KARNATAKA STATE ACTION PLAN ON CLIMATE CHANGE

VERSION 2

DRAFT REPORT

ENVIRONMENTAL MANAGEMENT AND POLICY RESEARCH INSTITUTE (EMPRI)

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Chapter 1: Introduction

1.1. Background and Context

In recent decades, changes in climate have caused impacts on natural and human systems across all continents. Climate change involves complex interactions and changing likelihoods of diverse impacts. Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal the vulnerability and increasing exposure of some ecosystems and many human systems to current climate variability.

The UNFCCC formed in 1992 prescribed a code of conduct for action among nations to achieve climate justice. Nations around the world, initiated actions as part of international commitments, as well as national requirements. In 2015, the Paris Agreement set forth international environmental jurisprudence for achieving common goals. Many countries came forward to hold the increase in global average temperature to well below 2°C above pre-industrial levels, increasing the ability to adapt to the adverse impacts of climate change, and lowering greenhouse gas (GHG) emissions, while promoting climate resilient development. Intervention areas proposed by countries included renewable energy, water management, agriculture, forestry, waste management and public transport.

The 2030 agenda for global sustainable development envisioned that development and application of technology are climate-sensitive, respect biodiversity and are resilient. One of the major goals is to take urgent action to combat climate change and its impacts. Emphasis is to be laid on cross-sectoral planning for recognizing and incorporating interacting priorities, such as agriculture, health, forestry, land-use planning, water resources, energy, education, etc.

Climate variability and extremes, and sustainable development have long been important in many decision-making contexts. Responding to climate-related risks involves decision making in a changing world, with continuing uncertainty about the severity and timing of climate-change impacts. Adaptation and mitigation choices in the near term will affect the risks of climate change throughout the 21st century. Thus, there is an urgent need to consider how impacts and risks related to climate change can be reduced and managed through adaptation and mitigation, while taking into consideration system vulnerabilities, for sustainable development.

The Government of India (GoI) released The National Action Plan on Climate Change (NAPCC) in June 2008 emphasising on appropriate long-term mitigation strategies for promoting sustainable development and growth with climate "co-benefits". The NAPCC has a clear set of actions in each of the key sectors of governance concerning natural resources (land, water, forests, biodiversity, etc.), energy, agriculture, infrastructure development and industry. The NAPCC through its sectoral missions provided a detailed road map for achieving the desired objectives. The NAPCC was to be implemented by each of the states through State Action Plans on Climate Change (SAPCC), approved and facilitated by the Indian government. Post the Paris Agreement and the NDC goals and targets, states are bound to assess their climate actions based on domestic priorities under the SAPCC and link them to key metrics that ensure alignment with India's goals under the NDC.

The Ministry of Environment, Forest & Climate Change (MoEF&CC) formulated and circulated a common framework for revision of SAPCC in 2019, clearly outlining 10 principles (Figure 1.1).

Principle 1

- SAPCCs should be a policy document of the States/UTs outlining the major initiatives and strategies reflecting the commitments and proposed actions in the state to tackle the vulnerabilities and impacts of climate change across the socio-economic sectors

Principle 2

- SAPCCs should envisage an inclusive, sustainable and climate resilient low carbon development pathways with a focus on climate change adaptation and mitigation within the key sectors in the States/UTs and should protect the poor and vulnerable sections of society from adverse effects of climate change

Principle 3

- SAPCCs should consider recent scientific assessments and projections on global warming vulnerability and impacts

Principle 4

- SAPCC should highlight the links with National Missions related to climate change

Principle 5

- SAPCC should also be built on the evolving socio-economic development context and priorities of the state

Principle 6

- States/UTs can strengthen existing climate action measures as well as launch new initiatives in their priority sectors Some of the initiatives can be introduced in the areas of efficient and cleaner technologies, promoting renewable energy generation, reducing emissions from transport sector, afforestation and greening activities and standardising knowledge management system for adaptation and mitigation

Principle 7

- Time period of the implementation of SAPCCs should be clearly brought out starting with the implementation cycle of NDCs i e 2021 2030 and beyond

Principle 8

- Financial resources required for the implementation of the action plan should primarily be leveraged from the existing budget of the State Governments and convergence with the relevant schemes and programmes

Principle 9

- SAPCCs should set out the institutional mechanism for implementation including stakeholder engagement ensuring inclusiveness along with the mechanism for capacity building and monitoring and evaluation with clear indicators for reporting

Principle 10

- SAPCCs should set out the institutional mechanism for implementation including stakeholder engagement ensuring inclusiveness along with the mechanism for capacity building and monitoring and evaluation with clear indicators for reporting

Figure 1.1: A common framework for revision of State Action Plan on Climate Change (Source: MoEFCC, 2019)

It is evident from the common framework that the revised SAPCC should not only envisage inclusive and sustainable development but climate-resilient low carbon development, and the vulnerability of poor sections of the society be tackled through a clear plan that is backed by latest knowledge, science, models, finance and institutional mechanisms.

1.2. Karnataka's SAPCC V.1

The Environmental Management and Policy Research Institute (EMPRI), Bengaluru, an autonomous body of the Department of Forest, Ecology and Environment, Government of Karnataka prepared the SAPCC for Karnataka. The Action Plan was endorsed by MoEF&CC, GoI in 2015. The SAPCC examined climate trends, projected vulnerabilities and outlined mitigation and adaptation priorities for the state. It included a review of policies and programmes for possible mainstreaming of climate change. It provided Karnataka's first comprehensive assessment of sectors that could be significantly impacted by climate change and highlighted various challenges and provided feasible action points to be implemented by various sectors in the state (SoER Karnataka, 2015).

The SAPCC V.1 was however conceived, mainly in response to developmental priorities. The concept of "green growth" articulated as "rethinking growth strategies with regard to their impacts on environmental sustainability and environmental resources availability to poor and vulnerable groups" formed the basic underlying principle of the action plan. The SAPCC comprised a set of 200 action points necessary to enhance Karnataka's preparedness for climate change spanning all key sectors. Many of these were proposed to foster the pursuit of sustainable development while enhancing climate change resilience. Subsequent to approval of the SAPCC, there have been efforts in the state to incorporate green growth concepts into planning mechanisms such as Low Emissions Development Strategies (LEDS), sustainable development, climate change resilience and response, and clean energy and sustainable land use.

SAPCC V.1 presented an assessment of historical climate trends and projections. It investigated possible impacts on natural resources and livelihoods such as agriculture, animal husbandry, fisheries, water resources, forests, biodiversity, wildlife, urbanization, health and energy. It also presented an inventory of GHG emissions. In SAPCC V.1, specific attention was given to the sensitive and fragile eco-zones of the Western Ghats, the coastal belt as well as to the semi-arid zone of north eastern Karnataka. The document was structured around key sectors which are the responsibility of specific government departments. Each chapter outlined the sector's significance for the state, followed by an analysis of trends and an assessment of projections vis-à-vis possible impacts of climate change and emerging vulnerabilities. Likewise, actions of Government of Karnataka and its policies that have a bearing on the way climate change may impact the respective sectors were reviewed, leading to identification of areas where interventions were needed.

Keeping the underlying principles of sustainable development, 31 priority areas were identified by SAPCC V.1 for the different sectors. A few priority areas identified included:

- ***Agriculture:*** Restructuring of agricultural power tariffs, creation of a policy body for devising cropping shifts, promoting dry land farming, rendering theft of sprinkler pipes unviable, creating a market for indigenous agricultural crops, etc.
- ***Animal Husbandry:*** Formulation of livestock insurance policy, expansion of breeding of indigenous cattle breeds, and increasing fodder production
- ***Water Resources:*** Enforce Karnataka Groundwater Act, create policy body for restricting groundwater use, introduce groundwater cess, devise capital subsidy for rainwater harvesting structures, integrate water resource management in public buildings, and revise pricing policy for irrigation water.
- ***Forest and Biodiversity:*** Estimate the carrying capacity of the Western Ghats, respond to invasion of alien species and clear forest encroachments.
- ***Coastal Zone:*** Promote effluent treatment plants, mangrove replanting, etc.
- ***Energy:*** Stabilizing the grid supply voltage, strategising energy audits, notifying the Energy Conservation Building Code, implementing NAPCC's Market Transformation for Energy Efficiency, scaling-up contributions from renewable energy sources, review of barriers in wind energy deployment, large-scale biofuel substitution in the transport sector, achieving greater deployment of improved *chulhas*, etc.

Other interventions proposed included conduct of regional research on climate change, documentation of adaptation practices and introduction of SAPCC updation process.

1.3. Why Update SAPCC?

Revision of SAPCC is needed because climate science has advanced, and there have been many developments in international climate negotiations and commitments of countries around the world. Broadly there are three main reasons for updating the SAPCC. They include:

- GoI has signed the Paris Agreement
    - This requires reducing GHG emissions and adaptation to climate change
- GOI has prepared and submitted the Nationally Determined Contribution to the United Nations Framework Convention on Climate Change (UNFCCC), that encompass:
    - Mitigation to reduce GHG emission intensity
    - Creation of carbon sink
    - Promotion of adaptation to climate change
- Scientific advancement
    - Improved climate model projections

- New climate change impact models
- New vulnerability/risk framework from the Intergovernmental Panel on Climate Change (IPCC)

Additionally, SAPCC revision is an opportunity to evaluate and quantify the benefits of adaptation and mitigation strategies planned and implemented through SAPCC V.1, and to estimate the standards of achieved green growth. It also provides an opportunity to adopt a green growth roadmap for Karnataka, incorporating the principles and practices into developmental projects, and screening for projects, and modes of implementation and execution strategies such as project design documents or policy implementation roadmaps. Recently, EMPRI in collaboration with Indian Institute of Science, Bangalore developed a toolkit for Green index development, which enables the auditing of government schemes and projects as per the guidelines and government orders developed for their implementation. The approach encompasses steps spanning the creation of a congenial policy environment to establishment of a baseline prior to implementation of green growth strategies and an analysis of the various options.

Finally, a revised SAPCC based on latest science will serve as the basis for seeking funding from Adaptation Fund of GoI, the Green Climate Fund, GEF, etc., and also from multilateral and bilateral agencies such as World Bank, ADB, UN agencies, kFW, SDC, DFID, GIZ, etc., for mitigation and adaptation projects.

1.4. Preparation of SAPCC V.2 - The Process and New Additions

As per the directives of the Ministry of Environment, Forest and Climate Change, Karnataka State initiated the process of revising its SAPCC in June 2019. The Core Group was constituted under the Chairmanship of Additional Chief Secretary and Development Commissioner, Government of Karnataka and as decided, chapter-wise discussion meetings were held to discuss the broad outline of each of the chapters, and representatives from various research and academic institutes were involved in writing chapters. Four modelling projects (climate change impact modelling for water resources, agriculture and forestry sectors and sectoral mitigation assessment) were assigned to reputed institutes.

In the SAPCC V.2 , the following advancements over SAPCC V.1 are adopted:

- Use of CORDEX 15-model ensemble for district level climate change projections for two periods—2030s and 2080s for two emission—RCP 4.5 (moderate emission) and RCP 8.5 (High emission) scenarios.
- Use of ensemble data on temperature and rainfall as input data for climate impact modelling of agriculture and forest sectors.
- Adoption of IPCC (2014) risk framework for vulnerability assessment.
-

Chapter 2: State Profile

2.1. Location and Geography

Karnataka has a total geographical area of 191,791 km^2 accounting for 5.83% of the total geographical area of India. By area, it is the sixth largest state of India. It is situated on the western edge of the Deccan Peninsula, and is located approximately between 11.5° N and 18.5° N latitudes and between 74° E and 78.5° E longitudes. The state is bounded by Goa to the northwest, Maharashtra to the north, Telangana and Andhra Pradesh to the east, Tamil Nadu to the south east and Kerala to the southwest. The western part is flanked by the Arabian Sea. The southern corner of the state is seated at an angle where the Western Ghats and the Eastern Ghats converge into the Nilgiri hills. The state extends to about 760 km from north to south and about 420 km from east to west. The capital of Karnataka state is Bengaluru (Bangalore).

Karnataka comprises parts of the Deccan Plateau, the Western Ghats Mountain Range and the Coastal Plains. The state can be divided into four physiographic landforms – the Northern Karnataka Plateau, the Central Karnataka Plateau, the Southern Karnataka Plateau and the Coastal Karnataka Region.

- The Northern Karnataka Plateau covers the districts of Belagavi, Bidar, Vijayapura, Yadgir and Kalaburagi. The Northern Plateau has an elevation of 300 metres to 600 metres from the sea level and slopes towards the east. The landscape is mainly covered with rich black cotton soil. The vast expanse of treeless plateau is interspersed with river plains, watersheds, residual hills and ridges. The river plains are represented by river Bhima, Ghataprabha, Krishna and Malaprabha.
- The Central Karnataka Plateau consists of the districts of Ballari, Chikkamagaluru, Chitradurga, Davanagere, Dharwad, Gadag, Haveri, Raichur, Koppal and Shivamogga. The elevation of the Central Plateau varies between 450 metres and 700 metres and slopes towards the east. The Tungabhadra river basin is located in this region.
- The Southern Karnataka Plateau includes the districts of Bengaluru Urban, Bengaluru Rural, Tumakuru, Ramanagara, Hassan, Kodagu, Kolar, Chikballapur, Mandya, Mysuru, and Chamarajanagar. This region is encircled by the Western Ghats on the west and the south, where the terrain has a high degree of slope. The Southern Plateau has a general elevation of 600 metres to 900 metres. But the Biligirirangan hills of Mysore district and the Brahmagiri range of Kodagu district have residual heights ranging between 1,500 metres to 1,750 metres. The Cauvery river basin forms a significant part of this plateau.
- The Coastal Karnataka region starts from the Western Ghats in the west and extends till the edge of the Karnataka Plateau in the east. The coastal region includes the districts of Uttara Kannada, Udupi and Dakshina Kannada. The terrain of this region

consists of rivers, creeks, waterfalls, ranges of hills and peaks. The coastal belt has an average width of 50 km to 80 km. It covers a distance of around 320 km from north to south.

2.2. Demographic Profile

The state of Karnataka is divided into 30 districts ((Figure 2.1) and 176 taluks, spanning 29,340 villages, and 347 cities and towns.

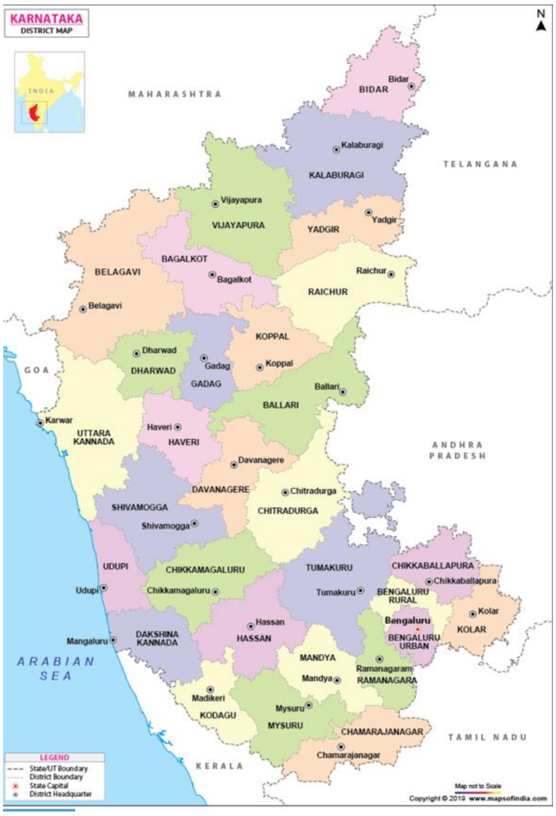


Figure 2.1: Karnataka state and districts (Source: Maps of India)

2.2.1. Population

In terms of population, Karnataka is the eighth largest state of India. As per the Census of India 2011, Karnataka had a population of 611,30,704 individuals (3,10,57,742 males and 3,00,72,962 females), comprising 5.05% of the country's population.

Population Trends - Rural and Urban

During the decade 2001-11, the state population witnessed a net addition of 82,80,142 persons to its 2001 population of 5,28,50,562. The male population increased by 41,58,824 and the female population increased by 41,21,318. Continuing the population growth trends of previous censuses, the state registered a growth rate of 15.67% over the 2001 Census, recording a decline of -1.84% in comparison with the growth of 17.51% registered during the 2001 Census over the 1991 Census.

The rural population of 3,75,52,529 grew at the rate of 7.63%, substantially less than the growth rate of 12.29% registered during the decade 1991-2001, the urban population (2,35,78,175) registered a growth rate of 31.27%, slightly higher than the growth rate of 29.15% recorded in 2001 Census (Figure 2.2).

Among the districts, Bengaluru Urban district, has witnessed the highest decennial growth rate of 46.68% followed by Yadgir, the newly created district, with 22.67%. Chikkamagaluru district, a predominantly coffee-growing district in the *Malnad* region, is the only district in the state which has registered a negative growth rate of -0.28%. Kodagu district another coffee-growing district in the *Malnad* region with a growth rate of 1.13% ranks 29, just above Chikkamagaluru district.

Only seven districts have registered decennial growth rates higher than the State average of 15.67%. Of the remaining 23 districts as many as 14 districts have registered a growth rate of below 10%.

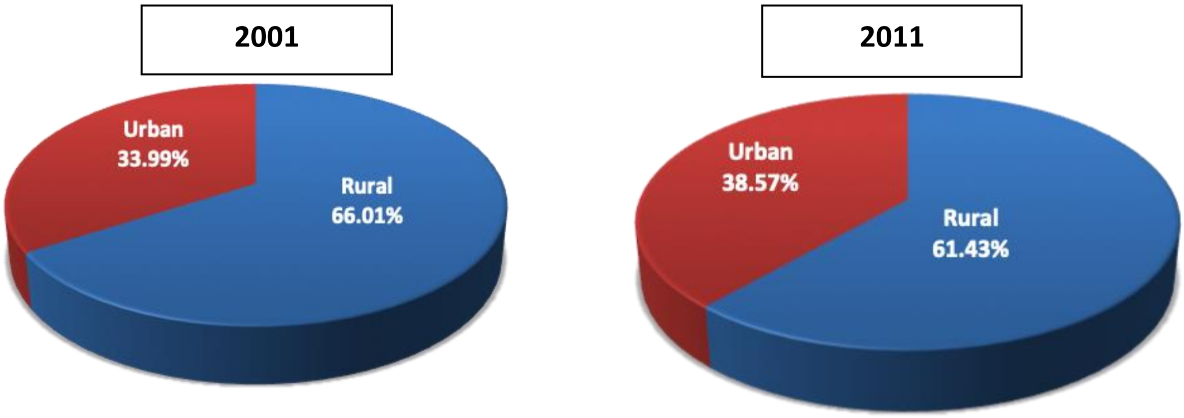


Figure 2.2: Proportion of rural and urban population in Karnataka during 2001 and 2011

2.2.2. District Wise Population: Rural and Urban

Bengaluru Urban district is the most populated district with 95,88,910 persons and accounts for 15.68% of the State's total population while Kodagu district with a population share of 0.90% is the least populated district. Except, Bengaluru Rural (9,87,257) and Kodagu (5,54,762) districts, the remaining 28 districts have population higher than one million. Of the 6,11,30,704 persons enumerated in the State, 3,75,52,529 persons reside in rural areas and 2,35,78,175 persons reside in urban areas.

In terms of urbanization, the State has witnessed an increase of 4.58% in the proportion of urban population in the last decade. Among the districts, Bengaluru is the most urbanized district with 90.93% of its population residing in urban areas followed by Dharwad (56.82%), Dakshina Kannada (47.59%), Mysuru (41.35%) and Ballari (36.30%). The least urbanized district in the State is Kodagu with 14.61%, preceded by Koppal (16.79%), Mandya (17.07%), Chamarajanagar (17.16%) and Yadgir (18.79%) as shown in Table 2.1.

The rural population grew at the rate of 7.63%, substantially less than the growth rate of 12.29% registered during the decade 1991-2001, while the urban population registered a growth rate of 31.27%, slightly higher than the growth rate of 29.15% recorded in 2001Census.

Table 2.1: District wise rural and urban population in Karnataka

State/District	Population			Percentage decadal growth (2001-2011)		
	Total	Rural	Urban	Total	Rural	Urban
Karnataka	61130704	37552529	23578175	15.67	7.63	31.27
Bagalkot	1890826	1292036	598790	14.46	10.11	25.13
Ballari	2532383	1613038	919345	24.92	22.17	30.06
Belgaum	4778439	3567739	1210700	13.38	11.43	19.55
Bengaluru Rural	987257	719564	267693	16.02	9.25	39.18
Bengaluru Urban	9588910	868971	8719939	46.68	11.82	51.39
Bidar	1700018	1276647	423371	13.16	10.29	22.76
Bijapur	2175102	1674311	500791	20.38	18.68	26.43
Chamarajanagar	1020962	845669	175293	5.75	3.46	18.37
Chikballapur	1254377	975188	279189	9.17	5.09	26.32
Chikkamagaluru	1137753	898079	239674	-0.28	-2.19	7.61
Chitradurga	1660378	1332012	328366	9.39	7.10	19.74
Dakshina Kannada	2083625	1091888	991737	9.80	-6.55	35.98
Davanagere	1946905	1317816	629089	8.71	5.60	15.85
Dharwad	1846993	797430	1049563	15.13	10.40	19.01
Gadag	1065235	685450	379785	9.61	8.86	10.99
Hassan	1776221	1399214	377007	3.17	-1.25	23.74
Haveri	1598506	1242442	356064	11.08	8.98	19.08
Kalaburagi	2564892	1732298	832594	17.94	16.64	20.74
Kodagu	554762	473659	81103	1.13	0.10	7.59
Kolar	1540231	1056953	483278	11.04	7.57	19.48
Koppal	1391292	1157659	233633	16.32	16.02	17.82
Mandya	1808680	1499831	308849	2.55	1.27	9.24
Mysuru	2994744	1756412	1238332	13.39	5.88	26.09
Raichur	1924773	1437359	487414	15.27	15.09	15.82
Ramanagara	1082739	815386	267353	5.06	-0.01	24.31
Shivamogga	1755512	1132286	623226	6.88	5.67	9.14
Tumakuru	2681449	2078665	602784	3.74	0.06	18.84
Udupi	1177908	843829	334079	5.90	-6.85	61.90
Uttara Kannada	1436847	1018216	418631	6.15	5.43	7.92
Yadgir	1172985	952482	220503	22.67	20.09	35.23

Source: Census of India, 2011

2.2.3. Occupation Pattern

The socio-economic development of a region is reflected in the proportion of workers engaged in various occupations. Occupation is always related to agriculture, industry and service sectors (Prasad and Pratap, 2017). The worker population ratio (WPR) indicates the proportion of workers/employed persons in the total population. WPR for Karnataka is 49.1% which is more than the all India average of 46.8%. The state average male and female worker population ratios (74.0% and 24.8%) are higher than the all India average. According to the nature of the work, there are three categories viz., self-employed, wage/salaried, and casual labourers. In Karnataka, the highest number of persons are self-employed (47.8%), followed by casual labourers (26.8%) and wage earners (25.4%). The State averages for casual workers and wage earners are higher than the national averages of 24.9% and 22.8%, respectively.

According to Census 2011, the Work Participation Rate (WPR) is defined as the proportion of total workers (i.e. main and marginal workers) to the total population. In Karnataka, 2,78,72,597 persons constituting 45.62% of the total population have enumerated themselves as workers. Among them, 1,82,70,116 (59%) are males and 96,02,481 (31.87%) are females. Among all the districts, Chitradurga with a WPR of 51.62% occupies the top position, followed closely by Chikballapur, Hassan, Tumakuru and Kodagu with WPR of more than 50% (Table 2.2). The lowest WPR of 41.25% is recorded in Bidar preceded closely by Uttara Kannada, Kalaburagi, Dharwad and Vijayapura with WPR between 42 and 43%. The highest proportion of male workers is registered in Mandya (63.55%) and the lowest proportion of male workers is recorded in Vijayapura (52.21%). Among female workers, the highest proportion is recorded in Chitradurga (41.93%) and the lowest proportion in Bengaluru (24.61%).

Table 2.2: District wise Work Participation Rate (WPR) – 2011 (in percentages)

Districts with highest WPR

District	**Total**	**Rural**	**Urban**
Chitradurga	51.62	55.13	37.43
Chikkaballapur	50.97	54.34	39.32
Hassan	50.87	54.55	37.17
Tumakuru	50.57	53.86	39.13
Kodagu	50.30	51.96	40.62

Districts with lowest WPR

District	**Total**	**Rural**	**Urban**
Vijayapura	42.61	45.40	33.30
Dharwad	42.49	51.06	35.98
Kalaburagi	42.36	46.64	33.49
Uttara Kannada	42.34	45.50	34.66
Bidar	41.25	44.33	32.00

Main and Marginal Workers: Of the total workers (2,78,72,597) in the State, main workers and marginal workers constitute 83.94% and 16.06% respectively. The proportion of main workers has marginally increased from 82.28% in 2001 to 83.94% in 2011. On the contrary, the proportion of marginal workers has slightly decreased from 17.72% in 2001 to 16.06% in 2011. According to census definition, total workers (main and marginal) have been further classified into four broad categories viz` cultivators, agricultural labourers, workers in household industry and other workers.

The number of agricultural labourers has increased in the State by 14.92% during 2001 to 2011. The State average of agricultural labourers is 25.7%. The proportion of male agricultural labourers has increased by a nominal 0.77% whereas that of females has registered a decline of 3.12%. The number of cultivators has decreased by 5.64% during the same period. The total number of workers engaged in household industry in the State are 9,13,227 persons, but the proportion has declined to 3.28% in 2011 from 4.08% in 2001. Workers other than agricultural labourers, cultivators or household industry are categorized as Other Workers and they account for 47.44% of total workers at the State level. In comparison to 2001 Census, the proportion of Other Workers has increased by 7.23% in 2011 Census. The proportion of male 'Other Workers' has increased from 48.42% to 53.61% and the proportion of female 'Other Workers' has increased from 25.16% to 35.71%.

2.3. Economic Profile

Karnataka state is on the mission to promote faster and inclusive growth. The advance estimates as per the Economic Survey of Karnataka, 2019-20 show that the Gross State Domestic Product (GSDP) at current prices is estimated to attain Rs. 1,699,115 crores at a growth rate of 10.0% and Rs. 1,201,031 crores with an expected growth rate of 6.8% at constant (2011-12) prices.

Gross State Domestic Product (GSDP) is the most important indicator in measuring the economic growth of a State. Karnataka has released advance estimates of GSDP for the year 2019-20. At current prices, the GSDP is anticipated to reach Rs. 16,99,115 crores with a growth of 10.0% and GDP to a level of Rs. 2,04,42,233 crores with a growth rate of 7.5%. The share of Karnataka's GSDP in All India GDP is 8.3% during 2019-20 (Figure 2.3).

As per the recent Karnataka budget for the financial year 2020-21, the Gross State Domestic Product (GSDP) of Karnataka for 2020-21 (at current prices) is estimated to be Rs. 18,05,742 crores. This is 6.3% higher than the revised estimate of 2019-20. The Gross State Value Added (GSVA) growth rate of the agriculture sector has increased to 3.9% in 2019-20 compared to -1.6% in 2018-19 on account of increase in production of food grains from 128 lakh tonnes to 136 lakh tonnes, oilseed production from 51 lakh tonnes to 56 lakh tonnes when compared to 2018-19. Similarly, in the livestock sector, milk production is anticipated to increase from 79 lakh tonnes to 88 lakh tonnes, egg production from 54 to 59 lakh and meat production from 1.1 lakh tonnes to 1.27 lakh tonnes. Fish production has also increased in 2019-20 (marine fish from 3.6 to 4 lakh tonnes, inland fish from 1.9 to 2.5 lakh tonnes) compared to 2018-19. The industry sector (comprising mining & quarrying, manufacturing, construction & electricity, gas & water supply) is expected to grow by 4.8% in 2019-20 against a growth of 5.6% during 2018-19. The service sector is expected to grow by 7.9% during 2019-20 compared to growth of 9.8% during 2018-19. The service sector is a major contributor to the overall GSDP as the share of the private corporate sector to this sector is significantly higher compared to other sectors.

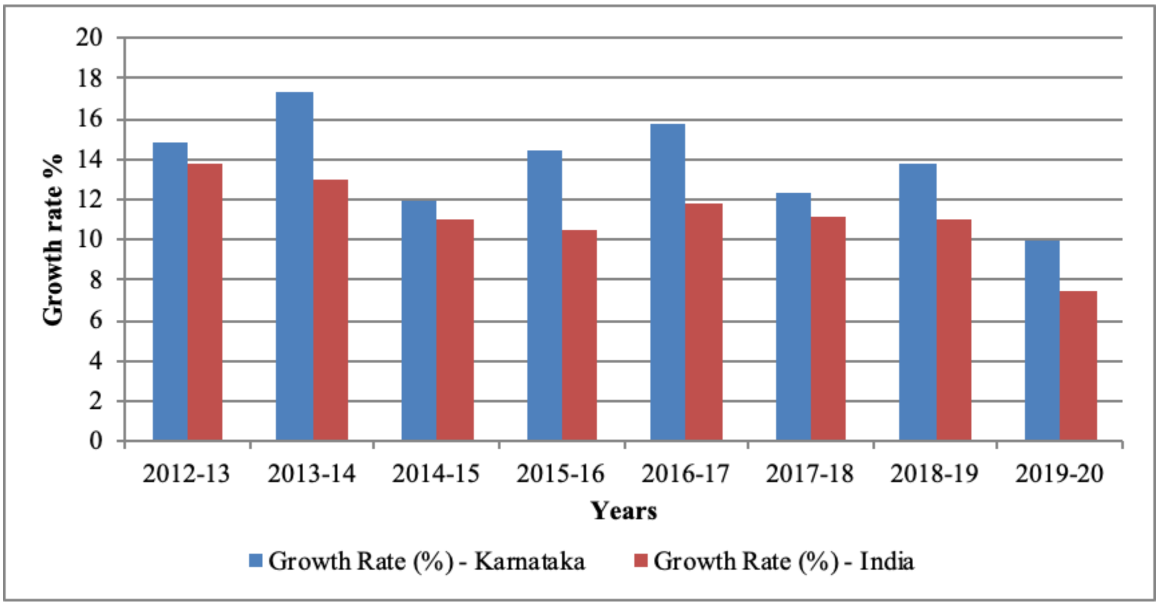


Figure 2.3: Annual growth rate of GSDP and GDP at current prices

In 2019-20, other services sector (Education, Health and other remaining services) with 11.2%, Real Estate, Professional Services & Ownership of Dwellings with 8.6%, Public Administration with 8.0%, Trade and Repair Services with 6.5% growth are the major contributors of the service sector to achieve the overall state economy growth rate. The advance estimates of Gross State Domestic Product (GSDP) of Karnataka for the year 2019-20 highlight that at constant (2011-12) prices the GSDP is likely to attain a level of Rs. 12,01,031 crores with a growth of 6.8%. The sectoral growth rate of Agriculture, Industry, and Services is expected to grow at 3.9%, 4.8%, and 7.9% respectively.

The per capita state income (i.e. per capita NSDP) at current prices is estimated at Rs. 2,31,246 during 2019-20 as against Rs. 2,12,477 in 2018-19 with an increase of 8.8%. Karnataka's per capita income is higher by 58% over All India per capita income of Rs. 135,050 (Figure 2.4) in 2019-20. The per capita district income at current prices (crores) for all the districts have also recorded a steady increase from 2011-12 onwards.

2.3.1. Poverty and Employment

In Karnataka, the percentage of people living below the poverty line during 2004-05 was 33.3% which declined to 20.91% in 2011-12. The state's combined (Rural and Urban) poverty percentage is lower than the national average. The poverty line in Karnataka was Rs. 417.84 per capita per month in rural areas and Rs. 588.06 per capita per month in urban areas in 2004-05 whereas it was Rs. 902.00 in rural areas and Rs. 1089.00 in urban areas during 2011-12.

Under the Usual Principal & Subsidiary Status (UPSS), unemployment rate (in %) in Karnataka is 4.8% considering both urban and rural (all age groups) population for the year 2017-18, which is very less compared to India's rate of 6%. In Karnataka, the rural area unemployment rate is 4% for males and 3.4% for females whereas in urban areas, for males it is 6.3% and for females, it is 7.2%.

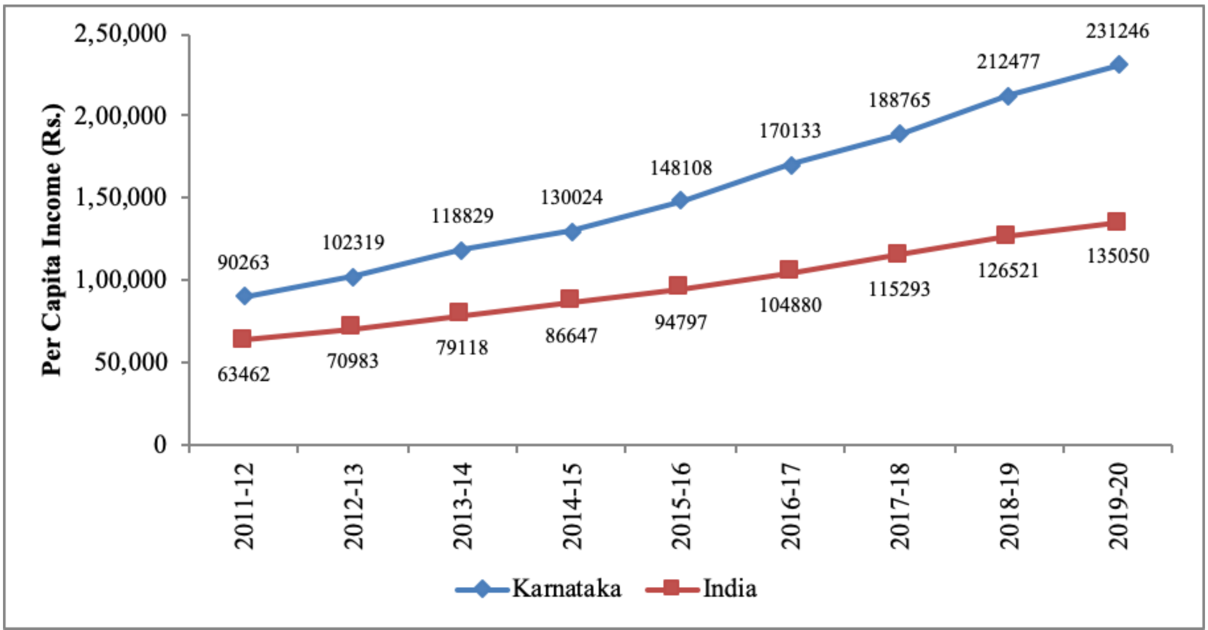


Figure 2.4: Trends in per capita income (Rs.) in Karnataka and India

2.4. Land Use Pattern in Karnataka

The geographical area of the state is classified into forest, land put to non-agricultural use, barren and uncultivable land, permanent pastures and other grazing lands, cultivable waste, miscellaneous trees and groves, etc. not included in net area sown, current fallows, other fallow land, and net area sown (Table 2.3). As per the land utilization statistics of 2017-18, the net cropped area was 98.95 lakh hectares, accounting for 51.94% of the geographical area of the state. It has decreased during 2017-18, compared to 2010-11.

Table 2.3: Land use in Karnataka

Land use type	Area ('000 ha)	Percentage
Geographical Area	19,179	
Reporting area for land utilization	19,052	100.00
Forests	3,073	16.13
Not available for land cultivation	2,248	11.80
Permanent pastures and other grazing lands	904	4.74
Land under misc. tree crops and groves	277	1.45
Culturable wasteland	409	2.15
Fallow land other than current fallows	525	2.76
Current fallows	1,572	8.25
Net area sown	10,044	52.72

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2014-15)

2.4.1. Agriculture

More than three fourths of the land in Karnataka is under rainfed cultivation. Karnataka state has been divided into 10 agro-climatic zones. The dominant crops grown in Karnataka are cereals, pulses, oilseeds and cash crops. Important food crops in the state include ragi, paddy, jowar, maize and bajra; pulses like red gram, bengal gram, field bean, cowpea and horse gram; oilseed crops like groundnut, sunflower, safflower and sesame. Cotton, sugarcane, coffee, tobacco and mulberry are the major commercial crops. Cereals, Pulses, Oilseeds, Cotton, Sugarcane and Tobacco account for 46%, 30%, 13%, 6%, 6% and 1% respectively of the total agricultural cropped area (Figure 2.5).

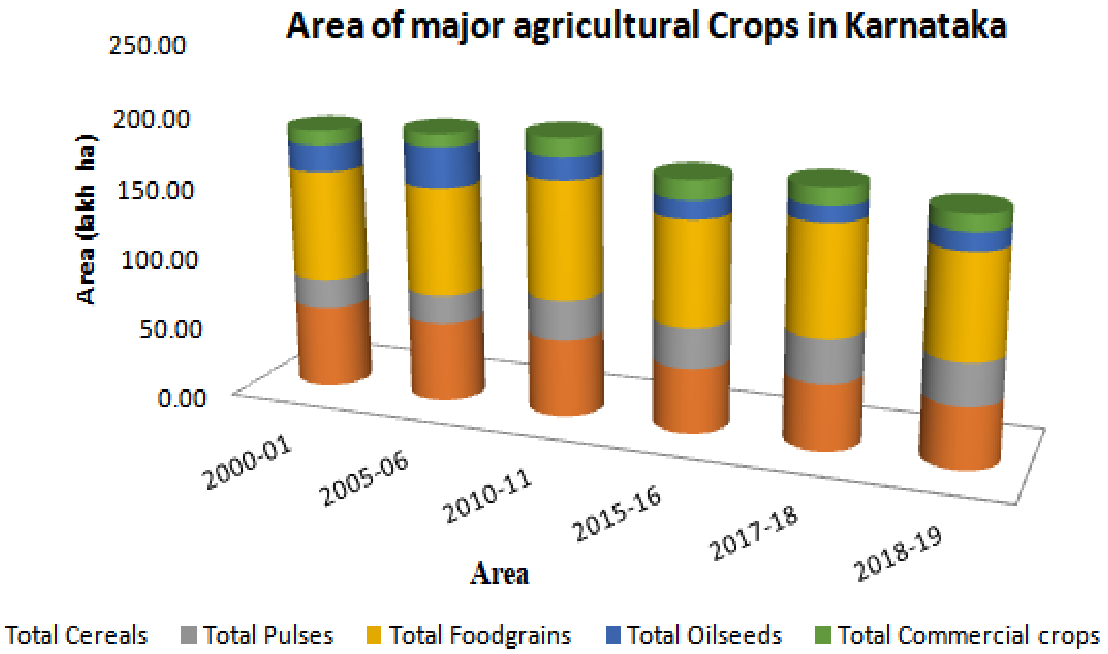


Figure 2.5: Area under major agricultural crops in Karnataka

Annexure A.1 gives a detailed picture of the trends in cropping pattern in Karnataka. The area under maize, tur, Bengal gram, cotton and soya bean are witnessing an increasing trend in recent years, whereas crops like sunflower, jowar, groundnut etc. are witnessing a declining trend as per the statistics of 2018-19 in comparison to the last decades.

Area under irrigation and sources of irrigation

There has been a gradual increase in the irrigated area in the state. Expansion of groundwater and surface water resources has helped increase cultivated area under irrigation. Trends in irrigated area are given in Annexure A.2. The net irrigated area has increased from 26.43 lakh hectares in 2000-01 to 34.90 lakh hectares in 2010-11, which then started to decrease gradually to 31.55 lakh hectares during 2017-18. The percentage gross irrigated area in the total cultivated area has slightly increased from 27% in 2000-01 to 30% in 2017-18.

Canals, wells, tanks, tube/bore wells and reservoirs are the main sources of irrigation. Out of the 119.94 lakh hectares of gross cropped area, 36.39 lakh hectares were irrigated during 2017-18. Among all sources of irrigation, tube/bore wells (44.82%) accounted for the highest proportion of the net irrigated area followed by canals (29.95%) and wells (9.16%). Source wise area irrigation is presented (Annexure A.3)**.**

Trends in crop production and productivity

The area and production for the total food grains including cereals and pulses have increased in the last two decades from 78.04 to 80.98 lakh hectares and from 109.6 lakh tonnes 110.46 lakh tonnes in the year 2000-01 and 2018-19, respectively. Specifically, the yield for maize has increased from 3,361 Kg/hectare to 4,519 Kg/hectare. So, the production increased from 21.36 lakh tonnes during 2000-01 to 56.1 lakh tonnes in the year 2017-18. But, it had decreased during 2018-19. Similarly, the production of pulses increased to 22.12 lakh tons in 2017-18 as against 9.51 lakh tons during 2005-06. But it decreased to 18.46 lakh tons yet again in 2018-19. The production of food grains had risen to 1951 lakh tons in 2017-2018 (Figure 2.6).

The production of cotton has increased to 18.44 lakh bales in 2017-2018 from 5.85 lakh bales in 2005-06. A hike was noticed despite a reduction in the area to 5.47 lakh hectares. The increased production was solely contributed by the improvement in yield during the period under reference wherein the yield of cotton increased to 603 kg in lint in 2017-2018 from 253 kg in lint in 2005-06. Productivity of major crops are given in Annexures A.4.

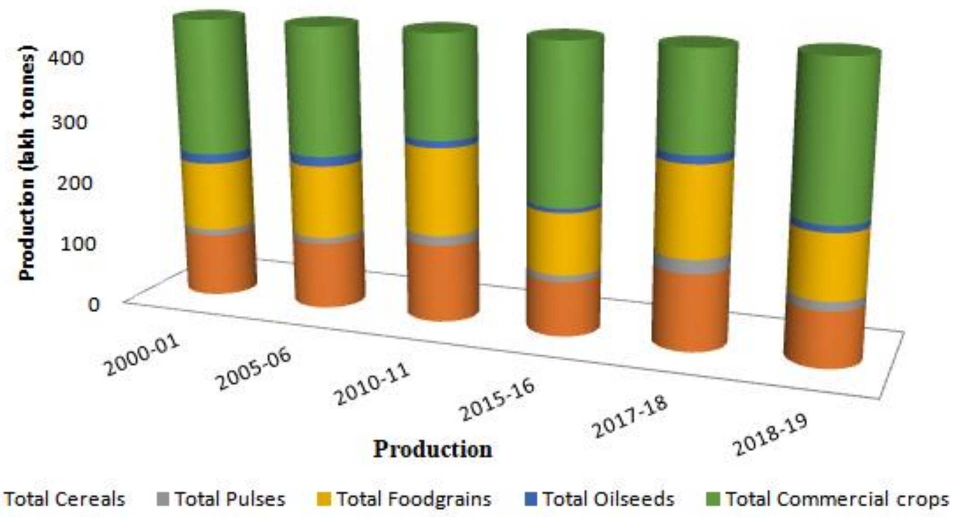


Figure 2.6: Production of major agricultural crops in Karnataka

The advanced estimates indicate the expected food production of 102.03 lakh tonnes of cereals and 17.37 lakh tonnes of pulses against the target of 117.22 and 21.45 lakh tonnes, respectively for 2019-20. Likewise, oilseeds production is estimated to be 10.73 lakh tons against the target of 14.71 lakh tonnes; and cotton is likely to be 14.75 lakh bales against the target of 16.58 lakh bales for the year 2019-20.

2.4.2. Livestock

As per the 19th Livestock Census, Karnataka has 2.9 crores of livestock and 5.3 crores of poultry population. The share of livestock and poultry population in Karnataka in overall India accounts for 5.41% and 7.33%, respectively. The density of livestock was estimated at 151.21 per sq. km and 47,468 per lakh of human population. The livestock and poultry statistics is given in Annexure A.5. Karnataka stood 11th among the Indian States in milk production during 2018-19 (7.90 million metric tonnes during the year 2018-19). Details of the production of the major livestock products, namely, Milk, Meat, Wool and Eggs are given in Annexure A.6.

2.4.3. Water Resources

Surface and groundwater constitute water resources in Karnataka. Surface water is available in Karnataka in the form of rivers, lakes, waterfalls, reservoirs, etc. The lakes and tanks meet a portion of the State's water demand. There are 36,753 traditional tanks that have a potential command area of about 685,000 hectares. Karnataka is blessed with seven river basins. The total catchment area of all the seven-river systems is 19,05,000 sq. km.

Surface water availability: There are seven river systems in the State viz., Krishna, Cauvery, Godavari, North Pennar, South Pennar, Palar, and the West Flowing Rivers. Utilization of water in the West Flowing Rivers is hampered due to difficulties in construction of large storage reservoirs. Yield in the seven river basins is estimated at 3,418 TMC at 50% dependability and 2,934 TMC at 75% dependability. Yield in the six basins (excluding west flowing rivers) is estimated at 1,396 TMC at 50% dependability and 1,198 TMC at 75% dependability. The economically utilizable water for irrigation is estimated at 1,695 TMC.

Groundwater availability: Availability of ground water is estimated at 485 TMC. Ground water resources have not been exploited uniformly throughout the state. Exploitation of ground water in the dry taluks of North and South interior Karnataka is higher as compared to that in Coastal, Malnad and irrigation command areas. There is deficiency of water for drinking, agricultural and industrial use in the dry taluks of North and South interior Karnataka. Where adequate surface water is available, utilization of ground water resources is minimum. In about 43 taluks, there is over exploitation of ground water resources. Further, groundwater exploitation has exceeded 50% of the available ground water resources in 29 taluks of the State. These 72 taluks are critical taluks from the point of view of ground water exploitation. Due to over exploitation of ground water resources, more than 3 lakh dug-wells have dried.

2.4.4. Forest Resources

The state is endowed with diverse climate, topography and soils which has resulted in rich biodiversity. The diverse ecological niches support characteristic flora and fauna. The Western Ghats comprising evergreen, semi-evergreen and deciduous forests which covers about 60% of the forest area of state, is recognized as one of the 35 biodiversity hotspots in the world and one of the four biodiversity hotspots of India, As per the Champion and Seth classification of the forest types (1968), the forests in Karnataka belong to seven forest groups, which are further divided into about 40 major and minor forest types/sub-types. Protection and management of degraded forest through community participation is a major thrust area of the state forest department besides biodiversity conservation and eco-tourism.

According to the State of Forest Report (2019) of the Forest Survey of India, the recorded forest area in Karnataka is 38,575,48 sq. km, which is 20.11% of the geographical area of the State. According to forest canopy density classes, the state has 4,501 sq. km under Very Dense Forest, 21,048 sq. km under Moderately Dense Forest and 13,026 sq. km under Open Forest, totalling about 38,575 sq. km (Table 2.4 & Figure 2.7).

Table 2.4: Trends in forest area in Karnataka according to canopy classes (in sq. km)

Forest Type	1999	2005	2011	2015	2019
Very Dense Forest	-	464	1777	1776	4501
Moderately Dense Forest	24,832	21,633	20,178	19,997	20,138
Open Forest	7,513	13,139	14,220	13,644	11,395
Scrub	4,478	3,151	3,172	3,123	4,494
Non-Forest	1,54,804	1,53,408	1,52,408	1,51,179	1,47,217

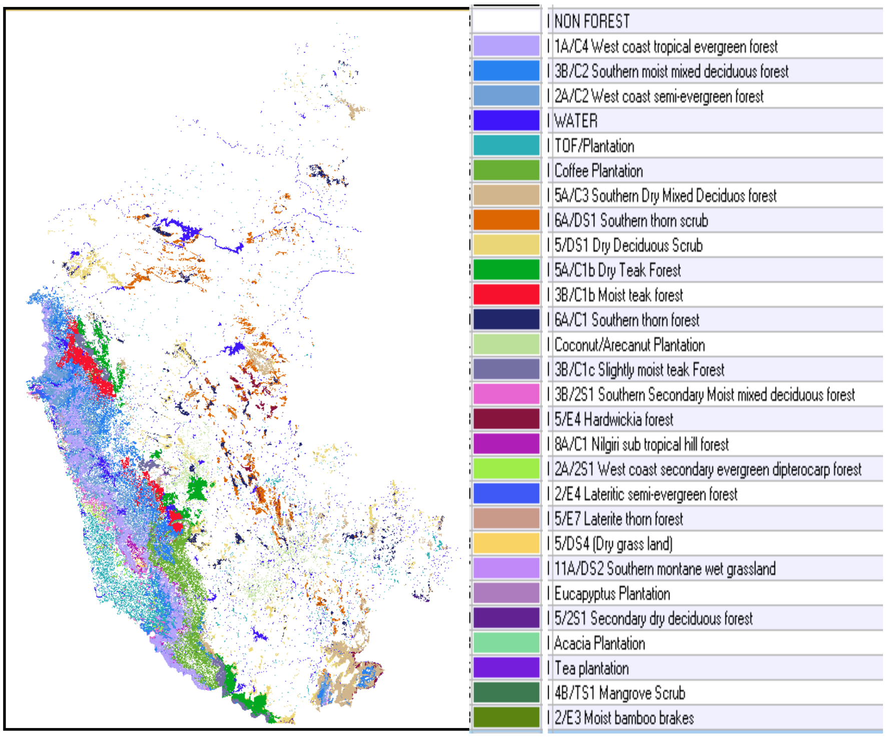


Figure 2.7: Forest cover map of Karnataka in 2019 (Source: Forest Survey of India 2019)

2.5. Energy Profile - Supply and Demand

The primary energy sources in Karnataka are coal, wind, hydro, nuclear, renewable, etc. Over the last year, Karnataka has emerged a renewable energy leader and country's biggest renewable power producer with an installed capacity of 12.3 GW. This includes solar capacity of 5 GW, wind capacity of 4.7 GW, and around 2.6 GW of other renewables such as small hydro, biomass, heat and power co-generation. The state's coal power capacity is around 9.8 GW.

