitions
- Solar-roof top options for school and office buildings under the department of education

8.2.4 Energy & Petrochemicals

- Assist in rolling out mitigation policies related to renewable energy and energy efficiency
- Assist in Grid updating, smart grid creation, and reduced T&D losses during power supply across Gujarat
- Support towards efficient phaseout of coal based thermal power plants in Gujarat
- Actions towards resilient grid infrastructure in the wake of climate related disaster occurrence

8.2.5 Finance

- Main streaming climate finance and related green budget initiatives through promoting climate impact investing by the state government

8.2.6 Food, Civil Supplies & Consumer Affairs

- Promotion of modern warehousing and food supply systems including solar cold storages
- Promotion of modern cooking fuel to ensure indoor air quality and social co-benefits of climate actions
- Actions towards achieving the 'nutrition for all' vision to ensure reduced malnutrition for increased healthy and resilient society.
- Promotion of consumption of local and indigenous crops especially cereals to ensure balanced diets and reduced rice cultivation related emissions
- Actions towards resilient food supply infrastructure in the wake of climate related disaster occurrence
- Support in availability and resilient supply of food and other essentials towards climate related disaster relief

8.2.7 Forests & Environment

- Assist in rolling out sink related policies on afforestation and trees outside forest
- Biodiversity conservation
- Promotion of mangrove conservation
- GPCB to ensure safe water and air quality

8.2.8 General Administration

- The Administrative Reforms and Training Division of the General Administrative department may play a major role in upgrading knowledge and skill of the officers/ employees towards climate change related sensitization for individual actions
- Support implementation of climate actions undertaken by Climate Change Department through training to officers/employees regarding the role each government department can play in achieving the policy objectives

8.2.9 Home

- The Home department to ensure communication protocols during disaster situations
- Inclusion of Green Building and renewable energy norms for the police and civil defense infrastructure, office buildings and housing.

8.2.10 Health & Family Welfare

- Emergency medical care during climate changed induced disasters
- Create low-carbon Infrastructure for medical and paramedical education through green buildings and use of solar energy across education facilities
- Inclusion of climate change related health impacts in public health education curriculum
- Use of solar roof top across PHCs and public healthcare facilities
- Research related to health impacts of climate change in Gujarat

8.2.11 Industries & Mines

- Encourage low carbon industrial development and mitigation technology products e.g. solar panels
- Encourage environment friendly practices for industrial development and mining
- Promotion of rural and cottage industries to develop rural climate resilient economy
- Promote green and eco-friendly tourism as a means to educate and encourage climate friendly behavior among the tourists
- Ensure availability civil aviation infrastructure and other essential industrial goods in the wake of climate change induced disasters

8.2.12 Information

- To support in creating public awareness related to the climate actions undertaken by the state government through various media
- To create public awareness towards encouraging individual actions for reducing the impacts of and enhancement of mitigation, resilience and adaptation measures through various media

8.2.13 Labour & Employment

- The employment wing responsible for the vocational training and guidance of labour resources to ensure availability of new “green” job training opportunities e.g. – training in repair and maintenance of solar panel, training in building construction using energy efficient materials, EV repairs, etc
- The sub department on Rural Labour may encourage skills on sustainable farming practices
- Labour Policies in accordance with the needs of Environment, Health and Safety requirements due to impacts of climate change

8.2.14 Legal

- Provision of legal services towards achieving environmental and climate justice in the state
- Examination of clauses of all bills relating to imposition of legislation of punishments by the fine, penalty or imprisonment, for enforcing any environmental law in Gujarat
- Ensure the buildings and premises under the department including regular courts to be “green” and climate friendly.

8.2.15 Legislative & Parliamentary Affairs

- Support in designing climate change related legislature in Gujarat
- Support in dissemination of information on climate change related legislature
- Ensure appropriate inclusion of climate change related affairs in the tentative business of the Assembly session as and when required

8.2.16 Narmada and Water Resources, Water Supply and Kalpsar

- Early warning mechanisms and flood monitoring for surface water bodies
- Water resources augmentation to ensure availability of drinking water
- Inclusion of actions towards water harvesting and groundwater recharge structures, improvement of soil moisture retention capacity, wetland restoration, dam construction and improved reservoir capacity, integrated water resources management, irrigation system, and water supply to agricultural lands, adequate planning of drainage systems, water transfer and protection against soil erosion and loss of soil fertility

8.2.17 Panchayats, Rural Housing and Rural Development

- Including climate change resilience and adaptation measures in the village development plans through the district development boards
- Village housing schemes through rural housing board for ensuring resilience of the poorest to the vagaries of climate change
- Watershed development and water conservation programmes across villages
- Ensure implementation of "Green and Smart" village program
- Village development training to include climate action at local and Panchayat levels
- "green' jobs through rural livelihood promotion to ensure financial resilience of villagers to climate change

8.2.18 Ports and Transport

- Designing and development of climate-resilient buildings and infrastructure at ports towards damage accruing from the cyclonic and sea-level rise based impacts of climate change
- Designing and development of climate-resilient buildings and infrastructure at transport hubs
- Clean-fuel based transportation modes and vehicles to be encouraged
- Use more resilient materials, construction methods, or design standards for new and renovated transport infrastructure

8.2.19 Revenue

- Disaster Preparedness and Management related to climate change impacts
- Administer disaster relief related to climate change induced disaster events

8.2.20 Roads and Buildings

- Ensure development of "green" roads through research and demonstration of "green" materials and technology for road construction
- Ensure "green" building construction for all the public buildings owned by the state governments through use of renewable energy, efficient cooling techniques and sustainable construction materials

8.2.21 Science and Technology

- Research and Development of "clean' and "green" technologies for mitigation and adaptation of climate change in Gujarat

8.2.22 Social Justice and Empowerment

- Welfare schemes with a focus on empowerment and economic welfare of the backward sections of the society to enhance the resilience towards impacts of climate change in order to establish climate justice

8.2.23 Sports, Youth and Cultural Activities

- Organize training and awareness camps for youth for sensitize towards climate change mitigation needs, impacts and adaptation options
- Using the medium of cultural activities – literature, music, drama etc to spread awareness on climate change related issues

8.2.24 Tribal Development

- Support in development of a compendium of rational indigenous and traditional practices on adaptation in selected sectors like agriculture, forestry, water resources (floods and droughts) in various agro-ecological regions of Gujarat
- Support in providing solar pump set to tribal farmers in the state
- "green" campus for sports university

8.2.25 Urban and Urban Housing Development

- Promote sustainable urban development through various schemes on municipal energy efficiency, waste to energy, clean public transport etc for climate change mitigation
- Promotion of plantation activities and urban green and blue space conservation through master and town planning tools to enhance resilience of urban areas
- Promote green building through urban housing schemes
- Green municipal budgeting and ease of access of climate finance for municipalities

8.2.26 Women and Child Development

- Preparation of welfare schemes for women in the wake to disaster rehabilitation
- Child nutrition schemes to enhance physical resilience of children towards impacts of climate change
- Awareness of climate change and its impacts on women and child development through Anganwadis

CHAPTER 9

Monitoring and Evaluation

Picture Courtesy: shutterstock.com

Monitoring and Evaluation

An assessment of GHG mitigation will begin by estimating the baseline emissions for the state. A key component here has to be to institutionalize rigorous monitoring of progress. Appropriate indicators and an online platform need to be used to assess progress for different initiatives and to indicate improvements in climate resilience and GHG mitigation. Monitoring should also be done in the field and also by using remote sensing technology (SAC, ISRO) to reduce costs and provide accurate information. Reputed research institutions will take the lead in the monitoring process.

Multiple steps need to be taken to build long-term capacity. Stakeholder workshops need to be conducted to disseminate learnings from various projects and programmes and share information about scalable initiatives with relevant government officials and stakeholders. SAC, ISRO will also be brought in to provide support through training of officials in satellite data usage. Information about the programmes and policies need to be disseminated through SAC web portals like VEDAS and MOSDAC (see Appendix 8 for an example of a SAC portal).

There are many components built into the programme that will ensure long run sustainability of this plan.

1. Partnership between stakeholders

The plan envisages partnerships between the government, research institutions, financial institutions, private players, civil society and citizens to select and implement different initiatives in selected regions. As a starting point, the Climate Change Department is already partnering with different research institutions to get their inputs through the CMCCC. The plan will need to involve coordination among different stakeholders. E.g., for initiatives in urban areas, the programme will involve interaction between urban local governments, the Government of Gujarat, the Climate Change Department, research institutions and implementation organizations in the public and private sectors. These interactions will enable stakeholders to network and build relationships that can be leveraged for future work.

2. Capacity building for government

Implementing different initiatives will require significant investment in time and effort from governments at different levels – local, state and national. The programme will involve regular interaction with research institutions and with sectoral and domain experts who will be integral to the Technical Advisory Committee and Project Steering Committee. These interactions, and the experience of being involved in climate action through the initiatives being implemented will build capacity in the state to implement similar initiatives in the future. Apart from this, capacity building workshops will be conducted to disseminate information and build capacity among relevant stakeholders.

3. Creation of a database

The plan will lead to the creation of a database at two separate levels. Firstly, significant research base that may require the creation of a database for different regions and a separate database cataloguing potential initiatives. Secondly, a database will need to be created during the implementation of different initiatives in rural and urban areas. This database may be designed to track progress for different types of initiatives and will help future decision makers evaluate and select appropriate initiatives for their region. SAC, ISRO has agreed to the creation of a web portal to actively track and disseminate information.

9.1.1 Knowledge, Awareness, Training & Capacity Building

Raising public awareness about the impacts of climate change is an extremely important part of the strategies towards climate action plan of Gujarat. Awareness campaigns and programs inform people about the impacts of their actions and behaviour on the global climatic systems and brings in climate literacy especially among youth and students- the leaders of tomorrow. Such programs support decision-making, capacity building at community levels towards resilience, mitigation and adaptation of sustainable lifestyles

9.1.1.1 Bal Urja Rakshak Dal

This program aims to mobilise school children as guardians of energy. It is designed to provide the teachers and students with the life skills on energy to encourage energy efficiency and low emission behaviour. Each of the 15,0000 schools has a team of students that form the school's Bal Urja Rakshak Dal (BURD). Since its inception in 2003-04, almost 7,50,000 students and 30,000 teachers have been a part of this program.

9.1.1.2 Setting up Centre of Excellence

Gujarat has envisioned to set-up a Centre of Excellence on Climate Change for synthesis of knowledge which will facilitate quantification of the impacts of climate change and natural resource management. This will include developing deeper understanding of the inter-linkages between climate change economics, mitigation and adaptation needs while advocating for better policy and financial instruments to be developed to address the challenges of climate change.

9.1.1.3 Vision 2030

The Vision 2030 is a holistic development and growth roadmap curated for the state based on the vision to have a climate-resilient Gujarat. The state has formulated a Vision for Sustainable Development and Growth 2030 illustrating the targets and strategies for different sectors. These strategies aim to mainstream climate change while enabling a sustainable low carbon development across all the key sectors. The vision incorporates the underlying objective of the sustainable development goals which aims at encouraging social development that contributes to a low carbon economic development while ensuring inclusive growth for all communities. The Vision 2030 ca n be considered as a guidebook for developing cross sectoral approach for the state while setting an example at the sub-national level for climate action to be adopted by other states.

9.1.1.4 Climate change subject in school curriculum

It is important to create awareness for climate change to the young generation. Climate Change is a multi-disciplinary subject. Therefore, it is important to introduce this subject from primary and secondary school level. Comprehensive content for school curriculum is being developed to incorporate this subject without increasing additional burden to young students.

9.2.2 Research and Demonstration Projects

There are several opportunities across sectors to further enhance research and demonstration of climate change mitigation, vulnerability and impact reduction, resilience building and adaptation actions. Table 9.1 describes some of these research and demonstration projects to may be taken up in Gujarat for enhanced climate action.

Table 9.1: Possible research and demonstration projects for adaptation, vulnerability assessment inventorizaiton and mitigation

S. No	Type/ Sector	Title	Description
A	**Capacity building-enhancement/ Mitigation**		
1	All Sectors	Formation of CMCCC	Formation of Chief Minister's Council on Climate Change as an advisory council to the state for facilitation of guidance on climate action
2	All Sectors	Climate Financing through Green Climate Fund	This project will create a proposal for mitigation and adaption climate actions for Gujarat that could be funded through Green Climate Fund
3	All Sectors	Organizational and Institutional Issues for Climate Change	Creating awareness at all levels (grassroot to policy) on climate change, vulnerability and adaptation issues for industry and infrastructure, energy, agriculture, LULUCF sectors, through sectoral workshops in various (vulnerable) regions of the country; dissemination; publication etc.
4	All Sectors	Educating and informing the corporate sector about the emission abatement technologies and projects.	Create awareness about Climate Change in business sector, especially on impacts on industry, cleaner production, CDM etc.
			Role of insurance as a tool of adaptation for long life assets.
5	All Sectors	Knowledge creation and dissemination on Climate Change	Creating awareness at all of governance on climate change, vulnerability and adaptation issues across sectors - industry and infrastructure, energy, agriculture, and LULUCF.
6	Inventory Estimation	To establish a GHG reference laboratory for generating and disseminating certified reference materials	(a) This will involve preparation and dissemination of gas-CRMs of CO_2, CH_4, and N_2O. Calibration of Gas Chromatographs (GCs) used for baseline monitoring for above gases.
			(b) Preparation of uncertainty budget for baseline monitoring for above gases for homogenization of uncertainty of measurements. Validation of test methods and Organization of proficiency tests for measurement of above gases.

S. No	Type/ Sector	Title	Description
7	Inventory Estimation	Nodal center for synthesis and coordination of uncertainty reduction in GHG emissions	This center will essentially validate, synthesize and ensure application of Good practices for uncertainty management and Quality assurance and Quality control. Periodic training will be conducted to update researchers on the latest good practice guidance for undertaking measurements and also train personnel for undertaking measurements in various sectors. Following the guidance specified by the IPCC good practices report, this agency will act as a third party for implementing the QA/QC measures.
8	Gujarat's Emission Scenarios	Generation of future GHG emission scenarios for Gujarat	Articulation of alternate development pathways for and quantification of key driving forces. These alternate scenarios will be congruent to IPCC scenarios and Indian climate change scenarios.
9	Vulnerability Assessment and Adaptation	Integrated Impact Assessment for Gujarat including long-term emission scenarios, GHG abatement policies and adaptation measures.	Develop an integral impact assessment modeling framework using sectoral models, consistent scenarios and databases. It is proposed to deploy modular integration that is integrating modules consisting of individual sectoral models, run using similar climate, emission and socio-economic scenarios. The basic thrust will be on generating common and finely gridded databases for use in models.
10	Energy	Setting up of Energy systems model for medium and long term energy and environmental policy for Gujarat	Economy-energy-environment modeling using Indian emission scenarios and shared databases developed under other projects. Major outputs will include projection of alternate GHG emission pathways, energy intensities, technology and fuel mix, and energy sector investment requirements for Gujarat in medium to long-term.
11	Energy	Impact of Climate Change on energy demand and resultant change in emission pattern	Increase in temperature and changing climate is likely to affect the energy demand. Almost all the sectors will experience change in the demand based on the location. The increased demand for energy will also affect the resultant emissions, as most of the increased demand will be fulfilled by the power sector, which depends primarily on coal
12	Energy	Utilization of Greenhouse Gases (Carbon dioxide and Methane) for production of fuels and chemicals.	This will involve conversion of CH_4 and CO_2, producing syngas with low H2 / CO ratio, (nearer to one) which is highly desirable in gas to liquid fuels conversion technology using iron based catalysts. Conversion of methane gas by development of solid acid catalysts based on heteropoly acids and other catalysts to value added chemicals like methanol, formaldehyde and ethylene.

S. No	Type/ Sector	Title	Description
13	Energy	Minimization of CO_2 and other polluting gaseous levels by suitably developing soft coke technology as the source of rural/semi urban domestic energy	This will involve development of more energy efficient soft coke technology utilizing inferior coal. Development of suitable provisions for less emitting/arresting the GHG. Improvement of the present technology for making it more suitable for rural use. Generation of data /techno-economic as well as socio-economic evaluation. Improvement in design/ Development of the fixed/movable domestic soft coke cook-stove in view of energy efficiency as well as emission of GHG
14	Energy	Cleaner electricity production through hydrogen technology	This project will be expected to develop a demonstration of use of hydrogen fuel for electricity production.
15	Energy	Carbon Dioxide Sequestration in Geologic formations with enhanced oil recovery and use of bio-energy with carbon capture and storage.	This will involve examination of the potential for CO_2 sequestration in geologic formations/ difficult to pump/depleted oil well. Identification of depleted oil well/geologic formations in Gujarat suitable for CO_2 sequestration. Develop mathematical models for reservoir simulation of CO_2-EOR and a mathematical model for oil-water flow in oil beds.
16	Energy	Promotion of biomass pellets for energy uses	This project will be expected scale up and commercialization of use of biomass-based pellets as biofuel for energy uses.
17	Energy	Promotion of bioethanol and biodiesel blending for transportation purposes	This project will be expected scale up and commercialization of use of biofuel production systems transportation energy uses.
18	Energy	Blockchain based Peer-to-peer energy sharing and trading platform	This project will be developing a peer to peer sharing and trading platform for energy using block-chain technology due to penetration of rooftop solar system, electric vehicles and energy storage, and decentralized energy generation.
19	Energy	Role of Technology in Abatement and Adaptation of Climate Change Impacts on Energy Sector	Conduct intensive studies for abatement and adaptation of energy efficient technology and methods and identify points of leverage in market chains and institutional regimes for demand side management measures for abatement
20	Energy	Fuel Switching	Research and demonstration projects for penetration of low and no carbon fuels in transport sector
21	Energy	CO2 capture and storage	Demonstration project for CO2 capture and storage at one high concentration CO2 stream plant in Gujarat

S. No	Type/ Sector	Title	Description
22	Energy & Industry	Solarization of power production	This project would promote use of solar energy across the state especially for power supply to large point sources of emission and the MSMEs
23	Energy & Industry	Carbon Trading Scheme	Developing plan and strategy for implementation of a carbon trading scheme. The project will also include pilot phase implementation
24	Energy/petroleum	Geological storage of CO2 in exploration/ recovery of petroleum gas etc.	This will involve injection of CO2 in the petroleum wells for recovery of petroleum gas and other products
25	Energy	Penetration of energy efficient technologies, e.g. Energy efficient road bitumen laying machine	Demonstration projects for increased penetration of efficient technologies (supply and demand management based) such as heat rate reduction, electric arc furnaces, energy efficient processes, efficient lighting, agriculture pump-sets etc, in order to enhance scale and acceptance of efficiency interventions for GHG emission abatement.
26	Energy	Cleaner gas through use of Bio-CNG	This project will be expected to develop a demonstration of commercial use of bio-CNG for transport and industrial applications
27	Energy	Penetration of Electric Vehicle and efficient battery technology	This project will look into demonstration projects for EV use and charging infrastructure
28	Energy and Agriculture	Recovery of Methane from Landfills and Paddy Fields	The study will involve Study of methane efflux in different seasons at various sites. The components of the measurements will include investigation on CH_4 production potential of different methanogenic bacteria under different conditions, the process of augmentation of CH_4 formation through biological and non-biological means, suppression of CH_4 oxidation through manipulation of edaphic factors and use of inhibitors.
			The study will also investigate and demonstrate the options for maximum recovery of CH_4 gas from landfills and paddy fields for heat and electricity production.

S. No	Type/ Sector	Title	Description
29	Industrial Processes	Ecologically-friendly and value added steel making process based on VRDR-SAF-ESR route	The proposed process attempts use hot charging of DRI into submerged arc furnace (SAF)/ Electro-slag Crucible Melting Furnace (ESCF) from which the hot liquid steel enters the electro-slag casting equipment to produce high quality alloyed steel product of near-net shapes. The process is expected to be environment friendly and techno-economically attractive even on a medium scale of operation. The process has the flexibility to treat various feed materials and produce a range of different steel products based on the local demand. Since the DRI based route by-passes the conventional components such as coke and sinter making, the process would require much less energy and would lead to substantial reduction in emission of CO_2 to the atmosphere.
30	Industrial Processes	Non-CO2 GHG emission abatement from process industries.	Abatement demonstration projects in industries such as nitric acid, paper, adipic acid
31	Energy, Industry and Infrastructure, and waste	Issues in technology Transfer for Abatement of GHG emissions in Gujarat	Facilitating transfer of technology from developed to developing countries through joint research and development, and adoption
32	Industry	Fiscal instruments for emission abatement from industries in Gujarat	Research and pilot projects
33	Industry	Energy efficiency improvement in MSME/SMEs	Research and demonstration of energy efficient technologies in energy intensive small scale industries in Gujarat
34	Agriculture	Cost effective abatement strategies for the agriculture sector	Developing abatement strategies for GHG reduction; Socio-economic evaluation of the abatement strategies; Possible consequences of the suggested abatement options on agro-ecological system (short- and long-term consequences)
35	Agriculture	Carbon sequestration in agriculture soils	Research and demonstration projects to sequester carbon in agricultural soils by adopting appropriate land use options
36	Agriculture	Enteric Fermentation	Research, development and demonstration of low-methane emitting feeds

S. No	Type/ Sector	Title	Description
37	LULUCF	Modeling efforts	Develop technical and institutional capacity for modeling, monitoring and verification of C-stock changes in LULUCF projects involving: developing models for predicting changes in stocks of different pools in different types of forestry projects; build capacities of institutions to undertake these activities; assisting project developers and project promoters; and, developing information packages.
38	LULUCF	Enhancing agroforestry in Gujarat	Implementing agroforestry in dry land farms to increase the tree resources on farms, increase the economic returns and to increase C-stocks.
39	LULUCF	Energy plantation in Gujarat for GHG emission abatement	Provide biomass sustainably for generation of biomass power, substituting fossil fuel energy. The activities will involve raising mixed species energy plantations in a phased manner, using high yielding package utilities; developing and implementing sustainable biomass harvesting practices to supply feedstock to biomass power utilities; and, installing biomass power plant, CCUS systems and supplying electricity to meet the decentralized power needs
40	LULUCF	Carbon sink enhancement and sustainable development in villages	Developing, implementing and disseminating an integrated and participatory approach to revegetation of village ecosystems for enhancing carbon sinks, conserving biodiversity and enhancing sustained flow of benefits to the local communities.
41	LULUCF	Degraded forest regeneration	To sequester carbon by regenerating degraded forests of involving: regenerating degraded forests for timber and non-timber forest products; involving local communities in protection and management of regenerating forests; and, promoting biodiversity.
42	LULUCF	Mangrove ecosystem rehabilitation	Rehabilitating degraded mangrove ecosystem in Gujarat to protect the coastal lands and sequester carbon involving identifying degraded mangrove; protecting and regenerating mangroves; monitoring the biodiversity, growth rate and C-stock changes
B	**Inventory estimation**		
43	Energy	Strengthen the activity data for GHG emission estimates from Gujarat’s transport sector	Analysis of the current vehicle types and their distribution in various cities across Gujarat and the fuel use. The railways, aviation and the waterways sectors will also be covered.