The major schemes in the energy sector in Karnataka are Deendayal Upadhyaya Gram Jyoti Yojana, Pradhan Mantri Urja Suraksha Evam Utthaan Mahabhiyaan (KUSUM), Solar Rooftop PV Systems, Solar Irrigation Pump Set Scheme/Solar Pumping Program for Irrigation, Surya Raitha, and Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya).

The State of Karnataka has achieved near self-sufficiency in power generation to meet the growing demand. The occasional gap due to seasonal variation in demand and supply is met through short term purchases. The State Government is sourcing power from all available sources including short term/energy exchange to meet the demand. Apart from augmenting its generation, the State has been importing power from central power-generating stations and also through energy exchanges for minimizing power shortages. In addition, the government is taking to conservation of energy through demand side management programmes.

Installed capacity: The total installed capacity both in public and private sector, including the State's share in the Central Generation Station (CGS) up to November 2018 is 26,843.83 MW. The installed capacity in the public sector is 13,019.00 MW (including CGS allocation) and the private sector's share is 13,824.83 MW. In the private sector capacity, the share of renewable energy sources of power generation (excluding the share of IPP Thermal & Mini Hydel) in overall installed capacity is 43.85%. The hydro thermal mix in generation in public sector including Central generating share is in the ratio of 1:2. The total power supply of 72,624.26 MU in 2017-18 was substantially higher than 65,392.54 MU in 2016-17 due to increased capacity addition to meet the demand for energy. The status of power sector in terms of both installed capacity and electricity generation in Karnataka is provided in Annexure A.7.

Distribution system: The Distribution of electricity, including retail supply, in the State is being undertaken by five Distribution Companies (ESCOMs). Further, one Rural Electricity Co-operative Society and two Special Economic Zones are also operating as Distribution Licensees (Annexure A.8).

2.6. State Government: Developmental Priorities and Policies

Reinforcing India's commitment to the national development agenda and 17 SDGs, the Government of Karnataka has implemented several policies, schemes and programmes for poverty alleviation, human development, gender and social equity, and for addressing climate change. The Karnataka SDG 2030-Strategy and Action plan is a road map for realizing the goals and targets of the State. Karnataka State has emerged a forerunner on various development sectors and is emerging as a model for other States. SDG 13: Climate Action demands "Urgent action" to "combat climate change and its impacts", incorporating both climate change mitigation and climate change adaptation. Karnataka is following a comprehensive path for effective implementation strategies considering the multidimensional nature (Social, Economic and Environmental) of SDG goals. A Sustainable Development Goals Coordination centre is established in partnership with UNDP to provide knowledge support to the Government. The major initiatives are integration of all programmes and policies to measurable indicators of SDGs through convergence and modification, creating awareness (Information, Education and Communication) about all governmental programmes, establishment of a single window agency, special focus on promoting skill development across sectors in a bigger way, higher emphasis on data collection and analytics related to SDG indicators, development through spatial mapping (GIS), Karnataka Open Data Initiative (KODI), Centre for Open Data Research, higher investments on transport connectivity and creation of development zones and Water Resource Management.

Implementing the SDGs requires new capacities and new ways of working in public institutions and among public servants. Enhanced capacities are needed to improve sectoral policies, envision the long-term impact of policies and possible scenarios as well as to collect and analyse data and statistics. Effective implementation of the 2030 Agenda therefore requires mobilizing and equipping public institutions and the government officials and calls for a new way of governance instead of the business-as-usual approach. The State is all set to accept the challenges and work in a mission mode to reach the agenda SDG-2030. It has put together strategies for action in agriculture and allied sectors, including promoting rain water harvesting, agroforestry, integrated farming systems, etc. Improved natural disaster management is planned to reduce urban flooding by proper maintenance of the drainage system, proper solid waste management and effective implementation of plastic ban, using ICT in developing advance warning systems, dissemination of information through SMS, web portal, radio, wireless communication, etc., among other things.

The government of Karnataka has been committed to social justice through securing social, economic and political development. The government has launched several successful policies (Women Empowerment Policy, Girl Child Policy, Karnataka State Child Protection Policy and Transgender Policy for deprived sections of community, policies for industries such as IT, BT, Aerospace, Start-ups, FPOs, Animations and Visual effects, Semi-conductors and Electric vehicle manufacturing), Karnataka Sakala Services Act, 2011 and (Amendment) Act, 2014 (guarantee of services to citizens in the State of Karnataka within the stipulated time limit) and programs like Krishi Bhagya, Anna Bhagya, Ksheera Bhagya, Indira Canteens, Runamukta Bhagya, Vidyasiri, Nirantara Jyothi Yojana, Basava Housing Scheme,

Arogya Bhagya Scheme, Citizen Service Centres (Bangalore One and Karnataka One),Unified Market Platform, Mobileone (multi-mode mobile governance platform), Pratibimba (track and measure departmental performance on programs/projects) etc. Public Affairs Index has ranked Karnataka second in transparency and accountability and third in governance based on 10 parameters comprising 25 subjects and 68 development indicators (GoK, 2018). The Green Index development is another effort in this direction.

Over and above this and all-encompassing with impacts—direct or indirect on the various resources, sectors and sections of the society is the issue of climate change. This requires strategic and targeted planning and programme implementation to meet the country's NDC targets, while at the same time promote mitigation and adaptation synergistic with development in the states. The State Action Plan on Climate Change V.2 is a move in that direction, aimed at chalking out a plan and identifying a prioritised set of mitigation and adaptation activities, along with financial outlay required for its implementation as well as monitoring and evaluation. It also is targeted towards identification of appropriate financial, institutional and monitoring and evaluation mechanisms for effective implementation.

Chapter 3: Climate Profile

3.1. Introduction

Climate in a narrow sense is defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to decades, to centuries to thousands of years (IPCC, 2017). Climate variability refers to variations in the mean state of temperature, monthly or seasonal rainfall, etc., and other statistics such as standard deviations, statistics of extremes, etc., beyond that of individual weather events. A comparison of projected climate is made with the climate of the recent period of 1985 to 2016 to estimate the magnitude of climate change. This is in contrast to the UNFCCC and IPCC reports, where comparison is made with pre-industrial periods. Thus, smaller magnitude of projected changes in climate can be expected in this report.

This chapter presents historical trends in temperature and rainfall, and climate change projections for the following periods and scenarios.

- ***Historical climate trends (Based on Indian Meteorological Department (IMD))***
    - *Rainfall* - 0.25° latitude x 0.25° longitude daily gridded dataset for the Indian region for the period 1987–2016
    - *Temperature* - 1.0°x1.0° gridded daily temperature data, spanning the period 1987-2015 for maximum and minimum temperature
    - *Rainfall variability* - assessed for the critical *Kharif* (JJAS - June to September) as well as the *Rabi* (OND - October to December) seasons.
- ***Climate change projections (based on Coordinated Regional Climate Downscaling Experiment - CORDEX)***
    - *Resolution for data analysis*: Grid scale of 0.5° x 0.5° resolution (~ 50 km x 50 km)
    - *Periods*: Short-term (2021–2050) and Long-term (2071-2100)
    - *Scenarios*: Regional Concentration Pathway (RCP) 4.5 (moderate emissions) and RCP 8.5 (High emissions).
    - *Climate change projections used are bias-corrected*.

Results from *bias-corrected* 15 CORDEX model simulations are used to produce the ensemble mean, which is used to assess future climate change. All data in this analysis is first re-gridded to a common 0.25° x 0.25° resolution which is the resolution of the IMD rainfall data. Change in temperature and rainfall during the projected period is computed as a difference between the model-simulated ensemble average of 30-year historical period and the projected 30-year period. District level averages of climatic variables were prepared using the outputs from the re-gridded 0.25° x 0.25° resolution (~ 25 km x 25 km) data. The mean value for the district is obtained by considering a mean of the multiple grids that may cover a district. Only grids that fall fully within a district and grids with >60% area falling within a district are considered for computing the mean. If a district falls within only one grid cell, that single grid cell value is used for the analysis. All the analysis is performed on these district means. However, maps of changes in temperature and rainfall are plotted on the district maps at 0.25° x 0.25° resolution.

The analysis has been done for the 30 districts of Karnataka using gridded (lat-long) information of the districts. All the Tables and Graphs present data for 30 districts. However, the spatial maps were available only for 27 districts as demarcated .shp (shape) files at the time of analysis of data for this report. Even *ISRO Bhuvan* Website presents maps using the old district boundaries only. The discussion on spatial trends is provided for all the 30 districts, considering the lat-long information available for the districts, even though map representation is for 27 districts.

3.2. Climate Profile and Characterization

The state of Karnataka enjoys three main types of climates—the coastal belt and adjoining areas enjoy hot with excessive monsoon rainfall typical of tropical monsoon climate; the southern part of the state experiences hot, seasonally dry tropical savanna climate, and the northern part of the state experiences hot, semiarid, tropical steppe type of climate. The summer season extends from March to May and the winter extends from January to February.

In Karnataka there are more than 100 meteorological stations spread across the state for weather monitoring. The temperature in the state ranges from 23°C to 43°C in summer and 9°C to 27°C in winter. The state average temperature for the period 2002 to 2018 is plotted in Figure 3.1. The state receives a normal annual rainfall of about 1,150 mm (ranging from 477 mm to 4,747 mm), from predominantly the southwest monsoon (about 73%). About 15% of rainfall is from the northeast monsoon and the remaining is received during the pre-monsoon season. There is a substantially high variability in spatial and temporal distribution of rainfall over the state. The annual rainfall is lowest (477 mm) in the eastern parts of Chitradurga district and highest (4,747 mm) over the Western Ghats. More than 2/3rd of the state receives less than 750 mm of rainfall.

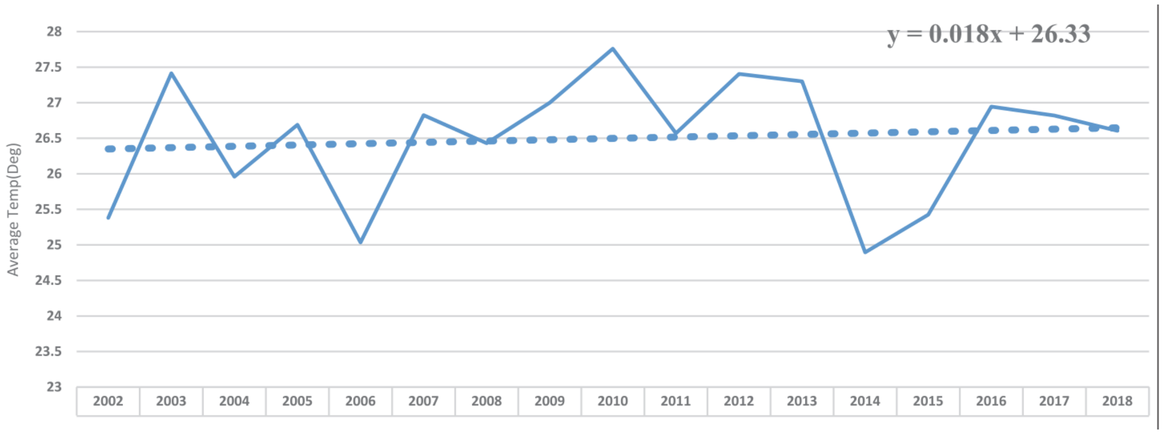


Figure 3.1: Trends in temperature during 2002 to 2018 in Karnataka

In general, the mean rainfall is lower in the districts of central parts of south interior and north interior Karnataka regions, in the range of 60 to 100 mm in June, 50 to 100 mm in July, 55 to 100 mm in August, and 82 to 100 mm—in parts of Haveri, Davanagere, Chitradurga, Mysuru and Chamarajanagar districts) in September. The southwest monsoon seasonal rainfall in this part of the state ranges from 250 to 500 mm and annual rainfall from 500 to 1000 mm (Figure 3.2).

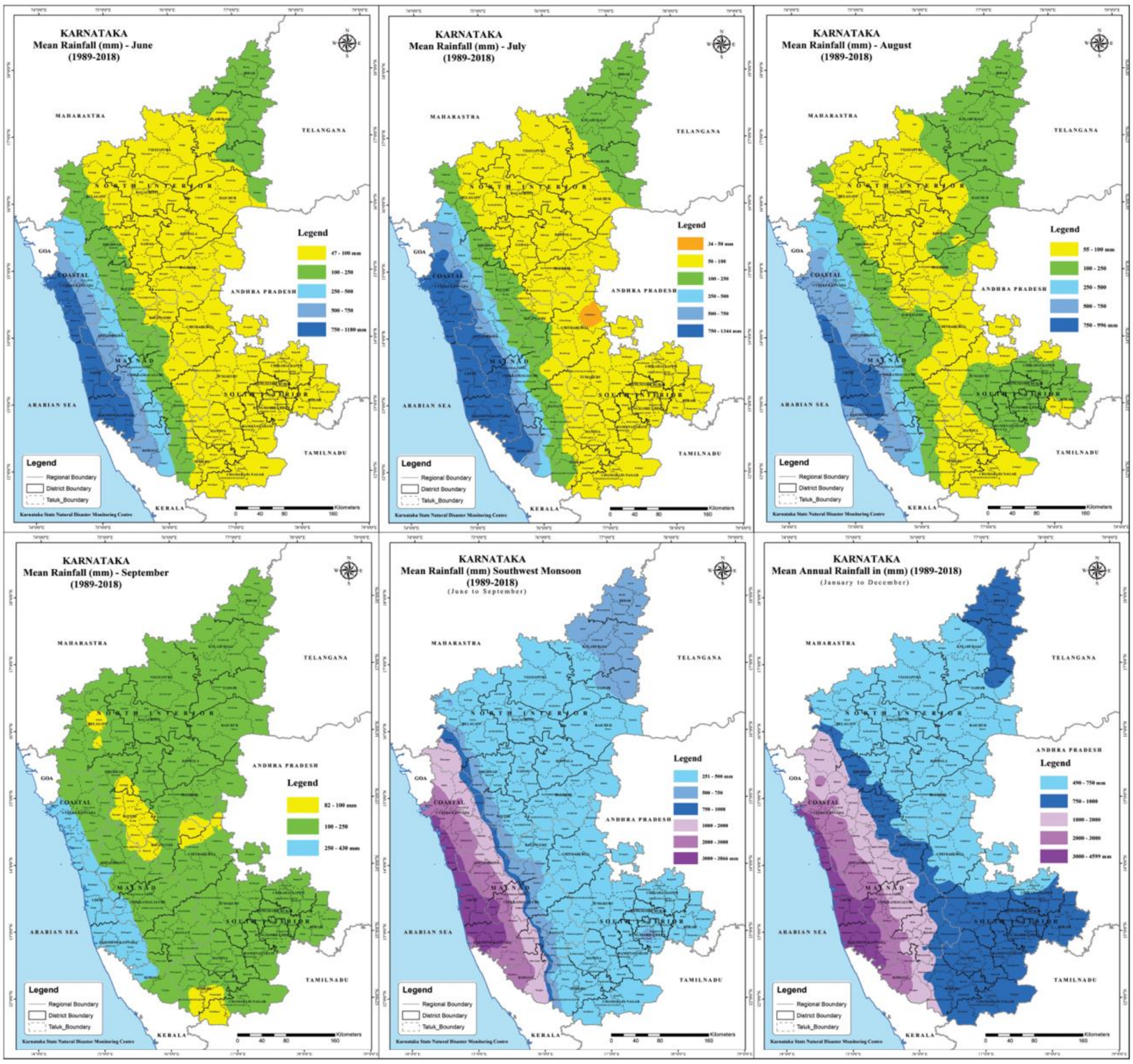


Figure 3.2: June, July, August, September, southwest monsoon season and mean annual rainfall in Karnataka during 1989-2018 (Source: KSNDMC, 2020)

According to KSNDMC (2020), the quantum of annual rainfall and number of rainy days have increased in south interior Karnataka and Malnad regions. During the same period, a reduction in amount of annual rainfall and marginal increase in number of rainy days is observed in north interior Karnataka and coastal regions.

The Kodagu, Kalaburagi, Yadgir, Dakshina Kannada, Uttara Kannada districts show a reduction in the amount of annual rainfall while an increase in rainfall over Shivamogga and Hassan districts is reported. Parts of Vijayapura, Bagalkote, Raichur, Koppal, Ballari, Gadag, Dharwad, Belagavi, Haveri, Davanagere, Chitradurga, Chikkamagaluru, Bengaluru and Ramanagara districts are reported to show higher inter-annual variability in rainfall. Further, in the last two decades an increase in extreme rainfall events have occurred in different regions of the state. At the same time, the frequency of occurrence of drought is also reported to have increased in the recent years.

The extreme weather events have caused loss of human life, livestock, critical infrastructure, private and public property. Also, these events have caused increase in hunger, malnutrition, vulnerability to diseases, and loss of livelihoods of communities in the state.

3.3. Historical Trends and Variability in Temperature

The historical trends in temperature during the period 1985 to 2015 and rainfall analysis for the period 1987 to 2016 are presented at the district level in this section. The focus is on summer maximum temperature (potentially causing heat stress) and winter minimum temperature (critical for human comfort and winter crops). Different periods are taken for temperature and rainfall analysis in accordance with data that was available, at the time of analysis.

Temperature in Karnataka showed a moderate warming trend during 1985 to 2015, for both the summer maximum and winter minimum temperature.

- The summer (March-April-May: MAM) maximum temperature in the districts of Karnataka was generally moderate to high and ranged from 31^{0}C in Mysuru and Mandya to 38.8^{0}C in Kalaburagi district.
    - During the historical period (1985-2015), the summer maximum temperature has increased in the range of 0.18^{0}C to 0.61^{0}C.
- The winter (December-January-February: DJF) minimum temperature during the same period ranged from 14.1^{0}C in Mysuru and Mandya districts to 18.3^{0}C in Dharwad district.
    - During the historical period (1985-2015), the winter minimum temperature has increased in the range of 0.30^{0}C to 0.65^{0}C.

Even at the national level, the maximum and minimum temperature has shown a warming trend of 0.17^{0}C and 0.14^{0}C per decade, respectively since 1981 (Krishnan and Sanjay, 2017).

3.4. Historical Trends and Variability in Rainfall

Total rainfall and its distribution are critical for agriculture and water supply. The rainfall trend is analysed in detail for the *Kharif* – JJAS (June to September) and *Rabi* seasons – OND (October, November, December).

- The total mean annual rainfall ranged from 476 mm in Chitradurga district to 4124 mm in Udupi district.
- The mean *Kharif* season rainfall ranged from 246 mm in Chitradurga district to 3812 mm in Udupi district.

- The mean *Rabi* season rainfall ranged from 110 mm in Raichur and Yadgir districts to 527 mm in Dakshina Kannada district.

Table 3.2 presents the mean annual, Kharif and Rabi season rainfall for the districts of Karnataka. The focus in this section is on the annual and Kharif season rainfall trends during the historical period.

Table 3.2: Historical (1987-2016) mean Annual, *Kharif* (JJAS) and *Rabi* (OND) season rainfall, Standard Deviation of *Kharif* season rainfall and CV of *Kharif* and *Rabi* season rainfall

	Districts*	**Mean annual rainfall (mm)**	***Kharif (JJAS) season***			***Rabi (OND) season***	
			Mean rainfall (mm)	**Standard Deviation (mm)**	**CV (%)**	**Mean rainfall (mm)**	**CV (%)**
<1000 mm mean annual rainfall	Chitradurga	476	246	111	45	129	54
	Vijayapura	544	349	141	40	131	62
	Gadag	548	326	127	39	124	66
	Ballari	557	327	148	45	156	61
	Bagalkot	568	328	153	47	121	63
	Davanagere	614	350	100	29	160	70
	Koppal	617	376	143	38	156	56
	Dharwad	624	390	109	22	129	54
	Raichur	633	448	132	29	110	81
	Haveri	659	364	119	33	161	72
	Yadgir	663	485	145	30	110	60
	Mandya	698	306	121	39	234	59
	Chikballapur	704	434	141	32	169	72
	Kalaburagi	710	523	199	38	119	61
	Chamarajanagar	741	346	98	28	249	47
	Kolar	771	389	136	35	271	50
	Mysuru	772	342	113	33	251	67
	Bengaluru Rural	781	430	116	27	209	52
	Belagavi	799	630	560	89	145	59
	Bengaluru Urban	800	399	124	31	242	47
	Tumakuru	824	466	150	32	201	44
	Ramanagara	877	459	158	34	227	60
	Bidar	911	692	204	30	134	74
>1000 mm mean annual rainfall	Hassan	1012	619	125	20	230	61
	Shivamogga	1679	1429	428	30	170	79
	Chikkamagaluru	1806	1430	146	10	208	57
	Kodagu	2043	1503	525	35	308	53
	Uttara Kannada	2157	1880	535	28	178	60
	Dakshina Kannada	3657	3145	729	23	527	40
	Udupi	4124	3812	754	20	460	42

**Districts are arranged according to mean annual rainfall*

3.4.1. Spatial Trends in Annual Rainfall

Historical annual rainfall analysis showed an increase in rainfall for most districts of Karnataka (Figure 3.3). The increase was up to 25%, with up to 15% increase in a majority of the districts during the historical period.

- Rainfall has increased in up to 10% in parts of the northern districts of Kalaburagi, Bidar, Vijayapura, Raichur, Bagalkot, Koppal, etc., and parts of the southern districts of Chamarajanagar, Chitradurga, Tumakuru, Mandya, etc.
- Rainfall has increased in the range of 10% to 15% in Kolar, Bengaluru Urban, Bengaluru Rural, Chikkamagaluru, Chitradurga, etc.
- Rainfall has increased in the range of 15% to 20% in parts of the Western Ghats districts of Kodagu, Hassan, Uttara Kannada, Belagavi, etc.
- Rainfall has increased in the range of 20% to 25% in parts of the Western Ghats districts of Kodagu, Udupi, Shivamogga, and Uttara Kannada districts.

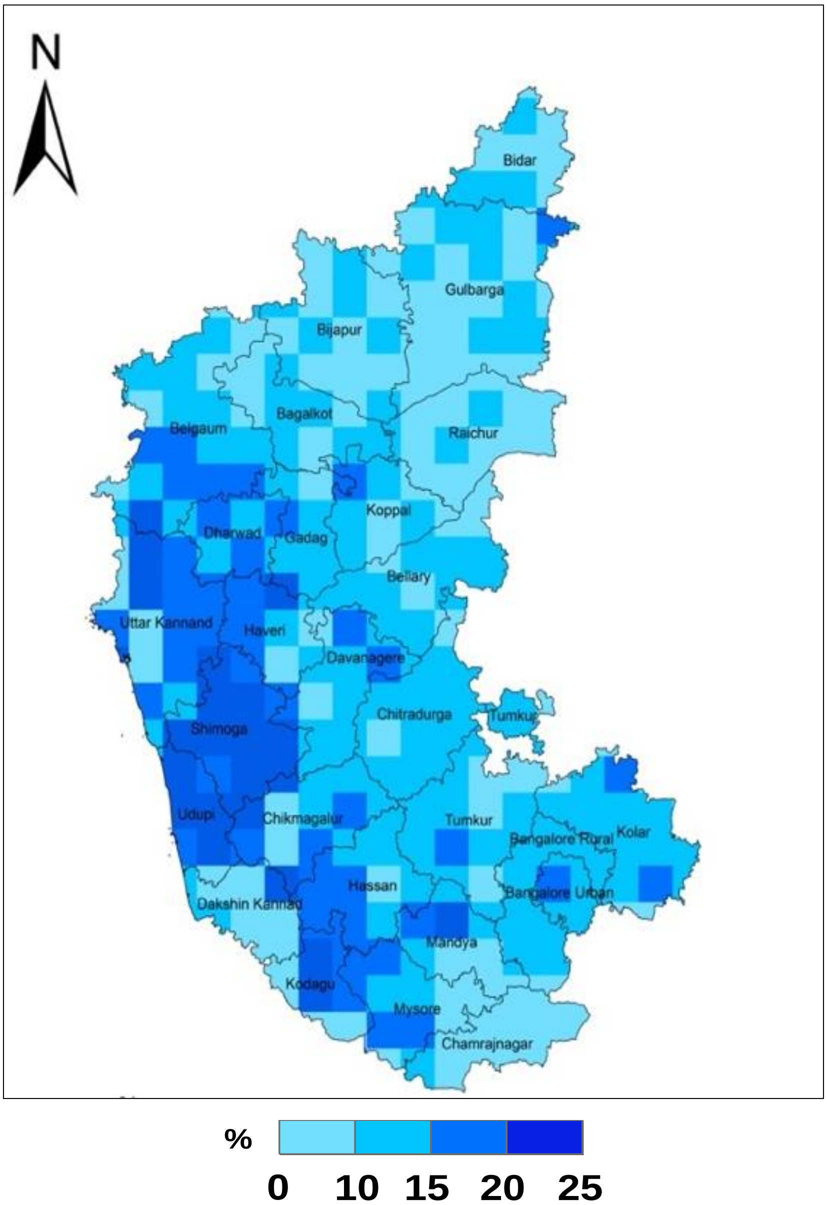


Figure 3.3: Trends in mean annual rainfall (in) during 1987 to 2016. *Discussion on spatial trends is provided for all the 30 districts, considering lat-long information available for the districts, even though map representation is for 27 districts.*

3.4.2. Spatial Trends in Kharif (JJAS) Season Rainfall

The trends in *Kharif* season rainfall are similar to that of annual rainfall in the districts of Karnataka during the historical period (Figure 3.4). *Kharif* season rainfall dominates the annual rainfall in most districts, even up to 92% (Udupi).

- Rainfall has increased up to 10% in parts of the northern districts of Kalaburagi, Bidar, Vijayapura, Raichur, Bagalkot, Koppal, etc., and parts of the southern districts of Chamarajanagar, Chitradurga, Tumakuru, Mandya, etc.
- Rainfall has increased in the range of 10% to 15% in Kolar, Bengaluru Urban, Bengaluru Rural, Chikkamagaluru, Chitradurga, etc.
- Rainfall has increased in the range of 15% to 20% in parts of the Western Ghats districts of Kodagu, Hassan, Uttara Kannada, Belagavi, etc.
- Rainfall has increased in the range of 20% to 25% in parts of the Western Ghats districts of Kodagu, Udupi, Shivamogga, and Uttara Kannada districts.

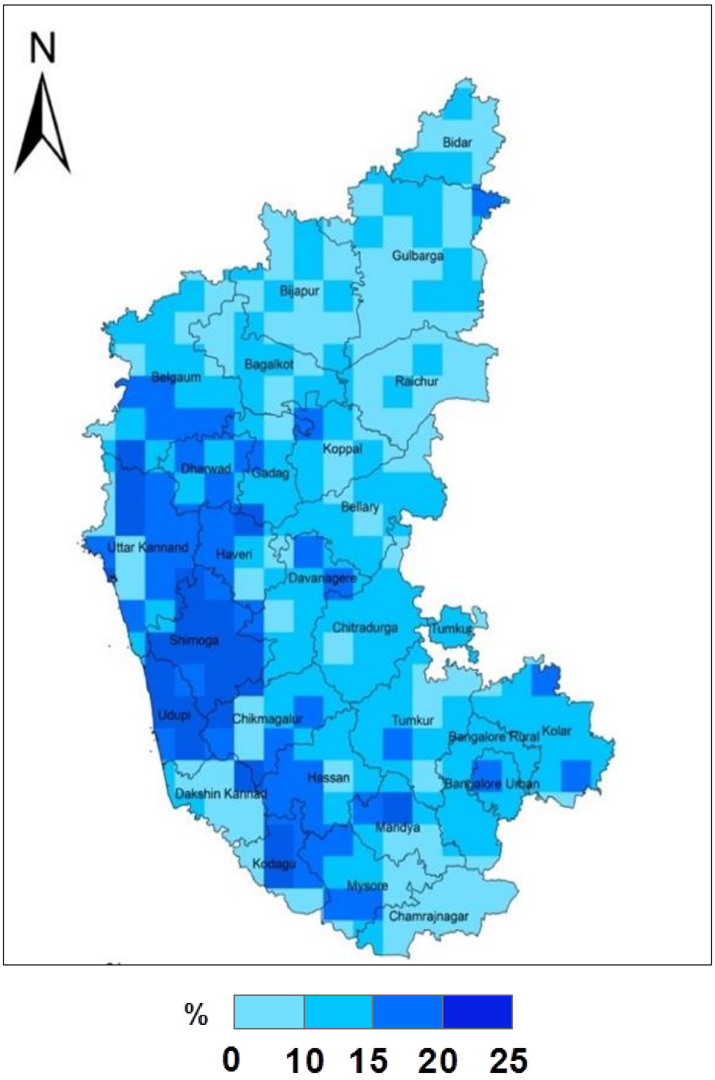


Figure 3.4: Trends in *Kharif* (JJAS) season rainfall (in percentage) during 1987 to 2016. *Discussion on spatial trends is provided for all the 30 districts, considering lat-long information available for the districts, even though map representation is for 27 districts.*

Increase in annual and *Kharif* season rainfall is observed in the districts of Karnataka, during the historical period of 1987 to 2016. The increase in *Kharif* season rainfall is relatively higher in the wetter Western Ghats districts (in the range of 15% to 25%), compared to the drier central, southern and eastern districts (in the range of 10% to 15%).

3.5. Kharif and Rabi Season Rainfall Variability during 1987 to 2016

One of the major challenges faced by agriculture is monsoon rainfall variability. Rainfall variability creates uncertainty and significantly impacts water availability and crop production. The seasonal rainfall variability for *Kharif* (JJAS) and *Rabi* (OND) seasons is analysed and presented in this section for the period 1987 to 2016. The mean annual rainfall, *Kharif* and *Rabi* season rainfall along with standard deviation and coefficient of variation (CV), an indicator of rainfall variability, are given in Table 3.2. Annex 3.2 presents the year-wise *Kharif* (JJAS) season rainfall across the districts of Karnataka. Annex 3.3 presents the annual, *Kharif* (JJAS) and *Rabi* (OND) season rainfall across the districts of Karnataka during the historical and projected RCP 4.5 and RCP 8.5 scenarios.

3.5.1. Kharif (JJAS) Season Rainfall Variability

The CV of *Kharif* season or JJAS rainfall was generally high in the districts of Karnataka and it ranged from 10% in Chikkamagaluru district to 89% in Belagavi district of Karnataka.

- ***Districts with very high rainfall variability of >50%***
    - Only Belagavi district receiving <1000 mm mean annual rainfall had very high CV of 89%.

- ***Districts with high rainfall variability of 25% to 50%***
    - *Districts receiving <1000 mm mean annual rainfall:* 21 of 23 districts had high rainfall variability in the range of 27% to 47% and these include Bengaluru Rural, Bagalkot, Ballari, Mandya, Gadag, Chitradurga, Vijayapura, Hassan, Bidar, Tumakuru, and others.

    - *Districts receiving >1000 mm mean annual rainfall:* 3 of the 7 districts had high CV in the range of 28% to 35%, and these include Shivamogga, Kodagu and Uttara Kannada districts.

- ***Districts with moderate rainfall variability (<25%)***
    - *Districts receiving <1000 mm mean annual rainfall:* Only Dharwad district had a moderate CV of 22%.

- *Districts receiving <1000 mm mean annual rainfall:* 4 of the 7 districts had moderate variability in the range of 10% to 23% and these include Udupi, Hassan, Dakshina Kannada and Chikkamagaluru districts.

Kharif season rainfall variability was high, in the range of 27% to 47% in 21 of the 23 districts receiving <1000 mm mean annual rainfall in Karnataka during the historical period. In the districts receiving >1000 mm mean annual rainfall, the *Kharif* season rainfall variability was in the range of 10% to 35%.

3.5.2. Rabi (OND) Season Rainfall Variability

The CV of *Rabi* season rainfall was very large as compared to the *Kharif* season rainfall during the historical period and ranged from 40% in Dakshina Kannada to 81% in Raichur district (Table 3.2).

- ***Districts with very high rainfall variability of >50%***
  - *Districts receiving <1000 mm mean annual rainfall:* 20 of 23 districts had very high rainfall variability in the range of 50% to 81% and these include Bengaluru Rural, Bagalkot, Ballari, Mandya, Gadag, Chitradurga, Vijayapura, Hassan, Bidar, Belagavi, and others.

  - *Districts receiving >1000 mm mean annual rainfall:* 5 of 7 districts had very high rainfall variability in the range of 53% to 79%, and these include Kodagu, Chikkamagaluru, Uttara Kannada, Hassan and Shivamogga districts.

- ***Districts with high rainfall variability of 25% to 50%***
  - *Districts receiving <1000 mm mean annual rainfall:* 3 of 23 districts had high rainfall variability in the range of 44% to 47% and these include Bengaluru Urban, Chamarajanagar and Tumakuru districts.

  - *Districts receiving >1000 mm mean annual rainfall:* 2 of 7 districts had high rainfall variability of 40% in Dakshina Kannada and 42% in Udupi district.

The CV of *Rabi* season rainfall was generally very high for the districts of Karnataka, in the range of 50% to 81% (in 20 of 23 districts) receiving <1000 mm mean annual rainfall. This will have implications for a *Rabi* season crop.

3.6. Climate Change Projections for the Short-term (2030s) and Long-term (2080s) Periods

Climate is projected to change in all parts of the world and India; including all states, districts and villages. Climate change projections are generally made at global, continental, regional (South Asia) and country level. It is important to assess and understand climate change projections at smaller scales for planning adaptation measures. In this section, climate change projections are assessed and presented at the district level, since district is a critical administrative unit. Further, IMD weather forecasts and agromet advisories are also at the district level. Temperature and rainfall projections for the two climate change scenarios of RCP 4.5 and RCP 8.5, relative to the historical period, for the short-term period of 2030s (2021-2050) and long-term period of 2080s (2071-2100) are presented in this section. Changes in the frequency of droughts and high intensity rainfall events are also assessed.

Ensemble mean results from *bias-corrected* 15 CORDEX model simulations (Table A1.2) are used for analysing the changes in temperature and rainfall, relative to the historical period. Temperature projections for summer (MAM: March-April-May) and winter (DJF: December-January-February) months, and rainfall projections for *Kharif* and *Rabi* seasons are presented in the following sections.

3.6.1. Temperature Projections for the Short-term (2030s) and Long-term (2080s) Periods

Increase in temperature alone, due to global warming, can impact crop yields directly, increase evapo-transpiration demand and moisture stress, ultimately contributing to increased water demand and irrigation needs for agriculture. Further, under extreme cases, high temperatures can lead to heat stress, harming humans and animals. The focus is on summer maximum temperature (potentially causing heat stress) and winter minimum temperature (critical for human comfort and winter crops).

Summer maximum temperature projections: Increase in maximum temperature during summer months (MAM) by 2030s and 2080s for the two climate change scenarios – RCP 4.5 and RCP 8.5, relative to the historical period of 1985 to 2015 is analysed and presented in this section. A rise in summer maximum temperature in the range of 0.5^0C to 2.5^0C is projected across the districts of Karnataka.

a. Short-term (2030s) – (Figure 3.5 – Left Panel): Warming is projected to be in the range 0.5^0C to 1.5^0C in the short-term, considering RCP 4.5 and RCP 8.5 scenarios.

1) RCP 4.5 scenario: Warming of summer maximum temperature is projected to be in the range of 0.5^0C to 1.5^0C across the districts of Karnataka under this scenario.

- Warming in the range of 0.5^0C to 1^0C is projected largely for the Western Ghats districts.
- Warming in the range of 1^0C to 1.5^0C is projected for the northern districts of Bidar, Kalaburagi, Yadgir, Bagalkot, Koppal, etc., and some of the central and eastern districts such as Chitradurga, Tumakuru, Davanagere and others.

2) RCP 8.5 scenario: Warming of summer maximum temperature is projected to be in the range of 0.5^0C to 1.5^0C across the districts of Karnataka, under this scenario.

- Warming in the range of 0.5^0C to 1^0C is projected for the Western Ghats districts of Uttara Kannada, Shivamogga, Udupi, Dakshina Kannada, part of Kodagu and Mysuru.

- Warming in the range of 1^0C to 1.5^0C is projected for all the northern and eastern districts of Karnataka.

b. Long-term (2080s) - (Figure 3.5 – Right Panel): Warming of summer maximum temperature in the range of 1^0C to 2.5^0C is projected in the long-term, considering RCP 4.5 and RCP 8.5 scenarios.

1) RCP 4.5 scenario: Warming of summer maximum temperature is projected to be in the range of 1°C to 2.5°C across the districts of Karnataka, under this scenario.

- Warming in the range of 1^0C to 1.5^0C is projected for the western parts of Karnataka including Udupi, Uttara Kannada, Dakshina Kannada, Kodagu, and Shivamogga districts.
- Warming in the range of 1.5°C to 2°C is projected for Tumakuru, Mandya, Chitradurga, Davanagere, Ballari, Gadag, Koppal, etc.
- Warming in the range of 2°C to 2.5°C is projected for the northern most districts of Bidar, Kalaburagi, Yadgir, Vijayapura, Bagalkot and Raichur.

2) RCP 8.5 scenario: Warming of summer maximum temperature is projected to be in the range of 1^0C to 2.5^0C across the districts of Karnataka under this scenario.

- Warming in the range of 1^0C to 1.5^0C is projected for the western parts of Karnataka including Udupi, Uttara Kannada, Dakshina Kannada, Kodagu, Shivamogga and Dharwad districts.
- Warming in the range of 1.5°C to 2°C is projected for parts of central Karnataka including the districts of Davanagere, Tumakuru, Ramnagara, Chitradurga, Mandya, and others.
- Warming in the range of 2°C to 2.5°C is projected for the northern most districts of Bidar, Kalaburagi, Yadgir, Raichur, Bagalkot, Koppal and Vijayapura.

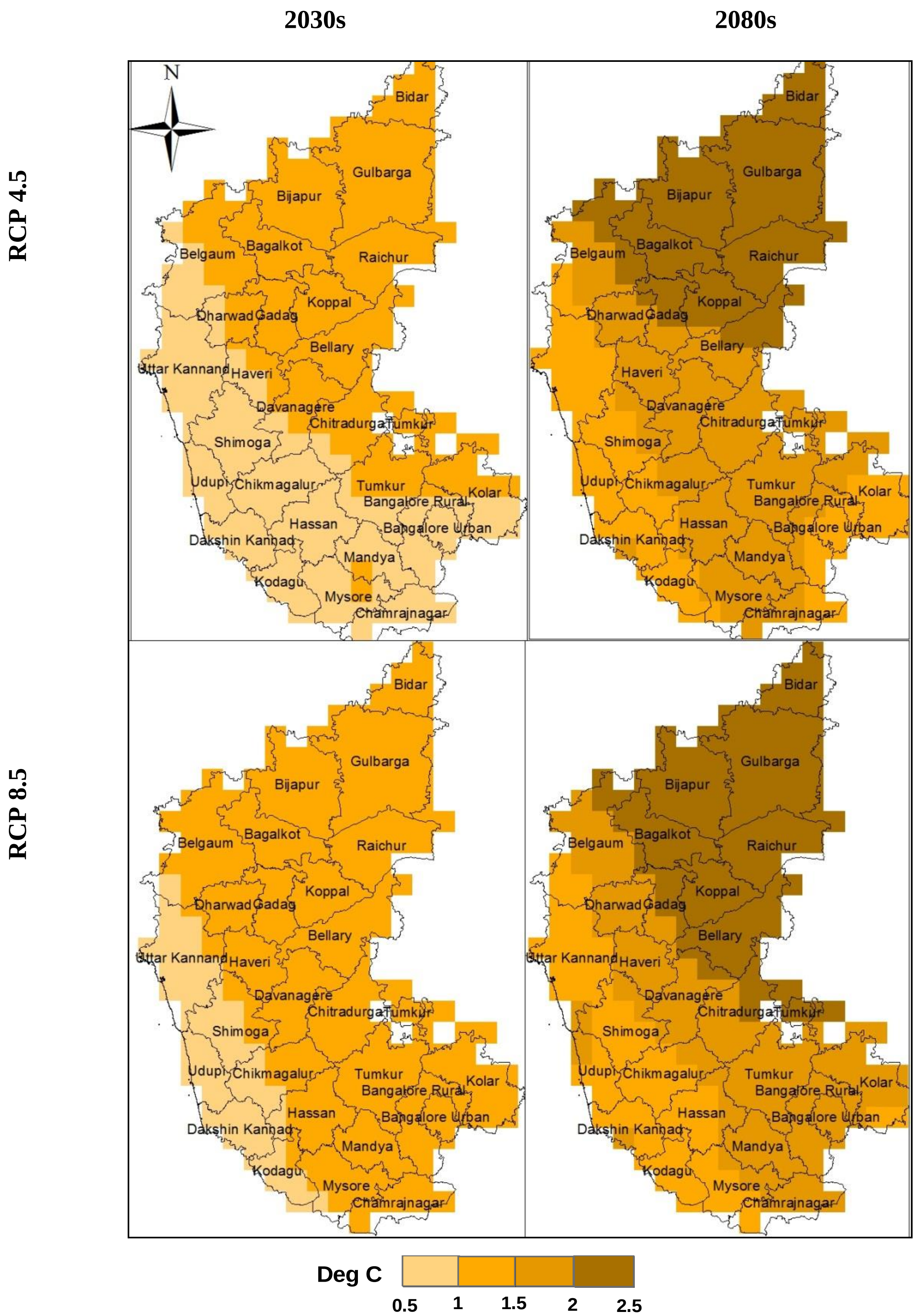


Figure 3.5: District-wise changes in summer maximum temperature (^{0}C) projected for the short-term (2030s) and long-term (2080s) under RCP 4.5 and RCP 8.5 scenarios relative to 1985 to 2015. *Discussion on spatial trends is provided for all the 30 districts,*

considering the lat-long information available for the districts, even though the map representation is only for 27 districts.

Winter minimum temperature projections: A rise in winter minimum temperature in the range of 0.5^0C to 2.5^0C is projected across the districts of Karnataka (Figure 3.6).

a. Short-term (2030s) - (Figure 3.6 – Left Panel): Warming of winter minimum temperature in the range of 0.5^0C to 2^0C is projected in the short-term, considering RCP 4.5 and RCP 8.5 scenarios.

1) ***RCP 4.5 scenario:*** Warming of winter minimum temperature is projected to be in the range of 0.5°C to 1.5°C, across the districts of Karnataka, under this scenario.
   - Warming in the range of 0.5°C to 1°C is projected for the southern and central districts of Karnataka.
   - Warming in the range of 1°C to 1.5°C is projected for the northern districts of Karnataka.

2) ***RCP 8.5 scenario:*** Warming of winter minimum temperature in the range of 0.5° to 2°C is projected in the long-term.
   - Warming in the range of 0.5°C to 1°C is projected for the southern and eastern districts of Karnataka.
   - Warming in the range of 1°C to 1.5°C is projected for the central and western districts of Karnataka.
   - Warming in the range of 1.5°C to 2°C is projected for the northern most districts of Karnataka.

b. Long term (2080s) - (Figure 5– Right Panel): Warming of winter minimum temperature is projected to be in the range of 1^0C to 2.5^0C in the long term, considering RCP 4.5 and RCP 8.5 scenarios.

1) ***RCP 4.5 scenario:*** Warming of winter minimum temperature is projected to be in the range of 1°C to 2.5°C, across the districts of Karnataka, under this scenario.
   - Warming in the range of 1°C to 1.5°C is projected for the southern districts of Tumakuru, Bengaluru, Mandya, Mysuru, etc.
   - Warming in the range of 1.5°C to 2°C is projected for Koppal, Ballari, Raichur, Davanagere, Haveri, Gadag, etc.
   - Warming in the range of 2°C to 2.5°C is projected for the northern districts of Bidar, Kalaburagi, Vijayapura and parts of Bagalkot and Belagavi.

2) ***RCP 8.5 scenario:*** The trends in warming under RCP 8.5 scenario are similar to that of RCP 4.5 scenario, with warming projected to be in the range of 1°C to 2.5°C, across the districts of Karnataka.
   - Maximum warming of 2°C to 2.5°C is projected for the northern districts of Bidar, Bagalkot, Kalaburagi, Vijayapura and Belagavi.

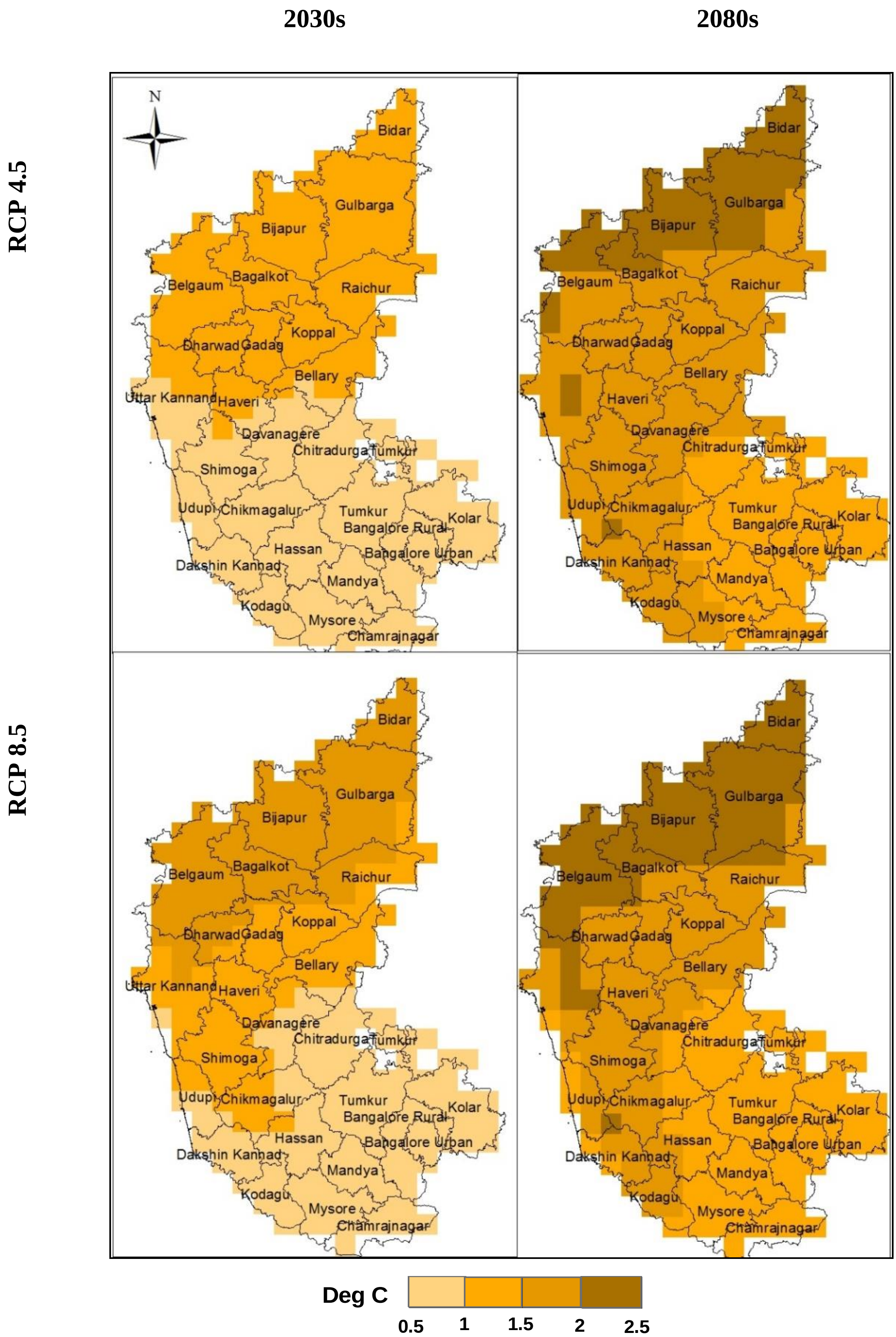


Figure 3.6: District-wise changes in winter minimum temperature (^{0}C) projected for the short-term (2030s) and the long-term (2080s) under RCP 4.5 and RCP 8.5 scenarios

relative to 1985 to 2015. *Discussion on spatial trends is provided for all the 30 districts, considering the lat-long information available for the districts, even though the map representation is only for 27 districts.*

The summer maximum and winter minimum temperature is projected to increase in the range of 0.5°C to 2.5°C in the short- and long-term periods, considering both RCP 4.5 and RCP 8.5 scenarios. Higher warming of both summer maximum and winter minimum temperature is projected particularly for the northern and northeastern districts of Karnataka. Further, warming of the northern most districts is projected to be in the range of 2°C to 2.5°C under both RCP 4.5 and RCP 8.5 scenarios.

3.6.2. Rainfall Projections for the Short-term (2030s) and Long-term (2080s) Periods

Any changes in rainfall pattern or magnitude could adversely impact water availability and crop production. Broad spatial trends in *Kharif* (JJAS) season rainfall are presented in Section 3.2.1 and Figure 3.7, for the short and long-term periods. Quantitative changes in *Kharif* and *Rabi* season rainfall at district level for only the short-term are presented in Section 3.2.2. Annex 3.3 presents Annual, *Kharif* (JJAS) and *Rabi* (OND) season rainfall during the historical and projected periods for the short-term period of 2030s (2021-2050).

Spatial trends in Kharif season rainfall for the short and long-term periods: Rainfall is projected to increase under both RCP 4.5 and RCP 8.5 scenarios, in the short and long-term periods.

a. Short-term (2030s) (Figure 3.7 – Left Panel): An increase in *Kharif* season rainfall in the range of 5% to 25% is projected in the short-term (2030s) for the districts of Karnataka, considering RCP 4.5 and RCP 8.5 scenarios.