S. No	Type/ Sector	Title	Description
44	Energy	GHG emission measurements and activity data assessment for biomass used for energy purpose	GHG emission measurements and activity data assessment for biomass used for energy purpose
45	Energy and Industrial processes	GHG inventory estimation	Data collection and GHG Inventory estimation for the various energy and industrial process sub-sectors
46	Energy	GHG emission measurement from large point sources – Steel Plants	Due to high requirement of coking coal for steel production, steel sector has a very high emissions per unit of production and contributes substantially to Indian CO_2 emissions. This project envisages GHG emission measurements from steel plants in Gujarat. The process based emissions will be distinguished and will be measured separately.
47	Energy	GHG emission measurement from large point sources – Petroleum Refineries	GHG emission measurements from petroleum refineries in Gujarat.
48	Energy	Methane emission measurement from oil and natural gas venting, flaring and transport	Cover all the major oil exploration sites in Gujarat
49	Energy	GHG emission measurement from Informal / Partially Informal Energy Intensive Sectors	GHG emission measurements from fully/ partially informal energy intensive sectors like brick manufacturing, sugar, ceramics, soda ash, textile, and chemical and dyes units.
50	Industrial Process	GHG measurement from in Lime and Cement sectors in Gujarat	GHG emission measurements from Lime and Cement plants in Gujarat.
51	Industrial Processes	GHG measurements from industrial processes	GHG measurements from industrial processes like nitric acid production, aluminium production, soda ash use, pulp and paper production in Gujarat
52	Agriculture	Inventory Estimation	Evaluation of sources and sinks of greenhouse gases related to agricultural activities including data collection and validation of age wise livestock, water regime wise rice paddy cultivation, sub-regional crop production, sub-regional synthetic fertiliser use.

S. No	Type/ Sector	Title	Description
53	Agriculture	Nitrous oxide emission from selected agricultural fields of rice and paddy	Irrigated rice and dry land farming are major sources of CH_4 and N_2O in selected agroecological zones consisting of irrigated as well as dry land farming. The project will measure CH_4 and N_2O emission coefficients from these.
54	Agriculture	Measurement of CH_4 and N_2O emission coefficient from enteric fermentation in animals and manure management.	This will involve establishment of CH_4 emission coefficients from different types of animal categories in India, with focus on the major emitters and N_2O emission coefficients measured from different types of manure management.
55	Agriculture	Measurement of N_2O emission coefficients from major soil types in Gujarat	This will involve establishment of network of stations for taking yearlong measurements of N_2O for representative soil types in Gujarat.
56	Agriculture	Soil carbon content assessment	To assess the organic carbon contents of Agricultural Soils in Gujarat at $1/2^0$ x $1/2^0$ grid
57	LULUCF	Land use pattern assessment for Gujarat's for GHG inventory estimation	Periodically monitoring and estimating the area under different forest types as well as to prepare a land use change matrix, describing the extent of land use change from one category to another.
58	LULUCF	Assessment of wood consumption in Gujarat for GHG inventory estimation	Estimating the fuelwood and commercial roundwood consumption, dung cake production and consumption, and agriculture crop residue consumption in Gujarat
59	LULUCF	Assessment of carbon pools in Gujarat for GHG inventory estimation	Estimating different terrestrial carbon pools namely vegetation biomass, soil and litter carbon stocks under various land use categories and assess changes in C-pools
60	Waste	Activity data improvement for the waste sector	Data collection and GHG Inventory estimation for various sub-sectors and Sub-regions
61	Waste	Measurement of emission from domestic and commercial waste water	(a) Measurement of CH_4 emission coefficient from domestic waste water with distinctive composition
			(b) Measurement of CH_4 emission coefficients from representative major affluent producing industries

S. No	Type/ Sector	Title	Description
62	Waste	Methane Emission from Selected Landfill sites	Methane measurements will be carried out in identified major landfill sites in cities of Gujarat – Ahmedabad, Surat, Rajkot, and Vadodara in India where systematic collection and dumping of solid waste takes place
C	**Vulnerability Assessment and Adaptation**		
63	Climate Change Modeling	Generation of high resolution regional climate change scenarios and investigating its impact on the Indian monsoon and on extreme climate events	This will involve detailed diagnostic analysis of climate model control runs to assess the skill in simulation of present day climate and its variability over Gujarat;
			Currently, assessments are available for CMIP5 with reasonable high resolution during the 21st century; However, there is need for improved assessment under CMIP6 scenarios. Moreover, application of regionalization techniques to improve the assessment of climate change on regional scale is required;
			Study of the sensitivity of monsoon climate to natural/anthropogenic perturbations by model output diagnostics and numerical experiments;
			Examination of the nature of possible changes in the frequency and intensity of severe weather and climate events (e.g., droughts/ floods, cyclonic storms, etc.)
			Interaction with various impact assessment groups and design specific climate change data products for use in their models through workshops and meetings;
			Warehouse for storage of all validated and downscaled data products for Gujarat, designed for regional climate change impact assessment, high-resolution scenario data for different administrative units of Gujarat (e.g., districts) and provide regular up gradation to keep pace with developments in the area.
64	Various relevant sectors	Development of vulnerability and adaptation scenarios for Gujarat	Develop sub-regional vulnerability and adaptation scenarios for Gujarat which integrate the cross linkages between different sectors of the economy. These scenarios will be congruent to the Indian climate change and emission scenarios.
65	Agriculture	Assessment of Vulnerability of Agriculture sector due to impacts of climate change and formulation of Adaptation Strategies.	(a) Studying the impacts of enhanced level of CO_2 on grain yield of cereals important to the economy (rice and wheat). The cereals under each category should be of different types of cultivars. Incorporating these results into modelling. Case study to understand the impacts of climate change on important crops in the Gujarat using modeling approach and formulating a matrix of alternate cultivar/ cropping pattern/farming practices etc. to adapt to climate change.

S. No	Type/ Sector	Title	Description
66	Agriculture	Crop insurance and climate change	Research to understand performance of various insurance models to develop comprehensive crop insurance packages for Gujarat's farmers.
67	Agriculture	Small and marginal farmers	Develop suitable adaptation policy and implementation of few pilot schemes to enhance the adaptive capacities of small and marginal farmers in Gujarat
68	Agriculture	Agronomic management	To evaluate alternate agronomic management options to sustain the agricultural production in relation to changed soil moisture availability in flood and drought prone regions of Gujarat
69	Agriculture	Soil and crop productivity	Evaluating the impact of climate change and its variability on soil and crops' productivity (5 years)
70	Agriculture	Developing genetic modified species	Will involve developing species and conducting trials of the same, and disseminating the findings through bio-technological advances for improving crop yields in drought prone states
71	Agriculture	Gridded database generation	To characterize the extent of rainfall variability, surface and ground water availability in various agro-ecological regions Gujarat
72	Agriculture	Promotion of peri-urban agriculture	Identification of potential of peri-urban agriculture in selected cities considering the potential impacts of climate change
73	Agriculture	Agricultural forecasting and data analytics	Agricultural forecasting based on climatic and water resources availability parameters to support farmers in appropriate crop management under changing climate
74	Agriculture	Farm to plate agriculture marketing	Direct farm to plate agricultural marketing and supply chain development
75	Agriculture/Water resources	Promotion of drip irrigation systems	This project will promote the use of drip irrigation system in water scarce regions of Gujarat as an adaptation measure to climate change
76	Agriculture, forestry and water resources (livelihoods)	Asset vulnerability assessment	Research to understand vulnerability by assessing type and extent of various livelihood assets--social, physical, financial, institutional and natural--of communities from various potential impact geographical regions.
77	Agriculture, forestry and water resources	Conventional adaptation practices	Develop a compendium of rational indigenous and traditional practices on adaptation in selected sectors like agriculture, forestry, water resources (floods and droughts) in various agro-ecological regions of Gujarat

S. No	Type/ Sector	Title	Description
78	Water Resources	To study the impact of climate change on the water resources and to develop adaptation strategies	Assessment of water resources taking into account the climate change. To identify future water scarce zones in Gujarat. To undertake case studies in some of the anticipated water scarce zones and devise adaptation strategies for availing water
79	Water Resources	Reducing uncertainties in assessing climate change variability and extreme events such as droughts and floods in Gujarat	Enhancing the temporal and spatial resolutions of GCM/ RCMs models to be more specific to India and using the precipitation and temperature series thus generated, as input to hydrologic models for forecasting droughts/ floods' variability and extremes in select water stressed river basins e.g. Sabarmati.
80	Water Resources	Impacts of climate change on water resources on transportation sector of agriculture goods	Will involve mapping the existing inter-state flow volume of agriculture goods and assessing impact of "drought" conditions on reduction in transportation and assessing opportunities for adapting to shortfalls in agriculture production relative to food security
81	Water resources	Assessing the effect of Global Warming on major rivers and aquifers	This study will assess aquifers and their behavior in Gujarat vis-à-vis their exploitation for water and hence greenhouse gas emissions
82	Water resources	Developing hot-spot (extreme scarcity) areas in Water resources sector and developing micro-level (household and community level) assessments of vulnerability and impacts of droughts	a) This will involve preparing overlays of maps—such as drought hazard map, groundwater development and degradation maps, surface water development, road network, district economic outputs, district human development indices, and superimposing the same to assess hot-spots for detail assessment of micro level vulnerability assessment b) Based on the identification of hot-spot states as above, conducting field surveys in randomly proportionate stratified sampled villages in each district.
83	Water resources	Mapping vulnerable population due to climate change impacts on water resources	Mapping temporal (at 5 years interval) and spatial (at district level) distribution of vulnerable population at risk at due to climate change impacts on water resources. This will involve mapping the current demographic trends in urban and rural population growths, overlaying the same with state developmental plans on infrastructure in water supply sector and water sector reforms parameters.
84	Water resources	Arid and semi-arid regions	Developing check-dams and water harvesting demonstration projects in each of the arid and semi-arid districts in Gujarat
85	Water resources	Water supply efficiency and water demand side management	Developing systems for efficient water supply systems and encourage measures for demand side management of water consumption

S. No	Type/ Sector	Title	Description
86	LULUCF	To study the impact of climate change on forestry and formulate adaptation strategies	Develop current (and past) climate and vegetation type linkages, correlation's and geographic maps of distribution. Evaluate, adapt and develop vegetation response models suitable for the complex, diverse vegetation types in Gujarat. Assess the vulnerability of different ecosystems to different scenarios of climate change. Assess the impacts of different climate change scenarios on vegetation ecosystems in terms of shifts in boundary, changes in area, biodiversity, regeneration and growth rates, and carbon sink capacity. Evaluate different adaptation options and implementation barriers to reduce adverse impacts of climate change. Develop policy, institutional and financial measures to implement adaptation measures.
87	LULUCF	Vegetation modeling	Develop, validate and disseminate dynamic vegetation models for assessing impact of climate change on forest ecosystem at the regional level, including: evaluation of existing dynamic vegetation models; adaptation/ modification/ development of dynamic vegetation models for application at regional scales; validation for current climate and vegetation; and, dissemination of information package on the dynamic vegetation model.
88	LULUCF	Ecosystem modeling	Long-term monitoring of vegetation response including monitoring climate changes and monitor vegetation changes; establishing linkage between climate change variables and forest vegetation characteristics
89	LULUCF	Adaptation policies for forest ecosystems	To assess the impact of forest policies, programs and schemes, to enhance resilience or reduce the vulnerability of forest ecosystem to projected climate change. Specifically, it will include review of forest policies, programs and schemes; suggesting policies, and programs to reduce vulnerability of forest ecosystems; assessing the implications of biodiversity, and dominant species to determine the vulnerability of forest ecosystems.
90	LULUCF	Assisting adaptation for vulnerable plant species	Anticipatory planting of vulnerable plant species to adapt to projected climate change involving identifying vulnerable species which are likely to migrate; planting along altitudinal gradient; monitoring performance of species; and making recommendations on anticipatory planting practices.
91	LULUCF	Enhancing Trees outside forest	Planting of indigenous species of trees outside forests to promote agroforestry in rural areas and green spaces in urban areas

S. No	Type/ Sector	Title	Description
92	Natural Ecosystems	To study the impacts of climate change on natural ecosystems such as the Banni Grasslands/ Gir Forest	This will involve study and modeling of impacts of climate change including sea level rise on the dominant forest species in the ecosystem. Modeling the impacts of sea level rise on appearance and disappearance of Islands in the coastal areas of the state (e.g. Pirotan Marine Park).
93	Coastal zones	Integrated adaptation policies for coastal zones	Identifying points of integrating the adaptation policy, having elements of both coastal zone management and sustainable development, into regional and local developmental planning and policies. Specifically, it will include: review of other policies--disaster abatement plans, land-use plans, watershed resource plans; understanding "local livelihood stresses" induced due to environmental factors such as groundwater degradation due to sea water intrusion, coastal flooding and erosion; understanding and documenting the local traditional knowledge systems used in combating these non-climatic stresses and climate change induced enhanced variability and extremes in flooding.
94	Coastal zones	Vulnerability assessment at coastal village level	Assessing vulnerabilities of communities from selected villages along the coast to climate change impacts by use of sustainable livelihood framework. Analyzing social dynamics and institutional landscape to identify points of leverage for short-term and long-term adaptation interventions
95	Extreme events and coastal zones	Impacts of climate change and extreme events on coastal zones	This study will include development of a sea level rise scenario due to climate change along the coastline of Gujarat. Study on impacts of sea level rise on specifically densely populated and area with important infrastructure. Impacts of sea level rise on fisheries.
96	Human Health	To study the Impacts of climate change on human health	This will involve identification of areas where malaria and other diseases related to extreme heat or cold events will be prevalent in the future climate scenarios. Identification of communities most susceptible to climate change. Undertaking case studies integrating climate change and socio-economic scenarios. Development of Adaptation matrix to combat the impacts of climate change
97	Health	Assessing vulnerability of communities exposed to extreme heat	A study will be carried out to identify areas which will experience recurrent intense heat due to climate change and assessment will be made of adaptation needs of communities in the climate change regime. For this the current adaptation practices including the government policies will be analysed.

S. No	Type/ Sector	Title	Description
98	Energy	Integrated model development for Assessment of Impacts on Energy Sector	Developing software modules for impact assessment of climate change on energy sector and "soft linking" the same with models of inventory estimation to get an integrated view.
99	Industry	Research on innovations	Research on adaptation innovations in industry for adaptation to climate change impacts
100	Energy and Infrastructure	Impacts of climate change on energy and infrastructure in the Gujarat	This study will involve specific case studies to evaluate the impacts of climate change on the energy availability and urban infrastructure in Gujarat. Evaluation of adaptation strategies including insurance to combat the impacts.
101	Energy and Infrastructure	Development of urban policy response for integrating climate change and sustainable development	This will involve identification of issues in urban areas relevant to climate change and a development of methodology for linking them to sustainable development This may be taken up in coordination with Covenant of Mayors of Gujarat on Climate Action
102	Industry and infrastructure	Assessment of Impacts on Industry and Infrastructure	Assessing impacts on industry and infrastructure through: preparation of a catalogue of historic extreme events, assessing the damages and providing the loss estimates in coastal and inland areas, showing the spatial distribution; developing detail GIS map covers with topographic, vegetation and geological details showing the major industries and infrastructure systems and their components; and, assessing sensitivities of different components with respect to various climate parameters.
103	Infrastructure, Industry	Climate change impact on coastal infrastructure and Industries	Coastal infrastructure is most vulnerable to the sea level rise and extreme events. Gujarat has many industrial complexes close to the coastal areas. The infrastructure such as roads, railway lines, and ports will be adversely affected by the changing rainfall pattern and extreme events
104	All	Extreme events and identification of vulnerable regions in India	Impact assessment to address a range of possible increase in temperature scenarios in floods, cyclones and droughts prone regions, as these different geographical regions are expected to experience variability in temperature changes due to climate change
105	All	Integrated Impact Assessment Modeling for Gujarat	Developing Integrated Assessment model to assess impacts of climate change and corresponding adaptation requirement, in addition to understanding possible abatement and adaptation measures, in various sectors --Water Resources, Agriculture, Terrestrial and Marine Ecosystems, Human Health, Human Settlements, Energy, and Industry

Fully committed and geared up to effectively address the challenges of Climate Change, by leading from the front and enlisting the participant of all stakeholders, the Government of Gujarat, in tune with the policies of the Central Government, has adopted a multi-pronged strategy to make the urban as well as rural areas climate-resilient through a slew of mitigation and adaptation measures with a thrust on a wide range of thematic sectors and with due regards to the interests of the masses in general and the vulnerable communities in particular towards the making of a fully climate-resilient Gujarat.

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Annexures

Annexure-1: Department-wise budget considering climate actions for 2021-22

Agriculture

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	**Revenue Account (Rs. in lakhs)**	**Capital account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**
Sector-A-General Services								
Other Administrative Services	0		50		101.32		109.426	0
Sector-C-Economic Services								
Crop Husbandry	282561	10000	259349	10000	310685	10000	335540	10300
Soil and water Conservation	15383.5	9214.53	15458.1	9214.53	2312.84	3	2497.87	3.09
Animal Husbandry	68398.9		74257.2		70458.8		76095.5	0
Dairy Development	5412.5		5412.5		18085.6		19532.4	0
Fisheries. (Charged)(Voted)	30354		35166.5		41879.1		45229.4	0
Agriculture Research and Education	65080.6		65125.3		41879.1		45229.4	0
Co-operation	72432.8	1	133773	1	70204.1	1	75820.4	1.03
Other Agricultural Programme	2044.87	5886.01	1711.33	3966.01	119018	9866.01	128539	10162
Minor Irrigation	312.04		274.47		1588.74		1715.84	0
New and Renewable Energy	100		0		867.8		937.224	0
Secretariat-Economic Services	2035.73		1687.65		1713.44		1850.52	0
Other General Economic Services	429.26		378.75		394.14		425.671	0
Capital outlay on Consumer Industries.		100		1140		1	0	1.03
Capital outlay on Ports and Light House		29125		27000		15000	0	15450
Sector-F-Loans And Advances								
Loans for Co-operation.		200.01		200.01		0	0	0
Loans to Government Servants etc.		26		16		0.02	0	0.0206
Gross Totals	**544545**	**54552.6**	**592643**	**51537.6**	**637309**	**34871**	**688294**	**35917.2**

Climate Change

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	**Revenue Account (Rs. in lakhs)**	**Capital account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**
New and Renewable Energy	2810	0	2485.00	0	3247.00	0	3571.7	0
Ecology and Environment	7300	0	102123.61	0	91935.12	0	101128.6	0
Secretariat-Economic Services	100.7	0	117.09	0	125.75	0	138.325	0
Gross Total	**10210.7**	**0**	**104725.7**	**0**	**95307.87**	**0**	**104838.7**	**0**

Education

Budget Estimates	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	24400.1		24826		24541		26258.87	0
Pensions and Other Retirement Benefits	273000		290300		341600		365512	0
Sector-B-Social Services								
General Education	1974588.6		2221317.06		2355217.77		2520083	0
Technical Education	93411.43		105878.21		102969.95		110177.8	0
Sports and Youth Services	2916.37		3577.59		3579.16		3829.701	0
Art and Culture	53.21		45.2		45.49		48.6743	0
Social Security and Welfare	155.03		110.5		123.05		131.6635	0
Nutrition	73423.42		68929.92		71079.78		76055.36	0
Secretariat-Social Services	1117.62		1085.87		1195.83		1279.538	0
Sector-C-Economic Services								
Other Scientific Research	0.3		0.3		0		0	0
Sector-B-Capital Account of Social Services								
Capital outlay on Education, Sports, Art and Culture		79843.21		57997.8		55278.22	0	56936.57
Sector-F-Loans And Advances								
Loans to Government Servants etc.		50.01		50.01		50.01	0	51.5103
Miscellaneous Loans		4010		4550		4550	0	4686.5
Gross Totals	**2443066.08**	**83903.22**	**2716070.65**	**62597.81**	**2900352.03**	**59878.23**	**3103377**	**61674.58**

Energy and Petrochemicals

Budget Estimates	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Other Taxes and Duties on Commodities and Services	2397.06		2450		2384		2503.2	0
Sector-C-Economic Services								
Power	541546.32		791453.51		840170.81		882179.4	0
Petroleum	0		56469		53355		56022.75	0
New and Renewable Energy	7523.01		55318.1		22761.01		23899.06	0
Industries	92.31		100		114		119.7	0
Secretariat-Economic Services	491.06		778.49		778.49		817.4145	0
Capital Outlay on Power Projects		272315.01		247888.21		246885.09	0	271573.6
Capital Outlay to Renewable Energy		0		50000		44900	0	49390
Capital Outlay on Petro-Chemicals Industries		0.02		5000		108750	0	119625
Sector-F-Loans And Advances								
Loans for Power Projects		8251.01		20000		20000	0	22000
Loan for General Financial and Trading Institutions		0		0		0	0	0
Loans to Government Servants etc.		16		16		16	0	17.6
Gross Total	**552049.76**	**280582.04**	**906569.1**	**322904.21**	**919563.31**	**420551.09**	**965541.5**	**462606.2**