1) ***RCP 4.5 scenario:*** Under this scenario, an increase in rainfall in the range of 5% to 20% is projected for the districts of Karnataka.
    - Rainfall is projected to increase in the range of 5% to 10% for Raichur, Koppal, Ballari, Gadag, Haveri, and parts of Kalaburagi, Vijayapura, Bagalkot, Dharwad, etc.
    - Rainfall is projected to increase in the range of 10% to 15% in the Western Ghats districts of Shivamogga, Belagavi, Uttara Kannada, and also Bengaluru Urban, Bengaluru Rural, Tumakuru, etc.
    - Rainfall is projected to increase in the range of 15% to 20% in the Western Ghats districts of Udupi, Kodagu, Dakshina Kannada, and part of Hassan and Chikkamagaluru.

2) ***RCP 8.5 scenario:*** Under this scenario, an increase in rainfall in the range of 10% to 25% is projected for the districts of Karnataka.
    - Rainfall is projected to increase in the range of 10% to 15% for a majority of the districts of Karnataka including Raichur, Koppal, Ballari, Gadag, Haveri, and parts of Kalaburagi, Vijayapura, Bagalkot, and others.

- Rainfall is projected to increase in the range of 15% to 20% for the northern most districts of Bidar, part of Kalaburagi, Vijayapura, Bagalkot, Belagavi, and parts of the Western Ghats districts of Chikkamagaluru, Hassan and Shivamogga.
- Rainfall is projected to increase in the range of 20% to 25% for the Western Ghats districts of Dakshina Kannada, Kodagu, part of Udupi, Chikkamagaluru and Hassan.

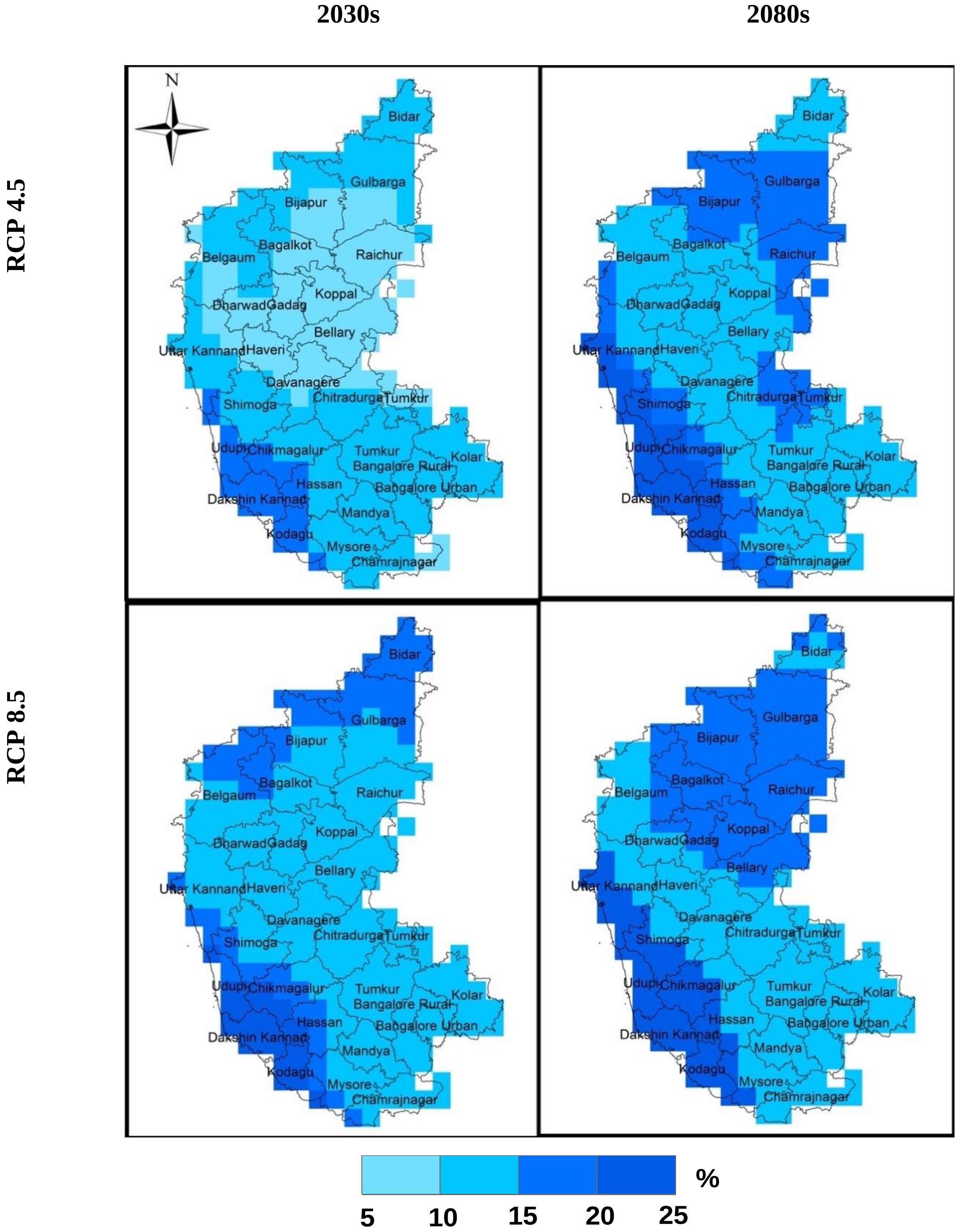


Figure 3.7: District-wise percentage changes in *Kharif* (JJAS) season rainfall projected for the short-term (2030s) and long-term (2080s) under RCP 4.5 and RCP 8.5 scenarios relative to 1987 to 2016. *Discussion on spatial trends is provided for all the 30 districts, considering lat-long information available for the districts, even though map representation is for 27 districts.*

b. Long-term (2080s) – (Figure 3.7 – Right Panel): An increase in *Kharif* season rainfall in the range of 10% to 25% is projected in the long-term (2080s) for the districts of Karnataka, considering RCP 4.5 and RCP 8.5 scenarios.

1) ***RCP 4.5 scenario:*** Under this scenario, an increase in rainfall in the range of 10% to 25% is projected for the districts of Karnataka.
   - Rainfall is projected to increase in the range of 10% to 15% for a majority of the districts of Karnataka including Bidar, Koppal, Ballari, Gadag, Haveri, Dharwad, and parts of Bagalkot, Tumakuru, Chitradurga, and others.
   - Rainfall is projected to increase in the range of 15% to 20% for the northern districts of Kalaburagi, Vijayapura, Raichur, and parts of Tumakuru, Chitradurga, Shivamogga, Mysuru, Chamarajanagar, and others.
   - Rainfall is projected to increase in the range of 20% to 25% for the Western Ghats districts of Udupi, Dakshina Kannada, Kodagu, part of Uttara Kannada, Chikkamagaluru and Hassan.

2) ***RCP 8.5 scenario:*** Under this scenario, an increase in rainfall in the range of 10% to 25% is projected for the districts of Karnataka.
   - Rainfall is projected to increase in the range of 10% to 15% for the districts of Bidar, Haveri, Tumakuru, Chitradurga, Kolar, Mandya, Bengaluru Urban, Bengaluru Rural, and others.
   - Rainfall is projected to increase in the range of 15% to 20% for the northern districts of Kalaburagi, Vijayapura, Raichur, Koppal, Ballari, Gadag, and part of Belagavi.
   - Rainfall is projected to increase in the range of 20% to 25% for the Western Ghats districts of Udupi, Dakshina Kannada, Kodagu, Uttara Kannada, Chikkamagaluru and part of Hassan and Shivamogga.

Kharif season rainfall is projected to increase in the range of 15% to 25% in the north eastern and Western Ghats districts under both RCP 4.5 and RCP 8.5 scenarios.

Quantitative changes in seasonal rainfall projections for the short-term (2030s) period: Quantitative changes in *Kharif* (JJAS) and *Rabi* (OND) season rainfall projected for the 2030s, under RCP 4.5 and RCP 8.5 scenarios, relative to the historical (1987 to 2016) period, are presented in this section, at the district level for 30 districts of Karnataka.

***a. Kharif (JJAS) season (Figure 3.8)*:** Increase in *Kharif* season rainfall in the range of 7% to 28% is projected for the districts of Karnataka in the short-term, considering RCP 4.5 and RCP 8.5 scenarios.

1) ***RCP 4.5 scenario:*** Under this scenario, an increase in *Kharif* season rainfall in the range of 7% to 18% is projected for all the districts of Karnataka.

   - *Districts receiving <1000 mm mean annual rainfall*: The increase in rainfall is projected to be in the range of 7% (Davanagere) to 17% (Kolar), with >10% increase in rainfall projected for 14 of 23 districts.

- *Districts receiving >1000 mm mean annual rainfall:* The increase in rainfall is projected to be in the range of 14% (Shivamogga) to 18% (Uttara Kannada, Dakshina Kannada and Udupi). In Hassan and Chikkamagaluru districts, a 16% increase, and in Kodagu, a 15% increase in *Kharif* season rainfall is projected.

2) ***RCP 8.5 scenario:*** Under this scenario, an increase in *Kharif* season rainfall in the range of 13% to 28% is projected for the districts of Karnataka.

   - *Districts receiving <1000 mm mean annual rainfall:* The increase in rainfall is projected to be in the range of 13% (Davanagere and Gadag) to 28% (Belagavi), with >20% increase in rainfall projected for 6 of the 23 districts.

   - *Districts receiving >1000 mm mean annual rainfall:* The increase in rainfall is projected to be in the range of 19% (Shivamogga and Uttara Kannada) to 25% (Kodagu).

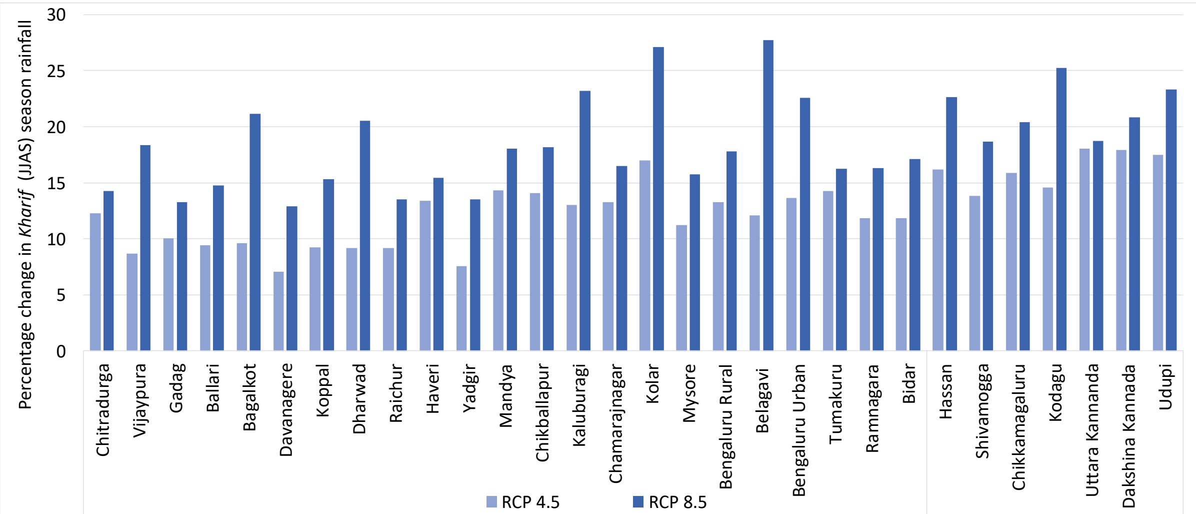


Figure 3.8: Projected percentage change in *Kharif* (JJAS) season rainfall during the short-term (2030s) relative to the historical period (1987-2016) under RCP 4.5 and RCP 8.5 scenarios. *Districts are arranged according to mean annual rainfall.*

In Karnataka, an increase in rainfall magnitude during *Kharif* season, compared to the recent decades, is projected with higher percentage increase in rainfall particularly for districts receiving >1000 mm mean annual rainfall. In the districts receiving <1000 mm mean annual rainfall, >10% increase (up to 17%) in rainfall is projected for 14 of the 23 districts under RCP 4.5 scenario, and for all the districts (13% to 28%) under RCP 8.5 scenario.

b. *Rabi (OND) season - (Figure 3.9):* An increase in *Rabi* season rainfall, in the range of 7% to 39% is projected for the districts of Karnataka in the short-term, considering RCP 4.5 and RCP 8.5 scenarios.

1) RCP 4.5 scenario: Under this scenario, *Rabi season* rainfall is projected to increase in the range of 7% to 27% for the districts of Karnataka.

- *Districts receiving <1000 mm mean annual rainfall:* Increase in rainfall in the range of 7% (Mandya) to 21% (Bagalkot) is projected, with >10% increase in rainfall projected for 20 of 23 districts.

- *Districts receiving >1000 mm mean annual rainfall:* Increase in rainfall in the range of 7% (Udupi) to 27% (Dakshina Kannada) is projected, with >10% increase in rainfall projected for all districts, except Udupi.

2) RCP 8.5 scenario: Under this scenario, *Rabi* season rainfall is projected to increase in the range of 10% to 35% for the districts of Karnataka.

- *Districts receiving <1000 mm mean annual rainfall:* Rainfall is projected to increase in the range of 14% (Ballari) to 35% (Chitradurga), with >20% increase in rainfall projected for 17 of the 23 districts receiving.

- *Districts receiving >1000 mm mean annual rainfall:* Rainfall is projected to increase in the range of 10% (Udupi) to 39% (Chikkamagaluru).

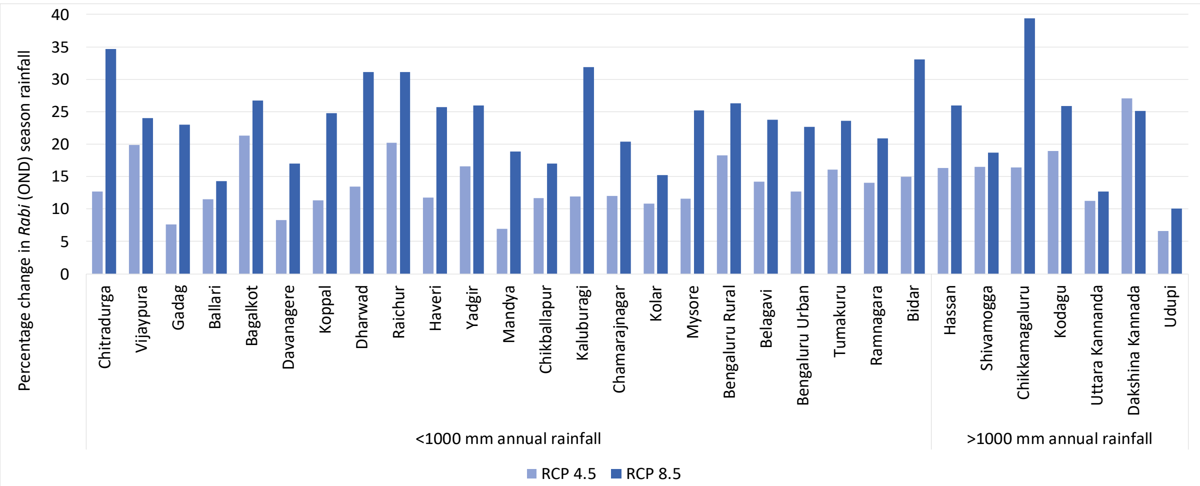


Figure 3.9: Projected percentage change in *Rabi* (OND) season rainfall during the short-term (2030s) relative to the historical period (1987-2016) under RCP 4.5 and RCP 8.5 scenarios**.** *Districts are arranged according to mean annual rainfall.*

In Karnataka, an increase in *Rabi* season rainfall, in the range of 7% to 39% is projected, considering RCP 4.5 and RCP 8.5 scenarios. Among the districts receiving <1000 mm mean annual rainfall, >10% increase (up to 21%) in rainfall is projected for 20 districts under RCP 4.5 scenario, and >20% increase (up to 35%) in rainfall is projected for 17 districts under

RCP 8.5 scenario. This will have implications for crop production, irrigation provision and disaster management.

3.6.3. Projected Kharif and Rabi Season Rainfall Variability for the Short-term (2030s) Period

The *Kharif* (JJAS) and *Rabi* (OND) season rainfall variability for the projected 30-year period (2021-2050) is compared with the historical period (1987-2016) and presented in this section.

Kharif (JJAS) season rainfall variability: The Kharif season (JJAS) rainfall variability is projected to decline in some districts and increase in others during the projected period, considering RCP 4.5 and RCP 8.5 scenarios (Figure 3.10).

1) RCP 4.5 scenario: Under this scenario, the CV of *Kharif* season rainfall is projected to decline for 13 districts and increase in the remaining 17 districts.

- *Districts receiving <1000 mm mean annual rainfall:* The CV is projected to decline for 10 districts and increase in the remaining 13 districts.
    - A marginal decline in CV in the range of 1% (Haveri and Chamarajanagar) to 7% (Bagalkot) is projected.
    - An increase in CV in the range of 1% to 14% is projected for 13 districts, with >10% increase projected for only Bengaluru Rural, Bengaluru Urban, and Kolar districts.

- *Districts receiving >1000 mm mean annual rainfall:* The CV is projected to decline for 3 districts and increase in the remaining 4 districts.
    - A marginal decline in CV in the range of 1% to 3% is projected for Kodagu, Shivamogga and Chikkamagaluru districts.
    - A marginal increase in CV in the range of 3% to 5% is projected: 5% for Uttara Kannada and Dakshina Kannada, and 3% for Udupi and Hassan districts.

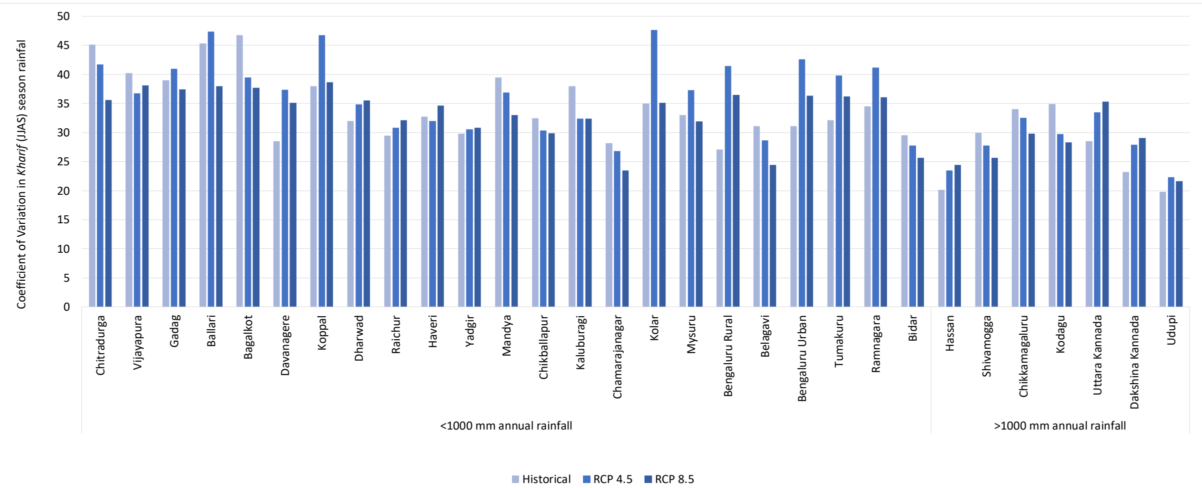


Figure 3.10: Coefficient of Variation in *Kharif* (JJAS) season rainfall during historical (1987-2016) and projected short-term (2030s) period under RCP 4.5 and RCP 8.5 scenarios. *Districts are arranged according to mean annual rainfall.*

***2) RCP 8.5 scenario*:** Under this scenario, the CV of *Kharif* season rainfall is projected to decline for 15 districts, remain the same for Kolar district, and increase for the remaining 14 districts.

- *Districts receiving <1000 mm mean annual rainfall:* The CV is projected to decline in 12 districts, remain the same in Kolar, and increase in the remaining 10 districts.
  - A decline in CV in the range of 1% (Mysuru) to 9% (Bagalkot and Chitradurga) is projected.
  - An increase in CV in the range of 1% to 9% is projected for 14 districts, with > 5% increase projected for only Davanagere and Bengaluru Rural districts.

- *Districts receiving >1000 mm mean annual rainfall:* The CV is projected to decline for 3 districts and increase in the remaining 4 districts.
  - A decline in CV in the range of 4% to 7% is projected for Kodagu, Shivamogga and Chikkamagaluru districts.
  - An increase in the range of 2% to 7% is projected: 2% for Udupi, 4% for Hassan, 6% for Dakshina Kannada, and 7% for Uttara Kannada district.

Rabi (OND) season rainfall variability: The Rabi season (JJAS) rainfall variability is projected to decline for a majority of the districts, increase or remain the same in a few districts during the projected period, considering RCP 4.5 and RCP 8.5 scenarios (Figure 3.11).

1) RCP 4.5 scenario: Under this scenario, the CV of *Rabi* season rainfall is projected to decline for 24 districts, remain the same for 2 districts and increase for 4 districts.

- *Districts receiving <1000 mm mean annual rainfall:* The CV is projected to decline for 19 districts, remain the same in Kolar and increase marginally by 1% and 4% in Tumakuru, Chamarajanagar and Bengaluru Urban districts.
  - A decline in CV in the range of 2% (Yadgir) to 34% (Davanagere) is projected, with >20% decline for 6 districts, including Gadag, Ballari, Haveri, Mysuru, Raichur and Davanagere.

- *Districts receiving >1000 mm mean annual rainfall:* The CV is projected to decline for 5 districts, remain the same for Dakshina Kannada and increase for Udupi (16%) district.
  - A decline in CV in the range of 2% to 12% is projected for Chikkamagaluru, Uttara Kannada, Kodagu, Hassan and Shivamogga districts.

2) RCP 8.5 scenario**:** Under this scenario, the CV of *Rabi* season rainfall is projected to decline for all the districts of Karnataka.

- *Districts receiving <1000 mm mean annual rainfall:* The CV is projected to decline in the range of 4% (Bengaluru Urban) to 40% (Davanagere and Haveri), with >20% decline in CV projected for 10 of the 23 districts, including Ballari, Raichur, Bagalkot, Chitradurga, and others, and 10% to 20% decline projected for 5 districts.

- *Districts receiving >1000 mm mean annual rainfall:* The CV is projected to decline in the range of 5% (Hassan) to 22% (Uttara Kannada).

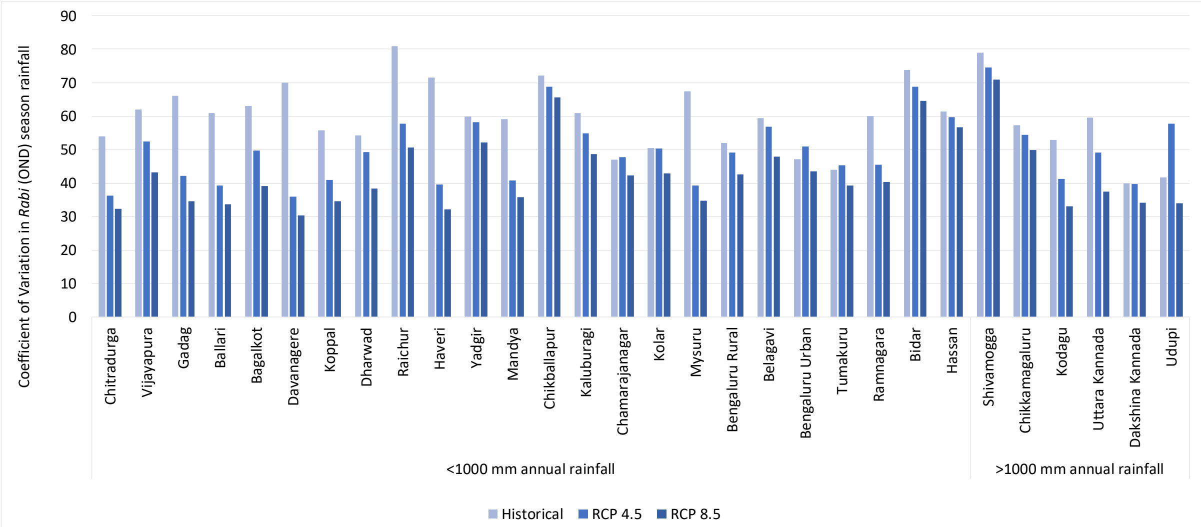


Figure 3.11: Coefficient of Variation in *Rabi (OND)* season rainfall during historical (1987-2016) and projected short-term (2030s) period under RCP 4.5 and RCP 8.5 scenarios. *Districts are arranged according to mean annual rainfall*

In Karnataka, a mixed trend in CV of the *Kharif* season rainfall is projected, compared to the historical period, while a decline in CV is projected during the *Rabi* season, under both RCP 4.5 and RCP 8.5 scenarios. The *Kharif* season rainfall variability is projected to decline for 13 and 15 districts under RCP 4.5 and RCP 8.5 scenarios, respectively. A marginal increase in CV is projected to be in the range of 7% to 14% in 7 districts under RCP 4.5 scenario and 5% to 9% in 3 districts under RCP 8.5 scenario for the districts receiving <1000 mm mean annual rainfall.

3.6.4. Projected Changes in Number of Rainy Days and High Intensity Rainfall Events for the Short-term (2030s) Period

High intensity rainfall events (mm/day) cause floods, landslides and crop damage. In this section, changes in the frequency of rainy days and an analysis of frequency of rainfall events of intensity of <50 mm, 51-100 mm and >100 mm per day are presented for the projected short-term (2030s) period.

Changes in the number of rainy days: Rainy day is defined as a day receiving >2.5 mm, according to IMD. A comparison of changes in the number of rainy days under RCP 4.5 and RCP 8.5 scenarios and the historical period shows an increase in almost all the districts of Karnataka (Figure 3.12).

1) RCP 4.5 scenario: The number of rainy days is projected to increase in the range of 1 to 6 days annually, compared to the historical period, for all the districts of Karnataka.

- *Districts receiving <1000 mm mean annual rainfall:* The number of rainy days is projected to increase in the range of 1 (Yadgir and Bidar) to 6 (Chamarajanagar) days annually,
  - The increase in the number of rainy days is ≥5 annually in 5 of the 23 districts, including Davanagere, Chitradurga, Dharwad, Kolar and Chamarajanagar.
- *Districts receiving >1000 mm mean annual rainfall:* The increase in the number of rainy days is projected to be in the range 1 (Udupi and Dakshina Kannada) to 6 (Uttara Kannada) days annually.
  - The increase in the number of rainy days is in the range 1 to 3 days annually in 6 of the 7 districts.

2) RCP 8.5 scenario: The number of rainy days is projected to increase in the range of 2 to 9 days annually, compared to the historical period, for all the districts of Karnataka.

- *Districts receiving <1000 mm mean annual rainfall:* The number of rainy days is projected to increase in the range of 3 (Belagavi, Mysuru, Bidar and Yadgir) to 8 (Kolar, Davanagere, Koppal and Vijayapura) days annually.
  - The increase in the number of rainy days is ≥5 annually in 19 of the 23 districts.

- *Districts receiving >1000 mm mean annual rainfall:* The number of rainy days is projected to increase in the range of 2 (Dakshina Kannada and Udupi) to 9 (Uttara Kannada) days annually.

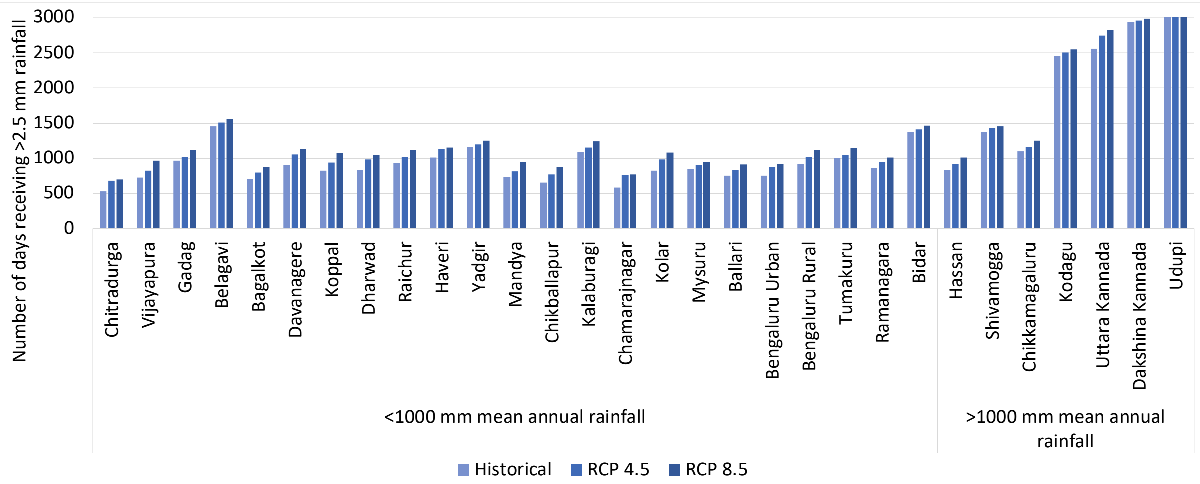


Figure 3.12: Number of rainy days in a 30-year period: Historical and projected number of rainy days under RCP 4.5 and RCP 8.5 scenarios. *Districts are arranged according to mean annual rainfall.*

In Karnataka, an increase in the number of rainy days is projected for a majority of the districts of Karnataka, under both RCP 4.5 and 8.5 scenarios. The increase in the number of rainy days is ≥5 days annually in 6 districts under RCP 4.5 scenario, and 22 districts under RCP 8.5 scenario.

'High' intensity rainfall events: This is any day receiving a rainfall of 51-100 mm. In this section, the frequency of occurrence of such an event under RCP 4.5 and RCP 8.5 scenarios is presented, relative to the historical period.

1) ***RCP 4.5 scenario (Figure 3.13 – Upper Panel):*** Increase in rainfall events of 'High' intensity relative to the historical period is projected for all districts, except Vijayapura, where no change, relative to the historical period is projected.
   - *Districts receiving <1000 mm annual rainfall:* Increase in the occurrence of 'High' intensity rainfall events, in the range of 1 to 2 events annually is projected for 22 of the 23 districts.
     - The increase annually is by: 2 events in 9 districts, including Bengaluru Urban, Bengaluru Rural, Kolar, Hassan, Kalaburagi, Mandya, etc., and 1 event in 13 districts.
   - *Districts receiving >1000 mm annual rainfall:* Increase in the occurrence of 'High' intensity rainfall events, in the range of 1 to 6 events annually is projected for all the districts.
     - The increase annually is by: 6 events in Uttara Kannada, 5 events in Udupi, 4 events in Dakshina Kannada, 3 events in Kodagu, 2 events in Shivamogga and Hassan and 1 event in Chikkamagaluru district.

2) ***RCP 8.5 scenario (Figure 3.13 – Lower Panel):*** Increase in rainfall events of 'High' intensity relative to the historical period is projected for all the districts of Karnataka.
   - *Districts receiving <1000 mm annual rainfall:* Increase in the occurrence of 'High' intensity rainfall events, in the range of 1 to 3 events annually is projected for all the districts of Karnataka.
     - The increase annually is by: 3 events in Kolar, Bengaluru Rural, Kalaburagi and Mandya, 2 events in 13 districts, including Bengaluru Urban, Dharwad, Haveri, Yadgir, Raichur, Koppal and others., and 1 event in 7 districts.
   - *Districts receiving >1000 mm annual rainfall:* Increase in the occurrence of 'High' intensity rainfall events, in the range of 2 to 8 events annually is projected for all the districts of Karnataka.

- The increase annually is by: 8 events in Dakshina Kannada, 6 events in Udupi, 5 events in Uttara Kannada, 4 events in Kodagu, 3 events in Shivamogga and Hassan and 2 events in Chikkamagaluru district.

‘Very High’ intensity rainfall events: This is any day receiving >100 mm rainfall. In this section, the frequency of such an event under RCP 4.5 and RCP 8.5 scenarios is presented, relative to the historical period.

1) ***RCP 4.5 scenario (Figure 3.13 – Upper Panel):*** Increase in rainfall events of ‘Very High’ intensity relative to the historical period is projected for 25 of the 30 districts of Karnataka.
    - *Districts receiving <1000 mm annual rainfall:* Increase in the occurrence of ‘Very High’ intensity rainfall events is marginal by 1 event annually in 19 districts, including Bengaluru Urban, Bengaluru Rural, Kolar, Kalaburagi, Mandya, Dharwad, Haveri, etc. No change in occurrence of ‘Very High’ intensity rainfall events is projected for Vijayapura, Ballari, Bagalkot and Kolar districts.

    - *Districts receiving >1000 mm annual rainfall:* Increase in the occurrence of ‘Very High’ intensity rainfall events, in the range of 1 to 2 events annually is projected for all districts except Udupi.
        - The increase annually is by: 2 events in Uttara Kannada and 1 event in the remaining districts.

Frequency of rainfall events under RCP 4.5 scenario							
	Districts	<50 mm rainfall		51-100 mm rainfall		>100 mm rainfall	
		Historical	RCP 4.5	Historical	RCP 4.5	Historical	RCP 4.5
<1000 mm mean annual rainfall	Chitradurga	3646	3561	14	78	0	21
	Vijaypura	3643	3625	15	23	2	12
	Gadag	3635	3582	20	45	5	33
	Belagavi	3607	3540	45	88	8	32
	Bagalkot	3644	3592	13	56	3	12
	Davanagere	3643	3564	17	66	0	30
	Koppal	3637	3576	22	59	1	25
	Dharwad	3631	3567	23	71	6	22
	Raichur	3638	3570	21	60	1	30
	Haveri	3643	3545	15	76	2	39
	Yadgir	3653	3592	7	43	0	25
	Mandya	3645	3570	12	57	3	33
	Chikballapur	3640	3584	19	43	1	33
	Kalaburagi	3635	3538	20	84	5	38
	Chamarajanagar	3649	3610	10	33	1	17
	Kolar	3644	3585	15	60	1	15
	Mysuru	3642	3590	15	40	3	30
	Ballari	3642	3603	17	45	1	12
	Bengaluru Urban	3625	3542	33	87	2	31
	Bengaluru Rural	3637	3544	23	93	0	23
	Tumakuru	3631	3575	26	60	3	25
	Ramnagara	3616	3563	41	65	3	32
	Bidar	3605	3560	48	65	1	35
>1000 mm mean annual rainfall	Hassan	3636	3539	22	90	5	42
	Shivamogga	3638	3542	22	88	7	45
	Chikkamagaluru	3647	3591	12	51	1	18
	Kodagu	3504	3379	140	231	16	50
	Uttara Kannada	3398	3180	222	390	40	90
	Dakshina Kannada	3063	2929	513	623	84	108
	Udupi	2878	2715	607	760	175	185

Frequency of rainfall events under RCP 8.5 scenario							
	Districts	<50 mm rainfall		51-100 mm rainfall		>100 mm rainfall	
		Historical	RCP 8.5	Historical	RCP 8.5	Historical	RCP 8.5
<1000 mm mean annual rainfall	Chitradurga	3646	3561	14	88	0	40
	Vijaypura	3643	3625	15	61	2	22
	Gadag	3635	3582	20	56	5	18
	Belagavi	3607	3540	45	69	8	60
	Bagalkot	3644	3592	13	67	3	20
	Davanagere	3643	3564	17	67	0	45
	Koppal	3637	3576	22	88	1	45
	Dharwad	3631	3567	23	80	6	49
	Raichur	3638	3570	21	85	1	47
	Haveri	3643	3545	15	71	2	34
	Yadgir	3653	3592	7	55	0	32
	Mandya	3645	3570	12	90	3	42
	Chikballapur	3640	3584	19	44	1	29
	Kalaburagi	3635	3538	20	101	5	56
	Chamarajanagar	3649	3610	10	34	1	31
	Kolar	3644	3585	15	95	1	30
	Mysuru	3642	3590	15	87	3	64
	Ballari	3642	3603	17	39	1	41
	Bengaluru Urban	3625	3542	33	89	2	47
	Bengaluru Rural	3637	3544	23	110	0	45
	Tumakuru	3631	3575	26	90	3	37
	Ramnagara	3616	3563	41	70	3	43
	Bidar	3605	3560	48	98	1	71
	Hassan	3636	3539	22	112	5	72
>1000 mm mean annual rainfall	Shivamogga	3638	3542	22	101	7	67
	Chikkamagaluru	3647	3591	12	65	1	33
	Kodagu	3504	3379	140	250	16	77
	Uttara Kannada	3398	3180	222	370	40	122
	Dakshina Kannada	3063	2929	513	762	84	140
	Udupi	2878	2715	607	800	175	191

Figure 3.13: Frequency of rainfall events with intensity of below 50 mm, 51-100 mm and >100 mm rainfall/day during historical and projected short-term period under RCP 4.5 and RCP 8.5 scenarios. *Districts are arranged according to mean annual rainfall.*

2) ***RCP 8.5 scenario (Figure 3.13 – Lower Panel)*****:** Increase in rainfall events of 'Very High' intensity relative to the historical period is projected for all districts, except Gadag where no change is projected.

- *Districts receiving <1000 mm annual rainfall:* Increase in the occurrence of 'Very High' intensity rainfall events annually is by: 1 event in 14 districts, including Kolar, Mandya, Dharwad, Haveri, Chamarajanagar, etc., 2 events in 8 districts, including Bengaluru Urban, Bengaluru Rural, Kalaburagi, etc.

- *Districts receiving >1000 mm annual rainfall:* Increase in the occurrence of 'Very High' intensity rainfall events, in the range of 1 to 3 events annually is projected for all the districts.
  - The increase annually is by: 3 events in Uttara Kannada, 2 events in Hassan, Shivamogga, Kodagu and Dakshina Kannada, and 1 event in Chikkamagaluru and Udupi districts.

In Karnataka, increase in the occurrence of 'Very High' and 'High' intensity rainfall events is projected, largely in the range of 1 to 2 events annually, under both RCP 4.5 and RCP 8.5 scenarios. 'Very High' intensity rainfall events are projected to increase in the range of 1 to 2 events annually, for 25 districts under RCP 4.5 scenario and 29 districts under RCP 8.5 scenario.

3.6.5. Projected Frequency of 'Drought' Years for the Short-term (2030s) Period

The criterion and definition for droughts is provided in Section 2.5. The focus is on droughts during the short-term period (2021-2050) for policy making. Occurrence of 'Drought' years for the short-term period is projected, relative to the historical period (1987-2016) under RCP 4.5 and RCP 8.5 scenarios considering the *Kharif* season (JJAS) rainfall (Figure 3.14) for the 2030s.

1) ***RCP 4.5 scenario:*** A decline in the frequency of 'Drought' years under RCP 4.5 scenario, compared to the historical period is projected for all the districts of Karnataka, except Udupi.

- *Districts receiving <1000 mm annual rainfall:* Occurrence of 'Drought' years is projected to decline marginally in the range of 1 to 3 years in 22 of the 23 districts.
  - The projected decline in 'Drought' years is by: 1 year in 14 districts, 2 years in 16 districts, and 3 years in Bengaluru Urban and Gadag districts.

- *Districts receiving >1000 mm annual rainfall:* Occurrence of 'Drought' years is projected to decline marginally in the range of 1 to 2 years in 5 of the 6 districts. Only in Udupi district, no change is projected.

- The projected decline in ‘Drought’ years is by: 1 year in Shivamogga and Chikkamagaluru, and 2 years in Hassan, Kodagu, Uttara Kannada and Dakshina Kannada districts.

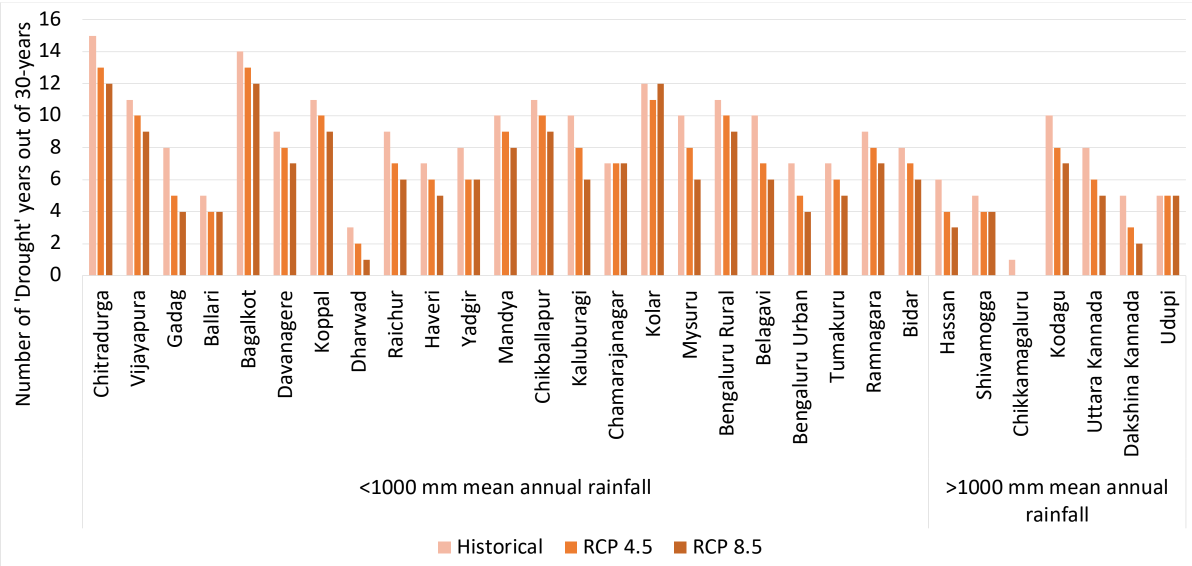


Figure 3.14: *Kharif* (JJAS) season ‘Drought’ year frequency (No. of years) during the historical (1987-2016) and projected short-term (2030s) period under RCP 4.5 and RCP 8.5 scenarios. *Districts are arranged according to mean annual rainfall.*

2) ***RCP 8.5 scenario:*** A decline in the frequency of ‘Drought’ years under RCP 8.5 scenario, compared to the historical period is projected for 27 of the 30 districts of Karnataka.
   - *Districts receiving <1000 mm annual rainfall:* Occurrence of ‘Drought’ years is projected to decline marginally in the range of 1 to 4 years in 21 districts, and no change in 2 districts – Kolar and Chamarajanagar.
     - The projected decline in ‘Drought’ years is by: 1 year in Belagavi, 2 years in 13 districts, 3 years in Bengaluru Rural, Raichur and Chitradurga, and 4 years in Mysuru, Kalaburagi, Bengaluru Urban and Gadag districts.
   - *Districts receiving >1000 mm annual rainfall:* Occurrence of ‘Drought’ years is projected to decline marginally in the range of 1 to 3 years in 6 of the 7 districts.
     - The projected decline in ‘Drought’ years is by: 1 year in Shivamogga and Chikkamagaluru, and 3 years in Hassan, Kodagu, Uttara Kannada and Dakshina Kannada districts.
     - No change in occurrence of ‘Drought’ years is projected for Udupi district.

‘Drought’ years are projected to decline, in the range of 1 to 3 years under RCP 4.5 scenario, and 1 to 4 years under RCP 8.5 scenario, in a majority of the districts of Karnataka.

3.7. Limitations of this Assessment

The results presented are likely to have some uncertainty due to the following reasons:

- Coarse resolution of the projected climate change data.
  - The climate change information is derived from CORDEX data at 0.5° x 0.5° resolution, which is not adequate for decision making at farm or village or sub-watershed level, but is likely adequate at the district mean level. As we have not downscaled this data to a finer resolution, the sub-grid variability within the 0.5° x 0.5° resolution grid is not captured in the analysis, which is likely to introduce some uncertainty.
- There could be potential uncertainty arising out of the methodology used to estimate the district averages.
- Absence of an analysis of the statistical significance of projected changes.
  - This is a compromise that was made to keep the study as simple as possible.

However, we note that the direction of changes in temperature, rainfall and extreme events are largely in agreement with the literature at global, south Asia and national levels.

The focus of this study is on the short-term period (2021 to 2050), for policy relevance and to guide decision making in the short-term. Climate change projections for RCP 4.5 (moderate emissions) and RCP 8.5 (high emissions) scenarios are provided to highlight the range of possibilities. The climate projections for Karnataka are fully consistent with the national level report on climate change from Ministry of Earth Sciences, which concludes, "Climate models project an increase in the annual and summer monsoon mean rainfall, as well as frequency of heavy rain occurrences over most parts of India during the twenty-first century" (Krishnan et al., 2020).

It is clear from this assessment that climate in the districts of Karnataka—both temperature and rainfall have changed over the historical period and in the future, while temperatures are projected to increase, summer monsoon rainfall is also projected to increase. Further, heavy rainfall events are also projected to increase indicating changes in the magnitude, frequency and timing of occurrence of these events—all with implications for natural resource sectors such as fisheries, forests, water, etc., and socio-economic systems such as agriculture and health, and communities in different districts. The projected changes are variable across space and time, underpinning the need for considering climate risks in planning and implantation of state development plans and projects. It also highlights the importance of aligning state goals with national plans and commitments such as the NDC, so as to ensure realisation of international commitments.

Chapter 4: Vulnerability Assessment

4.1. Definition and Conceptual Framework

Vulnerability is a dynamic and context-specific characteristic, determined by human behaviour and societal organisations. It influences the susceptibility and adaptive capacities of human or social-ecological systems exposed to hazardous climatic or non-climatic events and stresses. IPCC 2007 report considered vulnerability as a resultant of exposure, sensitivity and adaptive capacity to 'a system attribute' represented by the internal properties of the system (sensitivity and adaptive capacity). IPCC 2014 framework assesses vulnerability as an endogenous system property independent of exposure. This new concept eliminates the complexities related to the assessment of the nature and dosage of exposure to hazard. Such treatment of vulnerability avoids the chances of maladaptation, and in combination with the benefits of restored health of the system, offers a win-win strategy. The conceptual framework showing the components and scenarios for assessment of risk and vulnerability is presented in Figure 4.1. Vulnerability under this construct is assessed as a snapshot vulnerability under the current climate (current vulnerability) as well as the future climate (climate change vulnerability). Risk is assessed under current climate variability and under future climate change. Vulnerability is assessed under the current and the future climate, independent of hazard and exposure. Dealing with the drivers of current vulnerability can potentially reduce the current as well as the future risks.

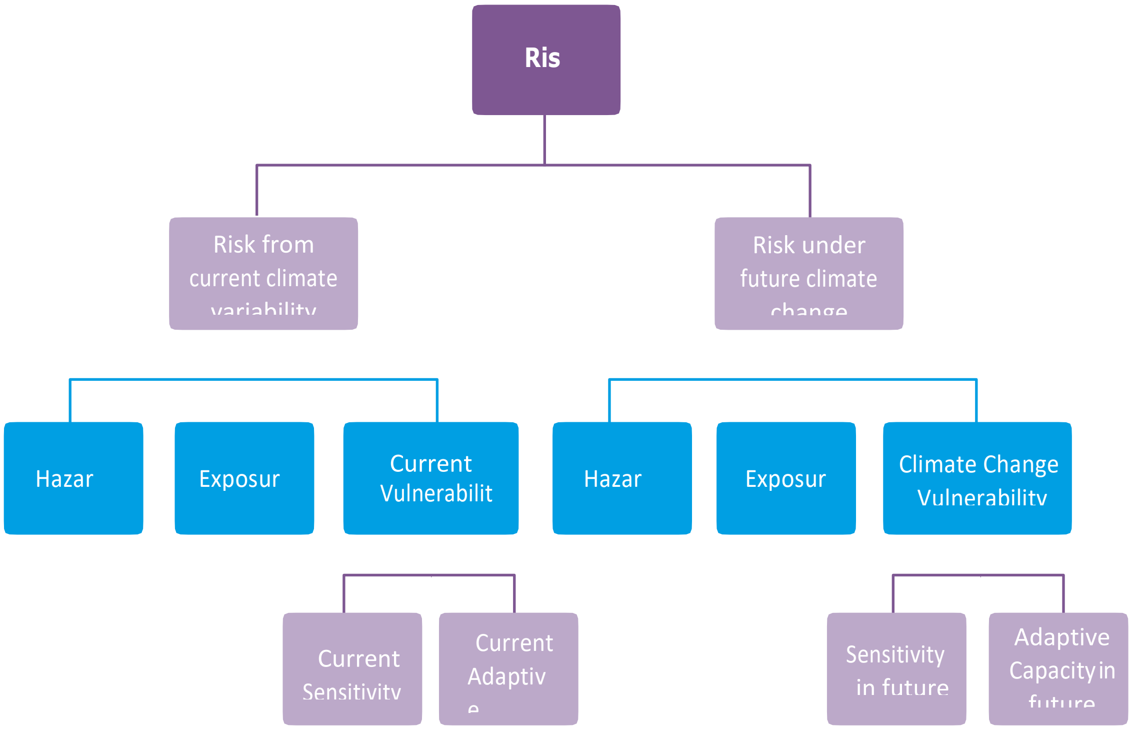


Figure 4.1: Conceptual framework showing the scenarios and elements for the assessment of risk and vulnerability according to the IPCC 2014 framework

4.1.1. Need for Vulnerability Assessment

Vulnerability assessment can and needs to be conducted for systems and communities under current climate as well as climate change scenarios. However, conducting assessment of vulnerability under climate change is complex because of the need for data on all indicators considered for assessment for a future period. According to the Intergovernmental Panel on Climate Change (IPCC), addressing current climate vulnerability is the first step towards adaptation. Assessment of current climate vulnerability is needed for:

- *Identifying current and potential hotspots:* It assists to identify the current and potential vulnerability hotspots by comparing susceptibility to climate change in multiple systems (e.g. mountain communities, cropping, arid zone, forests and water resources). It allows better understanding of the factors driving the vulnerability of a climate change hotspot (e.g., a specific geographical area, which is more likely to be severely affected by climate change than others).
- *Identifying entry points for intervention:* Information on the factors underlying a system's vulnerability can serve as a starting point for identifying suitable adaptation interventions.
- *Tracking changes in vulnerability and monitoring and evaluation (M&E) of adaptation:* A relatively new approach is to use vulnerability assessments to track changes in vulnerability over time. This complements the existing methods for M&E of adaptation measures and generates additional knowledge on the effectiveness of adaptation.