Finance

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Taxes on Sale, Trade etc	140		165.53		153.95		166.266	0
Collection Charge under State Goods & Services Tax	33611.59		31887.47		34757.55		37538.2	0
Other Fiscal Services	290.5		290		249.9		269.892	0
Appropriation for reduction or avoidance of Debt	120000		120000		150000		162000	0
Interest Payments (Charged)	1923717.55		2044525.01		2271617.23		2453347	0
Secretariat-General Services	2081.14		2165.24		2193.49		2368.97	0
Treasury and Accounts Administration	19489.21		19312.09		20650.06		22302.1	0
Pensions and Other Retirement Benefits (Charged)	800		1000		1300		1404	0
(Voted)	1132730.05		1172107.26		1183020.05		1277662	0
Miscellaneous General Services	701000.01		751000.01		801000.01		865080	0
Sector-B-Social Services								
Water Supply and Sanitation	88.13		121.98		71.98		77.7384	0
Social Security and Welfare	1025.2		850.2		840.1		907.308	0
Sector-C-Capital Account of Economic								
other General econonmic services	3795.13		4810.26		7261.32		7842.23	0
Sex vices							0	0
Investment in General Financial and Trading Institutions	0		0		0		0	0
Sector-E-Public Debt								
Internal Debt of the State Government (Charged)		1471583.28		1587402.24		1715823.36	0	1853089
Loans and Advances from the Central Government (Charged)		71843.73		71692.1		72645.84	0	78457.5
Sector-F-Loans And Advances								
Loans to Government Servants etc		35		35		35	0	37.8
Sector-G-Inter-State Settlement								
Inter-State Settlement (Charged)		0.01		0.01		0.01	0	0.0108
Gross Total	**3938768.51**	**1543462.02**	**4148235.05**	**1659129.35**	**4473115.64**	**1788504.21**	**4830965**	**1931585**

Food, Civil Supplies & Consumer Affairs

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-C-Economic Services								
Food, Storage and Warehousing	5907.41	10744.77	5902.78	8899.44	6557.43	7482	7082.024	7706.46
Secretariat-Economic Services	2902.97		1575.14		3564.86		3850.049	0
Civil Supplies	72006.74		64832.18		84860.07		91648.88	0
Other General Economic Services	2056.92		2716.07		2190.62		2365.87	0
Sector-F-Loans And Advances							0	0
Loans to Government Servants etc.		0.02		0.02		0.02	0	0.0206
Gross Total	**82874.04**	**10744.79**	**75026.17**	**8899.46**	**97172.98**	**7482.02**	**106890.3**	**7706.481**

Forest and Environment

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	3		30.46		10		13	0
Sector-B-Social Services								
Water Supply and Sanitation	1018		1428.66		673.76		875.888	0
Sector-C-Economic Services								
Forestry and Wild Life (Charged)	23	45751.22	64.3	45213.19	50	55503.78	65	61054.16
(Voted)	45698.14		59845.13		82754.97		107581.5	0
Ecology and Environment	1030.5		2267		2473.75		3215.875	0
Secretariat-Economic Services	1339.6		1179.13		989.92		1286.896	0
Sector-F-Loans And Advances								
Loans to Government Servants etc.		22		22.25		22.25	0	24.475
Gross Total	**49112.24**	**45773.22**	**64814.68**	**45235.44**	**86952.4**	**55526.03**	**113038.1**	**61078.63**

General Administration

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Governor (Charged)	788.28		803.6		905.45		996.00	0
Council of Ministers	570.57		410.3		586.7		645.37	0
Administration of Justice	241.59		219.33		220.81		242.89	0
Elections	14728.85		48376.55		13038.37		14342.21	0
Public Service Commission (Charged)	2098.28		2900.47		3259.15		3585.07	0
(Voted)	1495.95		1594.36		1357.53		1493.28	0
Secretariat-General Services	9803.69		9093.18		9412.2		10353.42	0
Vigilance (Charged)	41.08		32.62		33.23		36.55	0
(Voted)	268.87		196.46		153.9		169.29	0
Other Administrative Services	2214.54		2144.4		2451.69		2696.86	0
Sector-B-Social Services								
Social Security and Welfare	339.92		291.7		246.44		271.08	0
Sector-C-Economie Services								
Secretariat-Economie Services	2236.01		2166.94		2360.44		2596.48	0
Census, Surveys and Statistics	3405.59		3574.1		11118.62		12230.48	0
Capital Outlay on public works		10955.6		524		0	0.00	0
Capital Outlay on Other Administrative Services		10000		0.01		0.01	0.00	0.0103
Capital Outlay on Other Rural Development Programme		97777		105897		106877	0.00	110083.31
Sector-F-Loans And Advances								
Loans to Government Servants, etc..		69		59		59	0.00	60.77
Gross Total	**38233.22**	**118801.6**	**71804.01**	**106480.01**	**45144.53**	**106936.01**	**49658.98**	**110144.0903**

Gujarat Legislature

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
State Legislature (Charged)	47.6		52.1		48.6		53.46	0
(Voted)	3588.92		4642.95		5088.96		5597.856	0
Sector-F-Loans And Advances								
Loans to Government Servants							0	0
etc.		29		29		29	0	29.87
Gross Total	**3636.52**	**29**	**4695.05**	**29**	**5137.56**	**29**	**5651.316**	**29.87**

Health & Family Welfare

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	27.64		27.13		27		29.7	0
Sector-B-Social Services								
Medical and Public Health	504039.04	165492.09	578879.49	112122.99	627394.61	84832.8	690134.1	93316.08
Family Welfare	135417.43	900	205244.72	507	233966.27	1016	257362.9	1117.6
Secretariat-Social Services	1305.21		1412.39		1455.13		1600.643	0
Capital outlay on Housing		10011.5		2560		215	0	236.5
Sector-F-Loans And Advances								
Loans to Government Servants etc.		45		15		20	0	22
Gross Total	**640789.32**	**176448.59**	**785563.73**	**115204.99**	**862843.01**	**86083.8**	**949127.3**	**94692.18**

Home

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
State Excise	1871.88		1964.36		1974.77		2172.247	0
Interest Payments (Charged)	0.01		0.01		0.01		0.011	0
Secretariat-General Services	1750.49		1807.71		1950.82		2145.902	0
District Administration	38.14		38.85		44.76		49.236	0
Police	422124.07		497764.87		583340.1		641674.11	0
Jails	15430.89		18908.79		19497.74		21447.514	0
Vigilance	499.79		477.44		50		55	0
(Voted)					1242.1		1366.31	0
Other Administrative Services (Charged)	35		60		39364.29		43300.719	0
(Voted)	30162.04		31456.92				0	0
Capital outlay on Police		24755.86		52461.93		45240.6	0	46597.818
Sector-B-Social Services								
Social Security and Welfare	780.46		16562.75		7272.36		7999.596	0
Services Capital outlay on Housing		35195.37		36270.37		37463.39	0	38587.2917
Sector-F-Loans And Advances								
Loans to Government Servents etc.		1160		1205		505	0	520.15
Gross Total	**472692.77**	**61111.23**	**569041.7**	**89937.3**	**654736.95**	**83208.99**	**720210.65**	**85705.26**

Industries and Mine

Budget Estimates	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)
Sector-A-General Services							
Interest Payments (Charged)	0		0		0.6		0.66
Stationery and Printing	6955.3		7209.49		7118.9		7830.79
Other Administrative Services	6835		7873		5331.5		5864.65
Pensions and Other Retirement Benefits	11		2.75		23.4		25.74
Capital Outlay on Stationery and Printing		885.8		690		266	0.00
Sector-B-Social Services							
Other Social Services	1.8		1.8		1.8		1.98
Sector-C-Economic Services							
Co-operation	200		225		300		330.00
Village and Small Industries.	109224.44	256	123266.19	799.55	208401.93	683.5	229242.12
Industries	187213.66		278456.68		267202.13		293922.34
Non-ferrous Mining and Metallurgical Industrie	19071.63	155	21337.9	816	24969.72	781	27466.69
Civil Aviation	1420		2082.5		4701		5171.10
Secretariat-Economic Services	1715.46		2970.95		1988.91		2187.80
Tourism	8196		11030.4		13478.12		14825.93
Capital Outlay on Village and Small Industries							0.00
Capital Outlay on Iron and Steel Industries		10		10		0	0.00
Capital Outlay on other Industries		10411.4		58263.4		87618.68	0.00
Capital Outlay On Civil Aviation (Charged)		0		0		0	0.00
(Voted)		12650		34724		5083	0.00
Capital Outlay on Tourism		48400		47505		43800	0.00
Capital Outlay on other General Economics Services		1		1		1	0.00
Sector-F-Loans And Advances							
Loans for Village and Small Industries.		2		2		2.5	0.00
Loans for Engineering Industries		800		100		10	0.00
Loans to Government Servants etc.		20		16.5		16.5	0.00
Gross Total	**340844.29**	**73591.2**	**454456.66**	**142927.45**	**533518.01**	**138262.18**	**586869.81**

Information & Broadcasting

Budget Estimates	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Other Taxes and Duties on Commodities and Services (Charged)							0.00	0.00
(Voted)	1575.4		1167.38		1000		1030.00	0.00
Interest Payments (Charged)	0		0		0		0.00	0.00
Secretariat-General Services	182.38		188.1		140		144.20	0.00
Sector-B-Social Services								
Art and Culture	5		15		6		6.18	0.00
Information and Publicity	12659.78		13005.27		12989.99		13379.69	0.00
Sector-F-Loans And Advances								
Loans to Government Servants Etc.		30		15		10	0.00	10.30
Gross Total	**14422.56**	**30**	**14375.75**	**15**	**14135.99**	**10**	**14560.07**	**10.30**

Labour and Employment

Budget Estimates	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-B-Social Services								
Labour, Employment and Skill Development (Charged)							0.00	0.00
(Voted)	121205.49		102139.88		99600.67		102588.69	0.00
Social security and welfare	0		500		50		51.50	0.00
Secretariat-Social Services	1755.42		2530.9		2530.9		2606.83	0.00
Capital Outlay on other Social Services		3100		2555		7200	0.00	7416.00
Sector-F-Loans And Advances								
Loans to Government Servants etc.		9.4		1.7		1.7	0.00	1.75
Gross Total	**122960.91**	**3109.4**	**105170.78**	**2556.7**	**102181.57**	**7201.7**	**105247.02**	**7921.87**

Legal

es	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	20:
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Rev Acc (R la
Services							
Justice (Charged) (Voted)	21453.13		14660.36		16300.76		174
s (Charged)	94463.07		93062.25		99546.64		106
al Services	1445.05		1300.3		1655.64		17
rvices							
ent and Skill	4383.28		3077.04		3094.81		33
al Security and Welfare	2607.85		4646.87		3795.58		40
ices	1513.24		1576.2		1862.41		19
d Advances							
nents Servants etc.		177		52		45	0
	125865.62	**177**	**118323.02**	**52**	**126255.84**	**45**	**135**

Legislative & Parliamentary Affairs

et Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	202
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Ca Acc (R lal
-A-General Services							0	
ariat-General Services	744.84		808.98		852.83		903.9998	
-F-Loans And Advances							0	
to Government Servants		0.02		0.02		0.02	0	0.0
Total	**744.84**	**0.02**	**808.98**	**0.02**	**852.83**	**0.02**	**903.9998**	**0.0**

Narmada, Water Resources, Water Supply & Kalpsar

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	11000		20000		20000		21000	0
Sector-B-Social Services								
Water Supply and Sanitation	18888		21390		21392		22461.6	0
Capital Outlay on Water Supply and Sanitation.		200797.48		263184		319000	0	341330
Sector-C-Economic Services								
Major Irrigation (Charged)	0		142.69				0	0
(Voted)	32187.05		35683.46		35519.53		37295.51	0
Medium Irrigation (Charged)			45.87				0	0
(Voted)	20811.88		24567.93		23288.35		24452.77	0
Minor Irrigation	54884.48		60009.56		67141.17		70498.23	0
Command Area Development	1211.59		1118.41		1462.35		1535.468	0
Flood Control and Drainage	5662.33		5401.4		6941.01		7288.061	0
Secretariat-Economic Services	1760.17		1924.92		1973.25		2071.913	0
Capital Outlay on Soil and Water Conservation		336.25		228.3		194	0	207.58
Capital Outlay on Major Irrigation		478980.1		445280.1		361253.07	0	386540.8
Capital Outlay on Major Irrigation		23934.37		19183.9		21292.32	0	22782.78
Capital Outlay on Medium		4000		4007.83		10000	0	10700
Irrigation. (Charged) (Voted)		245850.76		269087.73		256304.19	0	274245.5
Capital Outlay on Minor Irrigation.		103119.15		115823.77		142642.38	0	152627.3
Capital Outlay on Flood Control Projects.		10482.82		10987.55		11287.02	0	12077.11
Capital Outlay on Power Project		6019.9		11019.9		18746.63	0	20058.89
Capital Outlay on Tourism		10000		3700		80000	0	85600
Sector-F-Loans And Advances								
Loans to Government Servants etc.		35		16		21	0	22.47
Gross Total	**146405.5**	**1083555.83**	**170284.24**	**1142519.08**	**177717.66**	**1220740.61**	**186603.5**	**1306192**

Panchayat, Rural Housing & Rural Development

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	38084		40096		45062.56		48667.56	0
Pensions and Other Retirement Benefits	70212.1		78922.1		85502.1		92342.27	0
Sector-B-Social Services								
Water supply and Sanitation	54389		59670.52		70624.93		76274.92	0
Housing	61329.5		118793.96		86605.53		93533.97	0
Social Security and Welfare	95.1		97.1		115.1		124.308	0
Secretariat-Social Services	999.67		933.08		1005.25		1085.67	0
Sector-C-Economic Services							0	0
Special Programmes for Rural	35733.3		38556.75		47551.16		51355.25	0
Development Rural Employment	35674		40196		43684		47178.72	0
Other Rural Development Programmes	228228.09		294325.04		343341.85		370809.2	0
Roads and Bridges	0.3		0.3		0.3		0.324	0
Sector-D-Grants-in-aid- and Contributions								
Compensation and Assignments to Local Bodies and Panchayati Rajn Institutions	13650.19		13754.69		14078.19		15204.45	0
Sector-F-Loans And Advances								
Loans for Housing				243.72		271.11	0	290.0877
Loans to Government Servants etc.		23		23		26	0	27.82
Miscellaneous Loans		302		197		105	0	112.35
Gross Total	**538395.25**	**325**	**685345.54**	**463.72**	**737570.97**	**402.11**	**796576.6**	**430.2577**

Ports & Transport

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Taxes on Vehicles	19888.31		21853.13		22604.77		24865.25	0
Sector-C-Economic Services								
Ports and Light Houses	5587		5787		6829.04		7511.944	0
Road Transport	30295.49		30979.76		40714.5		44785.95	0
Secretariat-Economic Services	242.7		245.28		261.81		287.991	0
Capital Outlay on Ports and Light Houses		2001		541		2001	0	2061.03
Capital Outlay on Road Transport		56052.4		52346.35		38989.4	0	40159.08
Sector-F-Loans And Advances								
Loans for Road Transport		9891.60		10293.85		13436.10	0	13839.18
Loans to Government Servants etc.		0.02		0.02		0.02	0	0.0206
Gross Total	**56013.5**	**67945.02**	**58865.17**	**63181.22**	**70410.12**	**54426.52**	**77451.13**	**56059.32**

Revenue

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Land Revenue (Charged)	1		1		1		1.1	0
(Voted)	14933.52		17065.52		17983.45		19781.8	0
Stamps and Registration	12864.96		13690.01		12038.69		13242.56	0
Interest Payments (Charged)	7		7		7		7.7	0
Secretariat-General Services	4354.43		4204.15		3851.35		4236.485	0
District Administration (Charged)							0	0
(Voted)	54793.09		55786.45		59935.04		65928.54	0
Pensions and Other Retirement Benefits	2		2.1		2		2.2	0
Miscellaneous General Services	88.79		106.04		108.04		118.844	0
Sector-B-Social Services								
Urban Development	2131.69		1241.36		2126.84		2339.524	0
Social Security and Welfare	94.63		103.48		127.27		139.997	0
Relief on account of Natural	169987.97		182929.05		275223.01		302745.3	0
Calamities							0	0
Sector-C-Economic Services								
Agriculture Research and Education	155		83		82		90.2	0
Other Special Area Programme	5278.47		5556.53		5802.88		6383.168	0
Secretariat-Economic Services	73.26		78.2		66.4		73.04	0
Other General Economic Services	582.01		608.37		629.42		692.362	0
Sector-D-Grants-in-aid- and Contributions								
Compensation and Assignments to	22400		30000		**30000**		33000	0
Local Bodies and Panchayati Raj							0	0
Institutions							0	0
Sector-B-Capital Account of Social Services								
Capital Outlay on Social Security		0.1		0.1		0.1	0	0.11
and Welfare.							0	0
Capital Outlay on other Social		8025.4		7500		16298.52	0	17928.37
Services							0	0
Sector-C-Capital Account of Economic Service							0	0
Capital Outlay on other General		1		26		1	0	1.1
Economics Services (Charged)							0	0
(Voted)		3		3		3	0	3.3
Sector-E-Public Debt								
Internal Debt of the State		**1**		1		1	0	1.1
Sector-F-Loans And Advances								
Loans to Government Servants etc.		26		26		26	0	28.6
Gross Total	**287747.82**	**8056.5**	**311462.26**	**7556.1**	**407984.39**	**16329.62**	**448782.8**	**17962.58**

Roads & Buildings - Part-I

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	1800		2000		5000		5250	0
Public Works (Charged)	90		127		127		133.35	0
(Voted)	54051.03		60530.72		62372.38		65491	0
Other Administrative Services	2777.58		3163.76		3382.71		3551.846	0
Miscellaneous and General Service	1700		2500		3000		3150	0
Capital Outlay on Public Works							0	0
(Charged) (Voted)		68757.6		53285.53		69398.07	0	71480.01
Sector-B-Social Services								
Water Supply and Sanitation	2750		2950		3000		3150	0
Housing (Charged)	0		5		0		0	0
(Voted)	19297.13		20186.17		21004.89		22055.13	0
Urban Development	1596.09		1637.53		1691.96		1776.558	0
Capital Outlay on Education, Sports, Art and Culture		36153.07		45216.54		43861.19	0	45177.03
Capital outlay on Housing		24920.6		28534.42		20797.8	0	21421.73
Capital outlay on Urban		9		9		9	0	9.27
Development (Charged) (Voted)		25441		31191		30433	0	31345.99
Capital Outlay on Information and Publicity				89		10	0	10.3
Capital Account on Welfare of Scheduled Caste, Scheduled Tribes, Other Backward Classes and Minorities		3756.91		5481.92		3868	0	3984.04
Capital Outlay on Social Security and Welfare		1255.77		2203.27		2914.33	0	3001.76
Capital Outlay on Other Social Services		21031.69		15944.78		11187.34	0	11522.96
Sector-C-Economic Services								
Animal Husbandry	1883.42		1000		1500.63		1575.662	0
Forestry and Wild Life	1442.57		1655.13		1720.93		1806.977	0
Roads and Bridges (Charged)	410		470		510		535.5	0
(Voted)	335153.13		339304.53		353286.95		370951.3	0
Secretariat-Economie Services	2108.6		2427.88		2483.57		2607.749	0
Capital Outlay on Crop Husbandry		1433.13		851.43		2126.5	0	2190.295
Capital Outlay on Animal Husbandry		6920.72		3273.27		3484.96	0	3589.509
Capital Outlay on Village and Small Industries		576.81		525		371.1	0	382.233
Capital Outlay on Civil Aviation		0		2524.86		500	0	515
(Charged) (Voted)		500		350		350	0	360.5
Capital Outlay on Roads and Bridges		250		1050		1050	0	1081.5
(Charged) (Voted)		285154.81		343411.7		349010.19	0	359480.5
Sector-F-Loans And Advances								
Loans to Government Servants etc.		22.5		22.5		22.5	0	23.175
Gross Total	**425059.55**	**476183.61**	**437957.72**	**533964.22**	**459081.02**	**539393.98**	**482035.1**	**555575.8**

Science & Technology

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Secretariat General Services	[illegible]		[illegible]		[illegible]		[illegible]	0
Capital Outlay on Miscellaneous General Services		113		16		26	0	[illegible]
Sector-C-Economic Services								
Other Scientific Research	[illegible]		[illegible]		[illegible]		[illegible]	0
Capital out-lay on other Scientific and Environment Research		[illegible]		0.03		[illegible]	0	[illegible]
Sector-F-Loans And Advances								
Loans to Government Servants, etc.		0.02		0.02		0.02	0	0.0206
Gross Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Social Justice & Empowerment - Part-I

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	223		240		260		280.8	0
Sector-B-Social Services							0	0
Welfare of Schedule Casts,	117578.9		122883.8		128019.7		138261.2	0
Schedule Tribes , other Backward							0	0
Classes and Minorities Social Security and Welfa	50997.48		78661.79		87560.64		94565.49	0
Secretariat - Social Services	795.45		1058.51		796.27		859.9716	0
Capital Account on Welfare of Scheduled Caste, Scheduled Tribes, Other Backward Classes and Minorities		1101		1101	1101		1189.08	0
Capital Outlay on Social Security and Welfare						100	0	103
Sector-F-Loans And Advances								
Loans for Welfare of Scheduled Caste, Scheduled Tribes, Other Backward Classes and Minorities		61110.4		60930.4		60630.4	0	62449.31
Loans to Social Security and Welfare						24.5	0	25.235
Loans to Government Servents etc.		16		16		16	0	16.48
Gross Total	**169594.8**	**62227.4**	**202844.1**	**62047.4**	**217737.6**	**60770.9**	**235156.6**	**62594.03**