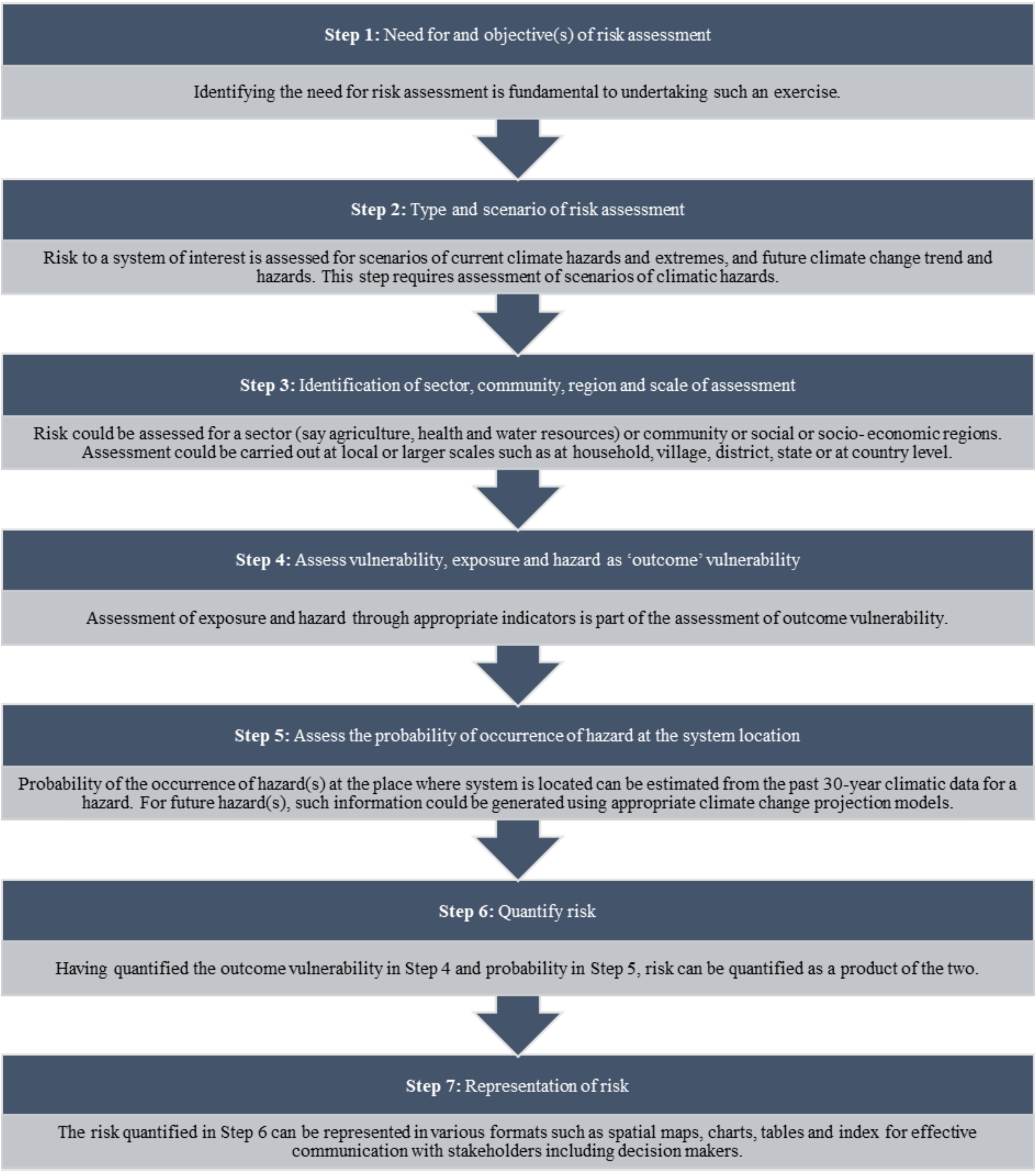
4.2. Methodology and Framework

The broad goals/objectives of vulnerability assessment in the context of climatic hazards and addressing climate change are as follows:

- Identification of the most vulnerable regions, sectors and communities – to raise awareness about vulnerability, ranking and prioritization for adaptation interventions
- Assist in adaptation planning – based on information on vulnerability profiles and drivers/sources of vulnerability
- Spatial adaptation planning – including temporal adaptation planning for current and future climate scenarios

Vulnerability assessment could be carried out at a micro-scale such as at a village level where households or farmers can be assessed for vulnerability. Similarly, vulnerability assessment could be carried out at a macro-scale such as at a district, watershed and state levels. One can rank the most vulnerable regions on a spatial scale and further select sectors within a region for vulnerability assessment. Vulnerability assessment could start from a sector and the appropriate scale could be identified. For example, if agricultural sector is the focus of vulnerability assessment, then the assessment will have to be made separately for sub-sectors such as irrigated agriculture, semi-arid agriculture, rainfed agriculture or mountain agriculture. Here, one could further select the scale for each of the sub-sectors such as: i) selecting higher elevation, mid-elevation or low-elevation mountain agriculture, ii) arid zone agriculture at state, district, block or village scale.

Vulnerability assessment is a multi-step process and includes seven major steps as shown below:



4.3. Assessment of Impacts of Climate Change

Climate change impact assessments identify and quantify the expected impacts of climate change. These assessments synthesize the current scientific knowledge of the expected impacts of climate change on a focus area, such as a resource, economic sector, landscape, or a region.

4.3.1. Biophysical Impact of Climate Change on Key Sectors

Communities depend on natural ecosystems such as forests and rivers, and socio-economic systems such as agriculture and fisheries for their livelihoods. Climate change will have impacts on these systems. In this section, the impacts of climate change on key sectors is presented.

4.3.1.1. Impact of climate change on agriculture sector

Agriculture and allied activities provide employment to two-thirds of India's total workforce and contribute to nearly 20% of the country's GDP. Any change in climatic factors such as temperature and precipitation, and non-climatic factors such as changes in the soil moisture affects Indian agriculture. Kumar and Parikh (1998) show that economic impacts would be significant even after accounting for farm level adaptation. The loss in net revenue at the farm level is estimated to range between 9% and 25% for a temperature rise of 2°C to 3.5°C. Sanghi, Mendelssohn and Dinar (1998) estimated that a 2°C rise in mean temperature and 7% increase in mean precipitation would reduce net revenues by 12.3% for the country as a whole.

Model and crops considered: Variations in the weather parameters have major impact on agronomic operations, growth response of a crop and its performance. Crop simulation models estimate the crop performance and productivity under changes in climate. A Crop Simulation Model describes processes of crop growth and development as a function of weather conditions, soil conditions, and crop management. Such models estimate the specific growth stage and biomass of crop with respect to change in soil moisture and nutrient. For this assessment, the InfoCrop model is used to estimate crop productivity under a climate change scenario.

- ***Crops considered:*** Crops considered for this assessment include Chickpea, Maize, Rice, Sorghum and Redgram.
- ***InfoCrop model:*** It is a generic crop model that simulates the effects of weather, soils, agronomic management (planting, nitrogen, residues and irrigation) and major pests on crop growth, yield, soil carbon, nitrogen and water, and greenhouse gas emissions. It helps to determine the potential yield of major crops under the climate change scenario. This model was downloaded from IARI website after registration.
    - ***Input data***
        - Data on climate parameters, soil properties and crop obtained from different authorized government agencies.
        - Data for crop yield from the Ministry of Agriculture from 2001-2018,
        - Climate data from 1981-2018 from Indian Meteorological Department (IMD).
        - Projected monthly rainfall data for different districts of Karnataka from Indian Institute of Science, for the period 2021 to 2050. The data is given in Annexure A.9.
        - Soil data from 2010-18 from NBSS & LUP.
        - Recommended dosage of fertilizers and other agronomic practices followed as per the package of practice developed by different Agricultural Universities.

Using the InfoCrop model, the average crop yields of different crops have been estimated and compared with actual yield for the same period. Then a coefficient factor between the actual yield and estimated yield for the same period has been generated for individual crops.

Existing physical and chemical properties of the soil have been used for the future period as well, assuming no major change in soil properties in the future. Technology trend, prevailing agronomic practices, pest and diseases incidence and crop loss due to pest and diseases activity have not been considered. Model was run for the year 2035 to estimate the crop yield, as it represents middle year or average time period. The estimated yields have been corrected using the correction factor obtained while estimating the actual normal yields with the estimated actual normal yields.

Projected impacts on different crops: The Stoichiometric crop weather model generated at UAS, Bangalore was used to estimate the productivity of Ragi crop. For Sugarcane and Groundnut, multiple linear regression statistical model developed by Agrometeorology Department, UAS, Bangalore has been used. On the basis of the model, net productivity changes of each crop have been computed and the same is presented in Table 4.1.

Table 4.1: Net changes in productivity and projected yield trends of major crops under the climate change scenario compared to the present productivity in different districts

Crop and % net change	Districts projected to have a decrease in yield	Districts projected to have an increase in yield
Chickpea **(13.5%)**	**Up To 44.8% decrease in** Bijapur, Chikmagaluru, Gulbarga, Koppal, Mandya, Mysore, Shimoga, Tumkur, Yadgir	**(Up to 50.7% increase in** Bagalkote, Bangalore Rural, Bangalore Urban, Belgaum, Bellary, Bidar, Chamarajanagar, Chikmagaluru, Chitradurga, Dakshina Kannada, Davanagere, Dharwad, Gadag, Hassan, Haveri, Kodagu, Kolar, Raichur, Ramanagara, Udupi, Uttara Kannada
Cotton **(55.6%)**	**34.0% decrease in** Bijapur	**Up to 190.1% increase in** all Cotton growing districts except Bijapur
Maize **(24.5%)**	**Up to 21.5% decrease in** Chikmagaluru, Kodagu, Mandya, Shimoga, Udupi	**Up to 68.2% increase in** all Maize growing districts except Chikmagaluru, Kodagu, Mandya, Shimoga, And Udupi
Rice **(-5.6%)**	**Up to 69.4% decrease in** Bagalkote, Bangalore Rural, Bangalore Urban, Chamarajanagar, Chikballapur, Chikmagaluru, Chitradurga, Davanagere, Dharwad, Hassan, Kodagu, Kolar, Koppal, Mandya, Mysore, Raichur, Ramanagara, Shimoga, Udupi, Uttara Kannada	**Up to 54.1% increase in** Belgaum, Bellary, Bidar, Bijapur, Dakshina Kannada, Gadag, Gulbarga, Haveri, Tumkur, Yadgir
Sorghum **(20.3%)**	**Up to 22.5% decrease in** Bagalkote, Belgaum, Chitradurga, Gadag, Koppal, Mandya, Ramanagara, Shimoga	**Up to 120.4% increase in** Bangalore Rural, Bangalore Urban, Bellary, Bidar, Bijapur, Chamarajanagar, Chikballapur, Chikmagaluru, Dakshina Kannada, Davanagere, Dharwad, Gulbarga, Hassan, Haveri, Kodagu, Kolar, Mysore, Raichur, Tumkur, Uttara, Kannada, Yadgir
Soybean **(28.9%)**	**Up to 14.6% decrease in** Haveri	**Up to 50.5% increase in** Bagalkote, Belgaum, Bidar, Davanagere, Dharwad, Gadag, Gulbarga, Hassan, Koppal, Mandya, Mysore, Shimoga, Tumkur, Uttara, Kannada, Yadgir

Crop and % net change	Districts projected to have a decrease in yield	Districts projected to have an increase in yield
Redgram **(19.2%)**	**Up to 46.8% decrease in** Chikmagaluru, Kolar, Mandya, Mysore, Ramanagara, Shimoga	**Up to 73.9% increase in** Bagalkote, Bangalore – Rural, Bangalore – Urban, Belgaum, Bellary, Bidar, Bijapur, Chamarajanagar Chikballapur, Chitradurga, Dakshina Kannada, Davanagere, Dharwad, Gadag, Gulbarga, Hassan, Haveri, Kodagu, Koppal, Raichur, Tumkur, Uttara Kannada, Yadgir
Wheat **(-0.6%)**	**Up to 36.5% decrease in** Bagalkote, Bellary, Bidar, Bijapur, Chitradurga, Davanagere, Gadag, Gulbarga, Haveri, Koppal, Raichur, Yadgir	**Up to 146.1% increase in** Belgaum, Bijapur, Dharwad, Shimoga, Tumkur
Ragi **(12.0%)**	**Up to 33.7% decrease in** Bidar, Dakshina Kannada, Davanagere, Dharwad, Shimoga, Uttara Kannada	**Up to 60.4% increase in** Bagalkote, Bangalore – Rural, Bangalore – Urban, Belgaum, Bellary, Bijapur, Chamarajanagar, Chikballapur, Chikmagaluru, Chitradurga, Gadag, Gulbarga, Hassan, Haveri, Kodagu, Kolar, Koppal, Mandya, Raichur, Ramanagara, Tumkur, Yadgir
Sugarcane **(6.1%)**	**Up to 13.5% decrease in** Bagalkote, Hassan, Mysore and Mandya	**Up to 29.7% increase in** Chamarajanagar, Belgaum, Bidar, Bijapur, Davanagere, Haveri and Shimoga
Groundnut **(-9.6%)**	**Up To 18.8% decrease in** Bangalore Rural, Belgaum, Bellary, Chikmagaluru, Chitradurga, Dharwad, Mandya and Tumkur	**Up to 8.7% increase in** Bijapur, Davanagere, Gulbarga And Mysore

The overall productivity of different crops during 2035 are given in Table 4.2.

- Gain in productivity: Chickpea (13.5%), Cotton (55.6%), Maize (24.5%), Sugarcane (6.1%).
- Loss in productivity: Rice (5.6%), Sorghum (20.3%), Soybean (28.9%), Redgram (19.2%), Wheat (0.6%), Ragi (12.0%), Groundnut (9.6%)

The range of yield performance in the state is presented in Figure 4.2 and Figure 4.3.

DISTRICTS	MAIZE		RICE		SORGHUM		WHEAT		RAGI	
BANGALORE -R		10.2	-37.8			15.0				23.2
BANGALORE -U		24.0	-69.4			7.8				9.3
C-NAGAR			-24.4			90.4				33.6
CHICKBALLAPUR	-6.5		-15.2			120.4				18.0
CHIKMAGALUR			-40.6			24.4				20.5
CHITRADURGA		36.3	-13.7		-11.1		-36.5			1.7
DAVANAGERE		12.9	-3.3			2.7	-33.2			
HASSAN		18.3	-9.1			2.3				1.6
KODAGU			-24.7							34.6
KOLAR		46.8	-10.0							16.9
MANDYA			-14.9		-3.8					0.4
MYSORE		43.3	-12.5			93.9				8.1
RAMANAGARAM		32.8	-12.7		-13.3					1.5
SHIMOGA			-14.0		-10.1				-37.7	
TUMKUR		68.2		7.1		29.0		146.1		10.0
UDUPI			-22.9						-50.9	
U. KANNADA		12.2	-7.5			0.5			-7.9	
SIK	-6.5	30.5	-20.8	7.1	-9.6	38.6	-34.9	146.1	-32.2	13.8
BAGALKOTE		34.1	-35.0		-22.5		-0.2			23.2
BELGAUM		47.2		22.2	-22.1			35.6		34.7
BELLARY		54.9		24.7		48.9	-25.1			9.8
BIDAR		41.1		23.5		4.1	-0.3			
BIJAPUR		27.3		17.3		73.8		10.0		11.4
DHARWAD		7.3	-17.7			18.4		3.8		
GADAG		40.0		26.4	-5.6		-20.6			37.6
GULBARGA		66.7		54.1		9.6	-28.7			11.5
HAVERI		4.4		18.1		28.9	-8.6			25.3
KOPPAL		44.4	-2.0		-4.3		-5.6			22.5
RAICHUR		7.4	-6.8			27.7	-21.8			11.4
YADGIR		44.2		30.4		22.1	-23.4			14.5
NIK		34.9	-15.4	27.1	-13.6	29.2	-14.9	16.5		20.2

Figure 4.2: District wise percentage deviation in productivity of maize, rice, sorghum, wheat and ragi under climate change scenario

DISTRICTS	REDGRAM		SOYBEAN		CHICKPEA		COTTON		SUAGARCANE		GROUNDNUT	
BANGALORE -R		22.4				17.6					-6.7	
BANGALORE -U		37.9										
C-NAGAR		42.9				50.7		190.1		6.3		
CHICKBALLAPUR		21.6				45.4		28.8				
CHIKMAGALUR	-18.9				-23.6			64.1			-42.0	
CHITRADURGA		47.8				46.1		45.9			-2.9	
DAVANAGERE		31.8		23.3		35.5		34.7		22.9		6.1
HASSAN	-26.2			29.3		27.1		4.3	-2.7			
KOLAR	-33.3											
MANDYA	-24.5			44.4	-44.8				-13.5		-7.3	
MYSORE	-35.2			27.5	-21.0			89.7	-10.2			12.9
RAMANAGARAM	-5.7					14.4						
SHIMOGA	-46.8			24.8	-25.7			37.3		11.3		
TUMKUR		12.3		50.0		48.5		21.1			-2.7	
U. KANNADA		10.5		47.2		26.2		36.7				
SIK	-27.2	28.4		35.2	-28.8	34.6		55.3	-8.8	13.5	-12.3	9.5
BAGALKOTE		35.4		42.1		32.4		62.7	-0.8			
BELGAUM		14.5		48.9		45.3		38.0		14.7	-42.9	
BELLARY		54.7				40.0		53.8			-34.0	
BIDAR		33.8		27.4		15.7		188.7		29.7		
BIJAPUR		57.7			-26.7		-34.0			6.6		10.2
DHARWAD		29.6		4.9		3.3		13.6			-11.8	
GADAG		44.9		5.8		30.6		63.9				
GULBARGA		48.2		22.6	-22.3			5.6				5.7
HAVERI		25.5	-14.6			4.0		142.9		3.1		
KOPPAL		73.9			-8.3			110.2				
RAICHUR						29.5		5.3				
YADGIR		43.4		50.5	-1.4			19.8				
NIK		42.0	-14.6	28.9	-14.7	25.1	-34.0	64.0	-0.8	13.5	-29.6	8.0

Figure 4.3: District wise percentage deviation in productivity of pulses and other crops under climate change scenario

4.3.1.2. Impact of climate change on livestock production

The impacts of climate change on livestock production could be broadly categorized into direct and indirect impacts. The direct impacts are primarily attributed to heat stress. However, by far, most of the productive losses are incurred by indirect pathways due to reduction in fodder resources, water availability as well as sudden disease outbreaks. Table 4.2 projects the changes in milk, meat and egg production in Karnataka state by 2030. It may be noted that despite the projected rise in temperature, livestock production will either increase or remain unaffected. This is of significance as it highlights the resilience of livestock sector to climate change in Karnataka.

Table 4.2: Projected livestock production statistics for Karnataka state

Projections of milk production (in tonnes)								
	Species/breed	**Production as per census (2011)**		**% change**	**Projected milk production**			
		2007	**2012**		**2017**	**2022**	**2027**	**2030**
1	CB cattle	1648	2346	42	3331	4670	6631	8222
2	Indigenous cattle	1229	1369	11	1519	1686	1871	1983
3	Buffaloes	1387	1675	20	2010	2412	2894	3241
4	Sheep & Goat	49	58	18	68	80	94	104
Projections of meat production (in tonnes)								
5	CB cattle	16383	17405	6	18449	19555	20728	21660
6	Buffaloes	9018	7858	-12	6916	6087	5357	4983
7	Sheep	35310	35094	-0.6	32989	31010	29150	29046
8	Goat	20549	24715	20	27680	33216	39859	44642
9	Pigs	10906	18286	67	30537	50996	85163	119228
10	Poultry	17787	37932	113	80795	172093	366558	612151
Projections of egg production (in lakhs)								
11	Poultry	20385	34699	70	58988	100279	170474	242073

Decline in feed consumption is one of the primary outcomes of heat stress in livestock exhibited so as to reduce the generation of metabolic heat. Apart from feed intake, feed conversion also significantly decreases on exposure to heat stress. As a consequence of all these, growth of the animal gets affected which is an economically important trait. Reduced milk production is probably one of the most deleterious impacts of climate change on livestock. Apart from observing a significant reduction in milk yield, severe alterations in milk quality variables have also been reported in livestock. Approximately 10 to 25 per cent reduction in milk production may be noticed as a consequence of climate change. The variation in milk yield and quality causes economic losses which again are of concern for sustainability of the farmers in Karnataka. Figure 4.4 describes the various impacts of heat stress on the reproductive ability and milk production in dairy cattle.

Increasing human population is also expected to pressurize the livestock sector as it ensures food security. However, heat stress is also reported to cause severe drop in meat quality and quantity. Alterations in the meat pH, water holding capacity of the meat, flavour, carcass weight and hot carcass yield in animals due to environmental stress affect the meat storage and marketing thereby leading to production losses. Reproduction is another trait of high economic importance to be adversely affected by climate change. This trait is highly sensitive to both environmental and nutritional stress having severe impact on livestock farming.

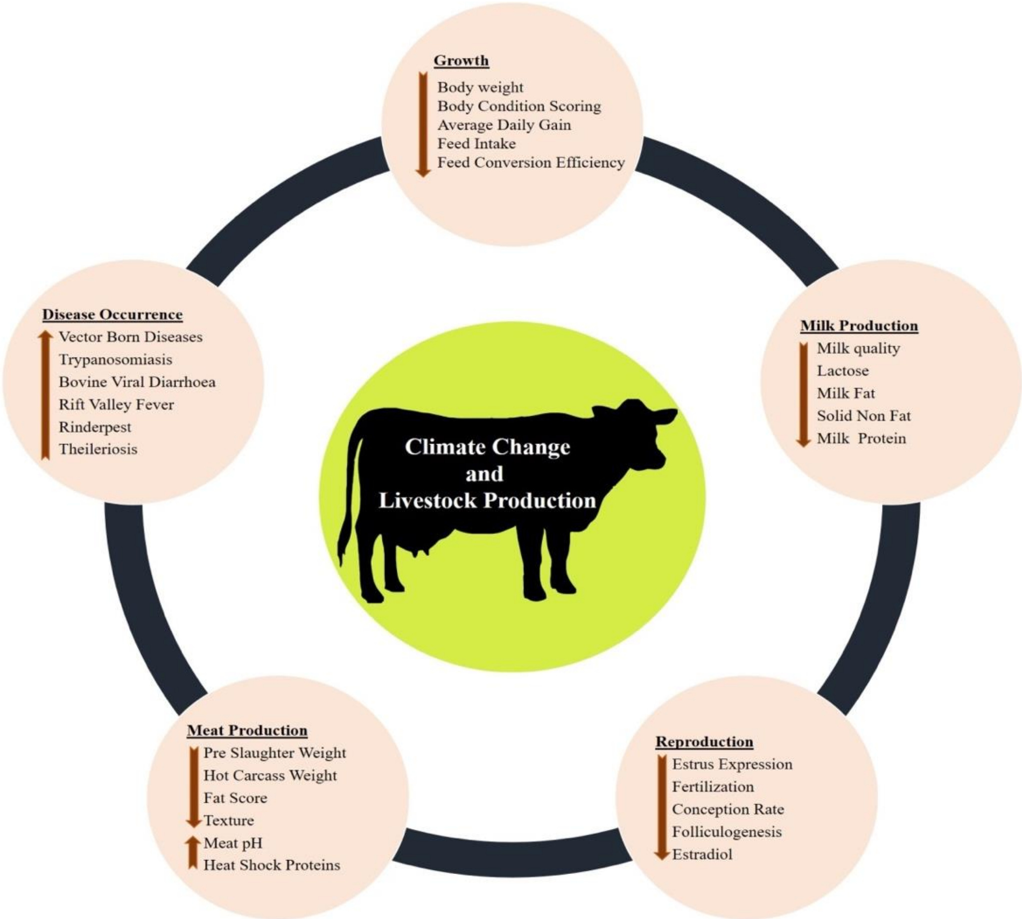


Figure 4.4: Impacts of climate change on livestock production

Climate change also has an indirect impact on livestock production by influencing fodder and water availability. Reduction in crop/fodder yield and alteration in the nutritive value not only hampers the agricultural sector rather it has an equal impact on livestock. Increasing human encroachment into agricultural land is already a concern across various regions in Karnataka. Reduction in fodder yield would further aggravate the situation. Provision of *ad libitum* drinking water is one of the important ameliorative strategies to reduce impact of heat stress in livestock. However extreme environmental conditions over the past few years have led to the drying of several water resources across Karnataka. Thus the animals are deprived of drinking water during harsh environments leading to severe reduction in their performance.

Over the past few years Karnataka has experienced varying extreme climatic conditions like heavy rainfall, flood and drought. Apart from the direct impact, these drastic variations in environment also enable the propagation and spread various pathogenic vectors. Disease outbreaks are the immediate outcome of any natural calamity. Thus, the livestock are prone to a number of diseases affecting their performance. Thus, climate change as a whole has an impact on multiple aspects of livestock production thereby needing a multidisciplinary approach towards its amelioration.

4.3.1.3. Impact assessment on fisheries and oceans due to climate change

Assessing a coastal area's vulnerability to the impacts of climate change involves the understanding of:

1) The climate projections for a given region or locale
2) What is at risk (climate change exposure and sensitivity), and
3) The capacity of society to cope with the expected or actual climate change (adaptive capacity).

Combined, these three factors define the vulnerability of people in a place to climate change.

Vulnerability of coastal fisheries: According to climate change projections (Second National Communication – SNC) 2012, the daily extremes in the surface air temperature in India can intensify in the future. The special pattern of the change in the highest maximum temperature suggests warming of up to 1-2 degree centigrade towards the 2050s, which may exceed to 4.5 degree in most places towards the end of present century. Such climate change is predicted to have a range of direct and indirect impacts on marine and freshwater capture fisheries, with implications for fisheries-dependent economies, coastal communities and fisherfolk. In Karnataka, 30,713 fishermen families comprising 1,67,429 fisherfolk (Marine Fisheries Census, 2010) are dependent on fish and fishery-based industries. Climate change would impact the vulnerability of fishery-based livelihoods among coastal communities of Karnataka. Fisheries and fisherfolk in Karnataka may be impacted by several vulnerability factors such as sea level rise, thermal stratification, ocean acidification, precipitation and freshwater availability which could have implications on the productivity of marine and freshwater fish stocks. These direct physical parameters of climate change could also have indirect impacts on the fisheries sector e.g. sea level rise and intensity of storms could impact coastal communities and there could be displacement and migration of fisherfolk population. Sand mining is another crucial parameter in terms of coastal vulnerability along the coast.

Impact of climate change on fisheries and fishing communities

Destruction of coastal infrastructure: On account of sea level rise, many of the foreshore facilities such as jettys, wharfs, harbours and other fish landing facilities along the coastline are likely to be submerged. In some cases, on account of extreme weather conditions such infrastructure could be destroyed. Hence, there is an immediate requirement to assess the vulnerability of these infrastructure and make necessary constructions at the earliest to provide sufficient number of foreshore facilities for the community. Further, on account of a large amount of sediment flow from the rivers, there is a possibility of sedimentation/deposition in the harbours/jetty areas, thereby reducing the depth. This requires continuous dredging to provide safe landing facility to the fishing boats.

Impact on islands: The Karnataka coastline has 94 islands such as Dev Bagh Island, Anjadiv Island, Kurumgad Island, Oyster Rock (Devgad Island), Sanyasi Island, Sadashivgad Island, Madlimgadh Island, Nethrani Island, Basavaraja Durga Island, Panna Island, Darya Bahadurgadh Island, St. Mary's Island, etc. Out of these, 23 islands are inhabited mostly by fishing community and farmers. Some of these islands have tremendous potential for tourism and fisheries. On account of sea level rise there is an imminent danger that these islands could be eroded or submerged over a period of time.

Erosion of coasts: Studies report erosion on the Karnataka coast to be due to direct wave action. In certain stretches, there is concentration of wave energy due to refraction and these areas are more vulnerable to erosion. Beaches adjacent to coast parallel rivers are also more vulnerable to erosion due to higher water tables that exist when the rivers flow full in monsoon. A research conducted by National Institute of Oceanography, Goa tabulated changes in the shoreline between 1990 and 2016 through remote sensing and applied statistical tools to determine the loss or gain in shoreline during the period (Figure 4.5 and Table 4.3). The study conducted around the entire shoreline reported that the State may be slowly eroding, with beaches such as Ullal in Dakshina Kannada losing more than 1 m of shoreline annually. Similarly Bhavikeri in Uttara Kannada was also seen to lose more than 1.3 m annually (or, 33.8 m since 1990). The study also reports Yermal (DK) and Devbagh (UK) have their beach shorelines increase by 3.1 m yearly .

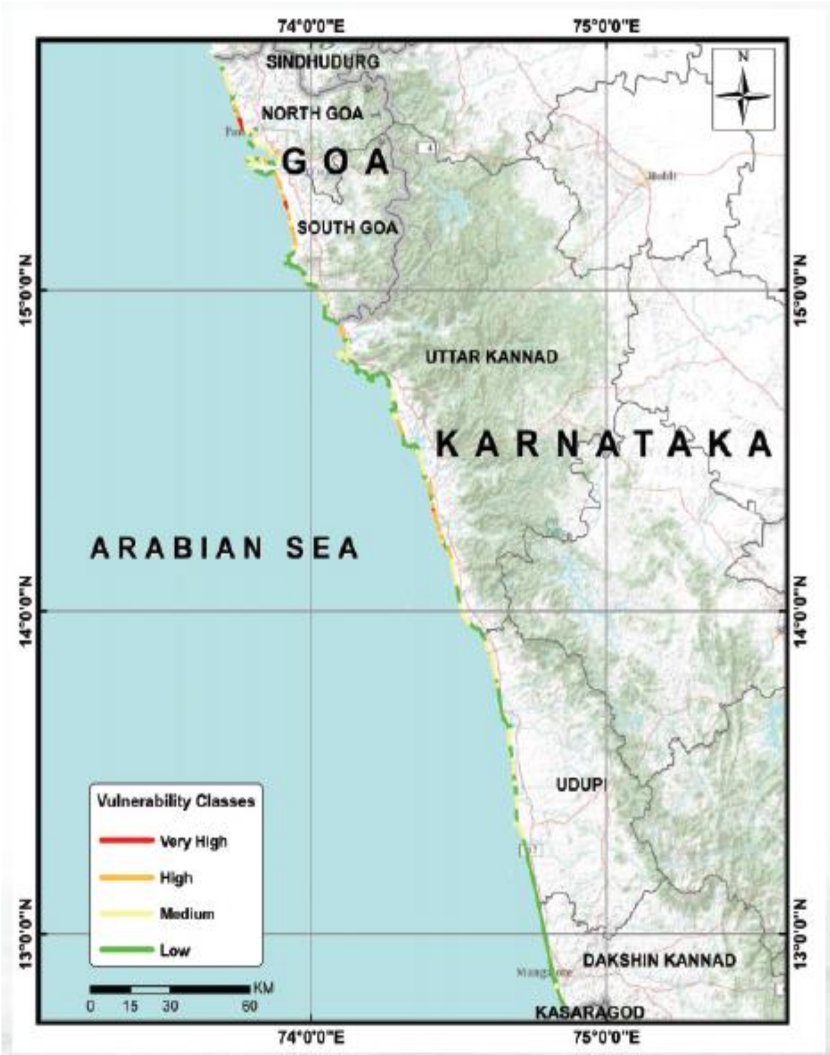
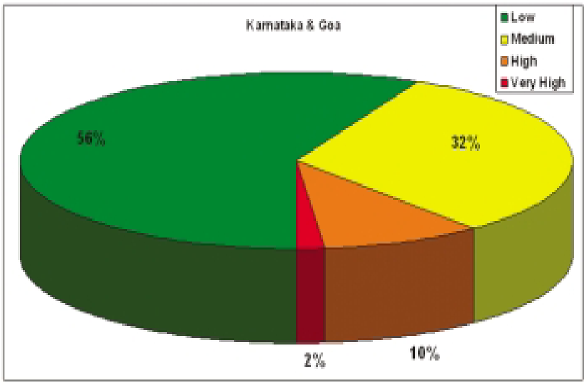


Figure 4.5: Erosion map for coastal Karnataka Source: INCOIS

Table 4.3: Coastal Vulnerability Index (CVI) along Karnataka and Goa coast

Statistics of CVI along Karnataka and Goa		
CVI	**Length (km)**	**% of Length**
Low	287	57.09
Medium	160	31.76
High	48	9.54
Very High	8	1.61
Total	**503**	**100.00**



Source: Coastal Vulnerability Atlas of India-2012, INCOIS, Hyderabad)

Increased incidence of toxic algal blooms and shellfish poisoning: On account of increased nutrients high BOD levels increase in Sea Surface Temperatures (SST) along with lower pH conditions would give rise to column stratification which is favourable for toxin producing dinoflagellates [Turner et al 2019]. Fish feed on dinoflagellates and bio accumulate the toxin which then get passed on to predatory fish via the marine food chain and finally to humans (Rajesh et al. 2018).

4.3.1.4. Impact of climate change on forest sector

The Fifth Assessment report of the IPCC concluded that changes in climate have already caused impacts on natural and human systems on all continents in recent decades. Extinction risks are projected to increase under all RCP scenarios, with risk increasing as per the increasing magnitude of climate change. Further, medium to high emission scenarios (RCP 4.5 to RCP 8.5) pose high risk of abrupt and irreversible regional scale changes in composition, structure and functions of terrestrial ecosystems.

Forest ecosystems in India are under stress due to the high dependence of communities on forest resources in addition to growing climate extremes and climate variabilities such as high levels of warming, drought, water stress, El Nino, etc. Further, the projected changes in mean climate and climate extremes contribute to additional vulnerabilities for forests. According to the State of Forest Report (2019) of the Forest Survey of India, the recorded forest area in Karnataka is 38,57,548 sq. km, which is 20.11% of the geographical area of the State. According to forest canopy density classes, the state has 4501 sq. km under Very Dense Forest, 21,048 sq. km under Moderately Dense Forest and 13,026 sq. km under Open Forest (Figure 4.6).

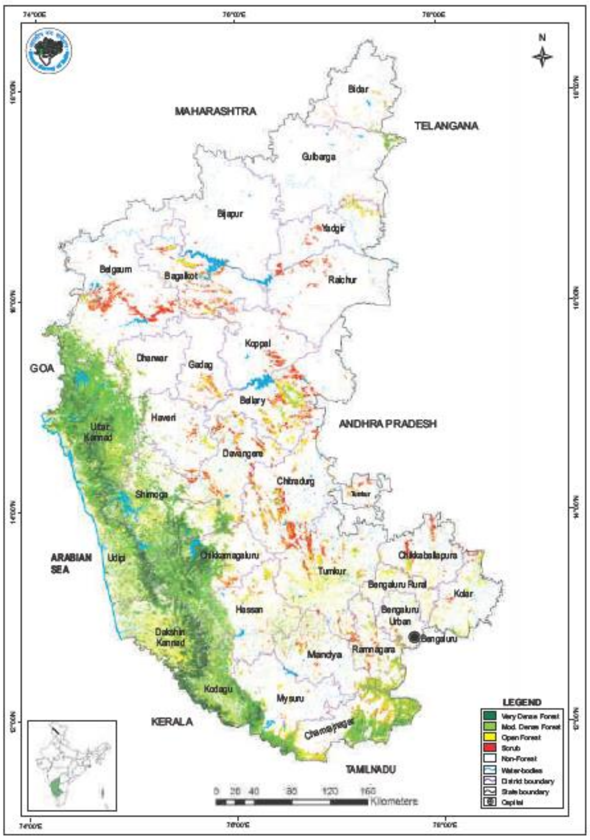


Figure 4.6: Forest cover map of Karnataka (Source: ISFR, 2019)

The State Action Plan on Climate Change (SAPCC, 2015) of Karnataka concluded that about 38% of forest area in Karnataka would be impacted by climate change by 2030s, and the projected climate would not be suitable for certain existing forest types and species present under SRES A1B scenario. It also noted that forests in the central and northern parts of the Western Ghats would be impacted by climate change.

Objectives

Impact of climate change on forests is assessed using latest CORDEX regional climate model outputs, under two RCP scenarios – RCP 4.5 and RCP 8.5. The key objective of this assessment is to assess the impact of projected climate change on the forests in Karnataka, in particular the forested grids that will undergo vegetation change, using a dynamic vegetation model - LPJ, and by using multi-model ensemble of high resolution downscaled (CORDEX/IITM) climate projections under two scenarios and for two periods.

- RCP 4.5 – Low emission scenario for short term (2030s) and long term (2080s) periods.
- RCP 8.5 – High emission scenario for short term (2030s) and long term (2080s) periods.

Dynamic Global Vegetation model (LPJ model): The dynamic global vegetation model used is the LPJ model (Lund-Postdam-Jena Model), developed by Department of Plant Ecology, Lund University, Sweden; Potsdam Institute for Climate Impact Research, Germany and Max Planck Institute for Biogeochemistry, Jena, Germany. The version of the model used is LPJ v-3.1. LPJ uses a modular framework to combine process-based, large-scale representations of terrestrial vegetation dynamics and land-atmosphere carbon and water exchanges (Sitch et al., 2003, Smith et al., 2001). LPJ is one of the extensively used vegetation models globally and has been validated for India by Sharma et al (2016). The model is at 0.5° latitude and longitude resolution with specified atmospheric CO2 concentration, soil type, monthly fields of temperature (degree Celsius), precipitation (mm/month), and cloudiness (%). The LPJ model is able to simulate transient structural changes in Earth's major vegetation types in response to variations in, among other factors, climate, water availability, and atmospheric CO_2 content. The model also simulates the Net Primary Productivity under projected climate change scenarios.

Input data for LPJ model: Climate data (temperature, precipitation and cloud cover) from CORDEX (Coordinated Regional Climate Downscaling Experiment) was used as the input for the LPJ model. Temperature and precipitation data from six CORDEX models from the IITM RCM ensemble were used for the two future scenarios. These models are listed in Table 4.4. The cloud cover data was obtained from the SMHI RCM ensemble.

Table 4.4: Input data to the LPJ model from six CORDEX models from IITM for forest impact modeling

Domain	Driving Model	Ensemble	RCM Model	Frequency	Variable
WAS-44	CNRM-CERFACS-CNRM-CM5	R1i1p1	RegCM4-4	monthly	hurs
	CSIRO-QCCCE-CSIRO-Mk3-6-0				tas
	MPI-M-MPI-ESM-LR				pr
	NOAA-GFDL-GFDL-ESM2M				sfcWind
	IPSL-IPSL-CM5A-MR				cld
	CCCma-CanESM2				

Impacts of climate change on forest types: LPJ model is run at national level for India and the grids falling in Karnataka state have been extracted to assess the impact of climate change on forest types. Figure 4.7 shows the forested grids that will be impacted by the changing climate in the 2030s (short term) and the 2080s (long term) for the two future scenarios: the RCP 4.5 and the RCP 8.5, compared to the historical baseline from 1975-2005 for Karnataka. Figure 4.7 also shows the distribution of various forest density categories across Karnataka

As it can be seen from Figure 4.7, vegetation change is projected for grids falling in the districts of Bijapur, Raichur, Koppal, Bellary, Chitradurga, Kodagu and Hassan districts under both RCP 4.5 and RCP 8.5 scenarios, in the 2030s as well as the 2080s. This means that the future climate at such locations would not be suitable for the existing vegetation or forest type and biodiversity. The forest type change may be accompanied by forest dieback and mortality.

RCP 4.5 scenario

Short Term (2030s): It can be observed that among the forested regions of Karnataka, forested grids in the districts of Bijapur, Raichur, Koppal, Bellary, Chitradurga, Hassan, Udupi, Mysore and Kodagu are projected to undergo change in the short term.

Long Term (2080s): Forested grids of the abovementioned districts projected to be impacted under the short term are projected to be impacted by climate change in the long term also.

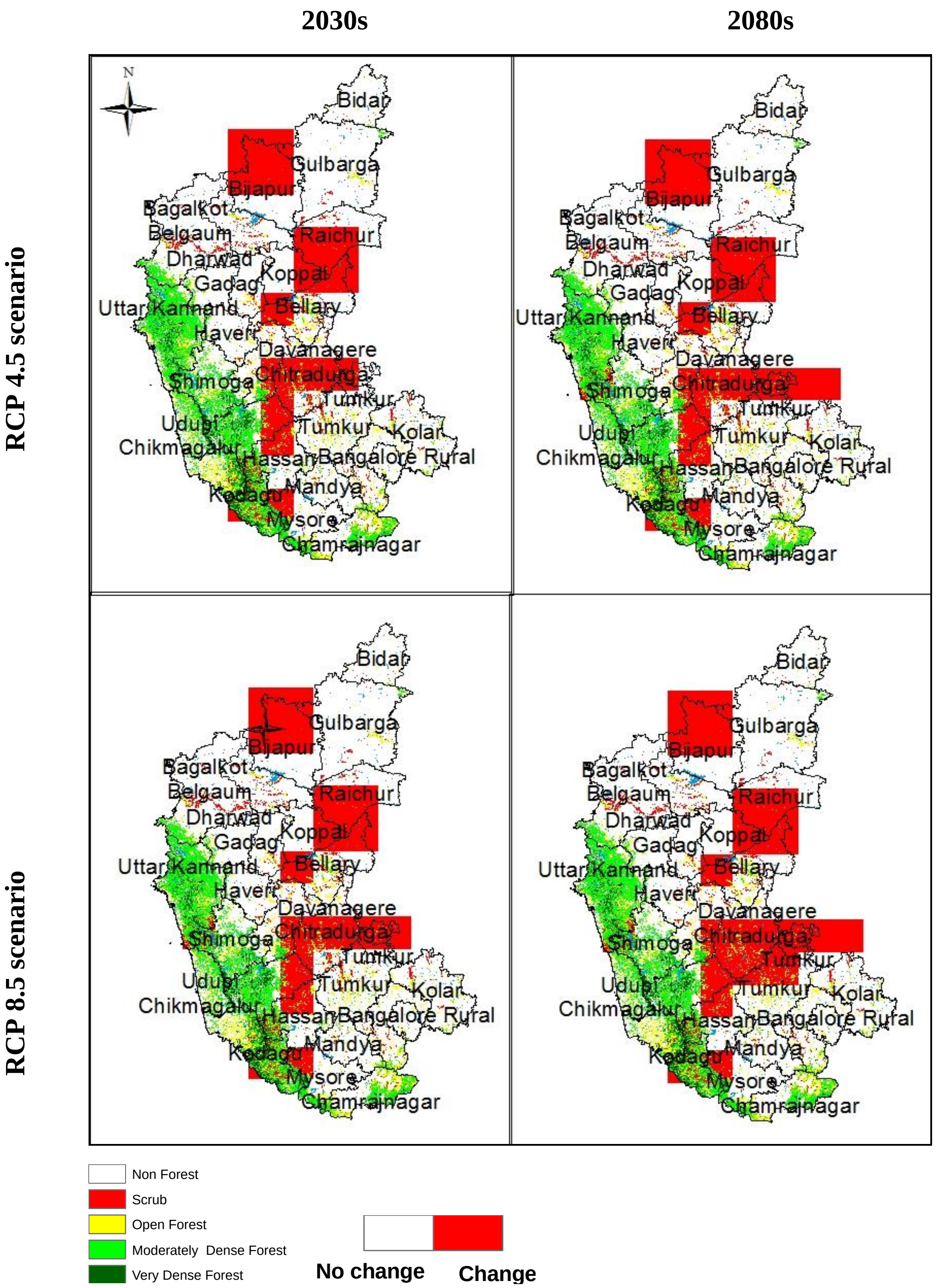


Figure 4.7: Grids undergoing change in forest type overlaid on forest density categories of FSI for the 2030s (2021-2050) and the 2080s (2071-2100) with respect to the historical baseline from 1975-2005 for RCP 4.5 and RCP 8.5 scenarios

RCP 8.5 scenario

Short Term (2030s): In the short term, the trends in vegetation change under RCP 8.5 scenario in the short term are similar to that projected for RCP 4.5 scenario in the long term with changes projected for the same districts of Karnataka.

Long Term (2080s): Even under RCP 8.5 scenario forested grids in the districts of Bijapur, Raichur, Koppal, Bellary, Mysore, Udupi, Hassan, and Kodagu are projected to be impacted by climate change in the long term. In addition, change in vegetation is projected for grids in Tumkur district also.

Change in vegetation is projected largely in the scrub and open forest areas of the state both in the short and long term under both RCP 4.5 and 8.5 scenarios. Change in Very Dense and Moderately Dense Forest is projected only for the Western Ghats district of Udupi in the short as well as long term periods under both RCP 4.5 and RCP 8.5 scenarios. The Western Ghats districts with high forest cover such as Uttara Kannada, Shivamogga, Chikmagaluru and Dakshina Kannada are not likely to be impacted as projected by the LPJ model and projected climate scenarios considered. However, this could change with improved knowledge and modelling in the coming years.

Impact of climate change on Net Primary Productivity: LPJ model simulations for RCP 4.5 scenario suggests that the mean forest NPP is projected to show a marginal increase of up to 20% by 2030s (short term) and a larger increase of up to 40% in the 2080s (long term) in Karnataka. Under RCP 8.5 scenario, an increase of up to 20% in NPP is projected for the 2030s and in the long term, the increase in NPP is projected to be up to 60%. Figure 4.8 presents the impact of climate change on Net Primary Productivity (NPP) of forests in Karnataka.

RCP ***4***.5 ***scenario***

Short Term (2030s): Under RCP 4.5 scenario, an increase in NPP of up to 20% is projected. The increase is up to 10% in the northern districts and higher increase in the range of 10% to 20% is projected for the central and southern districts of Karnataka, including the Western Ghats districts of Uttara Kannada, Shimoga, Dakshina Kannada, Kodagu and Hassan.

Long Term (2080s): Under this scenario, the projected increase in NPP is in the range of 20% to 40% across a majority of the districts of Karnataka. The increase in NPP is higher (30 to 40%) in the south eastern districts of Kolar, Tumkur, Bangalore Urban, Bangalore Rural, Chamarajanagar, Mandya and parts of Mysore districts. Increase in NPP in the range of 30% to 40% is projected for the coastal district of Dakshina Kannada also. In all the other districts of Karnataka, except Bijapur, Raichur and Gulbarga, and parts of Bagalkot, and Udupi districts where no change in NPP is projected, the projected increase in NPP is in the range of 20% to 30%.

RCP ***8***.5 ***scenario***

Short Term (2030s): The trends in NPP are similar to that projected for RCP 4.5 scenario in the short term. Under RCP 8.5 scenario, an increase in NPP of up to 20% is projected. The increase is up to 10% in the northern districts and higher increase in the range of 10% to 20% is projected for the central and southern districts of Karnataka, including the Western Ghats districts of Uttara Kannada, Shimoga, Dakshina Kannada, Kodagu and Hassan.

Long Term (2080s): Under this scenario, the projected increase in NPP is in the range of 20% to 60% across the districts of Karnataka. The increase in NPP is high in the range of 50% to 60% in the south eastern districts of Tumkur, Bangalore Urban, Bangalore Rural, and parts of Kolar, Chamarajanagar, Chitradurga and Mandya. Increase in NPP is projected to be in the range of 40% to 50% in a majority of the southern districts of Mysore, Mandya, Chitradurga, etc. In the thickly forested Western Ghats districts also, an increase in NPP in the range of 40% to 50% is projected.

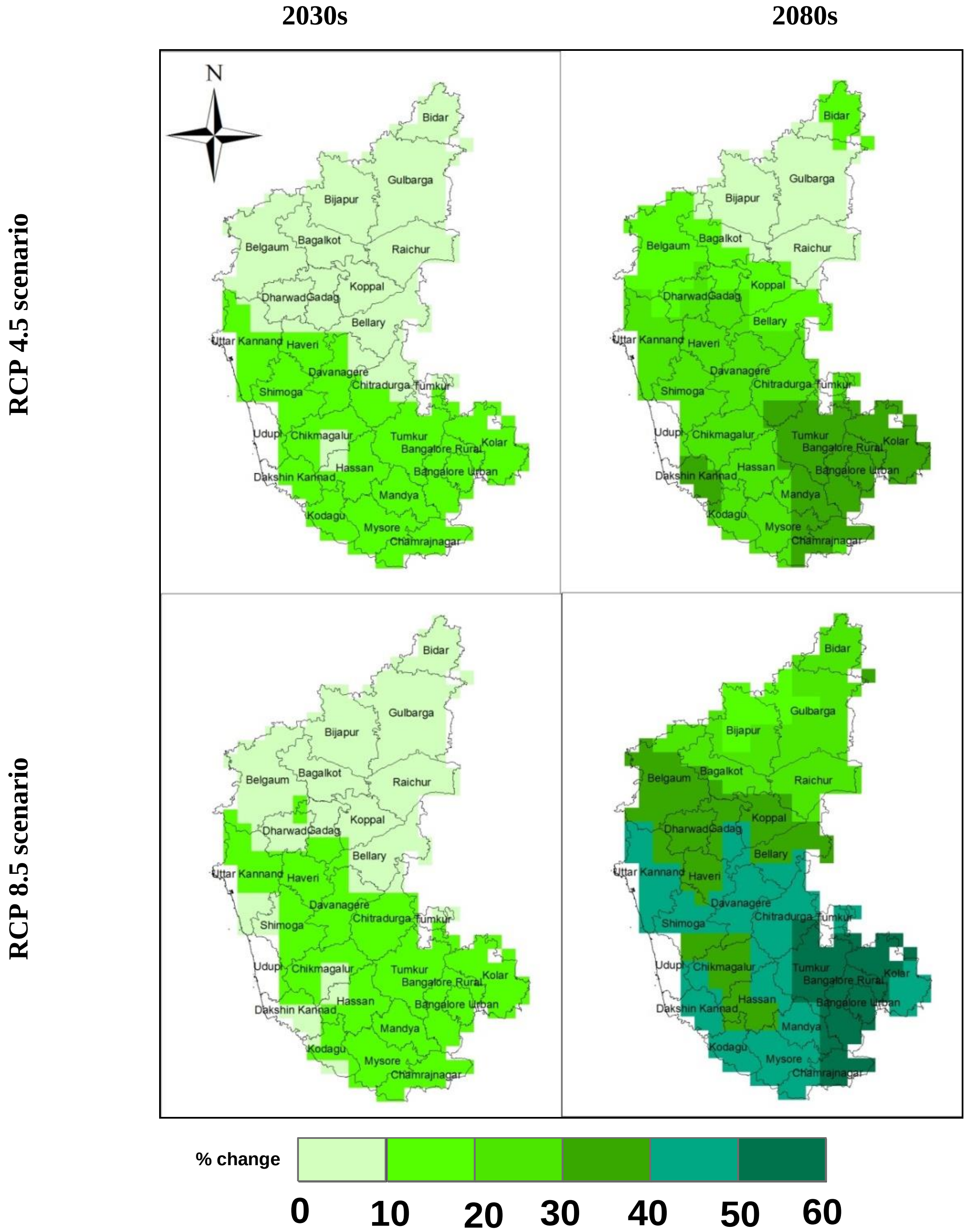


Figure 4.8: Mean NPP change in the 2030s (2021-2050) and the 2080s (2071-2100) with respect to the historical baseline from 1975-2005 for the RCP 4.5 and RCP 8.5 scenarios

Overall, NPP is projected to increase under both RCP 4.5 and RCP 8.5 scenarios. The projected increase is largely due to elevated CO_2 concentration in the atmosphere and fertilization. However, the model has limitations and does not consider soil nitrogen limitations and potential impacts of forest pests and fire under a changing climate.