Social Justice & Empowerment-Part-II

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Administration of Justice	251.7		254.7		253.40		278.74	0
Stationery and Printing	14		14		10.00		11	0
Capital Outlay on Medical on Public Works		2131.66		4912.2		3682.00	0	3792.46
Sector-B-Social Services								
General Education	28601.21		27694.54		27909.19		30700.11	0
Technical Education	1431		1041		966.01		1062.611	0
Sports and Youth Services	3116.68		2885.3		3017.30		3319.03	0
Art and Culture	170		175		175.00		192.5	0
Medical and Public Health	23354.42		30753.64		31216.35		34337.99	0
Family Welfare	15287.28		22646.79		18643.63		20507.99	0
Water Supply and Sanitation	8754.9		12734.07		10345.00		11379.5	0
Housing	30995.24		26582.75		20377.50		22415.25	0
Urban Development	64998.79		75080.65		83065.39		91371.93	0
Information and Publicity	851		851		875.00		962.5	0
Welfare of Schedule Casts, Schedule Tribes , other Backward Classes and Minorities	80960.06		91847.5		88910.95		97802.05	0
Labour, Employment and Skill	2053.76		1839.45		3162.03		3478.233	0
Social Security and Welfare Development	17740.44		24609.65		27370.76		30107.84	0
Nutrition	9009.5		8951.67		8840.90		9724.99	0
Secretariat - Social Services	321.71		374.71		368.81		405.691	0
Capital outlay on Education Sports, Arts and Culture		11264.69		8574.87		15464.91	0	15928.86
Capital Outlay on Medical and Public Health		10099.87		2894.57		1621.00	0	1669.63
Capital Outlay on Water Supply and Sanitation		3553.34		4600		4700.00	0	4841
Capital Outlay on Housing		1389.19		2032.31		858.55	0	884.3065
Capital Account on Welfare of Scheduled Caste, Scheduled Tribes, Other Backward Classes and Minorities		20440.08		15575		13723.69	0	14135.4
Capital Outlay on Other Social Services		1730.18		1356.84		1185.00	0	1220.55
Sector-C-Economic Services								
Crop Husbandry	7530.62		6765.03		8835.16		9718.676	0
Soil and Water Conservation	568.74		576.69		70.58		77.638	0
Animal Husbandry	1727.73		1638.97		1849.55		2034.505	0
Dairy Developement	266.25		266.25		1666.25		1832.875	0
Fisheries.	180		180		180.00		198	0
Forestry and Wild Life	150		320.67		297.87		327.657	0
Food Storage and Warehousing	50.62		20		30.00		33	0
Co-operation	2738		2736.06		2992.00		3291.2	0
Special Programmes for Rural Development	3427.5		7234.03		4475.36		4922.896	0
Rural Employment	3438		3862		4241.00		4665.1	0
Other Rural Development Programme	14593.72		18152.79		22359.95		24595.95	0
Minor Irrigation	943		959.5		691.00		760.1	0
Power	360		285		313.50		344.85	0
New and Renewable Energy	23		0		21.00		23.1	0
Village and Small Industries.	10861.98		10426.11		10691.41		11760.55	0
Industries	50		50		50.00		55	0
Roads and Bridges	48512		52812		52812.00		58093.2	0
Ecology and Environment	0		0		6469.13		7116.043	0
civil supplies	5918.48		5546.95		7474.30		8221.73	0
Other General Economic Services	2		545		676.00		743.6	0
Capital outlay on Forests and Wild life		4972.78		4973.81		5109.32	0	5262.6
Capital Outlay on Other Rural Development Programme		6885		6888		6885	0	7091.55
Capital Outlay on Major Irrigation		21403.09		21263.8		20945	0	21573.35
Capital Outlay on Medium bIrrigation.		455		105		200	0	206
Capital Outlay on Minor Irrigation.		8378.5		4521.58		4517.99	0	4653.53
Capital Outlay on Power Projects		1320		916		1007.6	0	1037.828
Capital Outlay on Village and Small Industries (Charged)							0	0
(Voted)		7		8		0.00	0	0
Capital Outlay on Tourism		600		1176.52		1022.00	0	1052.66
Sector-F-Loans And Advances								
Loans for Welfare of Scheduled Caste, Scheduled Tribes, Other Backward Classes and Minorities		4720		7252		6687.00	0	6887.61
Loans for Village and Small Industries		1		1		0.00	0	0
Gross Total	**389253.33**	**99351.38**	**440713.47**	**87051.5**	**451703.28**	**87609.06**	**496873.6**	**90237.33**

Sports, Youth & Cultural Activities

Major head	2018-19 Revenue Account (Rs. in lakhs)	2018-19 Capital account (Rs. in lakhs)	2019-20 Revenue Account (Rs. in lakhs)	2019-20 Capital Account (Rs. in lakhs)	2020-21 Revenue Account (Rs. in lakhs)	2020-21 Capital Account (Rs. in lakhs)	2021-22 Revenue Account (Rs. in lakhs)	2021-22 Capital Account (Rs. in lakhs)
Sector-A-General Services								
Other Administrative Services	11.59		11.59		14		14.42	0
Sector-B-Social Services								
General Education	327.31		371.03		385.85		397.4255	0
Sports and Youth Services	31172.07		32014.53		30577.79		31495.12	0
Art and Culture (Charged)							0	0
(Voted)	8753.56		9670.41		10197.25		10503.17	0
Secretariat—Social Services	715.77		714.98		660.92		680.7476	0
Capital Outlay on Education, Sports, Art and Culture		7116.01		4578.24		4697.52	0	4838.446
Sector-C-Economic Services								
Census, Survey & Statistics	0		0			0	0	0
Sector-F-Loans And Advances								
Loans to Government Servants etc.		6.06		21.02		6.01	0	6.1903
Gross Total	**40980.3**	**7122.07**	**42782.54**	**4599.26**	**41835.81**	**4703.53**	43090.88	4844.636

Tribal Development - (Part-1) Volume-III

Budget Estimates								
	2018-19	**2018-19**	**2019-20**	**2019-20**	**2020-21**	**2020-21**	**2021-22**	**2021-22**
Major head	**Revenue Account (Rs. in lakhs)**	**Capital account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**	**Revenue Account (Rs. in lakhs)**	**Capital Account (Rs. in lakhs)**
Sector-B-Social Services								
General Education	175.67		193.24		212.57		227.4499	0
Medical and Public Health	49.1		49.1		49.1		52.537	0
Water Supply and Sanitation	200		200		200		214	0
Welfare of Schedule Casts, Schedule Tribes, other Backward Classes and Minorities	45065.71		52873.82		53976.6		57754.96	0
Labour, Employment and Skill Development	21.21		21.21		21.21		22.6947	0
Secretariat - Social Services	205.51		171.23		183.39		196.2273	0
Capital Account on Welfare of Scheduled Caste, Scheduled Tribes, Other Backward Classes and Minorities		2336.79		3892.18		6179.11	0	6797.021
Sector-C-Economic Services								
Crop Husbandry	39.27		39.27		40		42.8	0
Animal Husbandry	27.92		27.92		30.71		32.8597	0
Fisheries.	4.76		5.28		5.28		5.6496	0
Forestry and Wild Life	32		32		25		26.75	0
Special Programe for Rural Development	134.84		148		163		174.41	0
Minor Irrigation	148.32		148.32		148.35		158.7345	0
Power	104		104		104		111.28	0
Village and Small Industries.	80		80		80		85.6	0
Roads and Bridges	100		100		100		107	0
Sector-F-Loans And Advances								
Loans to Government Servents etc.		5.5		5.5		2.5	0	2.75
Gross Total	**46388.31**	**2342.29**	**54193.39**	**3897.68**	**55339.21**	**6181.61**	59212.95	6799.771

Tribal Development - (Part-4) Volume-IV

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Land Revenue	426.66		887.28		1363.14		1444.928	0
Interest Payments (Charged)	600		500		500		530	0
Sector-B-Social Services								
General Education	69498.79		73827.71		78481.2		83190.07	0
Technical Education	5359.62		5411.35		5415.97		5740.928	0
Sports and Youth Services	3081.5		3253.95		3425.51		3631.041	0
Art and Culture	718.34		750.68		741.19		785.6614	0
Medical and Public Health	69245.15		81802.85		85481.85		90610.76	0
Family Walfare	18943.71		32220.96		33418.24		35423.33	0
Water Supply and Sanitation	3281.95		6465.76		3513.97		3724.808	0
Housing	78178.89		35278.14		31311		33189.66	0
Urban Development	68529.16		78623.18		91686.48		97187.67	0
Information and Publicity	2135		2109		1845		1955.7	0
Welfare of Schedule Castes,	159833.91		170854.61		182369.88		193312.1	0
Schedule Tribes and Other backward Classes							0	0
Labour, Employment and Skill Development (Charged) (Voted)	12292.59		11493.79		14245.4		15100.12	0
Social Security and Welfare	19310.68		32684.6		36783.36		38990.36	0
Nutrition	83887.14		82080.09		80896.08		85749.84	0
Sector-C-Economic Services								
Crop Husbandry	27697.07		24753.82		29130.81		30878.66	0
Soil and water conservation	12792.2		12835.29		1368.71		1450.833	0
Animal Husbandry	5366.09		5579.16		6089.51		6454.881	0
Dairy Developement	691.58		691.58		4709.81		4992.399	0
Fisheries.	1153.47		1173.37		1174.09		1244.535	0
Forestry and Wild Life	9216.64		9769.63		8435.62		8941.757	0
Food storage and Warehousing	1500.01		1300		1300		1378	0
Agricultur Research and Education	5157.9		4973.71		4809.26		5097.816	0
Co-operation	2072.2		1433.67		2546.31		2699.089	0
Special programe for Rural	21818.16		23638.17		25724.36		27267.82	0
Development							0	0
Rural Employment	8248		9302		10435		11061.1	0
Other Rural Development Programme	45006.02		55921.66		65822.62		69771.98	0
Other Special Area Programme	3951.59		4018.66		4227.87		4481.542	0
Minor Irrigation	9506.42		9643.13		9361.94		9923.656	0
Command Area Development	509.26		509.26		510.25		540.865	0
Power	1275		1215		1336.5		1416.69	0
New and Renewable Energy	257		100		103		109.18	0
Village and Small Industries.	7723.83		12369		9141.79		9690.297	0
Industries	45		40		40		42.4	0
Roads and Bridges	59180		59250		57790		61257.4	0
Secretariat-Economic Services	334.53		343.07		449.9		476.894	0
Tourism	400		300		570.06		604.2636	0
Civil Supplies	10344.88		10261.29		14499.34		15369.3	0
Other General Economic Services	314.67		350.23		490.83		520.2798	0
Sector-A-General Services								
Capital Outlay on Medical on Public Works		4403.92		2530.92		1751.35	0	1803.891
Sector-B-Capital Account of								
Capital outlay on Education, Sport, Arts and Culture		37166.48		30899.77		28475.78	0	29330.05
Capital outlay on Medical and Public Health		18287.03		8470.36		4897.65	0	5044.58
Capital Outlay on Water Supply and Sanitation		106326.53		139060		84800	0	87344
Capital Outlay on Housing		13669.65		13715.22		17783.53	0	18317.04
Capital outlay on Welfare of Scheduled Castes, Sheduled Tribes and other Backward Classes		10630.81		16621.28		21692.14	0	22342.9
Capital Outlay on Social Security and Welfare		500		55		11	0	11.33
Capital Outlay on Other Social Services		10017.28		8702.82		6870.55	0	7076.667
Sector-C-Capital Account of Economic Services								
Capital outlay on Animal Husbandry		150		45.36		186.58	0	192.1774
Capital Outlay On Forestry and Wild Life		17221.88		17956.1		19352.43	0	19933
Capital Outlay On Food Storage and Warehousing		152.51		626.28		294.1	0	302.923
Capital Outlay on Co-operation.		1		74.07		1	0	1.03
Capital Outlay on Other Rural		17038		17098		17038	0	17549.14
Development Programme							0	0
Capital Outlay On Other Special		2000		1000		1000	0	1030
Areas Programme							0	0
Capital Outlay on Major Irrigation		150		100		25	0	25.75
(Charged)							0	0
(Voted)		40729.52		34539.18		35257.58	0	36315.31
Capital Outlay on Mediumb Irrigation.		27884.52		49725.23		27699.37	0	28530.35
Capital Outlay on Minor Irrigation.		37129.2		65169.36		63883.93	0	65800.45
Capital Outlay On Power Project		38736		53021		48821	0	50285.63
Capital outlay on Consumer Indusries		50		392.92		50	0	51.5
Capital Outlay on Industries and Minerals		1		1		0	0	0
Capital Outlay on Roads and Bridges		49762		50762		40706	0	41927.18
Capital Outlay on Road Transport		11947.6		11157.65		8310.6	0	8559.918
Capital Outlay on Tourism		1950		3711.03		3753	0	3865.59
Sector-F-Loans And Advances								
Loans for Welfare of Scheduled Caste, Scheduled Tribes, Other Backward Classes and Minorities		1157.05		3000		2051	0	2112.53
Loans for Village and Small Indusries		1		1		0	0	0
Loans for Road Transport		2108.4		2194.15		2863.9	0	2949.817
Gross Total	**829884.61**	**449171.38**	**868015.65**	**530629.7**	**911545.85**	**437575.49**	**966238.6**	**450702.8**