4.3.1.5. Impact of climate change on water sector

Fresh water availability in the hydrological cycle such as surface-water levels and groundwater recharge to aquifers is drastically changing worldwide as a result of the combined effects of anthropogenic interventions, natural variability and climate change (Rodell et al., 2018). The natural infiltration for groundwater recharge that occurs beyond a threshold level of precipitation can be negatively impacted by temporal variability of precipitation, changes in temperature, intense and fewer rainfall events, short monsoons and long dry spells. The other potential climate risks for groundwater include shifts in water table levels in unconfined aquifers, sea water intrusion to coastal aquifers and increased demand and depend on whether regions have humid or arid climate characteristics as well. In addition, elevated evapotranspiration rates result in changes in soil moisture and particularly increases the groundwater salinity. The non-climatic drivers that may impact groundwater include population growth, food demand, land use and vegetation change, groundwater pumping regimes, damming of rivers, and conversion of dry land agriculture to irrigation. As such, climate change poses as a potential stressor of groundwater resources and its effects on the availability of groundwater need to be understood and determined (Taylor et al, 2013).

Surface water

Climate-change is predicted to have a major impact on water resources, with frequent droughts, erratic and intense rainfall events, reduced supply and growing demand. The state of Karnataka has seven river basins comprising of Godavari, Krishna, Cauvery, the West flowing rivers, South Pennar and Palar. The industrial and urban growth is primarily concentrated in the Krishna and Cauvery basins due to various factors. Figure 4.9 shows the study area along with the CORDEX grid points, gauging stations and sub-basins of the Cauvery catchment. The gauging stations selected are Sakleshpur, Chunchunkatte, K. M. Vadi, T. K. Halli, and Kollegal which are located in the Upper Cauvery basin.

Mujumdar and Kumar (2017) analysed the water balance in the Tungabhadra basin (2041-2060, under RCP 4.5) using the Soil and Water Assessment Tool (SWAT) and observed a decrease in the projected streamflow, as the increase in temperature, wind speed, and solar radiation is likely to increase the evapotranspiration over the basin and thus reduce the streamflow. As various atmospheric and land processes have an influence on the streamflow, the climate change impacts on streamflow should be estimated using a hydrological model and projected climate variables. For the same purpose, the well calibrated Variable Infiltration Capacity (VIC) model is utilized in the Upper Cauvery basin to simulate streamflow for future climate scenarios (from the year 2021 to 2060, under the emission scenarios of RCP 4.5 and RCP 8.5). The Variable Infiltration Capacity (VIC) model (Liang et al., 1994, 1996) is a semi-distributed macroscale land-atmosphere transfer model that represents surface and subsurface hydrological processes. It solves the energy and water balance equations at each time step for spatially distributed grid cells. The VIC model has been extensively implemented for numerous studies across the globe to address challenges related to water resources management and study the effect of climate change and land atmosphere interactions (Chawla & Mujumdar, 2015; Nijssen et al., 2001; Raje et al., 2014; Wu et al., 2018).

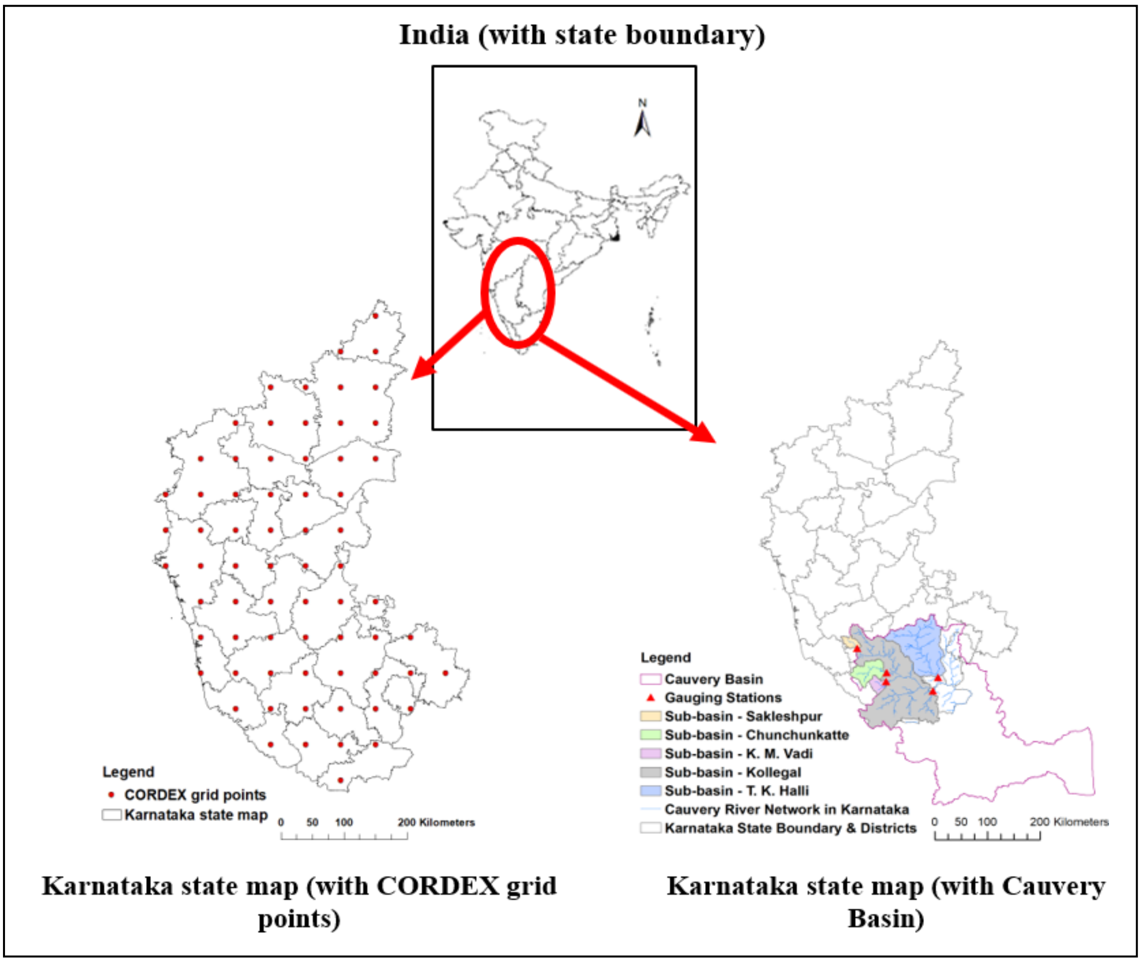


Figure 4.9: Karnataka state map with CORDEX grid points (left) and Cauvery basin, gauging stations, and sub-basins (right)

Model-VIC: The VIC model can run in both water balance and energy balance mode to compute the land- atmosphere fluxes. In this study, water balance mode at daily time step is adopted for computational efficiency. This mode assumes that the land surface soil temperature equals the near-surface air temperature and it follows the continuity equation at each time step. The model is set up for Upper Cauvery basin (basin area within Karnataka state) at 0.25-degree grids and the surface fluxes are computed at daily time scale. Meteorological forcing required to run the model include precipitation, maximum temperature, minimum temperature and wind speed at daily scale (D.S. Pai, 2014; A.K. Srivastava, 2009; J. Sheffield, 2006). VIC model also requires additional datasets such as elevation, soil characteristics which comprises of soil composition and bulk density and vegetation properties such as land use type, leaf-area index, albedo and crop characteristics (P.S. Roy, 2015; Nasa, 2013). The output fluxes from the model are surface runoff, baseflow, evapotranspiration and soil moisture computed for each grid. For simulating streamflow at the specified gauge locations, the flux files are fed into a routing model (Lohmann et al., 1998) which uses linear transfer functions for channel routing.

Dataset: All the datasets used in this study are freely available in the public domain (Table 4.5). IMD4 gridded datasets of historical daily rainfall were used in this study (D.S. Pai, 2014). ERA5 gridded monthly mean datasets of air temperature (at 2m above the surface) were used in this study (Hersbach, 2020). These are reanalysis datasets from the European

Centre for Medium- Range Weather Forecasts (ECMWF). For future projections of rainfall and temperature, the CORDEX South Asia (CORDEX SA) datasets were used in this study.

Table 4.5: Input datasets for VIC model for assessing impact of climate change on water resources

Period	**Climate variable**	**Product**	**Product unit**	**Spatial resolution**	**Duration**
Historical	Monthly rainfall	IMD4	mm	0.25^0 X 0.25^0	1979-2017
	Mean monthly air temperature	ERA5	K (converted to ^{0}C)		
Future	Monthly rainfall	CORDEX South Asia	$kgm^{-2\ s-1}$ (converted to mm/month)	0.5^0 X 0.5^0	2021-2099
	Mean monthly air temperature		K (converted to ^{0}C)		

The gauge discharge data was obtained from India – WRIS for the five gauging stations, Sakleshpur, K. M. Vadi, Chunchunkatte, T. K. Halli, and Kollegal located near the Karnataka state border (Table 4.6).

Table 4.6: Gauge discharge data (in cumecs)

Gauging station	**Catchment**	**Duration**	
		From	**To**
Sakleshpur	Upper Cauvery Catchment within the Karnataka State	January, 2002	December, 2013
K. M. Vadi		January, 1979	
Chunchunkatte		January, 2008	
T.K. Halli		January, 1978	
Kollegal		January,1971	

Source: **India-WRIS**

Assessment of water availability: In this study, on an annual basis, the catchment averaged estimates of (PET) were worked out for historical and future time periods. The estimates of monthly PET (in mm) were computed using the simple approach given by (Thornthwaite, 1944), which relates monthly evapotranspiration with monthly temperature as given below:

$$\mathrm{PET} = 16\mathrm{K}\left(\frac{10\mathrm{T_a}}{\mathrm{I}}\right)^{\mathrm{m}}$$

Where Ta is the mean-monthly air temperature for a given month in ^{0}C; K is the monthly adjustment factor that varies with the month and the latitude of a place (Teegavarapu, 2012); I is the temperature-efficiency (T-E) index also known as the annual heat index.

$$\mathrm{I} = \sum_{N=1}^{12} i$$

Here, i = (Ta / 5)1.514, the heat index of the N^{th} month. The exponent m depends upon I,

$$\mathrm{m} = (6.75 \times 10^{-7}) \times \mathrm{I}^3 - (7.71 \times 10^{-5}) \times \mathrm{I}^2 + (1.79 \times 10^{-2}) \times \mathrm{I} + 0.49239$$

The actual evapotranspiration, AET was estimated from PET from the Budyko relationship (Singh, 1992). At each grid point in a catchment, the annual water availability (i.e. R-AET) was estimated for both historical and future time periods. These are later averaged over all grids for each time step to get the catchment averaged time-series estimates of annual water availability. The future period was divided into two time periods: 2021-40 and 2041-60. Historical streamflow datasets were used to develop statistical rainfall-runoff relationships. This statistical relationship is being used to assess the change in projected streamflow using the CORDEX projected rainfall under RCP 4.5 and RCP 8.5 scenarios.

Changes in the projected mean annual rainfall, mean annual AET and mean annual water availability are shown in Table 4.7. These changes are with respect to their historical mean values. Figure 4.10 shows a decrease in the projected mean annual water availability across the Karnataka state except for RCP 8.5 in the far future.

Table 4.7: Changes (mm) in water availability in projected ensemble averaged across Karnataka

Duration	Variable	Change (in mm)
2021-40 (RCP 4.5)	Rainfall	58.45
	AET	86.78
	Water availability*	-28.33$
2021-40 (RCP 8.5)	Rainfall	100.31
	AET	104.01
	Water availability*	-3.70$
2041-60 (RCP 4.5)	Rainfall	119.54
	AET	128.02
	Water availability*	-8.481$
2041-60 (RCP 8.5)	Rainfall	195.4117
	AET	168.7183
	Water availability*	26.6934

** change in water availability = (change in rainfall) – (change in AET)*

$ negative value of change indicates a water stress situation

Mean annual rainfall (R); Mean annual actual evapotranspiration (AET); and Mean annual water availability in the future period (compared to the historical averages). Historical mean annual rainfall: 1133 mm (1951- 2017); Historical mean annual AET: 461 mm (1979-2017).These estimates are the average across the state of Karnataka.

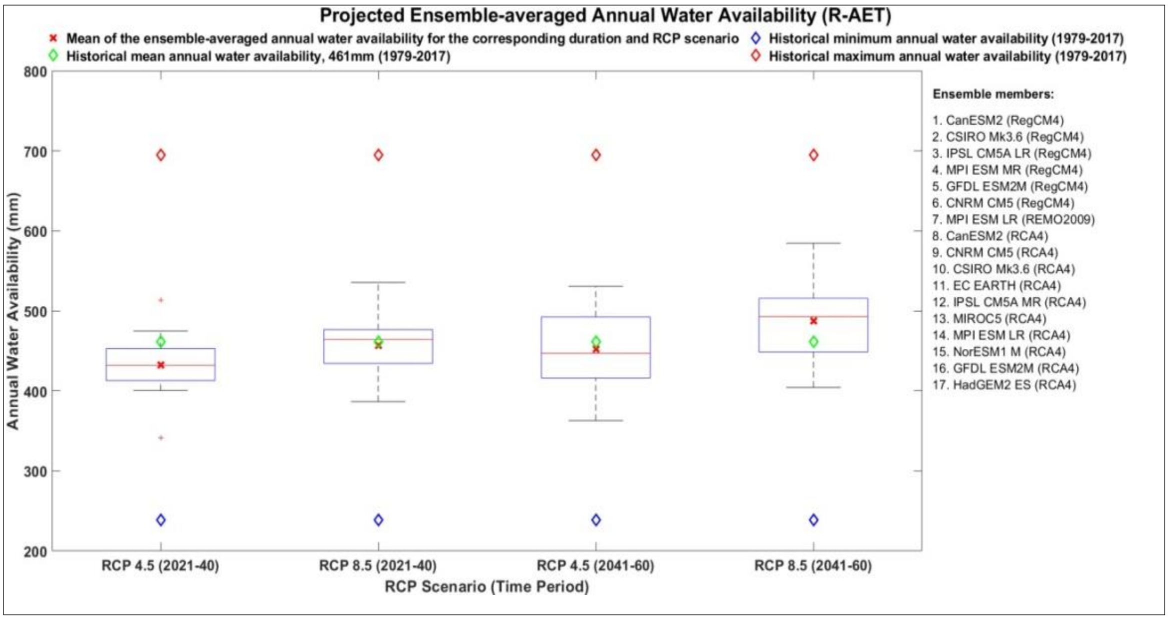


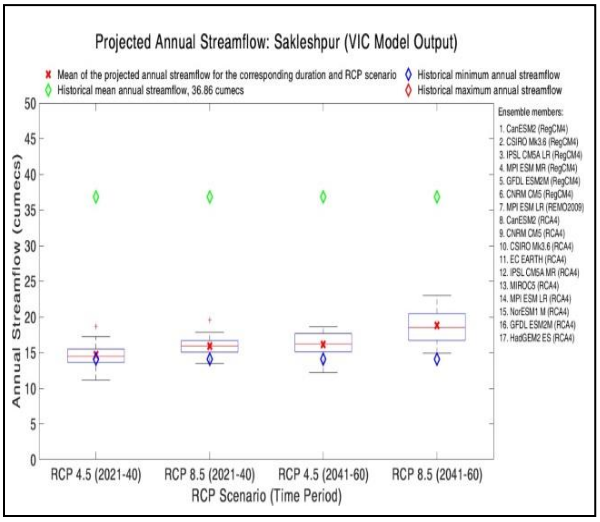
Figure 4.10: Projected ensemble averaged annual water availability (mm) over the Karnataka state

Streamflow projections: The VIC model can run in both water balance and energy balance mode to compute the land- atmosphere fluxes. In this study, water balance mode at daily time step is adopted for near- surface air temperature which follows the continuity equation at each time step. The model is set up for the Upper Cauvery basin (basin area within Karnataka state) with a drainage area of approx. 33770 sq. kms at 0.25-degree grids and the surface fluxes are computed at daily time scale.

Meteorological forcing required to run the model include precipitation, maximum temperature, minimum temperature and windspeed at daily scale. VIC model also requires additional datasets such as elevation, soil characteristics which comprises of soil composition and bulk density and vegetation properties such as land use type, leaf-area index, albedo and crop characteristics.

The output fluxes from the model are surface runoff, baseflow, evapotranspiration and soil moisture computed for each grid. For simulating streamflow at the specified gauge locations, the flux files are fed into a routing model (Lohmann et al., 1998) which uses linear transfer functions for channel routing. The well calibrated VIC model is utilized to simulate streamflow for future climate scenarios from 2021 - 2060. The results obtained for streamflow projections for the gauge locations Sakleshpur, Chunchunkatte, K. M. Vadi, T. K. Halli, and Kollegal located in the Upper Cauvery basin are presented (Figure 4.11).

The projected ensemble average mean streamflow for the gauging stations Sakleshpur and Chunchunkatte (located upstream of Upper Cauvery) is observed to be lower than the mean historical streamflow and it is likely to have increasing trend in the far future (Figure 4.11 (a) and (b)). The projected mean average streamflow for the gauging stations K. M. Vadi (located midstream of Upper Cauvery), T. K. Halli, and Kollegal (located downstream of Upper Cauvery) consistently exceed the historical maximum streamflow and show significantly increasing trends across all climate scenarios (Figure 4.11 (c), (d), and (e)). Percentage change in projected ensemble averaged mean annual streamflow is shown in



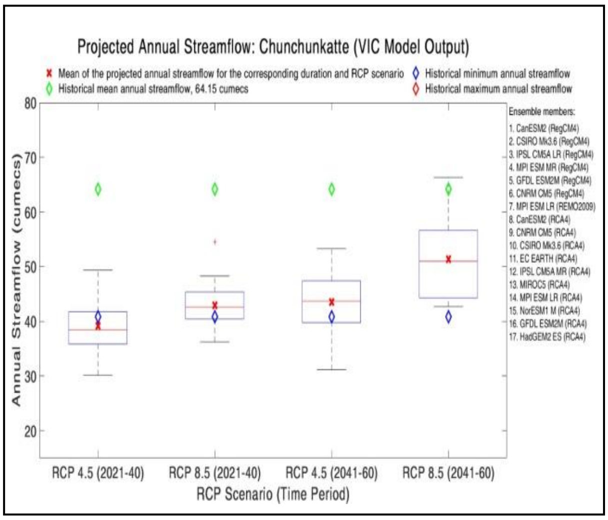
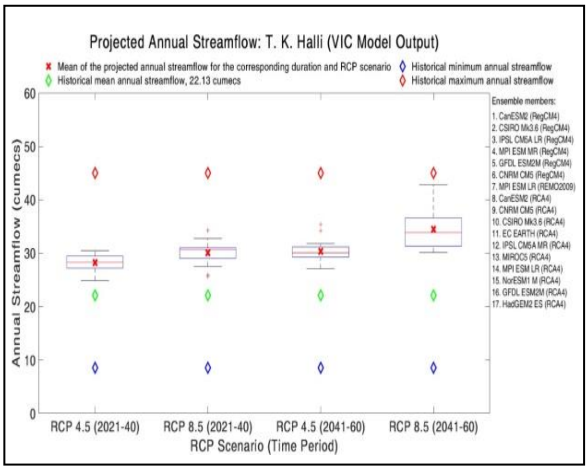


Table 4.8.



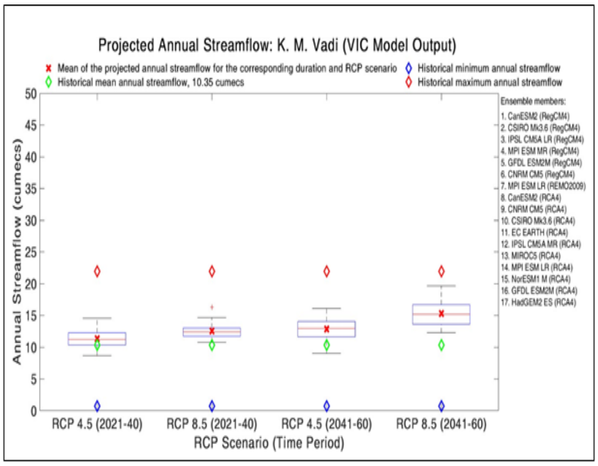
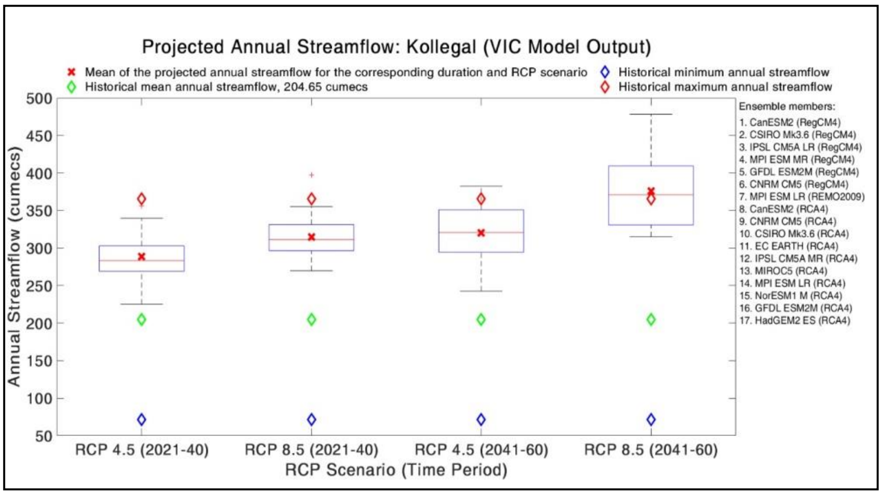


Figure 4.11: Projected ensemble averaged annual streamflow (cumecs) at a) Sakleshpur b) Chunchunkatte c) K. M. Vadi d) T.K. Halli e) Kollegal stations in the Upper Cauvery basin

Table 4.8: Percentage change in the projected ensemble mean annual streamflow (derived using VIC model simulations, and CORDEX projected temperature and rainfall outputs)

Gauging station	2021-40		2041-60	
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
Sakleshpur	-60.11	-56.76	-56.26	-48.99
Chunchunkatte	-38.93	-33.08	-32.16	-19.93
K. M. Vadi	9.91	21.53	24.05	47.78
T. K. Halli	27.61	35.94	37.32	55.75
Kollegal	40.98	53.83	56.65	83.72

- Historical mean annual streamflow for sub-basins Sakleshpur, Chunchunkatte, K. M. Vadi, T. K. Halli, and Kollegal are 36.86 cumecs, 64.15 cumecs, 10.35 cumecs, 22.13 cumecs, and 204.65 cumecs respectively.



The projected mean annual streamflow is lower than the historical mean streamflow for all the climate scenarios in Sakleshpur and Chunchunkatte sub-basins. K. M. Vadi, T. K. Halli, and Kollegal sub-basins show significant increase in the percentage changes in the projected ensemble averaged mean annual streamflow, especially, in the far future scenarios.

The projected streamflow across the five sub-basins in the Upper Cauvery basin show mixed trends, whereas the entire Upper Cauvery manifests increasing trends in streamflow for all climate scenarios. The projected water availability (R-AET) averaged over the entire state shows a slight decrease in the future time period (except for the RCP 8.5 in far future). These water availability estimates are averaged across the state of Karnataka and it is important to note that the rainfall shows a significant spatial variation in the state.

Table 4.9 shows the average percentage change in the projected mean annual streamflow averaged over the entire Upper Cauvery basin by considering estimates from all the available gauging stations. It should be noted that the contributing catchment area for the five gauging stations presented in this study are of significantly different sizes; Sakleshpur having the lowest (approx. 580 sq. kms) and Kollegal having the highest (approx. 20100 sq. kms) drainage area.

Table 4.9: Average percentage change in the projected mean annual streamflow averaged over the Upper Cauvery basin

	2021-40		**2041-60**	
Climate Scenario	***RCP 4.5***	***RCP 8.5***	***RCP 4.5***	***RCP 8.5***
Percentage change	16.91	27.28	29.42	51.63

Overall, the projected mean annual rainfall in the state, under the RCP 4.5 scenario, is likely to increase by 5.16% and 10.55% during 2021-40 and 2041-60, respectively. Under the RCP 8.5 scenario, it is likely to increase by 8.85% and 17.24% during 2021-40 and 2041-60, respectively. The VIC model simulations show mixed trends in the streamflow projections across various sub-basins in Upper Cauvery basin, whereas the Upper Cauvery as a whole manifest increasing trend in streamflow for all climate scenarios. A slight reduction in the projected mean annual water availability is likely to be observed for the entire state of Karnataka, except in the far future for RCP 8.5 scenario.

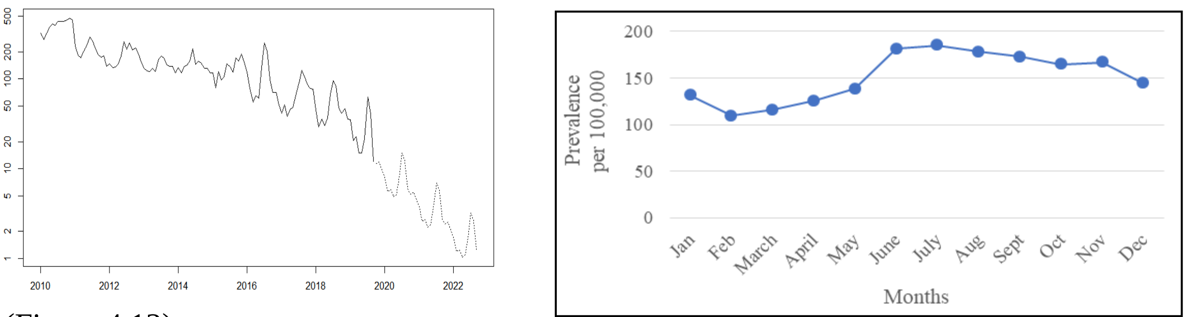
4.3.1.6. *Impact of climate change on human health*

Climate change affects the social and environmental determinants of health – like clean air, safe drinking water, sufficient food and secure shelter. Between 2030 and 2050, climate change is expected to cause approximately 250,000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress. The direct damage costs to health (i.e. excluding costs in health-determining sectors such as agriculture and water and sanitation), is estimated to be between US$ 2-4 billion/year by 2030. Areas with weak health infrastructure which are mostly in developing countries, will be least able to cope without assistance to prepare and respond. Reducing emissions of greenhouse gases through better transport, food and energy use choices can result in improved health, particularly through reduced air pollution.

Measuring the health effects from climate change can only be very approximate. However, a WHO assessment concluded that climate change is expected to cause approximately: 250,000 additional deaths per year between 2030 and 2050, 38,000 due to heat exposure in elderly people, 48,000 due to diarrhoea, 60,000 due to malaria and 95,000 due to childhood under nutrition

Vector borne diseases are highly sensitive to climate change and are one of the major contributors to the global burden of disease (WHO 2000). Hence, it is important to determine how climate change is affecting vector bionomics and vector-borne diseases. Incidence, duration and transmission rate of diseases increase exponentially due to even a small change in global climate. Further geographical distribution of disease might vary, such that transmission may become unsustainable in previously endemic areas, or sustainable in previously non-endemic areas.

Malaria: Prevalence rate of malaria was 432.2 per 100,000 persons in 2010 which decreased to 28.8 in 2019, the average being 169 per 100,000 persons per year. Linear regression equation developed between the prevalence of cases over time period indicated that the rate of change of prevalence of malaria was -36 cases per year. The seasonal variation revealed that maximum prevalence was between June to September, and least prevalence was in February. Autoregressive Integrated Moving Averages used to predict the incidence of disease for the year 2022 revealed that the prevalence of disease is likely to decrease in future



(Figure 4.12).

Figure 4.12: (a) Future predictions of Malaria prevalence using the Autoregressive Integrated Moving Averages (ARIMA) (b) Monthly average prevalence rate of Malaria (per 100,000 persons) from 2010-2019

Dengue: Prevalence rate of dengue was 42.2 per 100 persons in 2010 which decreased to 9.4

in 2019, the average being 18 per 100 persons per year. The linear regression equation developed between the prevalence of the cases over time period indicated that the rate of change of prevalence of dengue was -2.2 cases per year. The seasonal variation revealed that the maximum prevalence was found in the month of August and least in the month of May (Figure 4.13).

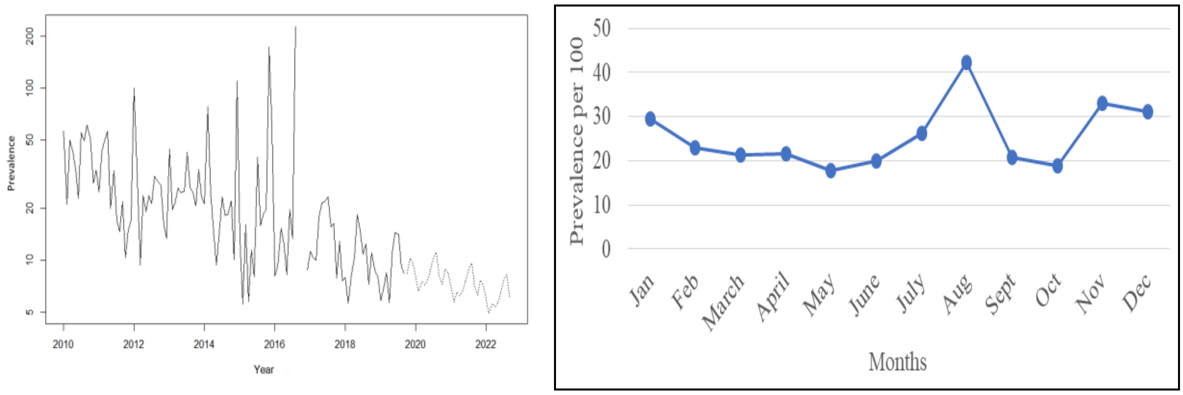


Figure 4.13: a) Future forecast of Dengue based on prevalence (ELIZA method) using Autoregressive Integrated Moving Averages (ARIMA) model b) Monthly average prevalence rate of dengue (per 100,000 persons) from 2010-2019

Cholera: Prevalence rate of cholera was 4.6 per 100 persons in 2010 which decreased to 0.0 percent in 2019, the average being 1.97 per 100 persons. The linear regression equation developed between the prevalence of the cases over time period indicated that the rate of change of prevalence of cholera was -0.55 cases per year. The seasonal variation revealed that the maximum prevalence was found between April to July and least in the month of October (Figure 4.14)

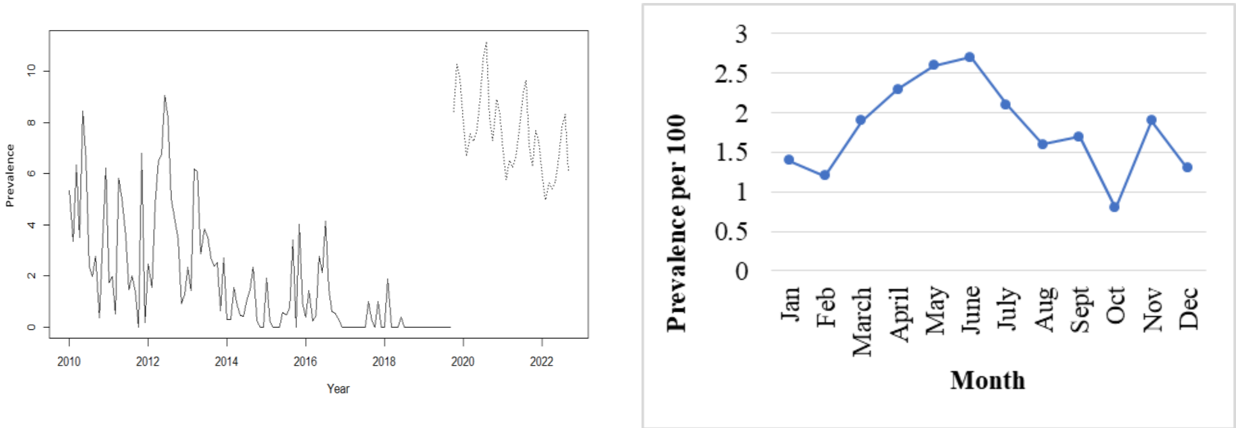
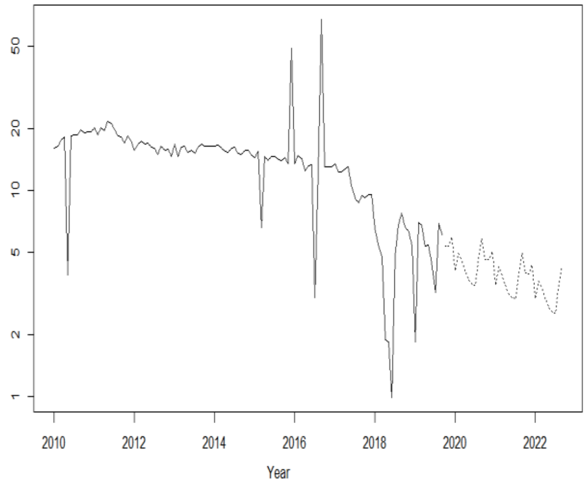
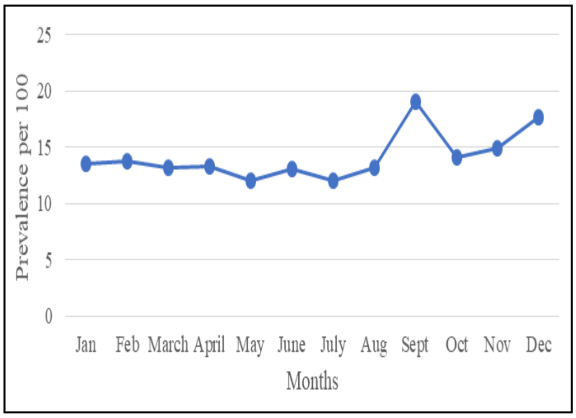


Figure 4.14: a) Future forecast of cholera prevalence using Autoregressive Integrated Moving Averages (ARIMA) model b) Monthly average prevalence rate of cholera (per 100,000 persons) from 2010-2019

Typhoid: Prevalence rate of typhoid was 17.3 per 100 persons in 2010 which decreased to 5.5 per 100 persons per year in 2019, the average being 13.27 per 100 persons per year. The





linear regression equation developed between the prevalence of the cases over time period indicated that the rate of change of prevalence of cholera was -1.43 cases per year. The seasonal variation revealed that the maximum prevalence was found between September to December and the least prevalence was in the month of February (Figure 4.15).

Figure 4.15: a). Future forecast of typhoid prevalence using Autoregressive Integrated Moving Averages (ARIMA) model b). Monthly average prevalence rate of typhoid (per 100,000 persons) from 2010-2019

It is clear from the previous sections that there are certain impacts already reported or documented from certain sectors and in the future, the various sectors will continue to be adversely impacted by climate change.

4.4. Assessment of Vulnerability

Vulnerability assessments go beyond impact assessments to determine a system's sensitivity and ability to adapt to climate change, and may be used in place of or in addition to climate change impact assessments. Vulnerability is defined as the degree to which a human or natural system is susceptible to, and unable to cope with, the adverse effects of climate change, including associated climate variability and extremes. Vulnerability could be assessed for biophysical and/or socio-economic systems.

Agricultural Vulnerability

Communities depend on natural ecosystems and socio-economic systems such as food production and fisheries for their livelihoods. Both of these are vulnerable to climate change, and interlinked. Agriculture, is the primary occupation for a large percentage of population in Karnataka, and the vulnerability of this sector has been assessed.

Bidar, Gulbarga, Bijapur, Koppal, Gadag, Bagalkote and Yadgir districts are more susceptible districts for climate change (Suresh Kumar et al. 2016). Chandrappa et al. (2019)

reported that sixteen districts in the state are above the average composite vulnerability index level. Bidar, Kolar and Yadgiri districts are highly vulnerable and Shivamogga, Davanagere and Udupi districts exhibit the least vulnerability to changing climate. More than 50 % of the area in the state has less than 100 mm of Soil Water Available Capacity (NBSS & LUP-1999), which increases its vulnerability to climate change.

Socio-economic Vulnerability

Socio-economic vulnerability assessment can provide powerful information useful for policy, project design, strategic planning, and project targeting. Socio-economic vulnerability assessment also aids identification of the most vulnerable social groups and the factors contributing to vulnerability.

A socio-economic vulnerability index was developed based on the Fifth IPCC assessment report for 30 districts of Karnataka. A total of twelve variables developed by Cutter et al (2003) were used in the construction of the district level social economic vulnerability index. These twelve variables include population density, schedule caste and scheduled tribe population, literacy rate, percentage of forest cover in the geographical area, employment provided under MGNREGA, net irrigated area, marginal workers, primary health centres, district level per capita income, access to banking services and disabled population. Data was obtained from various sources such as Census of India (2011), Karnataka State at a Glance-Statistical Report (2019-2), Report of District at a Glance (2018-19), Directorate of Economics and Statistics (2018-19), Forest Survey of India (2019) and Economic Survey of Karnataka 2017-18.

Figure 4.16 presents the socio-economic vulnerability ranking of districts of Karnataka as high, low and medium.

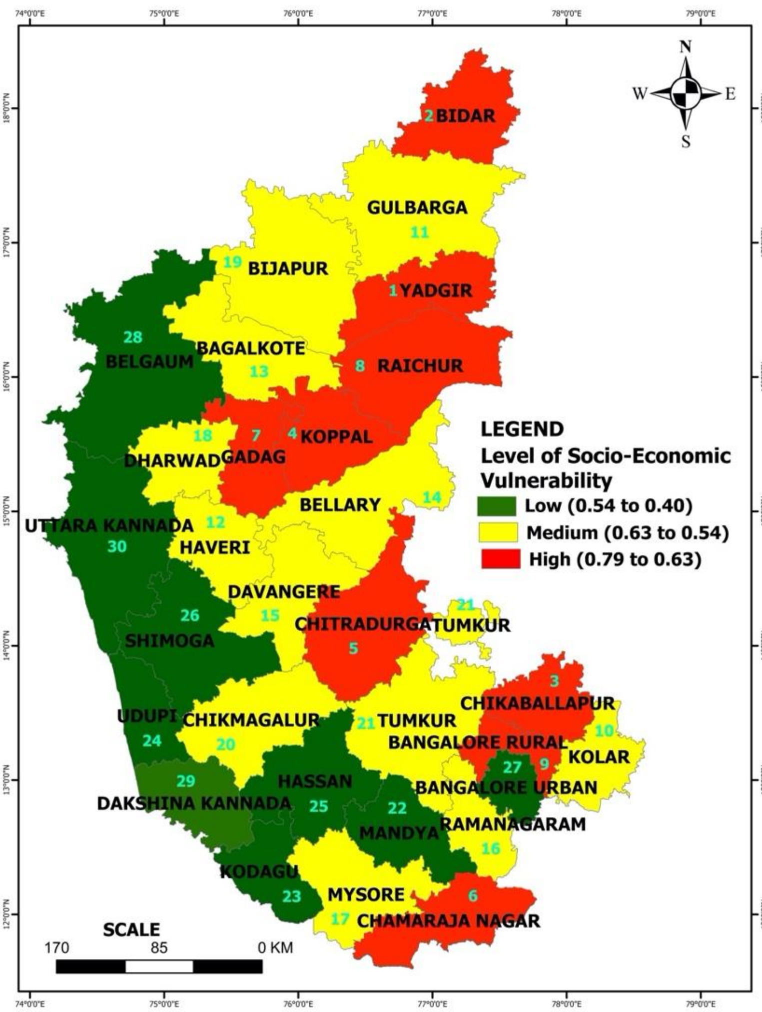


Figure 4.16: Socio-economic vulnerability index for Karnataka

The district with the highest socio-economic vulnerability is Yadgir (0.79), followed by second and third highest vulnerability districts i.e., Bidar index 0.72), Chikballapur district vulnerability index 0.68), respectively. While the lowest socio-economic vulnerability district shows that Uttara Kannada (vulnerability index 0.40), followed by second and third lowest districts i.e., vulnerability index 0.42) and Belgaum (vulnerability index 0.43), respectively. Furthermore, the medium socio-economic vulnerability districts include Tumkur (0.54), Chikmagaluru (0.55), Bijapur (0.56), Dharwad (0.58), Mysore (0.58), Ramanagara (0.59), Davanagere (0.59), Bellary (0.61), Bagalkot (0.62), Haveri (0.62), Gulbarga (0.63), and Kolar (0.63).

Findings suggest that Yadgir, Bidar, Chikballapur, Koppal, Chitradurga, Chamarajanagar, Gadag, Raichur, Bangalore rural districts are high socio-economically vulnerable among all the districts of Karnataka. Kolar, Gulbarga, Haveri, Bagalkot, Bellary, Davanagere, Ramanagara, Mysore, Dharwad, Bijapur, Chikmagaluru and Tumkur districts are medium socio-economic vulnerability to climate change in Karnataka. Mandya, Kodagu, Udupi, Hassan, Shimoga, Bangalore urban, Belgaum, Dakshina Kannada, Uttara Kannada are low socio-economic vulnerability to climate change in Karnataka.

Drivers of vulnerability

Population density: In Karnataka, Bangalore urban accounts for the highest population density, of 4381 persons/ per sq. km, while Kodagu district for the lowest population density of 135 persons/per sq. km. this could be because most of the migrant people are concentrated in Bangalore in view of the availability of better livelihood options. Furthermore, population size and density are the major factors behind increased per capita CO_2 emissions in the context of many developing countries (Ribeiro, H.V et al 2019).

Scheduled Caste/Scheduled Tribe Population: According to Census (2011), Kolar accounts for the highest population of marginalized communities and Udupi for the lowest among all districts. Balasubramanian M et al (2019) while studying climate change events observed adverse impacts on the livelihoods of scheduled caste population in both the districts of Kolar and Udupi in Karnataka. Raichur district accounts for the highest proportion of Scheduled Tribe population, while Mandya districts for the lowest proportion in Karnataka. Scheduled Tribe communities are also affected by adversely climate change effects in Karnataka. Balasubramanian M et al (2019) found that Scheduled Tribe and Scheduled caste households highly vulnerable to climate change in both the districts in Karnataka.

Literacy: Bangalore Urban accounts the highest literacy level among all districts in Karnataka, While Yadgir the lowest literacy in the state. Most of the coastal districts such as Dakshina Kannada, Uttara Kannada and Udupi display high levels of literacy. Chamarajanagar and Raichur districts remain characterized by low level of literacy in the state. Concerning climate change uncertainties, there is a need for climate change education in the state for improving awareness and devising proper coping mechanisms to deal with climate change.

Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA): A large number of people are working under MGNREGA in Belgaum (258966), Raichur (255756), Bellary (184444) and Hassan (147879). However, the proportion of people working under this scheme is relatively low in Bangalore urban (4025), Kodagu (11472) and Udupi (13807) districts. . This study has also found a positive association between the number of persons working under the scheme and vulnerability to climate change. For example, Uttara Kannada district displays a low vulnerability to climate change, while Yadgir, Bidar and Chikballapur districts show a high socio-economic vulnerability to climate change in Karnataka state. In this respect, Esteves et al (2013) and Srinivasan et al (2018) observe that MGNREGA is reducing the level of vulnerability to climate change as well as improving ecological sustainability.

Gross irrigated area: Belgaum (629441 hectare), Bagalkot (380314 hectare) and Bijapur (398278 hectare) districts account for highest net irrigated area in Karnataka, While, Kodagu (1491 hectare), Bangalore urban (18054 hectare), Udupi 47453 hectare) and Kolar (62619 hectare) districts account for respectively low net irrigated area in Karnataka. We found a negative association between irrigated area and vulnerability to climate change.

Primary health centers: Tumkur and Mysore account for the highest number (140) and (138) of primary health centres, while Kodagu he lowest number of primary health centres (29) in Karnataka. Patz et al., (2005) observed that climate change has had an adverse impact on the health of more than 5 million people over the last three decades around the world.

4.5. Conclusion

Assessment of impact of climate change on biophysical sectors such as forest, water, agriculture, and health, and socio-economic vulnerability assessment highlights that both biophysical and socio-economic systems are currently vulnerable and this will likely be exacerbated under a climate change scenario.

Impacts of climate change on water, forest, agriculture and health sectors are adverse according to modeling studies. The changes in climate will continue into the future, thereby increasingly adversely impacting the natural and managed systems, with socio-economic implications. The impacts of climate change and its implications on the socio-economic systems will be exacerbated by current existing vulnerabilities. The biophysical assessment of agricultural vulnerability and socio-economic vulnerability assessment at the district level reveals the existing vulnerabilities across the various districts, and also ranks them from high to low. This ranking and identification of drivers of vulnerability provides an opportunity to formulate strategies to address this vulnerability, and thereby help adapt in the short-term and build resilience in the long-term, in both biophysical and socio-economic systems.

Chapter 5: Climate Change Mitigation - Energy, Transport and Forestry

5.1. Introduction

Karnataka is one of the most industrialised and urbanised states in the country. The state ranked 4th in its contribution to India's gross domestic product (GDP) in 2016-17[1] (RBI, 2019). Karnataka is a leader in the IT (information technology) and biotechnology industries. The service sector is the largest contributor to the state GDP (with almost a two-thirds share), followed by manufacturing and agriculture[2]. With growing population, urbanisation, and industrialisation, the state's energy demand has increased—catalysing a subsequent surge in greenhouse gas (GHG) emissions. GHG emissions in Karnataka have grown at a compound annual growth rate (CAGR) of 4.4% for a decade, from 64 million tonnes of carbon dioxide equivalent (MtCO2e) in 2005 to 98 MtCO2e in 2015 (GHGPI, 2018).

Overview of the Chapter

This chapter is divided into four sub-sections. The first details all the major policies and programmes implemented in the state from 2012 onwards and its GHG implications. The second provides the inputs and assumptions considered for identifying the future mitigation actions, which could be prioritised by the state until 2030. The third sub-section identifies the list of GHG mitigation actions, its mitigation potential, investments required and barriers identified for its implementation. The fourth sub-section provides a broad implementation plan for the mitigation activities listed in the earlier section.

5.2. Ongoing Major Policies and Programmes: Effect and Implications for GHG Mitigation

The study analysed policies implemented from 2012 onwards, and also the targets, finance allocated and barriers (if any) for implementation in the state.

5.2.1. Power

GHG emissions from electricity generation contribute to about 50% of the emissions from energy sector in Karnataka. The emissions grew from 11.4 MtCO2e in 2005 to 28.6 MtCO2e in 2015. Emissions from the power sector grew at a CAGR of about 12% from 2005 to 2012 and then slowed down to 5% from 2012 to 2015 (GHGPI, 2017). The slowdown in emission growth rate can be attributed to the various policies and programmes implemented in the state as detailed below.

[1] At constant prices (2011-12 base year)

[2] In 2015-16, service sector contributed 66% to the state GDP, manufacturing 23% and, agriculture 11%.

Karnataka stands seventh in terms of installed capacity among all Indian states (CEA, 2020b). The state has a total installed capacity of 28.2 GW—9.5 GW coal, 13.8 GW renewable energy (RE), 3.7 GW large hydro, and 0.88 GW nuclear as on March 2019[3]. Karnataka's solar generation portfolio is impressive. The state is home to one of the largest solar power parks in the world, the Pavagada Solar Power Park, with a capacity of 2.05 GW (KSPDCL, 2020). The solar-installed capacity in the state rose from 13 MW in 2012 to 5.8 GW (including rooftop PV) in 2018. This accounted for nearly 21% of Karnataka's total installed capacity in 2018. Moreover, the state also has wind-power installations—stood fourth in wind-installed capacity in 2018, with a total installed capacity of 4.7 GW (17% of the total installed capacity) (PIB, 2019). Other RE-generating sources, such as small hydro and biomass-based power plants (including cogeneration in industries), accounted for 1.1 GW and 1.7 GW, respectively, in 2018. To sum up, nearly half of Karnataka's installed capacity in 2018 came from RE sources (Figure 5.1). Commensurately, the share of RE generation increased from 12% in 2012-13 to 31% in 2018-19[4], which is higher than the national share (22% in 2018- 19) (MNRE, 2019a).

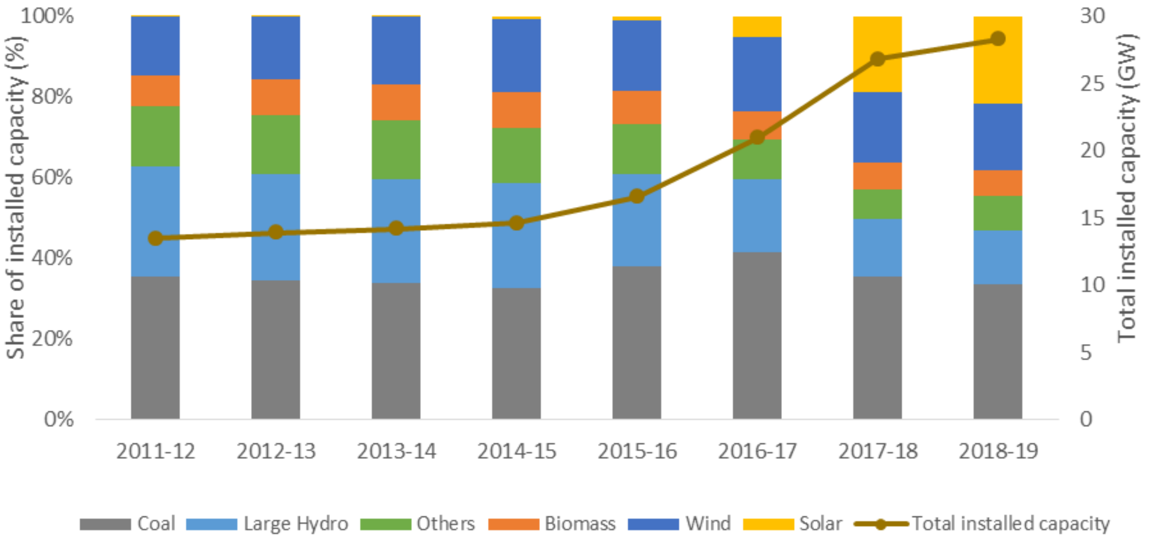


Figure 5.1: Share of installed capacity of various generating sources[5]

Source: (CEA, 2012, p. 2, 2020a; MNRE, 2019a); Data from Energy Department, Karnataka

The increase in RE electricity generation is mainly attributed to progressive RE policies in the state, such as the Karnataka Solar Policy, Renewable Energy Policy, and the Surya Raitha Scheme. Such initiatives helped Karnataka install the highest RE capacity among all Indian

[3] Year-wise renewable energy installed capacity data is from Energy Department, Government of Karnataka

[4] Excluding electricity purchase from other states (apart from power purchase agreements); the capacity utilisation factor of RE-based sources is very low compared to conventional power plants, the share of electricity generation will be lower than the installed capacity share.

[5] Others include nuclear, small hydro, waste to energy, diesel, and gas-based power plants

states. As a state nodal agency, the Karnataka Renewable Energy Development Limited (KREDL) is formulating and implementing policies to promote solar and other forms of RE.

The key objectives of these policies are to encourage public and private participation in the sector and boost decentralised RE generation where access to grid electricity is difficult. Along with setting up guidelines and activities to promote RE, these policies established installed capacity targets. The Solar Policy 2014–21 has a target of 6 GW (including 2.4 GW of rooftop photovoltaic–RTPV) of additional installations between FY 2014-15 and FY 2020-21. The state added 6 GW of solar-installed capacity between FY 2014-15 and FY 2018-19. Though ground- mounted solar installations saw a significant growth during this policy period, solar RTPV achieved only 240 MW of cumulative installed capacity as of March 2020. Procedural delays at nodal agencies and lack of state-governmental incentives have been major barriers to RTPV installation. The only incentive was the 30% capital subsidy provided by the central government to residential consumers (GEDA, 2016). Nonetheless, Karnataka was declared the best state for setting up RTPV solar projects based on the State Rooftop Solar Attractiveness Index—SARAL[7](MNRE et al., 2019).

Karnataka has recently introduced regulatory changes to make RTPV investment attractive (KERC, 2016). In March 2020, Bengaluru's power utility, Banaglore Electricity Supply Company (BESCOM), launched an RTPV subsidy scheme—Saura Gruha Yojane. This scheme is applicable for 30 MW grid-connected RTPV under the Central Finance Assistance (CFA) of the Ministry of New and Renewable Energy (MNRE) (BESCOM, 2020). Karnataka Electricity Regulatory Commission (KERC) approved three business models for RTPV installation— utility-centric, consumer-centric, and third-party owned (RESCO) models—and approved a generic tariff irrespective of the project model (KERC, 2020). In addition, to encourage investment, RTPV tariff has not been decreased for FY 2020-21, even though the PV module cost has come down drastically.

The Renewable Energy Policy 2009–14 set a target of 4.2 GW of additional non-solar RE capacity during the policy period (KREDL, 2009). The state achieved only 30% of targeted capacity additions between 2011 and 2014. The Renewable Energy Policy 2016–22 (draft) has provided a non-solar RE capacity addition target of 6 GW between 2016-17 and 2021-22 (KREDL, 2018b). The year-wise targets and capacity addition are provided in Table 5.1. The state overachieved its targets in 2016-17 and 2017-18, while the achievement was low in 2018-19.

Table 5.1: Year-wise targets and achievement for non-solar RE (2016-22)

Year	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
Target (MW)	850	900	950	1,025	1,075	1,200
Achievement (MW)	1,030	1,141	149	Not applicable		

Source: Karnataka Energy Department; KREDL, 2018b

The major barriers to non-solar RE are surplus power (installed capacity) in the state, cost decline of solar power projects, and long-term power purchase agreements (PPAs) between distribution companies (DISCOMs) and thermal power plants (TPPs). In addition, KERC recently notified a levy of 25% of normal transmission charges as wheeling charges for RE projects commissioned (open-access consumers) on or after 1 April 2018 (KERC, 2018). This regulatory change could impede future RE investments in the state.

Along with state policies, national programmes such as National Solar Mission and Renewable Purchase Obligations (RPOs) played a significant role in increasing RE share in the state's energy mix (MoP, 2018b). DISCOMs in Karnataka, such as Bangalore Electricity Supply Company (BESCOM), Mangalore Electricity Supply Company (MESCOM), and Gulbarga Electricity Supply Company (GESCOM) were able to purchase electricity generated from RE sources, surpassing the RPO target from FY 2014-15 onwards[6].

Though the key drivers of RE installation have been policy and programmes, other factors also played a part. These include decreased RE capital cost, better market conditions (supply-chain competitiveness), and financial stress of coal power plants in the state (high coal price and coal availability issues) (IEEFA, 2019). However, an analysis of these factors is beyond the scope of the current study.

The state had also attempted to improve the energy efficiency and plant load factor (PLF) of old coal-based power plants. A considerable lump sum amount of around INR 310 crore from the Karnataka Power Corporation limited (KPCL) budget was allocated for renovation and modernisation (R&M) and life extension (LE) activities at Raichur Thermal Power Station (RTPS) (KPCL, 2017). The key activities undertaken at RTPS are R&M and LE of boiler, turbine- generator, and control and instrumentation[7]. Alongside KPCL's activities to improve energy efficiency in its plants, other coal TPPs in the state had to improve their energy efficiency as part of the PAT scheme (BEE, 2012, 2016). Of the four power plants (4,280 MW) listed in the PAT-1 scheme, only two plants (860 MW) achieved the target. On the other hand, all TPPs under PAT-2 scheme in the state were able to meet the targets[8].

The PLF of coal-based power plants in Karnataka showed decreasing trend during 2012-18 (CEA, 2012, 2019). The PLF of coal TPPs decreased from 51% in 2011-12 to 34% in 2018-19. Coal shortage was a major challenge that Karnataka's thermal power plants faced in 2012– 18[9]. Issues in coal availability severely affected electricity generation in RTPS, Bellary TPP, and Yermarus TPS during this period (Shreyas, 2018). The coal supplied to RTPS and Bellary 1&2 units in 2018-19 were 12% and 10% lower than the coal supplied in 2012-13 (KPCL, 2013, 2019). The significant increase in RE-based installed capacity and their must-run status also adversely impacted coal-based electricity generation during this period.

Karnataka had also put in efforts to reduce its transmission and distribution losses (T&D). The T&D losses in the state fell from 19.96% in 2011-12 to 16.16% in 2018-19. Major policies

[6] Data from Energy Department, Government of Karnataka
[7] Data from Energy Department, Government of Karnataka
[8] Based on the data shared by Karnataka Renewable Energy Development Ltd.
[9] The coal supplied to RTPS was 7.73 million tonnes in 2012-13 and 6.84 million tonnes in 2018-19. The coal received in 2018-19 also accounts the coal supplied to Yermarus TPS and Bellary TPP.

and programmes to reduce T&D losses were undertaken as part of Ujjwal DISCOM Assurance Yojana (UDAY), Integrated Power Development Scheme (IPDS), Restructured Accelerated Power Development and Reforms Programme (R-APDRP), and Perform, Achieve and Trade (PAT) scheme. The state undertook various activities to reduce T&D losses; these include feeder segregation, distribution-transformer (DT) metering, energy audit (11 kV lines), installation of Device Language Message Specification (DLMS) smart metering (feeder level), and mapping of feeders to DTs and DTs to consumers (DISCOMs, 2020)[10]. Schemes such as Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUJY) and Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) helped to separate agricultural and non-agricultural feeders, electrify villages, and strengthen the transmission infrastructure in rural areas (MoP, 2018a). About INR 59 crore was disbursed in the 12th Five-Year Plan (2012-17) under the DDUGJY scheme for Karnataka (MoP, 2020). In addition, solar-based decentralised electricity generation in the state increased from 0.254 MW in 2011-12 to 7.7 MW in 2018-19 (MoSPI, 2013, 2020). However, ground-level studies conducted by the Center for Study of Science, Technology and Policy revealed discrepancies—owing to data-entry errors—in the DISCOMs' energy-audit process for T&D loss reduction. Also, a majority of distribution transformers were neither metered nor maintained properly in the state (CSTEP, 2019).

5.2.2. Industry

Karnataka is the fifth most industrialised state in the country. The industrial sector grew at CAGR of about 6% between 2004-05 and 2014-15, while contributing about 26% to the state GSDP (PRS, 2018). The major industries include iron and steel, cement, and petroleum refineries. The iron and steel, and cement sectors in the state contribute to nearly 80% of the total energy emissions in the state's industrial sector, while the refineries contribute an additional 9% in 2015 (GHGPI, 2018). The study focusses on these three industries for further analysis.

Karnataka produced about 17 Mt of crude steel in the year 2017-18 accounting to about 16% of the total steel production in India during the same period. The majority of the steel production in the state is based on the Blast Furnace-Basic Oxygen Furnace technology, in addition to production from coal-based sponge iron plants. It also hosts the country's only COREX-based steel production unit in JSW, Vijayanagar. The cement production from the state in 2017-18 totalled about 19Mt, contributing to about 8% of the national cement production. Iron and steel, and cement industries are the major energy-intensive industries in the state, accounting for more than 63% of the total industrial energy demand.

The state's industrial policies from 2009-14 to 2014-19 focus on improving the growth of the sector, with a 12% per annum target (GoK, 2016). The latest policy (2014-19) aims to enhance the contribution of the manufacturing sector to the state GDP, attract investment, etc. However, on energy conservation and emissions mitigation, the state's industrial sector is

[10] Based on discussions with KPTCL

mainly steered by national policies, such as the National Steel Policy (Ministry of Steel, 2017) and the PAT scheme under the National Mission on Enhanced Energy Efficiency.

Under PAT Cycle-I between 2012 and 2015, designated consumers[11] across key industrial sectors reduced their energy consumption by 0.36 million tonne of oil equivalent (MToE) against a target of 0.223 MToE (KREDL, 2018a) (BEE, 2016). As a result, the total reduction in CO_2 emission was 0.5 $MtCO_2e$ in the assessment year 2015-16. Despite achieving its PAT Cycle-I targets, the industrial sector is still one of the highest CO_2 emitters of the state.

5.2.3. Buildings

Karnataka's building sector (residential and commercial) consumed 35% of the state's total power demand in 2015-16 (CEA, 2016). This is slated to rise to 38% by 2026-27. With a growing population and an expanding service sector, the demand for energy is set to increase further, impacting emissions. Bengaluru's commercial floor space alone is expected to increase almost three-fold to reach 300 million sq. feet by 2030, driven by high growth in the services sector (CSTEP, 2014).

The buildings sector comprises the necessary infrastructure for the growth of the state economy, thus making it pertinent to ensure the sector's sustainable development. Buildings offer immediately available, highly cost-effective opportunities to reduce growth in energy demand, while helping meet other key sustainable development goals including poverty alleviation, energy security, and improved employment. Karnataka has in place several policies and programmes that promote energy efficiency in this sector. These policies not only enable the sector to save fuel but, as a result, also help mitigate GHG emissions from the sector.

One of the most important policies adopted by the state is the Energy Conservation Building Code (ECBC), which sets minimum energy performance standards for buildings. ECBC-compliant buildings are expected to consume 30%–40% less energy than conventional buildings. This was notified for adoption in all commercial buildings in November 2014. Twenty-five government buildings have been planned for ECBC compliance; four ECBC-compliant buildings are constructed and are operational. A noteworthy project is the ECBC-compliant Kumara Krupa Government Guest House in Bengaluru. The guest house has a built-up area of around 19,800 sq. m, with an energy performance index[12] (EPI) of 52 kWh/m^2. The state has also implemented the Street Lighting National Programme (SLNP), which aims to replace conventional street lights with efficient LED lights. About 9,882 conventional street lights have been replaced with LEDs by 2018-19.

On the domestic-housing front, Hosa Belaku/ Unnat Jyoti by Affordable LEDs and Appliances for All (UJALA) scheme has been one of the most popular schemes in Karnataka. UJALA scheme is the world's largest zero-subsidy LED-bulb distribution scheme and is

[11] Designated consumers are industrial units for which the government has notified mandatory energy savings targets as part of the PAT scheme under the Energy conservation Act 2001.

[12] Energy performance index (EPI) is total energy consumed in a building over a year divided by the total built-up area.

implemented by the Energy Efficiency Service Limited (EESL). EESL procured LED bulbs in large quantities through competitive bidding using a 'bulk-procurement model'. All of these are distributed via kiosks set up by either DISCOMs in the state. EESL makes the entire upfront investment for ensuring product availability at the outlets, and no upfront capital cost is borne by the DISCOMs/OMCs (barring manpower and space). Apart from LED bulbs, the UJALA scheme distributed LED tube lights and energy-efficient fans as well at a subsidised rate. The appliances are sold to the consumers at INR 70/LED bulb[13], INR 290/LED tube light and INR 1,110/ fan respectively, much below the market price. By June 2020, a total of 2.34 crore LED bulbs have been distributed in the state, against a target of 6 crore (by March 2019), making it a leader amongst the southern states of India. About 4.12 lakh LED tube lights and 72,000 energy-efficient fans were sold within the state through the scheme. As on 31st August 2018, about 0.8% of the LEDs with technical faults sold under this scheme were replaced free of cost by EESL (EESL & MoP, n.d.).

As one out of three urban households and nine out of ten rural households, do not have access to LPG as a primary cooking fuel, the Pradhan Mantri Ujjwala Yojna (PMUY) is also an important scheme in the state (CSTEP, 2014). As of September 2019, 31.5 lakh LPG connections have been sanctioned in the state. The LPG coverage[14] in the state increased from 79.9% to more than 100% from March 2017 to October 2019 (PPAC, 2019).

5.2.4. Agriculture

Agriculture is a major energy-intensive sector in Karnataka, especially for irrigation pumping. Agriculture sector accounts for 39% of the annual electricity consumption of the state (CSTEP, 2018). As of 2018-19, Karnataka had around 29 lakh irrigation pump sets, growing at a CAGR of 5.28% from 2012-13 to 2018-19[15]. In 2012, 98% of pumps were electrified in the state; and the share further increased to 98.2% by 2014 (Karnataka State Directorate of Economics and Statistics, 2012, 2015). The highly subsidised rates of electricity provided to farmers and unmetered connections have created a financial burden—~25% of the total revenues excluding subsidy—to the government[16]. In particular, Karnataka has seen an upsurge of 86% in the agricultural subsidies— from INR 4,993 crore in FY13 to INR 9,295 crore in FY18. Farmers use inefficient pump sets and rewind old pumps, as the electricity consumed for irrigation is unmetered, leading to more-than-necessary electricity consumption.

Agricultural demand side management (DSM) was taken up by distribution companies such as BESCOM, CESC, and HESCOM on a pilot basis, replacing conventional irrigation pumps with energy-efficient pumps with net energy savings of about 30%. By 2014-15, a total of 2,204 conventional pump sets were replaced in these pilot projects. In addition, the Ganga

[13] A 9W LED bulb sold through UJALA is available at INR 70 compared to INR 140 – INR 200 in the retail market (ICICI Securities, 2017)
[14] LPG coverage is calculated based on number of active connections and estimated households in the state
[15] Data from Energy Department, Government of Karnataka
[16] All pumps up to 10 HP are provided with free electricity

Kalyana Scheme was introduced in 2017, mandating installation of 4- or 5-star rated pump sets to get power supply.

The state government, along with the Ministry of New and Renewable Energy (MNRE), has initiated policies and schemes for installation of solar water pumps. From 2018, the Surya Raitha Scheme has been in effect in the state, aiming to provide solar-powered pump sets to farmers. The solar water-pump systems in Karnataka are installed by the agriculture department and other departments in coordination with KREDL. A total of 2,810 solar-powered pump sets have been installed during 2018-19[17].

The Pradhan Mantri Kisan Urja Suraksha Utthan Mahabhiyan (PM KUSUM), unveiled in 2019, was expanded further in the 2020-21 Budget. The scheme has three nation-wide components: 10,000 MW of decentralised ground-mounted grid-connected renewable power plants, installation of 17.5 lakh stand-alone solar-powered agriculture pumps, and solarisation of 10 lakh grid-connected solar-powered agriculture pumps (MNRE, 2018). The targets and budget for the KUSUM scheme for the state of Karnataka are yet to be announced.

Table 5.2. summarises the existing policies in Karnataka from 2012 to 2018.

Table 5.2: Ongoing major policies/programmes in major energy sub-sectors

Sub-Sector	Major Policies	Major Programmes/Schemes
Power	• Solar Power Policy 2011-16, 2014-21 • Renewable Energy Policy 2009-14, 2016-22 (draft)	• Perform, Achieve and Trade scheme (PAT) • Ujwal DISCOM Assurance Yojana scheme • Restructured Accelerated Power Development and Reforms Programme (R-APDRP) • Integrated Power Development Scheme (IPDS) • Renovation and modernisation (R&M)/Life extension (LE) / Retirement of existing power plants • Renewable Purchase Obligations (RPOs) • National Solar Mission
Transport	• FAME –2015 • Karnataka State EV and Energy Storage Policy • Metro Rail - National Metro Rail Policy	• Incentives for purchase of EVs • Tax rebate for purchase of EVs • Construction of Namma Metro • Improvement in bus fleet in road transport corporations • Implementation of bus rapid transit system
Industry	• Karnataka Industrial Policy 2014-2019 • PAT scheme	• Capital subsidy for practising energy conservation measures - up to INR 7.5 lakh • Capital subsidy for the use of non-conventional energy sources up to INR 15 lakh • Encourage industries with a connected load of above 100 KW to adopt energy audit

[17] Based on data from Energy Department

Buildings	• UJALA • Standards and labelling • Street Lighting National Programme	• Hosa Belaku • ECBC code for commercial buildings
Agriculture	• Ganga Kalyana scheme • Surya Raitha Scheme • National Solar Mission • KUSUM • Pradhan Mantri Krishi Sinchayee Yojana	• Mandatory installation of 4/5-star rated pumps for all new IP sets • Incentives for installing solar-irrigation pumps • Increasing coverage of irrigation and farm mechanisation

5.2.5. Forestry

Forest policies determine the status of forests; rates of deforestation and afforestation, levels of fragmentation, conservation and protection, and rates of timber and non-timber extraction. Vulnerability of forest ecosystems to climate change depends on the status of forests; biodiversity, fragmentation, afforestation practices, rates of extraction of timber etc. The forests in Karnataka are governed by policies formulated largely at the national level by the Government of India. Here we present firstly, some of the major forest policies and programs of India, secondly, the forestry programs being implemented in Karnataka, thirdly the barriers to implementation of some of the programs and policies are discussed.

Forest Policies

i) Forest Policy of 1894: The first, and major, forest policy in India was formulated in 1894. It was drawn after the Forest Department had demarcated, surveyed and mapped the forest area of India. The goals of the policy were: (a) to lay down certain general principles of forest management, (b) to formulate a forest policy that would serve agricultural interests more directly, (c) to maintain forests primarily for preservation of the climatic and physical conditions, and (d) to fulfil the needs of the people.

The forests were classified to reflect these objectives, according to their primary functions, into: forests where preservation was essential on climatic and physical grounds, forest for extraction of valuable timber for commercial purpose, and forests for use by community and as pasturelands. This exercise resulted in the demarcation of 78 Mha of forests into 92% as forests, 5% as community forests and 2% for private ownership. Further, forest classification was based on the quality/status of forests; 47% as Reserved forest, 30% as Protected forest and 22% as unclassified forests.

ii) National Forest Policy of 1952: The Forest Policy of 1952 was initiated to allow exclusive state control over forests and its management. The policy aimed to increase government control over forest resources and develop forests to meet the timber needs of industry and defence. It declared that village communities should not be permitted to exercise their traditional rights over the forests at the expense of national interest. The policy recognized the need for:

- balanced and complementary land use, under which the forests would produce the most and deteriorate the least,
- establishment of tree lands wherever possible, for the amelioration of` physical and climatic conditions and promoting the general well-being of the people,
- increasing supplies of fodder and small wood for making agricultural implements,
- sustained supply of timber and other forest produce required for defence, communication and industry, and
- getting the maximum revenue in perpetuity, while fulfilling the needs enumerated above.

iii) Social Forestry Phase (post 1980): The National Commission on Agriculture (NCA), 1976 suggested the setting up of a corporation to manage forests and to attract monetary assistance from various government and non-government sources. As a result, autonomous forest corporations were started and large-scale plantation activities began. The NCA report also suggested initiation of the social forestry programme on non-forestry lands such as village commons, government wastelands and farmlands to reduce pressure on forests. Social Forestry is India's as well as one of the worlds' largest afforestation programme and has covered more than 28 Mha. Survival rate of seedlings in plantations at the national level was 77%. Productivity recorded in farm forestry is 4.2 t/ha/year and in Forest Department plantations, 2.6 t/ha/year (Seabauer, 1992).

iv) Forest Conservation Act, 1980: The Forest Conservation Act of 1980 was enacted to regulate, reduce or ban indiscriminate diversion of forestland for non-forestry purposes and, to regulate and control forestland use change. Forest conversion is banned or regulated under the Act, effectively reducing deforestation. All forest conversion to non-forestry purposes has to be cleared by the Central Government as per this Act. If conversion is approved, then raising of compensatory plantations is mandatory.

v) Wild Life Act, 1972: The Wildlife (Protection) Act was passed in 1972 and subsequently revised in 2002. The goals of the Act are; to ensure protection of wild animals and to declare forests and habitats of wild animals as sanctuaries and national parks. The Wild Life (Protection) Amendment Bill, 2002 proposes to enhance penalties for violation of the provisions of the Act. It also proposes to create two new categories of Protected Areas, viz., 'Conservation Reserve' and 'Community Reserve'. There are 89 National Parks and 500 Wildlife Sanctuaries in India, covering an area of 156,640 sq. km. Conversion of forestland and extraction of timber and non-timber products is prohibited in the National Parks and Wildlife Sanctuaries.

vi) Protected Area (PA) and Biosphere Reserves: Protected Areas have been established for conservation of biodiversity (both flora and fauna). In India, PAs cover about 14.8 Mha, accounting for 14% of the forest area. The formation of Protected Areas has thus reduced developmental and commercial pressure on forests. Biosphere Reserves have been established with emphasis on conservation of biodiversity, its sustainable use, with communities as an integral part of the reserves. Thirteen Biosphere Reserves have been declared so far in India.

vii) The Forest Policy of 1988: The forest policies hitherto emphasized the importance of protecting forests, which are places of high faunal and floral diversity and national heritage sites. However, the success of several experiments in West Bengal and Haryana on participatory forestry encouraged the government to include local people in forest management (Poffenberger and Singh 1996; Ravindranath et. al., 1997; Saxena, 1997). The basic objectives of the National Forest Policy, 1988 are;

- Maintenance of environmental stability through preservation and, where necessary, restoration of the ecological balance that has been adversely disturbed by serious depletion of forests
- Conservation of the natural heritage by preserving the remaining natural forests with the vast variety of flora and fauna, which represents remarkable biological diversity and genetic resources
- Substantial increase of forest/tree cover through massive afforestation and social forestry programmes, especially on denuded, degraded and unproductive lands
- Meeting of the requirements of fuelwood, fodder, minor forest produce and small timber of the rural and tribal population
- Increasing the productivity of forests to meet essential national needs
- Encouragement of efficient utilization of forest produce and maximization of wood substitution.
- Recognition of rights of forest dependent communities.

viii) JFM resolution of 1990: Afforestation program under social forestry was dominated by monocultures of exotic species such as *Acacia auriculiformis*, *A. mangium*, Eucalyptus, Casuarina, etc., with minimal participation of local community and with Forest Department wholly implementing the program. One of the major criticisms of the social forestry program was that it did not meet its objectives such as meeting diverse biomass needs and participation of local communities. The program was helpful to the farmers who were market oriented (such as in Gujarat, Punjab and Haryana) but less helpful to meet the subsistence biomass needs, such as firewood, fodder and NTFP (Ravindranath et al., 1997), of rural poor and tribal communities. Therefore, the natural forests continued to get degraded. Thus, efforts were initiated to enhance forest cover through participatory process where people protect forests and derive benefits.

The policy aims at recognition of rights of organized communities over a clearly defined degraded patch of the forest. Communities are eligible to receive benefits for the responsibility of protection and conservation of specific forest patches. State level resolutions have legitimized JFM activities at all levels – from the state Forest Departments to the village communities.

Thus, India has formulated and implemented a large number of legislations, and forest conservation and reforestation programs. These programs have not been rigorously monitored and evaluated for their performance and impacts. However, these programs have contributed towards; a) stabilization of area under forests with marginal rates of deforestation, even though forest degradation may be continuing, b) producing fuel wood and industrial wood, thereby reducing pressure on the forests, and iii) involvement of local communities in protection and management of forests, even though there is inadequate empowerment of community institutions.

Afforestation and Forest Conservation Programmes in Karnataka

In Karnataka, several forest conservation and afforestation programs are implemented under centrally sponsored schemes, plan schemes and district sector schemes. Some examples of these programs as presented in the Annual Report 2018-2019 of the Karnataka Forest Department are presented here.

i) Forest Research: The main objective of the scheme is establishment and maintenance of tree preservation plots, raising and maintenance of clonal orchards, silvicultural research plots, species trial plots, espacement and manurial trial plots and seed development.

ii) Western Ghats Task Force: A special task force is established to advise the Government, regarding activities related to conservation and development of Western Ghats ecosystem.

iii) Development of Degraded Forests: Degraded forest areas are rejuvenated through afforestation and various other measures like protection, regeneration, and soil and water conservation under this scheme. Wherever there is enough rootstock, such areas are protected from biotic pressure thereby encouraging natural regeneration. Alternatively, plantations are raised in other areas. This scheme is being implemented in all districts of the State.

iv) Greening of Urban Areas: Under this scheme, it is envisaged to plant flowering and fruit bearing trees in urban areas. Tree parks and avenue plantations are to be established in towns and cities of the State. Supply of seedlings to the residents of urban areas is also one of the activities under this scheme.

v) Development and Preservation of Devarakadus (Daivivanas): Devarakadu forests are very unique and significant from religious and ecosystem perspective. This scheme has been introduced to conserve the valuable ecosystems in their pristine conditions as sacred groves and to allow natural evolutionary process to continue without any disturbance.

vi) Roadside Plantation: Raising roadside plantation is implemented by Karnataka Forest Department to compensate for trees cut for various developmental activities such as widening of roads.

vii) Raising of Seedlings for Public Distribution: To promote tree planting by public and farmers, seedlings are supplied by the department at subsidized rates to plant on individual lands. For this purpose, suitable local species are selected and 4”X6”, 5”X8” and 8”X12” sized seedlings are being raised every year by the department.

viii) Krishi Aranya Protsaha Yojane: As per the National Forest Policy, 33% of the geographical area must be tree cover. To achieve the goal, the Forest Department is implementing various afforestation programs. Since the target of afforestation is high, they are promoting voluntary involvement of farmers, public and NGOs. To enlist the cooperation of farmers and general public for increasing tree cover, the Government of Karnataka launched the “Krishi Aranya Protsaha Yojane”. As per the guidelines of the programme, the farmers, public and NGOs obtain seedlings at subsidized rates from the nearest nurseries of the department. Seedlings so obtained are planted in their lands and nourished, in which case they get incentive for each survived seedling from the Government. Apart from getting incentive they are also at liberty of using whatever yield they get from such seedlings.

ix) Samrudha Hasiru Grama Yojane: This scheme is envisaged to achieve self sustainability of available natural resources and to increase the tree cover. Under this scheme, at least one village in each forest division is adopted by the Forest Department to supply small timber, fodder, green leaves, and to install biogas plants, medicinal gardens etc., to cater to the needs of the villagers, also to supply bamboo and other raw materials to artisans. Besides, it is also proposed to take up afforestation and soil conservation works so as to improve ground water table.

x) Tree park: The objective of this scheme is to provide better environment to public in urban areas. Under this scheme, it is envisaged to set-up 4 urban forest parks near Bengaluru city and 29 such forest parks near each of District Headquarters in the state for providing good environmental facilities to the local citizens.

xi) Maguvigondu Mara Shalegondu Vana: This scheme has been introduced to create awareness regarding ecology and environment among school children and to encourage them to plant. Under this scheme, protected area available around educational institution is identified, and seedlings of fruit yielding, flowering and shade trees are provided to school authorities for raising plantations. Schools from Primary, College and up to Universities are involved in this scheme. Seedlings are distributed to school children for planting in their households or field on voluntary basis.

Thus, the Karnataka Forest Department is promoting and implementing several tree and biodiversity conservation and afforestation programs in all the districts of the state, in forest lands as well as private and public lands through distribution of seedlings or through promotion of plantations.

5.2.6. GHG Implications of Current Policies and Programmes

This study evaluated three scenarios to estimate the GHG implications of various existing policies (2012-18) as well as future mitigation actions (2021-30) as shown in Figure 5.2.

Base scenario: The state continues to use GHG-intensive technology (available prior to 2012) until 2030.

BAU scenario: In this scenario, the existing state and central level policies continues and a realistic target under each policy is considered. This scenario is divided into two distinct timelines- 2012 to 2018 and 2018 to 2030 as mentioned earlier.

- For the time period from 2012 to 2018, the BAU scenario would follow the historic trend from 2008 to 2012.

- For the time period from 2018-2030, the state and central government policies mentioned in the previous section (policies existing until 2018) have been continued in this scenario.

Policy scenario: This scenario comprises the effect of different policies. Like the earlier scenario, this scenario is divided into two distinct timelines.

- The analysis considers the actual achievement of the policies between 2012 to 2018
- Beyond 2018, more stringent policies are proposed compared to BAU scenario, leading to greater emission savings as depicted in Figure 5.2.

Based on the GHG emissions estimated from each scenario, the emission savings in the policy case with respect to the Base and BAU are calculated.

This section provides details on GHG mitigation from existing policies in the state (2012-18).

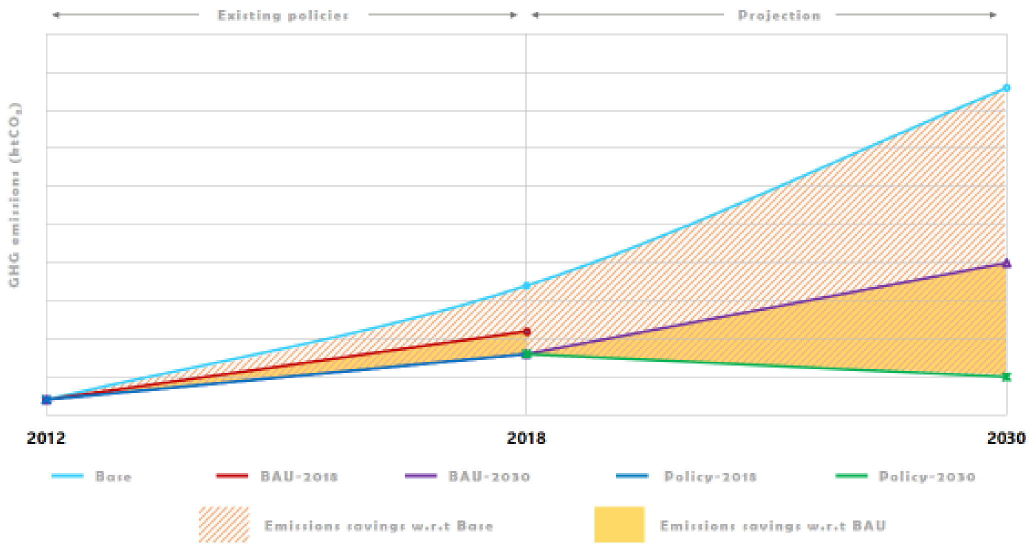


Figure 5.2: Scenario definitions[18]

Power

The three major policy initiatives undertaken by the state to decarbonise the power sector are: increase in the RE-based electricity generation, improvement in T&D infrastructure, and increase in energy efficiency of thermal power plants. The efficacy of the policies/schemes has been estimated in terms of emissions mitigated. Data for this evaluation are collated from secondary literatures and line departments (Annexure A.10).

It is important to note that the GHG mitigation for the power sector is calculated based on a consumption-based analysis. The analysis includes only the power consumed within the state (which includes the imports from other states as well). The actual electricity generation

[18] There are no numbers provided for emissions as this figure is used only for demo purpose

and generation requirement to meet the state's demand in 2018-19 are 71,681 GWh and 69,574 GWh, respectively. The various decarbonisation levers under the three scenarios for the power sector are described below:

- **Increased RE-based electricity generation:** In the absence of the newly- installed RE projects, the electricity generation to meet the demand would have been majorly from thermal power plants with a marginal share of RE[19]. This coal-dominant energy mix is defined for the Base scenario. In the BAU scenario, the share of RE is increased based on the historical growth between 2008 and 2012 (CAGR of 9.7%). For the actual scenario, the actual source-wise generation is considered for GHG analysis. The actual CAGR growth of RE-based electricity generation between 2012 and 2018 was 22%.
- **Improvement in T&D infrastructure:** A marginal reduction in T&D loss percentage, which is lower than PAT scheme targets (for DISCOMs), is considered for the Base case (CAGR ~ (-1%)) (BEE, 2016). In the BAU scenario, the historical trend in T&D loss reduction in the pre-UDAY period (2008-15) is continued (CAGR of -2.9%) till 2018. For the existing Policy scenario, the actual T&D loss percentage between 2012 and 2018 is considered (CAGR of -3.2%). This data is provided in Annexure A.10.
- **Energy-efficiency improvement of coal-based TPP:** Every power plant undergoes decrease in efficiency due to aging. There might be a slight improvement in their efficiency owing to nominal maintenance activities. Efficiency of a TPP is inversely related to its gross heat rate (GHR)[20]. In the Base scenario, a slight annual reduction in GHR (0.13%) is considered. This is based on a nominal annual increase in GHR of 0.2% due to aging and nominal annual decrease in GHR (0.33%) with maintenance activities (CERC, 2013; Korellis, 2014). In the BAU scenario, improvement in GHR of 0.3% (annual) is considered with improved maintenance activities. In the existing Policy scenario, actual plant-wise GHR collated from line departments and secondary literature is used. Actual annual GHR improvement varies from 0.16% (RTPS) to 2.3% (Bellary TPP). The plant-wise actual GHR data collated is provided in Annexure A.10.

The resultant source-wise electricity generation for the three scenarios is provided in Figure 5.3. The power sector mitigated about 33 $MtCO_2$ with respect to the Base case and 21 $MtCO_2$ with respect to the BAU scenario, cumulatively from 2012 to 2018. With high RE power installation in the state, the share of GHG mitigated is the highest from wind installations, followed by solar power projects.

[19] The base case considers a marginal increase in RE-based electricity generation at CAGR of 2%, based on the electricity generation data from 2000-2003.

[20] Heat rate is the total amount of input energy required to produce one kilowatt-hour (kWh) of electricity.

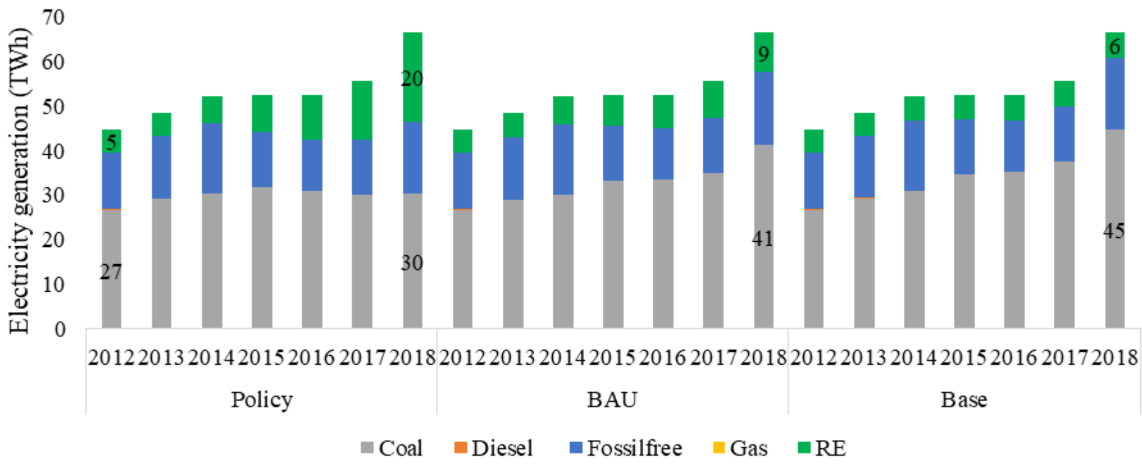


Figure 5.3: Electricity generation trajectories for three scenarios

Transport

In Karnataka, road is the dominant mode of transport for both passenger and freight, with the road network meeting about 95% of the total passenger demand (GoK & NITI Aayog, 2018). The large dependence on the road network and continued reliance on fossil fuels influence emissions in the transport sector. To mitigate GHG emissions from transport, three levers have been considered under the three scenarios.

The policies currently under implementation for EVs (FAME India and the Karnataka State EV and Energy Storage Policy 2017) are considered for the first lever on increased uptake of EVs in Karnataka. Increasing the share of public transport in Bengaluru by encouraging Mass Rapid Transit Systems such as Namma Metro as well as buses has been considered for the second. The third lever involves an increase in the share of public transport using buses for other major urban centres and regions in the state.

- **Increased uptake of EVs**: The Base case scenario assumes that no EVs have been registered in the state during the policy assessment period of 2012-2018. In the BAU scenario and the existing Policy scenario, the actual sales of EVs between 2012 and 2018 are considered to estimate the total emissions mitigated by the implementation of EV policies. The total cumulative emissions mitigated with respect to Base and BAU cases are 69 ktCO_2 and 38 ktCO_2 respectively.
- **Improved public transport scenario for Bengaluru**: The estimation for emission savings is based on the available historical trip mode share data for passenger road transport and metro in Bengaluru. The data for trip mode share was obtained from traffic surveys and secondary literature published by the Directorate of Urban Land Transport (DULT) and Bangalore Metro Rail Corporation Limited (BMRCL). For the Base case, the share of passenger trips by metro in total trips made in the city are assumed to increase from 0% in 2012 to about 2% by 2018 (UMTCL, 2011; Verma et al., 2018). The share of trips made by buses is assumed to decrease from 42% to 36% between the same period (BMRCL, 2019; DULT & Wilbur Smith Associatess, 2009). In the BAU scenario, while the mode share of buses is assumed to remain the same as in the previous

scenario, share of metro is assumed to marginally increase to 4%. In the Policy scenario, the share of metro in total passenger trips is assumed to increase to 6%. Meanwhile, the share of bus in total trips is assumed to marginally improve to 41% based on the estimates provided under the draft CMP 2019 (BMRCL, 2019; Performance Indicator, 2020). Due to the implementation of metro and improvement in passenger trip mode share by bus in the Policy scenario, emissions mitigated between 2012-2018 with respect to Base and BAU scenarios are estimated to be 966 ktCO_2 and 817 ktCO_2 respectively.

- **Improvement in public transport:** For rest of Karnataka (aside from Bengaluru) in the Base case, the share of public transport is assumed to increase only marginally—from 52% in 2012 to 53% in 2018 based on estimates from Karnataka state energy calculator (GoK & NITI Aayog, 2018). In the BAU and existing Policy cases, the public transport share is again assumed to increase to 53.5% and 54.2%, respectively, mainly due to the absence of focused policies to encourage public transport in the rest of Karnataka (GoK & NITI Aayog, 2018). Emissions mitigated under this lever during 2012-2018 w.r.t Base and BAU cases are estimated to be 331 ktCO_2 and 176 ktCO_2.

Industry

To estimate the emission reduction in iron and steel, and cement industries, the key levers considered are *improvement in energy efficiency* (through PAT) *and Process shift* (due to shift in production processes and process-level improvements). Under PAT Cycle-I, Karnataka had four Designated Consumers (DCs) in the cement sector and five DCs in the iron and steel sector; the average SEC reduction target was about 5% from the base year 2011-12 (KREDL, 2018a) (KREDL, 2018a).

- Under the *improvement in energy-efficiency* lever, the Base case assumes that energy-efficiency improvements are driven by autonomous improvement due to voluntary measures undertaken within the industry, without the intervention of any state/national-level policy. Under this scenario, we assumed an annual Specific Energy Consumption (SEC) improvement of about 0.2% from 2012 in both iron and steel, and cement sectors. In the BAU scenario, based on the targets prescribed under PAT Cycle-I, the annual improvement in SEC was assumed to be 0.4% in cement and 0.5% in iron and steel sectors between 2012 and 2018. These annual improvements lead to an SEC improvement of about 1.5% and 2% for cement, and iron and steel sectors, respectively, between 2012 and 2015. This lower level of improvement in SEC compared to the prescribed PAT targets was assumed by taking into account the progress on energy-efficiency measures in industrial units not covered under PAT. Similarly, in the Policy scenario, assuming that the industry is working towards implementing best available technologies and benchmarks for energy-efficiency improvement, an annual SEC improvement of about 1% in cement and 0.9% in iron and steel has been considered (GoK & NITI Aayog, 2018). Additionally, based on the available data, there was no shift in production processes that was assumed for these two industrial sectors between 2012 and 2018. Based on the aforementioned efficiency improvements in the cement and, iron and steel industries, the cumulative emissions mitigated with respect to Base and BAU scenarios are estimated to be 4,841 ktCO_2 and 2,598 ktCO_2.

Buildings

The major programmes in the building sector were the UJALA scheme and Street Lighting National Programme.

- **UJALA:** In the absence of the UJALA scheme, the lighting sector would have been dominated by incandescent bulbs. Because the scheme was launched in Karnataka only by 2015, the Base and BAU scenarios are assumed to be one and the same. The Base/BAU scenario is assumed to have continued the use of incandescent bulbs with negligible penetration of CFL bulbs. In the existing Policy scenario, the lighting energy demand and corresponding GHG emission reduction for 2.2 crore LED bulbs are estimated. A similar approach is used in the case of LED tube lights and energy-efficient fans.
- **Street Lighting National Programme (SLNP):** The scenario definition for SLNP is similar to the UJALA scheme. Base/BAU scenario considers conventional street lights, while existing Policy scenario considers LED streetlights. Because it is difficult to estimate the actual power consumption (wattage) of conventional and LED streetlights due to varied wattage based on their purpose, an average energy savings is estimated from the SLNP dashboard. As per the dashboard, a LED street light was estimated to save about 670 kWh/annum. This is multiplied with the number of street lights replaced to calculate the total savings.

The cumulative emissions mitigated by UJALA and SLNP from 2012 to 2018 are 3,817 ktCO_2 and 6 ktCO_2, respectively. Details on assumptions and methodology are provided in Annexure A.11.

Agriculture

The two major levers in Karnataka's agriculture sector for emissions mitigation are: replacement of regular pumps with energy-efficient (EE) pumps and installation of solar pumps.

- **Energy-efficient pumps:** There were three pilot projects for replacement of pumps with EE pumps in the state: Doddaballapur (2009), Nippani and Byadgi (2013), and Malavalli (2014-15).
  - Base scenario: No energy savings due to EE pumps (assuming no replacement with EE).
  - BAU scenario: Here we consider savings due to the Doddaballapur project, because it is the only project implemented before 2012.
  - Policy (actual) scenario: Energy savings by all three projects are considered.

The energy savings are based on monitoring reports prepared by the Energy Efficiency Service Limited (EESL) and approved by the State Energy

Department. The cumulative emissions mitigated via this lever in 2012-18 are estimated to be 17.24 ktCO_2 with respect to Base case and 10.14 ktCO_2 with respect to BAU.

- **Solar pumps:** As per the data provided by the Energy Department, a total of ~2,250 solar pumps have been installed in the state by 2018.
    - Base and BAU scenarios: The installation started in 2016, so both Base and BAU cases for this lever assume no solar pumps.
    - Policy (actual) scenario: For this scenario, the solar-pump lever considers the number of actual solar pumps installed in the period 2016-18.

The cumulative emissions mitigated due to this lever in the period 2012-18 are estimated to be 10 ktCO_2 with respect to Base and BAU cases.

The method for calculating the emissions mitigation potential of the existing policies in the agriculture sector has been described in Annexure A.10.

Table 5.3 details out the major policies or programmes in the state, barriers for implementation and its GHG emission mitigation potential and achievement for Policy (actual) scenario. The emissions are estimated using the actual policy implementation levers[21] as detailed above. Karnataka cumulatively mitigated 45 MtCO_2 and 29 MtCO_2 with respect to Base and BAU scenario from 2012 to 2018. The major share of emission mitigation was from the power sector due to implementation of high renewable energy projects in the state.

[21] Activity data were collected from line departments and government reports

Table 5.3: GHG implications of major current policies and programmes

Sector	Sub-sector	Major Policy/ Programme	Emission Mitigation Potential[22] ($ktCO_2$)	Cumulative Emission Mitigated: 2012 - 2018 ($ktCO_2$)		Barriers to Achieving the Potential
				w.r.t Base	w.r.t BAU	
Power	Solar (including RTPV)	Solar Power Policy (2011-16), 2014-21	4,368 (2014-18)	5,539 (2012-18)	4,137 (2012-18)	• High capital cost of solar PV in pre-2015/16 period • Lack of higher RPO targets to promote procurement of RE-based power in DISCOMs
	Wind	Renewable Energy Policy 2009-14 and 2016-22 (draft)	7,733 (2012-18)	14,862 (2012-18)	9,426 (2012-18)	• High capital cost of wind power plant • Revision of cost in tariff order led to an increase in tariff for wind power plants • Land availability issues • Lack of transmission infrastructure in wind zones
	Small hydro, biomass and co-generation			6,314 (2012-18)	4,067 (2012-18)	
	Transmission and distribution (T&D)	UDAY/IPDS/R-APDRP	No targets	4,433 (2012-18)	611 (2012-18)	• Data entry errors in the energy auditing process followed by DISCOMs for T&D loss reduction • Distribution transformers were neither metered nor maintained properly
	Maintenance activities in TPP	Maintenance, R&M/LE activities in coal power plants	4,143 (2012-18)	3,716 (2012-18)	2,656 (2012-18)	• Raichur and Bellary TPP couldn't meet the PAT-cycle-1, mainly due to the lack of R&M activities during PAT cycle-1 • Private TPPs such as Torangallu IMP TPP and Torangallu EXT TPP were able to meet PAT 1 and 2 targets • Bellary TPP improved their heat rate significantly during PAT Cycle-2
Other Energy		FAME 2012-18	No targets	37 (2012-	16 (2012-18)	• Lack of charging-infrastructure network

[22] Mitigation potential estimated only for policies with quantitative targets; calculated w.r.t Base scenario.
In cases where policies provide yearly target, the cumulative emission mitigation potential for the target period is estimated. In remaining policies, the annual mitigation potential for the target year is estimated.

Sectors	Transport			18)		• Additional incentives for procurement of new EVs and electrification of existing fleet
		Karnataka State EV and Energy Storage Policy 2012-18		31(2012-18)	22 (2012-18)	
		Improved public transport scenario for Bengaluru		966 (2012-18)	817 (2012-18)	• Absence of first- and last-mile connectivity for metro in Bengaluru • Integration of bus services and schedule with metro operations
		Improving public transport across Karnataka		331 (2012-18)	176 (2012-18)	• Absence of integrated land use and transport planning in other cities and town
	Industry	Perform, Achieve and Trade (PAT I & II)	1,813 (2012-18)[23]	4,841 (2012-18)	2,598 (2012-18)	• Lack of sector-specific targets for industries not covered under PAT • Inadequate coverage of the scheme across the industries, including MSMEs
	Agriculture	Agriculture Demand Side Management – Energy-efficient pumps: pilot projects	No targets	17 (2012-18)	10 (2012-18)	• Unmetered IP sets • Higher cost of pumps • Rewinding of old pumps
		National Solar Mission		10(2012-18) (2016-18)	10 (2012-18) (2017 and 2018)	
	Buildings	UJALA scheme, LED bulbs	3,626 (in 2019)	3,817[24] (2015-18)	3,817 (2015-18)	• Luminous intensity is low • A few bulbs got damaged within the warranty period
		Street Lighting National Programme		6 (2017 and 2018)	6 (2017 and 2018)	No information available

[23] Emission mitigation potential in PAT 1 (2012-15) and PAT II (2016-18) cycles are 304 ktCO_2 and 1,508 ktCO_2

[24] Includes cumulative savings from LED bulbs, tube lights and energy-efficient fans.