Urban Dev & Urban Housing

Budget Estimates								
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	17958.86		18602.24		20001.91		20601.9673	0
Sector-B-Social Services								
General Education (Charged)	3000.00		3000.00		3000		3090	0
General Education (Voted)	15000		16500.00		22075		22737.25	0
Water Supply and Sanitation	10921.27		24814.24		13486.03		13890.6109	0
Housing	101930.8		99444.03		68406.91		70459.1173	0
Urban Development	869310.33	3000	903617.59	1501	923539.41	50200	951245.5923	51706
Social Security and Welfare	35.94		39.00		44.4		45.732	0
Secretariat-Social Services	584.61		599.47		641.74		660.9922	0
Sector-C-Economic Services								
Ecology and Environment	1.00		1.00		20000		20600	0
Other General Economic Services	3109.07		4163.08		9585.96		9873.5388	0
Sector-D-Grants-in-aid- and Contributions								
Compensation and Assignments to Local Bodies and Panchayati Raj Institutions	820.00		820.00		820.00		844.6	0
Sector-F-Loans And Advances								
Loans for Urban Development		59200.00	0	50000.00		10320.75	0	10630.3725
Loans to Government Servants etc.		6.00	0	1.00		1.0	0	1.03
Gross Total	**1022671.88**	**62206.00**	**1071600.65**	**51502.00**	**1081601.4**	**60521.8**	**1114049.401**	**62337.4025**

Women and Child

	Budget Estimates							
	2018-19	2018-19	2019-20	2019-20	2020-21	2020-21	2021-22	2021-22
Major head	Revenue Account (Rs. in lakhs)	Capital account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)	Revenue Account (Rs. in lakhs)	Capital Account (Rs. in lakhs)
Sector-A-General Services								
Interest Payments (Charged)	90.00		85.00		85.00		87.55	0
Sector-B-Social Services								
Social Security and Welfare	23224.85	2	45222.29	182	43787.56	181	45101.1868	190.05
Nutrition	199887.18	11333	184685.6	4299.59	180887.61	9124.59	186314.238	9580.8195
Secretariat-Social Services	405		886.26		571.96		589.1188	0
Sector-F-Loans And Advances								
Loans to Government Servants etc.		9.00		5.5		0.6	0	0.63
Gross Total	**223607.03**	**11344.00**	**230879.15**	**4487.09**	**225332.13**	**9306.19**	**232092.094**	**9771.4995**

Annexure-2: Stakeholder Meeting Participants

Name	Affiliation
Dr. Narottam Sahu	GUJCOST
Shri R.H. Bhabhor	Department of Science & Technology
Shri A. P Makwana	Department of Ports & Transport
Shri B.V. Ruthra	Department of Education
Dr. Nisarg Joshi	Energy and Petrochemicals Department
R. J. Valy	Gujarat Urja Vikas Nigam Limited
Shri Paras Sanghvi	Urban Development Department
Kum. Jayshree Vasava	Women & Child Development Department
Shri Bharat Patel	Revenue Department
Shri Asar Gadhvi	Finance Department
Shri K. S. Maccwan	General Administration Department
Shri G. S. Rana	General Administration Department
Shri M. L. Bhagora	Panchayats, Rural Housing and Rural Development Department
Shri Sanketsingh Vaghela	Department of Forests and Environment
Dr. Yasmin Diwan	Agriculture, Farmer's Welfare and Co-operation Department
Shri B.S. Mehta	Industries and Mines Department
Shri Manish Pandya	General Administration Department

Annexure-3: Contributor's to Gujarat's SAPCC

- Shri S. J. Haider (Climate Change Department)
- Shri Mukesh Shah (Climate Change Department)
- Shri Rajesh Patel (Climate Change Department)
- Shri Shwetal Shah (Climate Change Department)
- Prof Amit Garg (IIM Ahmedabad)
- Prof. Vimal Mishra (IIT Gandhinagar)
- Prof. Udit Bhatia (IIT Gandhinagar)
- Dr. Vidhee Avashia (IIM Ahmedabad)
- Dr. Harsh Shah (IIT Gandhinagar)
- Mr. Jaypal singh Chauhan (IIM Ahmedabad)
- Ms. Jyoti Maheshwari (IIM Ahmedabad)
- Mr. Paresh Amleshwarwala (IIM Ahmedabad)
- Mr. Jigar Shah (IIM Ahmedabad)
- Ms. Pavithra Vijaykumar (IIM Ahmedabad)
- Ms. Aradhya Agarwal (IIM Ahmedabad)
- Mr. Saran Adhar (IIT Gandhinagar)
- Mr. Anuj Kushwaha (IIT Gandhinagar)
- Mr. Shanti Swarup Mahto (IIT Gandhinagar)

Annexure-4: Abbreviations

AC	Air Conditioners
AMC	Ahmedabad Municipal Corporation
AMRUT	Atal Mission on Rejuvenation and Urban Transformation
BLY	Bachat Lamp Yojana
BEE	Bureau of Energy Efficiency
BPL	Below Poverty Line
BCM	Billion Cubic Meter
BNU-ESM	Beijing Normal University Earth System Model
BRTS	Bus Rapid Transit System
CCS	Carbon Capture and Storage
CEA	Central Electricity Authority
CWC	Central Water Commission
CERs	Certified Emission Reductions
CESM1-CAM5	Community Atmospheric Model version 5
CFL	Compact Fluorescent Lamp
CMIP5	Climate Model Intercomparison Project
CMCCC	Chief Minister's Council on Climate Change
CO2e	Carbon Dioxide Equivalent
CRZ	Coastal Regulation Zone
CEIFs	Common Environment Infrastructure Facilities
CWMI	Comprehensive Water Management Index
CNG	Compressed Natural Gas
DFC	Dedicated Freight Corridor
D-SIR	Dholera Special Investment Region
DRR	Disaster Risk Reduction
DMIC	Delhi–Mumbai Industrial Corridor
DELP	Domestic Efficient Lighting Programme
EV	Electric Vehicles
DISCOM	electricity distribution companies
ECBC	Energy Conservation Building Code
EEFP	Energy Efficiency Financing Platform
EESL	Energy Efficiency Services Ltd.
ESCerts	Energy Savings Certificate
ESCO	Energy Services Company
EOR	Enhanced Oil Recovery
FAME	Faster Adoption and Manufacturing of Electric vehicles
FEEED	Framework for Energy Efficient Economic Development

FSI Forest Survey of India	
GAIC Gujarat Agro Industries Corporation Limited	
GAIL Gas Authority of India Ltd	
GDP Gross Domestic Product	
GEDA Gujarat Energy Development Agency	
GEV Generalized Extreme Value	
GFDL-ESM2M Earth System Model – Geophysical Fluid Dynamics Laboratory	
Gg Gigagrams	
GHG Greenhouse Gas	
GIDC Gujarat Industrial Development Corporation	
GIS Geographic Information System	
GTWGs Global Technology Watch Groups	
GNFC Gujarat Narmada Valley Fertilisers & Chemicals	
GoG Government of Gujarat	
GoI Government of India	
GPCB Gujarat Pollution Control Board	
GSVA Gross State Value Added	
GSDP Gross State Domestic Product	
GSEG Gujarat State Energy Generation Ltd	
GUDA- Gujarat Urban Development Company Limited	
GEC Gujarat Ecology Commission	
GERC Gujarat Electricity Regulatory Committee	
GGCL Gujarat Gas Company Ltd	
GGRC Gujarat Green Revolution Company	
GIDM Gujarat Institute of Disaster Management	
GLPC Gujarat Livelihood Promotion Company	
GMRC Gujarat Metro Rail Corporation	
GSDMA Gujarat State Disaster Management Authority	
GSPC Gujarat State Petroleum Corporation	
GSRTC Gujarat State Road Transport Corporation	
GUVNL Gujarat Urja Vikas Nigam Ltd.	
IMD Indian Meteorological Department	
ISRO Indian space Research Organization	
IPCC Intergovernmental Panel on Climate Change	
JGY Jyotigram Yojana	
JJAS June, July, August and September	
km2 square kilometre	
kW kilowatt	
kwh kilowatt-hour	
LED Light Emitting Diode	
LNG Liquefied Natural Gas	
LULUCF Land use, Land-use Change, and Forestry	
MTEE Market Transformation for Energy Efficiency	

MRTS Metro Rail Transit System

MEGA Metro-Link Express for Gandhinagar And Ahmedabad

MGNREGA Mahatma Gandhi National Rural Employment Guarantee Act

MSMEs Micro, Small, and Medium Scale Enterprises

MoEFCC Ministry of Environment, Forests and Climate Change

MNRE Ministry of New and Renewable Energy

MoP Ministry of Power

mm millimeters

MOFPI Ministry of Food Processing Industries

MoHFW Ministry of Health and Family Welfare

MoSPI Ministry of Statistics and Programme Implementation

MPI-ESM-LR Max-Planck-Institut für Meteorologie Earth System Model

MSW Municipal Solid Waste

MW Megawatts

NMC Narmada Main Canal

NAPCC National Action Plan on Climate Change

NDM National Disaster Management

NH National highway

NMEEE National Mission for Enhanced Energy Efficiency

NRLM National Rural Livelihood Mission

NDC Nationally Determined Contribution

NPP Net Primary Productivity

NITI National Institution for Transforming India

NTFP Non-Timber Forest Produce

NorESM1-M Norwegian Climate Center´s Earth System Model

NTPC National Thermal Power Corporation

ONGC Oil and Natural Gas Corporation

PCCA Paris Climate Change Agreement

PAT Perform, Achieve and Trade

PCPIR Petroleum, Chemicals and Petrochemicals Investment Region

PMP Phased Manufacturing Programme

PHPDT Passengers per hour per direction

PIM Participatory Irrigation Management

PM KUSUM Pradhan Mantri Kisan Urja Suraksha evem Utthan Mahabhiyan

R&D Research & Development

REC Renewable Energy Certificate

RPO Renewable Purchase Obligation

RCP Representative Concentration Pathway

SGL Sabarmati Gas Ltd

SAUNI Saurashtra Narmada Avtaran Irrigation

SST Sea Surface Temperature

SFDRR Sendai Framework for Disaster Risk Reduction

STP Sewage Treatment Plants

SHG	Self Help Groups
PV	Photovoltaic
SAC	Space Application Centre
SREX	Special Report: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
SEC	Specific Energy Consumption
SSP	Sardar Sarovar Project
SOP	Standard Operating Procedure
SPI	Standardized Precipitation Index
SPEI	Standardized Precipitation-Evapotranspiration Index
SAPCC	State Action Plan on Climate Change
SLNP	Street Light National Programme
SKY	Suryashakti Kisan Yojana
SDG	Sustainable Development Goal
T&D	Transmission and Distribution
UNFCCC	United Nations Framework Convention on Climate Change
UNCTAD	United Nations Conference of Trade and Development
UJALA	Unnat Jyoti by Affordable LEDs for All
ULB	Urban Local Bodies
VER	Verified/Voluntary Emission Reduction
WUA	Water Users' Association
WHO	World Health Organization