Forestry

IPCC (2014) in its Fifth Assessment Report concluded that: "land-related mitigation, including bioenergy, is projected to contribute 20% to 60% of total cumulative abatement by 2030, and 15% to 40% by 2100". Leveraging the mitigation potential of land use sectors is important in meeting emission reduction targets (IPCC, 2014).

The land use sector in India, according to the Biennial Update Report (2018) was a net sink of 301 $MtCO_2$ and forest sector in particular was a net sink of 68 $MtCO_2$ during 2014. India formulated the Greening India Mission (GIM) as one of the missions under the National Action Plan on Climate Change and envisaged enhancing ecosystem services and carbon sinks through afforestation on degraded forest lands in line with the national policy of expanding the forest and tree cover to 33% of the total land area of the country. The broad objective of the mission is to increase the forest and tree cover by 5 Mha, as well as to increase the quality of existing forest and tree cover in another 5 Mha forest/non-forest lands in 10 years.

India's "Intended Nationally Determined Contribution" Forestry Goal and Target: One of the key goals of India's NDC is "To create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030". Achieving the INDC forestry carbon sink target requires estimation of land availability, identification of forestry and agroforestry options suitable to different land categories and the area identified, meeting the local demands of biomass, conserving biodiversity, modeling/estimating CO_2 sequestration potential, and implementation at the state level.

Potential Land Categories for Carbon Sink Creation in Karnataka: The Nationally Determined Contribution (NDC) of India includes a target of creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030. In India, according to the Forest Survey of India:

- Forest cover is defined as "all lands more than one ha in area with a tree canopy density of more than 10%, irrespective of ownership and legal status". It includes forests, orchards, bamboo and palm.
- Tree cover is defined as, "tree patches outside the recorded forest area, exclusive of forest cover and less than the minimum mappable area of one ha and up to 0.1 ha. Such small patches comprising block, linear and scattered trees are not delineated as forest cover".

In Karnataka, the potential land categories available for carbon sink creation based on the assessment of area under different land categories are wastelands and rainfed agricultural lands, in addition to forest land (Table 5.4).

Table 5.4: Land categories and area available for carbon sink creation in Karnataka

Land category	Total area (ha)	Area for carbon sink creation (ha)	Rationale
Wastelands	1322,968	1271,319	Includes area under wasteland categories excluding Gullied and/ or ravinous land (Medium), Gullied and/ or ravinous land (Deep), Waterlogged and Marshy land (Permanent), Waterlogged and Marshy land (Seasonal), Land affected by salinity/alkalinity (Medium), Land affected by salinity/alkalinity (Strong), Degraded land under plantation crop, Sands-Riverine, Sands Coastal, Sands-Semi Stab -Stab>40m wasteland categories, considering the area under these categories is small and would require high investment
Rainfed cropland	6823,000	6823,000	Includes 69% of total net sown area. 31% of total net sown area of 9.9 Mha is irrigated according to 2016-17 Agriculture Statistics.

Carbon Sink Potential Estimated Through Modeling for 2030: Estimation of carbon sink potential for climate mitigation involves selection of scale, land categories, area, period, carbon pools and models for estimating the mitigation potential in 2030. The steps for estimating the carbon sink potential is outlined in Figure 5.4. The detailed account of steps is presented in Annexure A.13.

Step 1	Selection of scale of assessment
Step 2	Selection of land categories and estimation of area available for mitigation purposes
Step 3	Selection of model for assessment of mitigation potential or carbon sink potential
Step 4	Selection of forestry mitigation options and matching of options to identified land categories
Step 5	Selection of scenarios, carbon pools and period of assessment
Step 6	Model runs for estimating the mitigation potential

Figure 5.4: Approach to assessment of mitigation potential of forest sector in Karnataka

Mitigation scenarios: Three scenarios are considered for assessing the carbon sink enhancement potential in Karnataka. The total area considered under the different scenarios and the rationale is presented in Table 5.5.

i. ***Scenario 1: Baseline scenario***: This includes estimating the total mitigation potential, considering average annual afforestation by the Forest Department and promotion of agroforestry on rainfed croplands. This is computed in the following manner:

   a. Average area afforested annually under baseline scenario = about 59,000 ha/year (considering area afforested over the last five years by the Forest Department)
      - Total area to be afforested over the 10-year period – 2020-2030 is 3,99,000 ha, considering planting for 7 years during 2020-2027, since Carbon sequestration in the initial establishment period of 3 years is very low for accounting for the period under NDC.

   b. Additionally 6,94,400 ha of rainfed cropland, which is 10% of the total area under rainfed cropland is also considered for agroforestry.

In all, under this scenario, 10,93,400 ha is proposed to be afforested.

Table 5.5: Scenarios for assessment of mitigation potential of forest sector in Karnataka

Land category	**INDC category**	**Remarks**	**Proposed area (ha)**
		Scenario 1: Baseline Scenario	
Forestland		Considers baseline afforestation rate (average of last 5 years for the period 2014-15 to 2018-19) @ 59,000 ha/year with 7-year planting	3,99,000
Rainfed cropland		Considers 10% of total area under rainfed cropland for agroforestry	6,94,400
		Scenario 2: Double the Baseline Afforestation Scenario	
Forestland		Assuming doubling of baseline planting rate of 59,000 ha/year	7,98,000
Rainfed cropland		Considers 20% of area under rainfed cropland for agroforestry	13,88,800
		Scenario 3: NDC Scenario	
Wasteland	Forest Cover	Considers all the potential area under wastelands	12,71,319
Rainfed cropland	Tree Cover	Considers 100% of total area under rainfed cropland for agroforestry	69,44,000

ii. ***Scenario 2: Double the baseline afforestation scenario:*** Under this scenario, an afforestation is implemented at double the baseline rate of 59,000 ha/year over the 2020-2030 period, which is 7,98,000 ha. Additionally afforestation on 20% of rainfed cropland (13,88,800 ha) is considered for promoting agroforestry.

In all, under this scenario, 21,86,800 ha is proposed to be afforested.

iii) Scenario 3: NDC scenario: Under this scenario, the proportion of forest and carbon sink to be created by Karnataka, to meet the NDC target at the national level is computed in the following manner:

i. Total NDC target for forest sector = 2.5 to 3 billion tonnes of CO_2 equivalent by 2030.
ii. Geographic area of Karnataka as % of total geographic area of India = 19/328 Mha = 5.79% or approximately 6%.
iii. Total carbon sink to be created in Karnataka as contribution to NDC target by 2030 = @6% of 2.5 to 3 billion tCO_2 = 150 to 180 $MtCO_2$.

Mitigation options: Selection of appropriate mitigation options for implementation on different land categories will determine the potential success of implementation. Mitigation options compatible with different land categories have been identified (Table 5.6).

- The mitigation options for wasteland categories are in line with the broad sub-missions outlined in the Greening India Mission and the State Action Plan on Climate Change, to enable compatibility with government plans to have policy relevance.
- Promotion of agroforestry on agriculture lands or marginal croplands is also one of the sub-missions of the Greening India Mission. This has further received boost with the formulation of an Agroforestry Policy in India. This sub-mission or mitigation option in the case of this assessment is foreseen to be an option that has the potential to promote mitigation-adaptation synergistically by improving tree cover, biomass and carbon stocks (mitigation) on the one hand and strengthening the resilience or adaptation capacity of farmers practicing agroforestry by providing alternate income opportunities from tree products such as fuel wood, fodder and fruits.

Table 5.6: Matching of land categories and mitigation options and delivery of mitigation benefits

Land category		**Mitigation option**	**INDC target**	**Rationale for selection of mitigation option**
Wasteland	Wasteland – multiple categories	Afforestation	Forest cover	- Afforestation using short and long rotation species is an established option for reclamation of wastelands. - Helps increase tree cover, sequesters biomass and soil carbon, and promotes biodiversity - Provisions fuelwood and grass to local communities.
Cropland	Rainfed lands	Agroforestry	Tree cover	- Rainfed and marginal lands will gain tree cover, reducing the loss of soil organic carbon and enhancing the biomass and soil carbon stocks. - Farmers traditionally have the practice of growing trees on farm lands on the bunds and edges.

The broad categories of mitigation options considered primarily provide carbon sequestration benefits for mitigating climate change and in addition multiple co-benefits such as biodiversity conservation, employment generation and improved livelihoods.

- *Afforestation on wastelands:* Could potentially meet the fuel wood and industrial/structural wood requirements, generate non-timber forest products and reclaim land.
- *Agroforestry on rainfed croplands*: Produce timber species for economic returns and fruit yielding species for nutritional benefits and alternate and additional income. Tree planting on rainfed cropland provides co-benefits such as fodder species for livestock, improvement in soil fertility and watershed protection.

Carbon pools: Three of the five carbon pools identified by the UNFCCC Marrakech Accord (2001) are included in this assessment. They include aboveground biomass (AGB), belowground biomass (BGB, through an expansion factor) and Soil Organic Carbon (SOC).

Time-Period for assessment: Under INDC, a target of 2.5 to 3 billion tonnes of CO_2 sink is proposed to be achieved by 2030. Thus, in this assessment, a period of 2020-2030 (10 years) is considered.

Forest and Tree Cover Carbon Sink Potential of Forest Sector in Karnataka

Carbon sink potential is estimated considering forest cover and tree cover enhancement, according to INDC. Three scenarios – ‘Baseline potential’, ‘NDC potential’ and ‘Double the Baseline Afforestation Potential’ are considered for assessing the carbon sink enhancement potential for Karnataka. The sink potential estimated for the three scenarios is presented in Table 5.7.

⇒ **Baseline scenario potential**
  a. The mitigation potential of forest cover enhancement on degraded forestlands is estimated to be 27.22 $MtCO_2$ by 2030.
  b. Mitigation potential of tree cover enhancement on rainfed croplands is estimated to be 14.02 $MtCO_2$ by 2030.
  c. The total mitigation potential of forest and tree cover enhancement by 2030 under ‘Baseline Scenario’ is estimated to be 41.23 $MtCO_2$.

⇒ **Double the baseline afforestation scenario potential**
  a. Mitigation potential of forest cover enhancement considering doubling of baseline afforestation rate is estimated to be 55.43 $MtCO_2$ by 2030.
  b. Mitigation potential of tree cover enhancement on rainfed croplands considering 10% of the total area is estimated to be 28.03 $MtCO_2$ by 2030.
  c. The total mitigation potential of forest and tree cover enhancement by 2030 under ‘Double the Baseline Afforestation Scenario’ is estimated to be 83.46 $MtCO_2$.

⇒ **NDC scenario potential**
  a. Mitigation potential of forest cover enhancement considering 100% of the area under identified wasteland categories is estimated to be 86.72 $MtCO_2$ by 2030.

b. Mitigation potential of tree cover enhancement on rainfed croplands considering all the area is estimated to be 131.95 $MtCO_2$ by 2030.
c. The total mitigation potential of forest and tree cover enhancement by 2030 under 'NDC Scenario' is estimated to be 218.67 $MtCO_2$.

Table 5.7: Carbon sink enhancement potential estimates for Karnataka state

Land category	**INDC category**	**Proposed area (ha)**	**Total mitigation potential ($MtCO_2$) by 2030**
Baseline scenario potential			
Degraded Forestland		3,99,000	27.22
Rainfed Cropland	Tree Cover	6,94,400	14.02
Total		**10,93,400**	**41.23**
Double the baseline afforestation scenario potential			
Wastelands	Forest Cover	7,98,000	55.01
Rainfed Cropland	Tree Cover	13,88,800	28.03
Total		**21,86,800**	**83.46**
NDC scenario potential			
Wastelands	Forest Cover	12,71,319	86.72
Rainfed Cropland	Tree Cover	69,44,000	131.95
Total		**82,15,319**	**218.67**

Carbon pools considered: Aboveground biomass, Belowground biomass and Soil Organic Carbon; Growth rates: Considering conservative growth rates - Afforestation on wastelands/forestland is AGB = 1.5 t/ha/year + BGB (24% of AGB) + SOC (0.5 tC/ha/year); Agroforestry on rainfed croplands = AGB = 0.84 t/ha/year + BGB (24% of AGB) + SOC (0.5 tC/ha/year).

Contribution of Karnataka State to NDC Carbon sink target by 2030

Carbon sink potential by increasing forest and tree cover in Karnataka under the baseline scenario, considering current trends and rates of afforestation in forestlands and agroforestry in 10% of area under rainfed croplands is about 41 $MtCO_2$ by 2030. If a 'Double the Baseline Afforestation Scenario' is adopted a sink capacity of only about 83 $MtCO_2$ could be created. However, under the NDC scenario, which requires creation of additional forest and tree cover and carbon sink capacity: afforestation and agroforestry promotion covering all the area under wastelands as well as rainfed croplands may be needed and this could create a sink of about 218 $MtCO_2$ as against the target assumed at 150 to 180 $MtCO_{2.}$

The potential contribution of forest and tree cover enhancement in Karnataka under the 'Baseline Scenario' is only about 2% of the NDC target (of 150 to 180 $MtCO_2$), which could be increased to about 3% under the 'Double the Baseline Afforestation Scenario'. However, to create a sink capacity that is equivalent to 6% of the NDC target (of 150 to 180 $MtCO_2$), the carbon sink creation by 2030 in Karnataka will have to be increased quite significantly. The potential contribution to NDC target could increase to about 8% under the 'NDC

Scenario', if all the wasteland and dry land area is brought under afforestation and Agro-forestry, respectively.

5.3. Prioritised Sectoral Mitigation Activities for 2021-30

The detailed inputs and assumptions for all the energy sectors used for our projections are provided in Annexure A.12.

Power

The total mitigation potential from power sector in 2030 is 47,743 ktCO_2 and 15,963 ktCO_2 with respect to Base and BAU[25], respectively. Within this, non-fossil-based electricity generation contributed around 90% of the emission reduction, followed by T&D loss reduction and energy efficiency improvement in thermal power plants.

Within the non-fossil segment, solar-based electricity generation contributed the highest to emission savings. Therefore, installation of solar-based electricity generation needs to be prioritised. Resource constraints such as lack of grid infrastructure and undulating topography are minimal for solar-based power (unlike in wind and other RE-based sources). In addition, the cost of solar PV modules is expected to reduce by 34% in India by 2030 as compared to 2018 levels (IRENA, 2017). Moreover, shifting to solar PV from conventional fossil-fuel-based generation would reduce the state's dependence on other states for coal. The state would also focus on promoting RTPV installation in residential and commercial buildings. This would reduce the land-availability and grid-stability issues related to variable power generation. The ground-mounted solar and RTPV-installed capacity addition of 11 GW and 2.8 GW are needed between 2021 and 2030. With this capacity addition, 20,098 ktCO2 can be mitigated in 2030, with respect to the Base case.

As the developers need to make the investment, the state should focus on attracting investment by introducing regulatory changes. The recent announcement on imposing wheeling charges and transmission cost for open-access consumers would adversely affect investment in future (KERC, 2018). In the case of RTPV generation, the state adopted a gross metering system, instead of net metering, for commercial and industrial consumers (in December 2019) (KERC, 2019b). This could hinder the uptake of RTPV, as the tariff for the power supplied by DISCOMs is likely to be higher than the tariff at which power is procured from the same consumers. Developers had already approached the Appellate Tribunal for Electricity (APTEL) seeking to do away with net metering for commercial and industrial consumers (Energyworld.com, 2020). Going forward, KERC, DISCOMs, and KREDL together should devise innovative models to attract investments in RTPV.

The reduction in T&D loss in the Policy scenario could reduce emissions by 3,096 ktCO_2 with respect to Base and 1,259 ktCO_2 with respect to BAU. The energy-efficiency

[25] The emission savings excludes the impact of demand side electricity reduction (translating to 7,405 ktCO_2 and 2,952 ktCO_2 from base -BAU and BAU- policy scenarios)

improvements in state-owned plants could reduce emission by 1,101 ktCO_2 with respect to Base and 600 ktCO_2 with respect to BAU.

The state should also focus on improving T&D infrastructure, even though the potential is lower. This would reduce the financial burden of generation and distribution companies. Moreover, grid expansion and strengthening are essential during this period, to handle the higher share of variable power. However, the investment requirement for this activity has not been analysed in this study. The investment required to reduce T&D loss will be different for each DISCOM. Based on secondary literature review, a ballpark investment of around INR 300 crore is needed to reduce the T&D loss by 1% per DISCOM.

Transport

Karnataka was the first state in India to launch an EV policy, creating a favourable environment for adoption of EVs in the state. With concerted efforts being taken up both to encourage manufacturing and purchase of EVs, this is a clear priority for the state. Our analysis indicates that an increased uptake of EVs can be achieved between 2021 and 2030 through: a) a rigorous implementation of the state EV policy; b) provision of demand incentive through the FAME India scheme until 2030; and c) estimated emission savings of about 3,330 ktCO_2 and 3,118 ktCO_2 w.r.t to Base and BAU scenario, respectively, can be achieved in 2030.

In Bengaluru, with the Namma Metro on track to achieve operationalisation of its Phase II by 2030, the government should prioritise the augmentation of its bus services to improve the first- and last-mile connectivity. The integration of operation of bus services with that of Namma Metro and provision of bus stops at metro stations should also be prioritised to improve the uptake of public transport in the city. It is estimated that an improved public transport scenario in the city would result in an emissions savings of about 1,773 ktCO_2 and 1,107 ktCO_2 w.r.t to Base and BAU scenarios in 2030. The state should also focus on improving the public transport network across Karnataka by improving the bus fleet and adding new routes across the state under various road transport corporations. This improvement in public transport is estimated to result in a total emissions savings of about 2,954 ktCO_2 and 1,538 ktCO_2 with respect to Base and BAU scenarios.

Industry

The energy-efficiency measures considered in the industries sector significantly reduce energy demand as well as emissions. Our analysis indicates that by 2030, compared to the Base case scenario, an estimated 10% -13% reduction in emissions can be achieved from the cement, and iron and steel sectors. Though under the current policy framework, the impetus for energy-efficiency improvement is mainly driven by national-level polices, the state can play a more active role here. The state needs to prioritise the implementation of energy-efficiency measures in all industrial units in addition to the ones already covered under the PAT scheme.

With the implementation of energy-efficiency measures, the Policy scenario will see an emission reduction of about 3,105 ktCO_2 w.r.t Base case and about 6,933 ktCO_2 in cement, iron and steel and refineries sectors.

The only refinery in Karnataka—Mangalore Refinery and Petrochemicals Limited (MRPL)—has been included in the PAT scheme from Cycle II onwards. Refineries mainly achieve energy efficiency by minimising losses, reducing routine flaring, and improving crude composition (TERI, 2016).

- Base scenario: 2% specific energy consumption reduction by 2030 is considered here.
- BAU scenario: 4% specific energy consumption reduction by 2030 is considered.
- Policy scenario: We consider a slightly more aggressive (5% by 2030) reduction in specific energy consumption, and no requirement of grid electricity (assuming an adequate supply of in-campus solar power).

The emissions potential of MRPL with respect to Base is estimated to be 195 ktCO_2 and w.r.t BAU is estimated to be 49 ktCO_2 in 2030. The implementation of subsector-wise SEC reduction targets would be feasible when implemented in various stages.

Buildings

Our analysis indicates that Karnataka's commercial sector has the potential to further reduce 7% emissions from its buildings by 2030, via wider implementation of ECBC norms (assuming ECBC-compliant area is more than double than that in BAU scenario). Although the norms have been notified in 2014, not much has been done to encourage builders to move towards ECBC-based construction. The higher costs associated with such construction are a major hurdle, restraining this scheme from becoming a greater success. Innovative methods to boost ECBC adoption—including helping consumers realise the returns on their investment, such as energy saving and a reduced electricity bill—are necessary. Incentive mechanism on additional FSI could also be an option to encourage ECBC-compliant buildings.

In the domestic sector, policies promoting energy efficiency are a clear winner for emission mitigation. The policy scenario assumes a wider implementation of all schemes, resulting in lower emissions. An outstanding mitigation potential is offered by switching over to efficient lighting technologies. With 75% (by 2030) of the lighting needs being met by LEDs in the residential sector, the Policy scenario emits 48% lower emissions than that in BAU in 2030. This helps us conclude that an aggressive push for greater implementation of UJALA, along with standard and labelling programmes, will yield good dividends.

So far, only 38% of the target distribution of LED bulbs under UJALA scheme has been achieved in Karnataka, requiring the state to do more. A key inhibitive factor is the lack of awareness and motivation for people to opt for it [3]. Additionally, a lot of consumers, especially in remote areas, complain of distribution centres being either too far away (making it inconvenient to travel) or inadequately stocked. Consumers occasionally face problems with replacement (of a faulty appliance) under the warranty period. Most people become aware of the scheme by 'word of mouth' and may be motivated to purchase the appliance the first time only for its lower prices, without understanding the value it adds to energy efficiency and electricity bills. In such a case, they may go back to using older inefficient appliances if they are unable to obtain a replacement. These challenges can be overcome by revisiting the implementation mechanism in the state. There should be a strong focus on enhancing the distribution network. This, for example, could involve local entrepreneurs with a larger customer base and outreach. The state also needs to run effective advertisement campaigns that inform consumers of the benefit of switching to efficient appliances. These campaigns could rope in local celebrities, who have a wider connect to the semi-urban and rural consumers. Along with these, the complaint-redressal mechanism needs to be strengthened to ensure continuity in the use of efficient appliances.

The success of the UJALA scheme indicates that such an initiative could be replicated for other electrical appliances. We do have a standards and labelling programme in place, which provides rating for these appliances—thus helping the consumer understand the importance of energy efficiency. However, higher-rated appliances are more expensive, thus discouraging their adoption. EESL has launched the super-efficient ACs programme with a target to distribute 50,000 ACs in its pilot, at a price comparable to most energy-efficient ACs in the market[4]. Such a programme needs to be brought to the state level soon, so that residential consumers are encouraged to buy efficient ACs, refrigerators, and television sets.

These actions could lead to GHG mitigation of 4,148 ktCO_2 and 1,659 ktCO_2 w.r.t Base and BAU scenario in 2030.

Agriculture

The emission-mitigation potential of the Policy case w.r.t Base is 7,470ktCO_2, and w.r.t. BAU is 5,313 ktCO_2 in 2030.

With the 2020 Union Budget's renewed emphasis on solar energy for farming (with the PM-KUSUM scheme), installation of solar pumps is a clear priority. Under various MNRE schemes, around 2,250 solar pumps were installed in the state from 2011 to 2018. Assuming about 30% of all irrigation pump sets to be solar-powered stand-alone pump sets by 2030, agriculture sector has a carbon-mitigation potential of 3,282 ktCO_2 in 2030. In estimating this, we have also factored in a possible average power increase (7.5 HP by 2030, from present average 5 HP) of pump sets to account for possible receding groundwater levels. Given the current price of solar pumps (INR 4.85 lakh per pump) (CEEW, 2018; International Commission on Irrigation and Drainage (ICID), 2019), the total cost for this mitigation activity is estimated at approximately INR 66,684 crore for the period 2021-2030

Karnataka ESCOMs tried three pilot projects for agricultural demand side management. Karnataka is one of the early adopters of energy-efficient pumps, and is likely to continue with the installation, considering the success of the pilot projects. As per the Ganga Kalyana scheme, to get power supply the installation of 4- or 5-star rated EE pump sets has been made mandatory for all new irrigation pump sets, including borewells, with effect from 1 June 2017 (KREDL, 2015).

Forestry

Some potential programmes and projects that could be implemented in Karnataka to promote forest conservation and afforestation, contributing to the NDC target of the country under the Paris Agreement are listed below:

- *Climate Resilient Afforestation Programme:* Promote natural regeneration and mixed species planting in the afforestation programmes to enable risk spreading, and also increase genetic diversity. Anticipatory planting of tree species across latitudinal and altitudinal gradients, in particular identification of species from warmer districts and their promotion in districts projected to become warmer. Assisted migration to maintain or improve migration corridors, including active management to improve survival along the shifting vegetation especially in the transitional zones and by translocation of species.
- *Agro-forestry for Resilience Building in Rural Communities and Farmers:* Promote agroforestry and plantation forestry on farm lands, incorporating multiple tree species providing diverse economic products (fruits, seeds, etc.), apart from timber and fuel wood to build resilience among the farmers by supplementing their income and to reduce their dependence on forests.
- *Linking of Protected Areas, Corridors and Fragmented Forests:* Link Protected Areas and fragmented forests for securing corridors to facilitate species migration under a changing climate. Identify critical forest corridors and fragmented forests and promote ecosystem restoration through climate-resilient afforestation and by managing non-climate disturbances.
- *Research for Climate-Resilient Silviculture:* Develop/identify appropriate temperature, pest and fire tolerant species and silviculture practices to cope with changing climate and its impacts.

5.4. Barriers and Gaps to Mitigation Actions

There are certain barriers and gaps to implementation of mitigation actions in all the sectors. In this section, these are summarised. Table 5.8 summarises the various barriers and gaps in implementing the policy scenario (2021-30) in Karnataka.

Power

In power sector, major barriers are regulatory uncertainties, lack of grid infrastructure in wind energy zones, and land availability issues. As discussed previously, KERC recently increased wheeling charges for open-access RE consumers, making RE investment less attractive. Lack of grid infrastructure is the major drawback of wind-based electricity generation.

In RTPV, the key barriers are a lack of attractive investment models and DISCOMs' potential financial losses due to captive RTPV-based generation. Procedural delays in accessing central subsidies has also slowed down RTPV installation. Moreover, an accurate state-level RTPV potential assessment has not been done yet.

T&D loss reduction is hampered by poor maintenance of distribution transformers and their ineffective energy audit. Data-entry errors in DISCOMs' energy-auditing process pose another hurdle.

Heat-rate improvement in state-owned plants is affected by domestic coal availability, higher prices of imported coal, and expenses involved in installing pollution-control technologies. Coal-availability challenges force plants to work in part-load conditions, resulting in a reduced GHR. Regarding the financial barrier to improving energy efficiency, KPCL has allocated INR 2,000 crore for installing flue gas desulphuriser to reduce SO_x emissions in its plants (Shreyas, 2020). LOA for implementation of FGD for RTPS and YTPS on 14-08-2020 with completion period of 33 months is already issued. For BRTS, FGD implementation is retendered as on September 2020[26].

Transport

The implementation of prioritised policies and programmes for climate-change mitigation requires allocation of state-specific targets for EV sales and quick augmentation of charging infrastructure in the state. Increase in charging infrastructure across the state will be a crucial factor in achieving the State EV Policy target of 100% EVs in private transport fleet by 2030. The shift to EVs from conventional vehicles in larger state-run public transport corporations entails conversion of bus depots to meet the EV charging-infrastructure standards. Creating charging infrastructure at vantage points such as parking lots and fuel stations could facilitate the adoption of EVs among intermediate public transport operators (such as taxis and auto rickshaws). However, lack of standardisation of charging stations (enabling faster and uniform charging times) could be a barrier to rolling out large-scale installations needed to achieve the EV target in the state. At the institutional level, poor financial health of state road transport corporations could be a major challenge to augmenting the bus fleet and purchasing EV buses.

Industries

The implementation of subsector-wise SEC reduction targets would require energy-efficient technologies that are specific to production processes. Most low-capacity manufacturing plants still operate on outdated technology. They require newer energy-efficient technologies that improve both energy efficiency and the overall production rate. The lack of state level policy mandating energy efficiency targets to the units not covered under PAT is a barrier towards uptake of EE measures in MSMEs. The absence of a comprehensive technical database—which documents the type of production processes followed, equipment utilised, and raw materials used (including fuel) in each manufacturing plant (large- and small-scale)—hinders the progress of emission-mitigation activities such as target

[26] Based on information from KPCL

setting and monitoring. The lack of adequate technical assistance for incorporating EE measures in such industries is another challenge.

The implementation of energy-efficient measures requires considerable investments. Most small-scale low-capacity industries are struggling to stay afloat in this highly competitive market. The lack of sufficient financial aid (low-interest schemes and incentives for implementing EE measures) in such industries hinders emission-mitigation efforts.

Meanwhile, refineries have limitations towards achieving major energy-efficiency improvements. Their operation is typically continuous, with restricted shutdown. Therefore, there is limited space and time for implementation. There are also budget limitations (TERI, 2016).

Forestry

Afforestation and agroforestry promotion for carbon sink creation in wastelands and fallow lands that would contribute towards Government of India's NDC forestry goal and target of creation of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover.

Agriculture

Farmers have no incentive to switch from inefficient electric pumps to energy-efficient and solar pumps. This is the main barrier to implementing the two levers in the agriculture sector. Even though the solar-pump schemes are already providing 90% capital costs as subsidies and loans, they are perceived to be prohibitively expensive (in comparison with electric pumps running on free electricity) (Shah, 2018). Another barrier often cited for solar pumps is that their repair requires skilled labour, which might be locally scarce (FAO, 2018).

5.5. Conclusion

States must be highly proactive in climate-change mitigation efforts and contribute to India's NDC commitments. From the perspective of mitigation actions, they need to align state-level policies with NDC targets on emission intensity of GDP, share of fossil-free installed capacity, and carbon sink. The major decarbonisation measures that can help achieve these targets are high implementation of renewable-energy projects, energy-efficiency measures in key demand sectors (such as industry, buildings, agriculture, and transport), and afforestation. Karnataka is on-track for most of the policies and targets provided by the national government and has implemented various state-level policies as well. Karnataka was ranked as 'achiever' in the State Energy Efficiency Index 2019 prepared by Alliance for an Energy Efficient Economy (AEEE) and BEE (AEEE & BEE, 2019). With increase in GSDP, GHG emissions in Karnataka are likely to increase in future. However, the state has a huge potential for reducing its emission intensity of energy (tCO_2/TJ), which indirectly curtails the growth in overall emissions. Figure 5.5 and Figure 5.6 show the GHG-mitigation potential in 2030 with respect to Base and BAU scenarios (for energy sectors). The policy interventions could reduce the emissions by 69 $MtCO_2$ from Base and 29 $MtCO_2$ from BAU scenarios in

2030. The contribution of demand sector emission reductions are higher in the Policy scenario as compared to Base scenario.

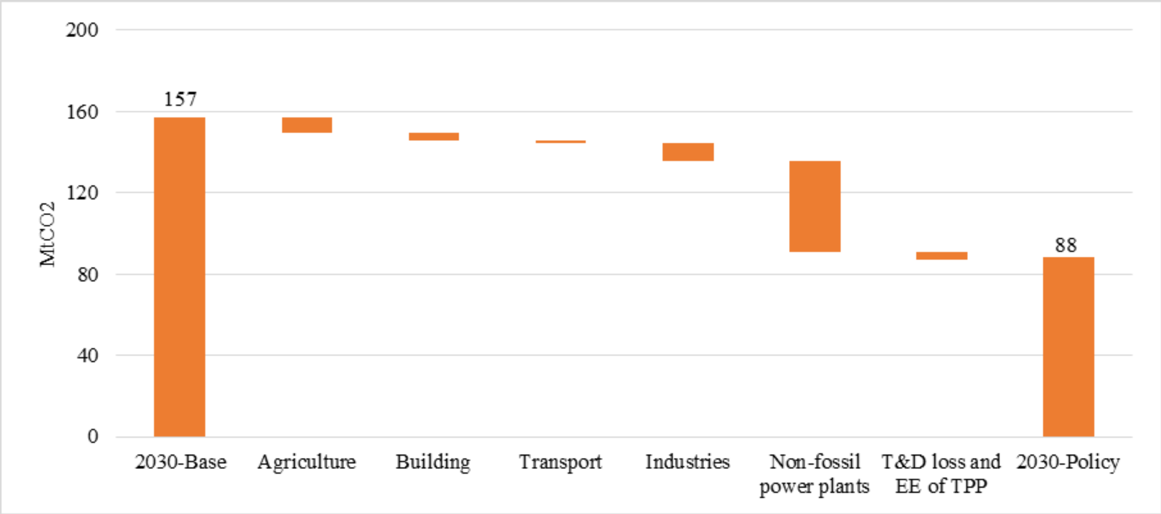


Figure 5.5: Energy-based GHG emission reductions w.r.t Base scenario[27]

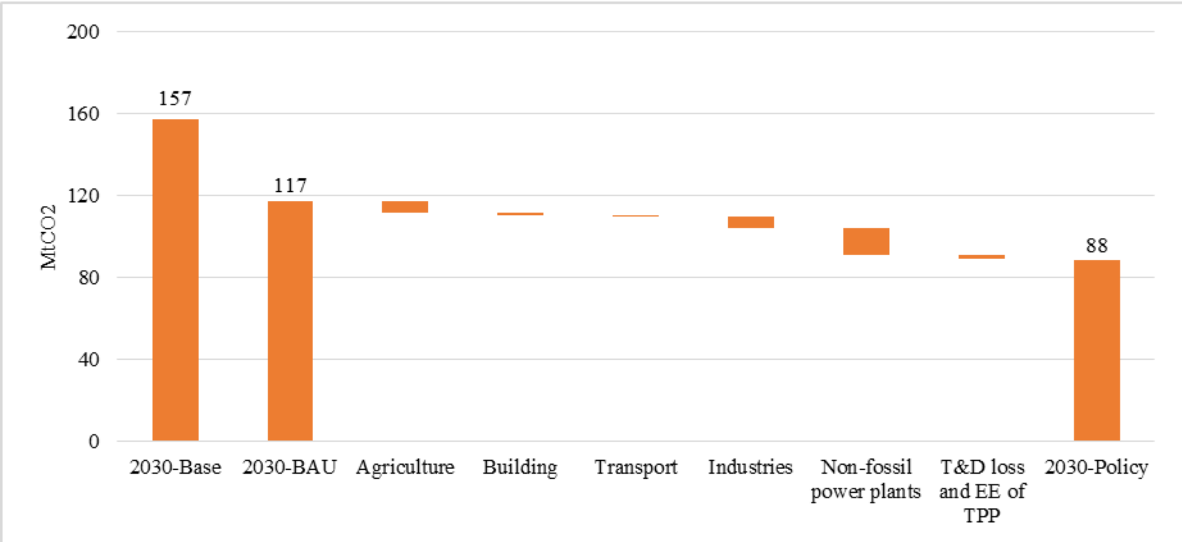


Figure 5.6: Energy-based GHG emissions w.r.t BAU scenario

[27] The total emissions for 2030-Base, 2030-BAU, and 2030-Policy do not include the emissions from cooking and tractors.

A few mitigation actions that the state could prioritise are:

- Higher uptake of renewables: With a high potential of renewables within the state, Karnataka could install an additional 5 GW of wind and 13.8 GW of solar-power based projects (including RTPV) by 2030.
- Boost energy-efficiency programmes in all demand sectors (agriculture, industries, buildings) within the state
- Ensure that solar pumps comprise at least one-third of all irrigation pumps
- Adopt efficient lighting: The state should continue distributing subsidised LED bulbs, so that at least 75% of the residential lighting points are LED-based.
- Mandate and include ECBC in residential building by-laws
- Improve the state’s charging infrastructure for higher uptake of electric vehicles
- Creation of carbon sinks in wastelands and fallow lands.

The highest mitigation potential in the energy sector is from RE installations, followed by energy-efficiency improvements in industries and agriculture. Energy-efficient pumps, solar-powered agricultural feeders, and solar pumps offer a huge reduction in energy consumption and subsidy (for free electricity to irrigation pumps ≤ 10 HP). Similarly, there is a good opportunity for GHG mitigation by reducing SEC in key industries like cement, and iron and steel. Forestry provides an opportunity for creating carbon sinks, along with multiple co-benefits in the short- and long-term.

Table 5.8: Barriers and gaps to implementation of mitigation actions

Sector	Prioritised mitigation activities	Barriers		
		Financial	**Technological**	**Institutional**
Power	Increase solar ground-mounted and wind-based electricity generation	• Inadequate financial mechanisms to support repowering of old wind projects	• Lack of grid infrastructure for power evacuation from RE project sites • Land-availability issues • Import dependence for PV module • State has very old wind-power projects operating at low CUF	• Regulatory uncertainties • Changed wheeling and transmission charges for existing projects
	Promote RTPV electricity generation	• High capital cost • Only central subsidy is available • Adverse effect on DISCOMs' financial health	• Lack of data on city-level RTPV potential (except in Bengaluru)	• Lack of innovative models to attract investments • Feed-in-tariff is lower than the energy charge of DISCOMs • Lack of adequate information for consumers to make investment decisions • Procedural delays in getting central subsidy
	Improve T&D infrastructure	• Financial stress on DISCOMs • High capital-investment requirement for T&D loss reduction	• Poor maintenance of distribution transformers • Lack of energy auditing of distribution transformer centres • Grid-stability issues are anticipated at higher RE projected installed capacity.	• Data-entry errors in the energy-auditing process followed by DISCOMs
Transport	• Electrify public and private vehicle fleet • Improve public transport share in Bengaluru and rest of Karnataka	• Large capital investment requirements • Poor financial health of State road transport corporations	• Fewer models to choose from • Inadequate charging infrastructure, leading to range anxiety • Unavailability of baseline transport statistics at the city and state levels	• Lack of integrated land-use and transportation planning in larger and upcoming cities • Little focus on enhancing public-transport infrastructure
Industries	• Improve energy efficiency across industries, including those not covered under the PAT scheme • Monitor implementation of EE measures in MSMEs	• High upfront cost of energy- efficient technologies • Partial or inadequate coverage of financial-incentive schemes to deploy EE technologies	• Lack of adequate data providing the status of production and energy use in large-scale industries as well as MSMEs	• Lack of state-level policies-mandating energy-efficiency norms for large industries and MSMEs • Lower coverage of PAT in upcoming cycles
Agriculture	• Implement solar and EE pumps, and solar-powered dedicated feeder connected to EE pumps	• High capital costs for solar pumps	• Unmetered connections, and rewinding of old pumps operating beyond their design lifetimes	• Lack of monitoring mechanisms for existing schemes to ensure EE-pump installation • Land acquisition for solar PV panels for powering dedicated feeders

Chapter 6: Adaptation

It is evident from climate modeling studies presented in Chapter 3 that there will be increase in both temperature and rainfall during the projected period of 2021 to 2050 or the 2030s. Also, climate impact modeling using dynamic models show that there will be adverse impacts on water resources - both groundwater and surface water, agriculture, forest ecosystems and health (Chapter 4). In addition, socio-economic systems across the districts of Karnataka are vulnerable because of multiple factors as presented in Chapter 4. This calls for targeted strategies for building resilience of systems—both natural and socio-economic through formulation of adaptation actions.

Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.

In this Chapter, adaptation strategies for agriculture, animal husbandry, forest, health, and water resources are presented.

6.1. Existing Adaptation Policies and Programmes - A Stocktake

There are several centrally sponsored schemes for promoting adaptation in the agriculture sector. Some such major schemes are that are centrally sponsored and state implemented are presented below:

6.1.1. Agriculture Centrally Sponsored Schemes

1) National Food Security Mission (NFSM): NFSM-Coarse Cereals has been divided into two parts and is aimed at (i) encouraging cultivation of coarse cereals covering Maize and Barley and ii) promotion of nutri-cereals, which include Jowar, Bajra, Ragi and other small millets (Kodo, Barnyard, Proso, Foxtail and Little Millet).

2) Direct Benefit Transfer (DBT) to farmers for adoption of improved technologies*:* For the first time, the incentives are being directly transferred to the farmer's account for adoption of improved technologies especially in paddy, pulses and oil seeds' cultivation, with an aim to increase production and reduce the cost of cultivation. Here, incentives are also provided to technology promoters.

3) Research and management for saline water in bio-saline agriculture: Bio-saline agriculture involves management of water salinity and promoting research on "halophyte cultivation" for soil reclamation.

4) Millet package: Millets cultivation is necessary to achieve nutrition security, healthy diet and to cope with droughts for protecting vulnerable farmers. With this aim, a policy to promote millets has been introduced.

5) Crop insurance (Pradhan Mantri Fasal Bima Yojana): Karnataka Raitha Suraksha Pradhan Mantri Fasal Bima Yojana is being implemented from 2016-17 to help farmers buffer crop loss due to floods, drought, unseasonal rains and other natural calamities. This amount is utilized for paying state share of premium subsidy to insurance companies.

6) Rashtriya Krishi Vikas Yojane: Under this Scheme, funds have been provided for incentivising high yielding variety of crops and providing certified seeds to farmers, agriculture mechanization, enhancement of soil health, watershed activities, strengthening of market infrastructure, infrastructure to promote extension service, support to organic and bio fertilizers, research activities by State Agricultural Universities, agro processing, strengthening of laboratories for quality control activities, production of quality planting material of horticulture crops, comprehensive piggery and poultry development, augmenting animal vaccine production, installation of rain gauge stations etc. Many of these activities contribute to adaptation directly or indirectly.

9) National e-Governance Plan-Agriculture: This is a centrally sponsored scheme-Mission Mode Project on Agriculture. This project aims at offering agricultural services in an integrated manner through the Central Agriculture Portal (CAP) and State Agriculture Portals by providing services such as information on pesticides, fertilizers and seeds, providing information on soil health, information on crops, farm machinery, training and good agriculture practices.

6.1.2. Agriculture - State Government Schemes

1) Krishi Bhagya: Krishi Bhagya scheme is being implemented in Karnataka since 2014-15 covering 132 taluks of 25 districts in the state. It mainly focuses on dry land areas of the state with an average rainfall less than 850 mm from the past 25 years. The main aim of this scheme is to improve rainfed agriculture with efficient management of rain water, and enhancing farm productivity. The thrust is on water conservation and promoting dry land horticulture. The components of the scheme are farm ponds, polythene lining/alternate lining models, diesel pumpsets, micro-irrigation (drip/sprinkler), net around the farm ponds. In addition to all these components, dry land farming method recharge of bore well is provided to special package taluks. The scheme is being implemented in both coastal and mainland regions.

2) Weather forecast & crop advisories at gram panchayat level: In collaboration with Karnataka State Natural Disaster Management Centre (KSNMDC), it is proposed to reach weather forecast and agriculture related information and advisories to 12 lakh farmers in 747 “Raitha Samparka Kendras”.

3) Soil Health Mission: The key objective of this programme is to issue soil health cards once every 2 years to farmers to address nutrient deficiencies in fertilization practices.

4) Farm mechanization & agro processing: To enable farmers to carry out agricultural activities at the right time and to reduce dependence on agricultural labour, farm machineries are distributed under farm mechanization scheme at subsidised rates.

5) Comprehensive management of pest and providing guidance to farmers using electronic medium: The Department of Agriculture intends to adopt e-technology for pest and disease control management, and issue of advisories. Under this programme, it is envisaged to cover over 12 lakhs farmers every year by providing timely plant protection advisory.

6) Organic farming: Department of Agriculture has established organic village site programmes of 100-hectare blocks in all taluks of the State with the main objective of promoting it as an eco-friendly sustainable method of farming that optimises use of natural resources.

7) Chief Minister's Sookshma Neeravari Yojanae National Mission on Sustainable Agriculture (NMSA): This is a centrally sponsored mission on micro irrigation to facilitate all categories of farmers especially small and marginal farmers to install micro irrigation units at lowest price in order to increase water use efficiency and thereby increase production and productivity. In order to emphasise judicious and efficient use of water, sprinkler and drip irrigation units are distributed at 90% subsidy for 2.0 ha and 50% subsidy for up to 5 ha, covering an area of about 2.4 lakh ha.

8) National Mission on Sustainable Agriculture (NMSA): There are two sub-schemes implemented under this and they include:

a) *Rainfed Area Development*: Aims at promoting integrated farming system with emphasis on multi-cropping, rotational cropping, inter-cropping, mixed-cropping practices with allied activities like horticulture, livestock, fishery, agro-forestry, apiculture etc. to enable farmers not only in maximizing the farm returns for sustaining livelihood, but also to mitigate the impacts of drought, flood or other extreme weather events.

b) *Paramparagat Krishi Vikas Yojana (PKVY*): Revised Guidelines for PKVY have been issued by the Government of India. PKVY is a sub-component of Soil Health Management scheme under NMSA, aimed at ensuring long term soil fertility build up, resource conservation and production of safe and healthy food without use of agro-chemicals. It also aims to empower farmers through cluster approach, input production, quality assurance, value addition and direct marketing through innovative means.

9) Bhoo Samruddhi: Bhoo samruddhi scheme is in implementation with an objective to increase crop yields by 20% and farmers income by 25% in pilot areas. One district in each Revenue Division has been selected on pilot basis (Bidar, Chikkaballapur, Dharwad & Udupi districts). Under this the Krishi Abhiyana programme aims to create awareness among the farming community on diversified farming activities and extension initiatives by organizing local exhibitions about new technologies in agriculture and allied fields at the Hobli level.

10) Agri start-ups: Various start-ups have been supported to promote the emergence of new innovation start-ups by looking at the current population growth, with the availability of resources for every acre of land and every drop of water to achieve the objective of food security.

11) Development of vacuum technology for storage of seeds and agriculture produce: Dharwad Agriculture University has developed vacuum technology for long term storage of chilly, onion, cotton, soybean, groundnut and paddy.

6.1.3. Forestry Policies

The forest policies formulated so far in India have been broadly aimed at conservation, reduction of pressure on forests and provisioning of biomass to forest dependent population for their fuel and fodder needs, apart from generating revenue through production and sale of timber. The policies have evolved over the decades and the shift in focus from production forestry to protection forestry and currently participatory forestry is evident. Table 6.1. presents some such policies and its implication for adaptation.

Table 6.1: Forest policies, their features and implications for climate change adaptation

Forest Policies	Implications for Adaptation
Indian Forest Act, 1927 Forest Conservation Act 1980	➢ This Act aimed at reducing deforestation and enhancing forest cover will potentially lead to improved biodiversity conservation. This has implications for adaptation as biodiverse intact natural forests are less vulnerable to climate change impacts as compared to monocultures.
Forest Policy of 1894 National Forest Policy of 1952 National Forest Policy 1988	➢ These policies have no direct climate change context. However, with the policies grounded in maintenance of the ecological balance approach, they would promote conservation of biodiversity, which will make the forests resilient to climate change. Further, local stakeholders' involvement in the management of local forest resources, strengthens the coping capacities (adapt) of communities in the context of climate uncertainties.
Joint Forest Management 1990	➢ This guideline that led to the formulation of the large scale JFM programme pan India potentially has positive adaptation implications for the forest ecosystems as well as communities. o ***Ecosystem:*** Reduced pressure on natural forests thereby keeping the biodiversity intact that is better adapted to climate change. o ***Community:*** Diversified livelihood opportunities are important as the vulnerability of communities that depend on a single or few forest products is expected to be higher than communities that have access to a wide range of products, many of which respond differently to climate change. ➢ Risk of raising of monoculture plantations
Wildlife Protection Act (WCS) 1972 National Wildlife Action Plan	➢ Recommends strict conservation zones free of all habitations and modern-day facilities, tourism, etc., critical for avoiding habitat fragmentation and degradation. Has the potential to promote adaptation.
National Biodiversity Act 2002	➢ Promotes conservation of biodiversity and biodiverse natural forests are better adapted to climate change and resilient to attack by pests and fire.
Forest Rights Act 2006	➢ Recognizes the rights of forest dependent communities and provides opportunity for utilization of local knowledge for forest management and adaptation. ➢ This Act legalizes human activity inside forests which may have negative impacts on regeneration due to increase disturbance through grazing, land use change, etc. This potentially can increase the vulnerability of forests to climate change.
Social Forestry (post-1980)	➢ Predominated by monocultures in the past, therein making single species stands or plantations vulnerable to pest attack and fire, one of the larger impacts of a changing climate.

6.1.4. Forestry Programmes

Table 6.2 presents some of the forestry programmes implemented in the state and discusses the key features of these programmes and its implications for climate change mitigation and adaptation. As can be seen from Table 6.2, all the programmes contribute to conservation and at the same time lead to building of resilience in the communities dependent on them or the forest ecosystem itself by conserving biodiversity which is one of the key factors determining the resilience of forest ecosystems.

Table 6.2: Forestry programmes, features and implications for climate change adaptation

<table>
<tr><th>Programmes</th><th>Features</th><th>Implications for Adaptation</th></tr>
<tr><td>Greening India Mission</td><td>➢ Enhancing carbon sinks in sustainably managed forests and other ecosystems
➢ Enhancing resilience of vulnerable species/ecosystems to changing climate
➢ Enabling adaptation of forest-dependent communities to climatic variability</td><td>➢ Promotes ecosystem as well as community resilience through targeted activities for promoting adaptation through regeneration, restoration, tree cover enhancement that help connect forest fragments and also promotes livelihood diversification activities, which reduces the vulnerability of forest dependent communities.
➢ Promotion of exotic species and monoculture plantations may enhance the vulnerability.</td></tr>
<tr><td>National Forest Action Plan 1999</td><td>➢ Protect existing forest resources
➢ Improve forest productivity
➢ Reduce total demand for biomass
➢ Strengthen the policy and institutional framework Expand the forest area</td><td rowspan="2">➢ Conservation and protection of forest resources, thereby biodiversity which has positive implications for climate change adaptation
➢ Improved participation of communities in management of forests, thereby providing an opportunity for utilizing strategic indigenous knowledge on adaptation.
➢ Inappropriate choice of species such as exotics/invasive species may increase vulnerability.</td></tr>
<tr><td>National Afforestation Programme</td><td>➢ Develop forest resources with people's participation, with focus on improvement in livelihoods of forest-fringe communities
➢ Aims to accelerate the on-going process of devolving forest protection, management and development functions to decentralized institutions</td></tr>
<tr><td>Protected Areas</td><td>➢ The NFP has advocated maintaining genetic continuity among the Protected Areas. The Wildlife Protection Act has included two categories of PAs, namely conservation and community reserves in its 2002 amendment.</td><td>➢ Protected Areas are key to buffering unpredictable impacts of impending climate change as they help retain intact patches of forest, avoiding fragmentation which is an adaptation strategy.</td></tr>
<tr><td>Compensatory Afforestation</td><td>➢ In case of diversion of forest land to non-forest purposes – the user will identify land and develop forest and transfer it to forest dept. or pay the cost of afforestation (2 ha of afforestation for every ha of forest converted)</td><td>➢ Conservation, protection and improved regeneration would potentially reduce vulnerability
➢ Risk of monocultures being raised that could be prone to fire and pest attacks.</td></tr>
</table>

It is evident from Table 6.2 that many of the ongoing forestry programmes currently have positive implications for adaptation and proposed Greening India Mission is targeted towards promoting adaptation. Specifically, programmes such as the Protected Area Management and the Joint Forest Management Programme have potential to contribute positively to sink creation and conservation as a mitigation option and also to improving the resilience of forest ecosystems, and the communities dependent on them. Agro-forestry, tree conservation programme and soil moisture conservation works carried out in addition to rehabilitation of degraded forests are activities clearly identified by the Greening India Mission under the National Action Plan for Climate Change and could contribute positively to adaptation. The important factor to be taken into consideration in the afforestation programmes is promotion of native and mixed species forestry, so as to ensure they contribute to adaptation.

6.1.5. Water Sector Policy and Programmes

Micro irrigation comes to the aid of water scarce regions facing hydrological constraints, particularly within resource poor farming communities that are dependent on rain-fed agriculture. Karnataka initiated the micro irrigation schemes in 1991 in horticultural crops and for agricultural crops from 2003-04. A centrally sponsored scheme initiated in 2005-06 that granted a subsidy of 50% in the ratio of 80:20 shared by the Centre and State governments led to micro irrigation gaining momentum; in 2010, the scheme was scaled up and renamed as the National Mission on Micro Irrigation (NMMI). The funds allocated under the Mission have increased from Rs.143.7 crore in 2009-10 to Rs.150 crore in 2012-13. According to Palanisami et al. (2011), Karnataka has the potential to operate 7.45 lakh ha under drip irrigation, but only 23.8% is currently utilized under this water management strategy. Figure 6.1 shows the linkage between micro irrigation (MI) adoption, vulnerable areas and the potential of Karnataka in addressing them.

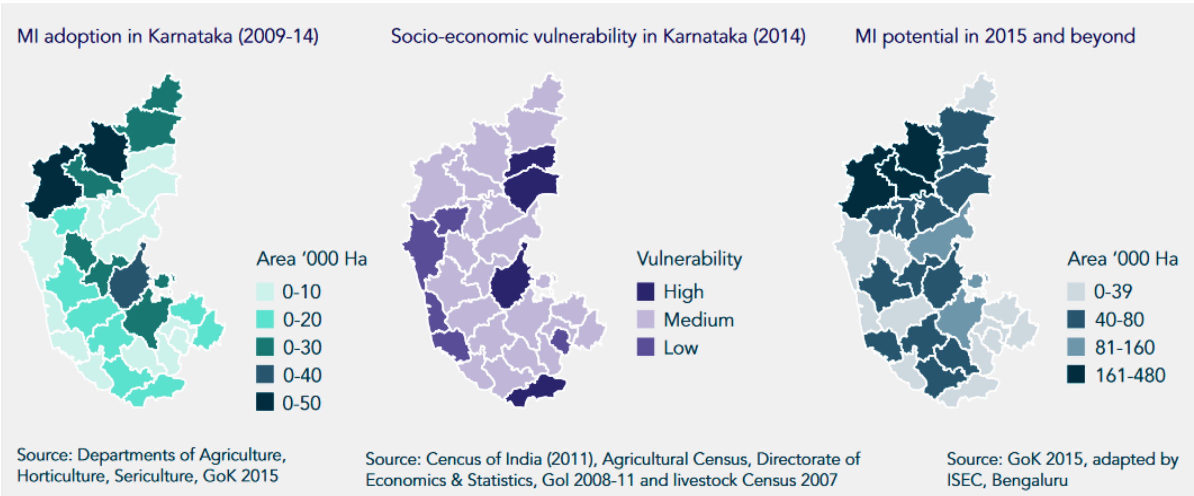


Figure 6.1: Micro irrigation in Karnataka *(Source: Global Green Growth Institute, 2015)*

Area covered under micro irrigation (Drip and Sprinkler) in Karnataka is presented in Table 6.3. Table 6.4 describes the fund flow and schemes in Karnataka.

Table 6.3: Area Covered under micro irrigation in Karnataka (in ha) (As on 31.03.2018)

State	Drip	Sprinkler	Total
Karnataka	581340	705300	1286640
India	4779604	5474803	10254407

Table 6.4: Summary of micro irrigation in Karnataka

Departments Involved	Agriculture	Horticulture (NMMI)	Horticulture (Oil Palm)	Sericulture
Type of MI	Mainly Sprinkler and drip	Mainly Drip	Drip	Drip
Crops	Cereals, pulses, oilseeds, cotton and sugarcane	All Horticultural crops	Oil palm	Mulberry
Schemes	NMMI SCP/TSP	NMMI SCP/TSP	ISOPOM, RKVY SCP/TSP	Catalytic Development Programme *Reshme Varadaan* SCP/TSP
Operated under	State and District sector	State sector	State sector	State sector
Fund flow				
GOI to State (GOI Share)	RTGS to Bank account	RTGS to Bank account	To State Treasury	To State Treasury
GOI Share to Districts	State to Districts through banks	State to Districts through Banks	State to Districts through Treasury	State to Districts through Treasury
GOK Share	Through Treasury (District sector + state sector)	Through Treasury (District Sector)	Through Treasury	Through Treasury along with GOI share
Treatment of year-end balance	GOK share lapses at the end of the year GOI funds in bank account available for next year	GOK funds are drawn on GIA bill and added to GOI share in Bank accounts Both GOI and GOK funds remain in various bank accounts and available for next year	GOK share lapses at the end of the year GOI funds needs revalidation	GOK share lapses at the end of the year GOI funds needs revalidation for next year

Implementation of adaptation strategies for groundwater in Karnataka

1) Ramthal Project: One of the largest drip irrigation projects in the world is located in Hundgund Taluk, Bagalkote District, Karnataka. This community drip irrigation project, apart from addressing socio-agronomical aspects, providing capacity building and agronomic support in the region also seeks to link farmers with markets under the Drip-to-Market Agro Corrdior (DMAC) as shown in Figure 6.2. In terms of physical scale of infrastructure, a total of 2,150 km length of pipeline was laid for this drip irrigation project which was executed by Megha Engineering and Infrastructures Limited (MEIL). Every farmer in this DMI system received water through a cylinder installed in their respective farmlands. This system enables them to mix fertilizers and pesticides in the cylinder and eliminated water wastage.

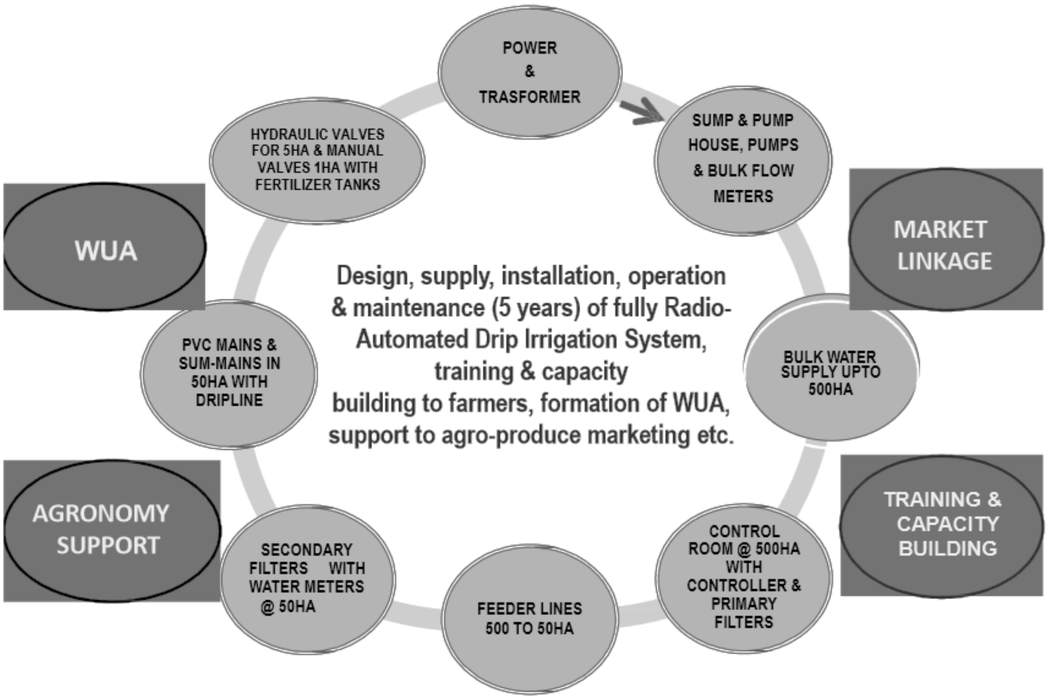


Figure 6.2: Ramthal Project

2) Shiggaon lift irrigation scheme: It is a state commissioned sprinkler irrigation system in Savanur Taluk where 1.5 tmcft of water is diverted from a diversion weir constructed across the Varada, a tributary of the Tungabhadra River to irrigate 9,900 ha of land. Under the project, 1.36 tmcft of water is utilised for irrigation and 0.14 tmcft for pumping water to five minor irrigation tanks. The total cost of the project was estimated at Rs.238 crore and is expected to benefit drought affected areas covering 30 villages in Shiggaon, Savanur and Hanagal Taluks of Haveri District. The modus operandi entails that the total irrigated area be divided into 119 blocks of approximately 80-85 ha. With each block being provided a portable overhead sprinkler irrigation system connected to a sump.

3) Tank irrigation: Tank irrigation increases water storage, which is a key climate change adaptation strategy. Towards this end, Palanisami et al (2010) makes a case for irrigation tanks and illustrates the potential of this adaptation response with options for improvement. They include using tanks for multiple purposes apart from irrigation such as fishery, social forestry, silt, brick making, etc., conversion into percolation ponds, canal lining and sluice management for recharge, tank modernisation and groundwater supplementation. A land-based model developed for ascertaining the future investment needs indicated that system tanks will have more opportunities for improvement compared to non-system tanks as marginal returns to investment will be higher in former tank irrigation.

4) Crop diversification: A High-Level Committee on restructuring of the Food Corporation of India in 2014 found that although the Minimum Support Prices (MSPs) were announced for 23 crops, the effective price support was essentially for wheat and rice. This resulted in a highly skewed incentive structure that favoured the cultivation of water intensive crops viz. wheat and paddy, which depend heavily on ground water for their growth. Anitha et al (2016) computed that paddy required 5000 liters of water, while the cost of irrigating non-rice crops such as millets or groundnut was only a quarter of the latter crop. Therefore, the researchers concluded that millets are climate smart crops that used minimal water and could be harvested within a short duration of 70-90 days. The Karnataka State Water Policy 2019 in its report highlights the need to encourage a shift away from water-intensive paddy and sugarcane cultivation towards millets and pulses by providing minimum support prices and procurement policies for the latter.

5) Water harvesting: Rainwater harvesting is an effective water technology for climate change adaptation. Literature shows that adaptation to fluctuating climate with rainwater harvesting existed throughout history in ancient texts such as the *Rigveda*, *Atharva veda,* Kautilya's *Arthasastra*, Varahamihira's *Brihatsamhita* as well as Kalhana's *Rahatarangini* (Pandey et al, 2003). Over time, its decentralized attributes have extensively helped owners benefit from the direct management of demand and supply. These cost effective technologies; both traditional and modern, adopt simple processes and therefore the cost of infrastructure, including the pumps and energy inputs are minimal. In the process, they also contribute to the reduction of greenhouse gas emissions. Therefore, enabling policies for rainwater harvesting uptake and implementation are a first step for increased adoption as well as towards mitigating the impact of climate change.

6) Watershed development: The integrated watershed development program is one of the major programs executed by the Indian Government in all the States for roughly over a decade to mitigate the impacts of climate change in agriculture. Karnataka Watershed Development Department is the forerunner in operationalising the integrated watershed management program and SUJALA watershed management programs. The approach of these programs has been to holistically restore ecological balance by harnessing, conserving and developing degraded natural resources such as soil, vegetative cover and water. These objectives are in pursuance of outcomes for reduction of soil and nutrient loss, potential run-off, improvement in water management, regeneration of natural vegetation and ground water recharge. These interventions resulted in 18,500m^3 of net water storage capacity, 45000m^3 gross water conserved as a result of refilling during the monsoons, apart from other benefits of productivity enhancements, new livelihood and market links.

7) Local management/governance of groundwater: Groundwater governance is indicated to help address local externalities that balance the benefits and costs of reducing common pool losses. This conclusion is based on a study that examines 10 basins located on six continents that vary in terms of intensity and type of water demand, hydrogeological properties, climate, and social and institutional characteristics. They found that in basins that faced a drawdown the high cost of coordinating large-scale governance institutions caused a de facto state of open access resource use. However, in some cases, the local nature of externality problems allowed for effective local management actions (Edwards & Guilfoos, 2020).

8) Policy and regulatory measures: The Centre launched a unified Ministry of Jal Shakti in May 2019 as response to the critically escalating water crisis in India. Subsequently, the *Jal Shakti Abhiyan* (JSA) was initiated as a campaign on intensive water conservation built on citizen participation to accelerate water conservation. In the short term, the campaign focuses on integrated demand and supply-side management of water at the local level, including creation of local infrastructure for source sustainability using rainwater harvesting and groundwater recharge among others. While, in the long term, the government launched the Jal Jeevan Mission (JJM) that aims at ensuring piped water supply to all rural households by 2024. This program was implemented in 1592 blocks of India's 256 water stressed districts identified by the Central Ground Water Board in 2017.

6.2. Proposed Strategies for Adaptation

6.2.1. Agriculture Adaptation Strategies

Changes in the magnitude of precipitation and distribution pattern, increase in temperature, radiation, altered wind speed and increased potential evapotranspiration cause changes in the available water to agricultural crops, and also impacts crop water requirement for completion of crop life cycle. Hence, the productivity of the crops exposed to such weather changes have the tendency to respond differently as the changes are not even at all the growing stages. Adaptation can help buffer the damage to crops. Here some strategies for promoting adaptation in agriculture sector in Karnataka are presented.

1) Weather-based cropping pattern: Based on the amount of rainwater available, soil properties, evapotranspiration and growing period, suitable crops have to be identified for each district, taking into consideration climate change projections. Rice and sugarcane crops need to be replaced with maize and millets in a phased manner in Mandya, Belagavi, Ballari and Raichur districts. Rice and Sugarcane require large quantities of water and adequate amount of water is not available in these districts, even today and the situation is likely to worsen under a climate change scenario. Agricultural adaptation involves changes in cropping pattern across different districts and meteorological regions. Some recommendations are presented in Table 6.5.

Table 6.5: Crops recommended in different meteorological zones under climate change scenario

	Cropped area to be reduced	**Cropped area to be increased**
South Interior Karnataka	Rice and Groundnut	All crops except Rice and groundnut
North Interior Karnataka	Wheat and Groundnut	All crops except wheat and Groundnut
Hilly	Chikpea, Maize, Rice, Sorghum and Redgram	Cotton, Soybean, Ragi and Sugarcane
Coastal	Rice and Ragi	All crops except Rice and Ragi

2) Strengthening the agromet advisory services in the State: Agromet advisory provides information about previous weather, available soil moisture, crop status, future weather forecast, requirement of the crop for normal growth and agricultural operations to be taken up by farmers including integrated pest management to protect normal crop growth in a given soil. Weather-based Agromet Advisory Services (AAS) need to be provided to enhance adaptation of farmers to changing climatic conditions. Efforts at broader scale viz., Sate Level, District level can help in reducing the vulnerability to some extent but reaching the grass root level i.e., each village and each farmer is more effective in overall reduction of climate change effect. At present AAS are being issued up to only the taluk level through Gramin Krishi Mausam Seva (GKMS) and District Agro met Units (DAMU) of IMD in association with Agricultural Universities, besides KSNDMC.

3) Flood adaptation strategies (Long Range): North-west Karnataka districts are experiencing floods due to excess rainwater released from Maharashtra and also experience heavy rainfall once every 4 to 5 years. This is projected to worsen under climate change even in the short-term. Efforts need to focus on diverting excess flood water and reducing the quantity and force of water over the system. Provision of a large number of drainage/irrigational canals on either side of the rivers and community tanks along with canals can help in reducing the impact.

4) Organic farming: Organic grain production requires energy consumption of only 6% as compared to 46% for conventional production. Organic farming reduces the need for external inputs such as chemical pesticides, herbicides and fertilizers. Organic agriculture includes biodiversity, irrigation, plant nutrition and natural pest management. This builds soil fertility In the long run, and therefore builds resilience of the agriculture system.

5) Soil health: Soil's capacity to provide services depends on its quality (physical, chemical, biological) as moderated by the total and reactive carbon pools. Most agricultural soils contain lower organic carbon (pool). The decline in soil organic carbon is enhanced by soil erosion and other degradation process and is reflected in poor soil quality. Perpetual use of extractive farming practices and mining of soil fertility also depletes soil organic carbon. Conversion to restorative land use and adoption of recommended management practices creates positive C and nutrient (N, P, K, S) budgets which can enhance SOC pool while restoring soil quality. Adoption of RMP's by the resource-poor farmers can be promoted by paying soil carbon credits, green water credits and biodiversity credits. Low carbon farming practices would help cut down carbon emissions (mitigation). Often tank silt application improves soil organic carbon, water holding capacity and soil nutrients. Soil health card helps in maintaining soil health besides reclamation. Site Specific Nutrient Management and fertilizer recommendation based on Soil Test Crop Response will go a long way in reducing indiscriminate use of fertilizers.

Implementation plan: In order to achieve the goal of adaptation, the following implantation plan could be adopted for agriculture

1) Strengthening Agromet Advisory Services: Advance (3-5 days) information on likelihood of weather leads to proper management of resources for agricultural operations to minimize risk and facilitate growth and realize optimum crop yield. The farmers who have adopted the Agromet Advisories in their day to day operation have realized an average additional benefit of 31.45%, 24.65%, 16.20% and 20.56% in Finger millet, Red gram, Field bean and Tomato crops respectively. This clearly indicates that Agromet Advisories can enhance the productivity of the crops. Hence this has to be expanded.

2) Weather based cropping pattern: Different districts have different soil and weather parameters. Based on the amount of rainwater available, soil properties, evapotranspiration and comfortable growing period, suitable crops need to be identified for each district based on the anticipated climate change. Area under each crop, sowing window, growing and harvesting period could be identified for effective utilization of rain water and high economic returns to the farming community.

3) Rainwater management in rainfed areas: Various soil and water conservation measures relevant for rainfed agriculture include short and long term measures. Following rainwater management strategies have good scope for adaptation in regions receiving more than 700 mm rainfall.

Short term measures

- *In-situ* measures for rainwater management in rainfall areas.
- Off season tillage like fall and summer ploughing
- *Conservation furrows*
- *Ridges and furrows system in long duration widely spaced crops*
- *Cover cropping*
- *Micro catchments for tree systems*
- *In situ and ex situ green manuring.*
- Medium term measures rain water management in rainfed areas.
- Stone and vegetative field bunds along the contour for soil and water conservation, Trench cum bunding for soil and water conservation

Long term measures

- Water harvesting through farm ponds, check dams and nalabunds
- Contour trenching for runoff collection
- Seepage ponds in hilly areas
- Ground water recharge structure (percolation tanks).
- Recharge through defunct wells.

6.2.2. Animal Husbandry Adaptation Strategies

Decline in feed consumption, reduced milk production, severe alterations in milk quality and reproductive ability are the primary outcomes of heat stress and climate change in livestock. Heat stress is also reported to cause severe drop in meat quality and quantity. Alterations in the meat pH, water holding capacity of the meat, flavour, carcass weight and hot carcass yield in animals due to environmental stress affect the meat storage and marketing, thereby leading to production losses. Livestock production thereby needing a multidisciplinary approach towards its amelioration and adaptation.

Reducing environmental stress on livestock requires a multidisciplinary approach with emphasis on animal nutrition, housing and animal health. Figure 6.3 describes the various amelioration strategies available to counter the heat stress challenges in livestock. Some of the biotechnological options may also be used to reduce thermal stress. It is important to understand the livestock responses to environmental stress in order to design modifications for nutritional and environmental management, thereby improving animal comfort and performance. A range of technologies are needed to match the different economic and social needs of smallholder farmers.

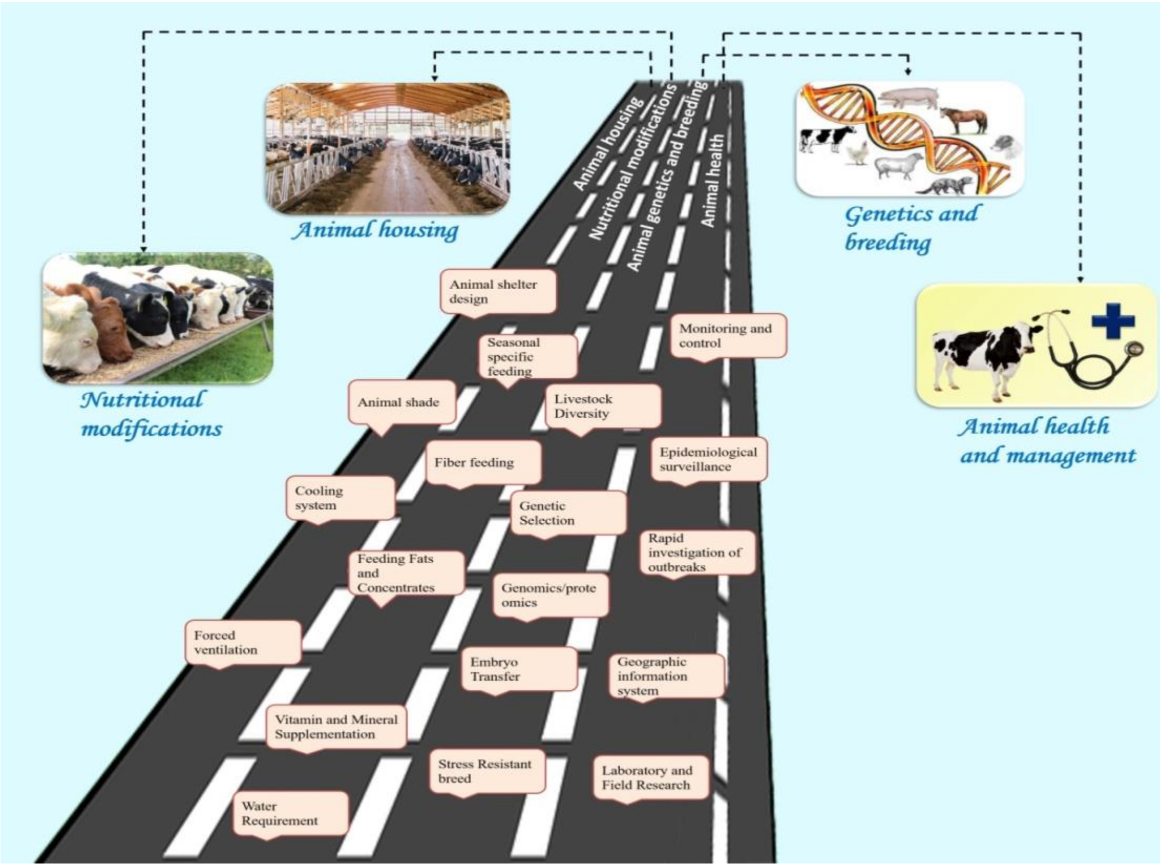


Figure 6.3: Adaptation strategies to sustain livestock production under climate change

The amelioration strategies can be broadly grouped into four categories: housing management, nutritional modifications, genetics and breeding, and health management, as mentioned in Table 6.6.

Table 6.6: Livestock adaptation strategies under ensuing climate change scenario

Parameters for livestock adaptation	**Respective livestock adaptation strategies**
Production adjustments	Change in quantity and timing of precipitation
Breeding strategies	i) Identifying and strengthening local breeds that

	have adapted to local climatic stress and feed sources ii) Improving local genetics through cross-breeding with heat and disease-tolerant breeds
Market responses	i) For example, promotion of interregional trade and credit schemes
Institutional and policy changes	i) Removing or introducing subsidies, insurance systems ii) Income diversification practices iii) Livestock early warning systems
Science and technology development	i) Understanding of the impacts of climate change on livestock ii) Developing new breeds and genetic types iii) Improving animal health iv) Enhancing soil and water manage
Capacity building for livestock keepers	i) Understanding and awareness of climate change ii) Training in agro-ecological technologies and practices
Livestock management systems	i) Provision of shade and water to reduce heat stress from increased temperature ii) Reduction of livestock numbers in some cases iii) Changes in livestock/herd composition iv) Improved management of water resources

1) Genetic development of less sensitive breeds: Genetic selection has been a traditional method to reduce effects of environment on livestock by development of animals that are genetically adapted to hot climates. There is a need to take up breeding programmes to develop climate resilient breed using available rich germplasm rather than solely focusing on production traits. Integration of marker-assisted selection into animal breeding systems should make selection for traits conferring thermo-tolerance more rapid. The recent advancement in global expression technologies (whole genome arrays, RNA sequencing) is poised to be effectively utilized to identify those genes that are involved in key regulatory/metabolic pathway for thermal resistance and thermal sensitivity. Gene knockout technology will also allow better delineation of cellular metabolic mechanism required for acclimatization to thermal stress in sheep and goat. By knowing the various genes responsible for thermo tolerance we can change the genetic structure of animal and drift towards superior thermo tolerant ability.

***2) Improving water availability*:** Water harvesting offers a method of effectively developing the scarce water resources of arid regions. Technique is to use water ponding dikes which slow down surface runoff, allow infiltration and increase soil moisture, and promote significant vegetation growth for habitat cover and forage. The use of stock tanks as water sources on rangeland for cattle grazing is a traditional method that has one of the least construction costs amongst a variety of possible methods.

3) Improving animal health*:* A changing climate will cause changes in the patterns of endemic diseases in livestock. Development of effective and sustainable animal health service, associated with surveillance and emergency preparedness systems, sustainable animal disease control and prevention programmes, are some of the most potential adaptive strategy that could be implemented to ameliorate and mitigate adverse impact of climate change on livestock health. Additionally, reduction of movement of livestock across different regions for trade or other management related reason could also reduce the spread of transboundary diseases

4) Female empowerment*:* Women play an important role as producers of food, managers of natural resources, income earners and caretakers of household food and nutrition security. They have a significant role in dealing with issues such as energy consumption, deforestation, burning of vegetation, population growth, economic growth, developing scientific research and technologies, and policy making, amongst others. Livestock are most important asset for women. But, most of the livestock are owned by men. With respect to livestock, women are heavily involved in small ruminant production and it is easy for them to get into production. Hence consorted efforts are needed in defining the complexities and changes associated with livestock ownership. Proper mechanisms should be put in place for securing women's access and control of livestock and other assets. This can be easily achieved by creating index-based livestock insurance for women and women-owned livestock as well as by developing a separate fund for both women and livestock.

5) Early warning system and communication: **Strengthening climate information and Early Warning Systems (EWS) for climate resilient development and adaptation to climate change** is to help farmers respond to both short-term/rapid onset climatic hazards (e.g. cyclones, floods and storms), as well as long-term/slow onset hazards (e.g. drought and long-term climate change). This not only reduces the immediate impact of any environmental hazard on livestock but also give the farmer sufficient time to prepare for the upcoming hazard.

6) Capacity building programmes: Success of adaptation strategies depends upon how effectively those strategies are being transferred to the ultimate target groups the poor and marginal farmers. Developing suitable capacity building program (CBP) is very crucial for successful implementation of adaptation strategies. CBP should be (a) country driven and issue based, (b) should occur within a framework of integrated interdisciplinary problem solving, (c) is much more than training, it requires institutional strengthening and human resource development and (d) should encourage potential for interaction and dialogues among diverse stakeholder groups. Building capacity of different stakeholders in parallel with the above adaptation strategies would help wider research and development communities to put climate, vulnerability and adaptation information into active use for pro-poor development.

7) Other livestock adaptation strategies

- Developing and promoting drought-tolerant and early-maturing crop species

- Adopting Integrated Disease Surveillance Response systems and emergency preparedness to prevent, mitigate, and respond to epidemic
- Strengthening meteorological services to provide timely weather and climate forecast/information early-warning systems
- Promoting and strengthening aquaculture, poultry raising, and the like as alternative livelihood options
- Developing and promoting guidelines for using herbal and alternative medicine for improving livestock production
- Increasing agriculture extension activities
- Migration of herds along the rivers to find better fodder during drought
- Conserving natural genetic resources
- Identify ecologically and socially sound options for improving water availability
- Developing technological interventions to meet the climate change challenge
- Strengthen access to appropriate veterinary services, including community animal health workers.

6.2.3. Coastal Sector and Fisheries Adaptation Strategies

Marine and coastal systems are considered to be extremely vulnerable to climate change. Analysis of coastal climate change adaptation requires combining environmental and resource economics with other disciplines. Sea level rise, ocean warming and acidification, and increased storminess threaten to alter or intensify biophysical coastal changes, which have a direct impact upon the lives and livelihood of coastal fishing communities. Local adaptation to climate change impacts are increasingly observed across communities. Based on the coastal and fishing vulnerability of Karnataka state, various adaptation strategies have been identified for each of the aquatic environment and the concerned agro-climatic zone (Table 6.7). The implementation of the identified adaptation strategies could be undertaken in the following manner:

1) ***Reduce the pressure on marine fisheries:*** Implementation of proper mesh size regulation, reduction in lending of licenses for new vessels, minimize subsidy on fuel, follow uniform fishing ban on neighboring states, extend fishing ban period to three months instead one month.
2) ***Provide alternative livelihood to the fishing communities:*** Livelihood in the form conducting trainings for development value added products like Prawn pickle, Preparation of fish cutlets, fish pickle, prawn pickle, fish balls, Fish patties, Prawn chutney powder, fish Chikuwa, Smoked fish sausage in natural casing, Crab cutlets, Coastal tourism, Artefacts and handicrafts from shells, bones and bamboo, Pollution control in coastal water and marine water, environment impact assessment of coastal

and marine projects, riverine and estuarine management for fisheries conservation are other options.

3) ***Identify low lying salinized land area and promote agri cum fish culture:*** To develop areas which are inundated with salt water and tend to grow salt resistant paddy crop along with fish like tilapia which can tolerate saline conditions

4) ***Promote mariculture:*** Using cages in sheltered coastal waters for coastal water fish species which have high market value e.g. fishes like Groupers, Cobia, Seabass etc. mariculture could be promoted.

5) ***Promote edible oyster, seaweed, pearl oyster culture*** in identified marine waters by rope and rack methods

6) ***Establish hatcheries for the production of fish and shellfish fingerlings/spats for undertaking culture:*** Development of hatcheries is lacking in marine sector and still there is a dependency on wild caught fish seed for culturing coastal and marine water varieties. Hence development of hatcheries would be very much vital to get more seed.

7) ***Identify eroding sides and adapt suitable erosion control methods for preventing erosion:*** Conserve critical coastal environments such as mangrove areas, coastal shelter beds, salt marshes, creeks and lagoons, backwaters, and other breeding and spawning grounds for fish and shellfish.

8) ***Skill development***: To enable fishing communities to take up other economic activities, promote skill development activities.

9) **Provide safe housing** to the coastal communities preferably beyond the hazard line on the landward side.

10) ***Provide appropriate rescue relief and rehabilitation*** mechanism in case of adverse climatic conditions.

11) ***Assess all the existing fisheries related infrastructure*** such as jetties, wharf, ports, fishing harbors, breakwaters, groins etc. with regard to rising sea level and increased current and wave action and accordingly undertake necessary modification/repairs of the infrastructure.

Table 6.7: Potential adaptation activities for fisheries sector in different agro-climatic zones

Agro climatic zone	**Districts**	**Adaptation strategies**
Coastal Zone	Dakshina Kannada, Udupi and Uttara Kannada	i) To reduce the pressure on the marine fisheries ii) To provide alternative livelihood to the fishing communities iii) To provide skill development to enable fishing communities to take up other economic activities iv) To provide safe housing to the coastal communities preferably beyond the hazard line on the landward side v) To provide appropriate rescue relief and rehabilitation mechanism in case of adverse climatic conditions vi) To identify low lying salinized land area and promote agri cum fish culture vii) Promote mariculture by cages in the sheltered coastal waters and to produce economic variety of fish such as seabass etc. viii) Promote edible oyster, seaweed, pearl oyster, culture in identified marine waters by rope and rack methods. ix) Establish hatcheries for the production of fish and shellfish fingerlings/spats for undertaking culture. x) Identify eroding sides and adapt suitable erosion control methods for preventing erosion xi) Conserve critical coastal environments such as mangrove areas, coastal shelter beds , salt marshes, creeks and lagoons, backwaters, and other breeding and spawning grounds for fish and shellfish
Hilly zone	Uttara Kannada	i) Promote fisheries such as tor, mahseers, puntius sp. ii) Promote ornamental fish culture using endemic hill fisheries such as loaches, suckers, barbs, catfish, eels etc. iii) Establish hatcheries for culturing cold water fisheries iv) Provide safe housing to the fishing communities habituating the hills v) Provide alternative livelihood to the hill communities so as to cope up during adverse climatic conditions vi) Promote economic activities such as game fishing, home stay tourism and other by product preparations vii) Establish conservation and protection sites by notification to protect the endemic aquatic flora and fauna viii) Identify vulnerable sites which are prone to landslides, flooding and relocate people from such sites to safer locations ix) Promote integrated agri and aquaculture along with livestock for livelihood securities of hill communities x) Establish good communication system to the households and to the disaster management centers.
Northern dry zone	Vijayapura, Gadag, Bagalkot	i) To identify the water areas including riverine sources, ponds, lakes, and reservoirs ii) Upgrade the existing hatcheries and nurseries to provide adequate number of fish seeds for aquaculture to be
Northeastern dry zone	Kalaburagi, Raichur, Bellary, Yadgir, Koppal	

<table>
<tr><th>Agro climatic zone</th><th>Districts</th><th>Adaptation strategies</th></tr>
<tr><td>Northern transition zone</td><td>Dharwad, Belgaum, Haveri</td><td rowspan="6">undertaken in the above aquatic environment
iii) Establish fish feed production centers
iv) Establish fish diagnostic centers also mobile vans.
v) Adequately build capacity and train the farmers
vi) Establish cold chain to transport the harvested fish to the markets/processing centers
vii) Promote skill development for ornamental fish culture, aquaponics, re-circulatory aquaculture system, aquatic plant culture
viii) Promote research and development to identify suitable resilient fish varieties, seed production technologies and improve feed varieties for each of the fish species and agro-climatic zone.
ix) Improve information system and establish linkage with farmers to resolve the problems faced by the farmers in their farms</td></tr>
<tr><td>Central dry zone</td><td>Tumakuru, Chitradurga, Davanagere</td></tr>
<tr><td>Eastern dry zone</td><td>Bangalore Rural, Bangalore Urban, Kolar, Ramnagara, Chikballapur</td></tr>
<tr><td>Southern dry zone</td><td>Mysore, Kodagu, Mandya, Chamarajanagar</td></tr>
<tr><td>North Eastern transition zone</td><td>Bidar</td></tr>
<tr><td>Southern transition zone</td><td>Hassan, Shimoga, Chikmagaluru</td></tr>
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6.2.4. Groundwater Adaptation Strategies

Groundwater systems are both directly and indirectly influenced by climate change through replenishment by recharge rates and changes in groundwater use respectively. As of March 2018, Karnataka is the second highest state after Maharashtra (43,43,670), which has energized 24,19,435 pumps. Of the total number of deep tube wells (118763) a majority of them (118141) are owned by private farmers. Agriculture in the state also consumes 37.19% of the total electricity sold (58152.32 Gwh), the second highest after Rajasthan that is primarily used for irrigation (energizing 21428411 pumpsets as of 2017-18). Projected water requirement of the State is likely to increase to 42.7 BCM by 2025 and 58.8 BCM in 2050. While, the estimated demand for irrigation water is 28 BCM in 2025 and is projected to increase to 36.2 BCM in 2050. With increased dependence on groundwater extraction, the State has been able to sustain a level of food grain production at roughly 120 lakh tonnes, in spite of consecutive drought situations for four years (2011-12 to 2014-15) (Economic survey 2015). However, with climate variability in the State, the southwestern regions of the State are projected to experience a further decline in rainfall (Jogesh & Dubash, 2014).

Ground water systems are critical to climate-change adaptation and require appropriate structural and non-structural management if they need to sustain a growing population. Some of the potential adaptation options currently available are illustrated in Figure 6.4. They should include both demand and supply side management to ensure that groundwater withdrawals are revised in alignment with realistic assessments to minimise dependence on groundwater. The supply-side management entails appropriate measures for recharge enhancement, taking into consideration the potential feedback loops associated with climate-change induced changes in precipitation patterns and the need to ensure adequate water quality for aquifer recharge.

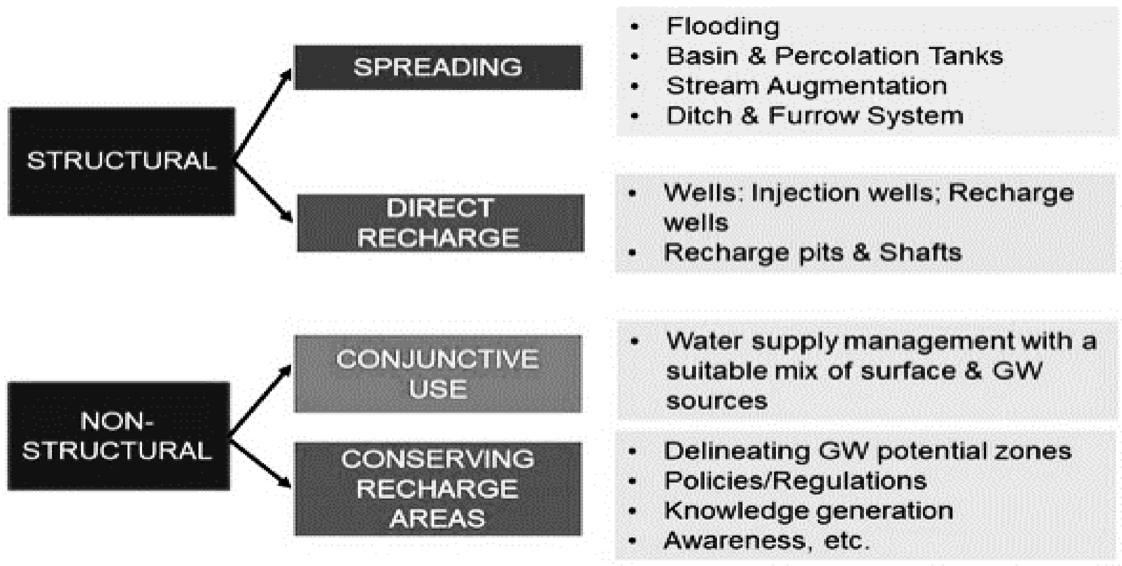


Figure 6.4: Potential adaptation options for groundwater management (Source: Shrestha et al., 2018)

1) Demand management: Some of the measures include dry-season crop planning towards higher-value and less water consumption crops, adoption of precision irrigation technologies, regulatory measures to restrict or control groundwater abstraction or use such as restricting depth of irrigation wells, establishing and operationalising minimum distances between irrigation units among others.

2) Micro irrigation: Micro irrigation includes drip and sprinkler irrigation methods. Drip irrigation method has three significant advantages: (i) as water is supplied through a network of pipes, the evaporation and distribution losses of water are minimum or completely absent, (ii) unlike flood irrigation, water is supplied at a required time and level and thus, over-irrigation is avoided, and; (iii) while water is supplied for the whole crop area in conventional method of irrigation. Several research studies have concluded that the adoption of micro-irrigation projects have resulted in water saving, productivity gains, reduced cost of cultivation and income enhancement at the farm level in comparison to crops cultivated under flood method of irrigation (Narayanamoorthy, 2004a, 2005; Namara et al 2005; Kumar & Palanisami 2010, 2019).

3) Regulatory measures: Climate change demands rethinking of the regulatory framework to protect and conserve groundwater. Currently, the existing regulatory framework has not adapted to the challenges and falters in addressing evolved environmental concerns (Cullet, 2014). Although, there have been efforts in this direction such as the two Bills that are likely to have implications on controlling the exploitation of groundwater, viz. the Model Bill for the Conservation, Protection, Regulation and Management of Groundwater, 2016 and the National Water Framework Bill, 2016, are awaiting enactment. In particular, the Model Groundwater Act, 2016 adopts a wide perspective of groundwater regulation that includes conservation and protection measures. This incorporates the link between regulation of groundwater and climate change in the preamble. Cullet (2017) states that this approach is in contrast to existing laws that pivot only the regulation of its multiple uses, without integrating social equity and human rights dimensions in groundwater regulation. The Government of

Karnataka also implemented the Karnataka Ground Water (Development and Maintenance Rules and Control) Act in 2011 to prevent the overuse of ground water. However, a particular clause related to no limit on the number of irrigation wells per farmer in the Groundwater Regulation and Control Act, is a cause for concern (Chandrakanth et al, 2019).

A recent development relates to the Karnataka Jnana Aayoga Task Force's Report on the Karnataka State Water Policy 2019[28]. It recommended a complete overhaul, including passing an overarching water framework law to protect the goals of water governance, re-moulding of the groundwater act and irrigation act nested within a law for setting up water regulatory authorities at state, basin and sub-basin level. The report also advocated the reforming of water-related agencies that encourage transparency and accountability in the governance of the pollution board and water boards. In addition, a new task for collection, analysis, research, dissemination and outreach of water data to provide information at all levels of this nested water governance and to the public to help stimulate efficient, sustainable and equitable water management in Karnataka.

4) Other measures: Few other measures that could be implemented for adaptation include:

- Quality monitoring: India currently has 15974 groundwater quality monitoring wells under the Central Ground Water Monitoring Board. Of them, Karnataka has 1466, as of March 2018. Most of the contamination by fluorides and arsenic has been triggered by deep groundwater pumping. While, nitrate and biological contamination is from inadequate sanitation. Therefore, the long-term solution would entail the rejuvenation of groundwater by controlling over pumping and groundwater source protection.
- Farmers and users of groundwater need to be educated to treat water with wisdom, respect and equity and encourage the concept of shared wells
- Training on efficiency and judicious usage: groundwater recharge, pumping stipulated volume of water through sound water budgeting, not maximizing output per acre, but maximizing net returns per rupee of the cost of water is crucial
- Installation of a low-cost water measuring device at each bore well, or IoT technologies that monitor abstraction to help the farmer learn the volume of water pumped per day, per crop on each fragment of land.

6.3. Barriers and Gaps in Implementation of Adaptation Actions

Although there have been policies and programmes formulated and implemented over the years in the state, there are certain gaps and barriers to achievement of the full potential of these policies and programmes in different sectors. Some such barriers are outlined here.

Agriculture

[28]https://www.indiawaterportal.org/sites/indiawaterportal.org/files/karnataka_state_water_policy_kja_recommendation_2019.pdf accessed on 06-06-2020

1) No definite policy is available to adapt to weather based cropping pattern to realize the potential production under the changed scenario.
2) Assured market and higher economic returns over cost of cultivation for recommended crops is not guarantee, which is discouraging the farmers to adapt the recommended crops based on weather.
3) Millet crops do not realize the higher economic returns and hence farmers opt for other crops. The economic compensation mechanism may attract the farmers to go for millet crops.
4) Financial Assistance to the farming community on opting Agri-Horti and Agro-Forestry system.
5) Strengthening the dissemination of Agromet Advisories to the farming community on real time basis for immediate adaptation.
6) Policy development on the issue of risk management on adaptation of cropping pattern for the change scenario.

Animal husbandry

Significant uncertainty relates to the nature and extent of regional climate change impacts, impacts across agricultural industries, and impacts over time. The challenge for governments and agricultural industry stakeholders is to deal with these uncertainties through further research and the development of policies and farm management approaches that are flexible enough to deal effectively with a range of potential climate change outcomes. Science and technology are lacking in thematic issues, including those related to climatic adaptation, dissemination of new understandings in rangeland ecology, and a holistic understanding of pastoral resource management. The key thematic issues on environment stress and livestock production includes: early warning system, multiple stress research, simulation models, exploitation of genetic potential of native breeds, suitable breeding programme and nutritional intervention research. The integration of new technologies into the research and technology transfer systems potentially offers many opportunities to further the development of climate change adaptation strategies. The only concern for livestock sector in the face of changing climate scenario is the reduction in the production capabilities of indigenous livestock population. Therefore, research efforts are needed to improve the productive potential of indigenous livestock population in the Karnataka state. In this line, some new initiatives on the research front is needed to refine the existing breeding program both to conserve indigenous germplasms as well as to improve their productive potential through marker assisted selection.

Water

- Increased frequency and intensity of droughts, floods and other natural events affecting project implementation
- Delays due to litigations, tribunal awards, Supreme Court cases, compensation payable to land, to farmers, administrative lapses if any
- Delays due to lack of capital, infrastructure, knowledge, awareness among stake holders, farmers, Government, NGOs

- Delays due to lack of knowledge of existing laws, rules, regulations, institutional failures
- Gaps in implementation due to technical factors – e.g. faulty location of farm ponds responsible for poor harvest of water resources, faulty location of bore well points leading to failure of bore wells.

Health

Adaptation measures that mitigate the health impact of climate change can be taken up in three different levels, namely, primary, secondary and tertiary.

- Primary level measures to stop spread of mosquitoes, prevent spread of disease
- Secondary level (surveillance, monitoring) looks at preventive measures taken in response to early evidence of impact
- Tertiary level (effective medical treatment) focuses on actions taken to lessen the health effects.

There are certain policies and programmes being implemented in India across all sectors that directly or indirectly contribute towards climate change adaptation. There is a need to overcome the identified barriers in implementation of existing programmes and implement additional targeted adaptation strategies in the various sectors to buffer from shocks and losses that would incur because of changes in climate and its adverse impacts, that exacerbates current vulnerabilities.

Chapter 7: Financing Roadmap

7.1. Introduction

The costs of climate change are highly pervasive in nature. The Stern Review (2007) observes that the economic costs of climate change are significant and capable of severely aggravating economic and environmental problems in poor countries. The Stern Report, therefore, warns that “if we don’t act, the overall cost and risks of climate change will be equivalent to losing at least 5% of global gross domestic product (GDP) each year, now and forever. If a wider range of risks and impacts are taken into account, the estimates of damage could rise to 20% of GDP or more” (Stern 2007). Climate change affects everyone; however, the economic development benefits a few due to unequal distribution of income or benefits of development. The Environmental performance Index of 2020 shows that majority of the developing countries including India face serious challenges to conserve and manage their natural resources.

Policy efforts towards mitigation and adaptation of climate change remain a challenge, given the poor financial resources made available at the global and regional level. In this backdrop, the present chapter makes an effort to account and analyse the extent and nature of climate finance available for climate change actions at Global, India and Karnataka state level. It accounts and analyses the extent and nature of climate finance in different sectors of the economy, in recent years. This chapter also tracks climate financing for adaptation and mitigation activities in India and Karnataka and offers policy suggestions for sourcing of climate finance for implementing the State Action Plan.

7.1.1. Approach and Methodology: Climate Financing

This chapter relies on the definition and approach of the United National Framework Convention on Climate Change (UNFCCC) Article 2.1(c) of the Paris Agreement, which states that “making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development”. The study considers two sources of climate financing for analysis: Funding Source Analysis and Expenditure Analysis. For funding sources, the information and data were obtained from approved project documents, national development budget reports, a project list from development partners, projects available on the Pacific Climate Change Portal, information on the Climate Funds Updated website and project listings on the websites of respective climate funds. The Information for the expenditure analysis was primarily extracted from National and State Budgets.

7.2. Sources of Climate Finance: Global, National and State Level

Climate finance includes both public and private finance, and all scales - global, national and state level.

7.2.1. Climate Finance—Global

Global Climate Finance avenues are available under the UNFCCC and the Kyoto Protocol. There are four important sources of climate finance, globally and these include:

1. Global Environment Facility (GEF) replenishment;
2. Special climate change fund;
3. Least developed countries fund;
4. Bilateral and multilateral sources.

The total fund available from the UNFCCC and Kyoto protocol is estimated to be around USD 10 billion per year. These funds are mainly channelled through Clean Development Mechanism (CDM) projects. Global climate finance is also provided by the World Bank and through bilateral aid programmes. The total annual multilateral and bilateral climate funding is estimated at USD 15 billion. Given the magnitude of emission of GHGs and resultant climate change in the world, the global climate fund is too small and inadequate to meet the climate investments needs in developing countries. The climate finance flows are given in Figure 7.1. Most of the funds are targeted towards achieving energy efficiency, promoting renewable energy and sustainable transport. The total global funds available through multilateral, bilateral and multilateral development banks is estimated be USD 58 billion and they are mainly directed towards adaptation, mitigation, REDD-Plus and cross cutting technology. These funds have been made available in the form of grants, concessional loans and other forms.

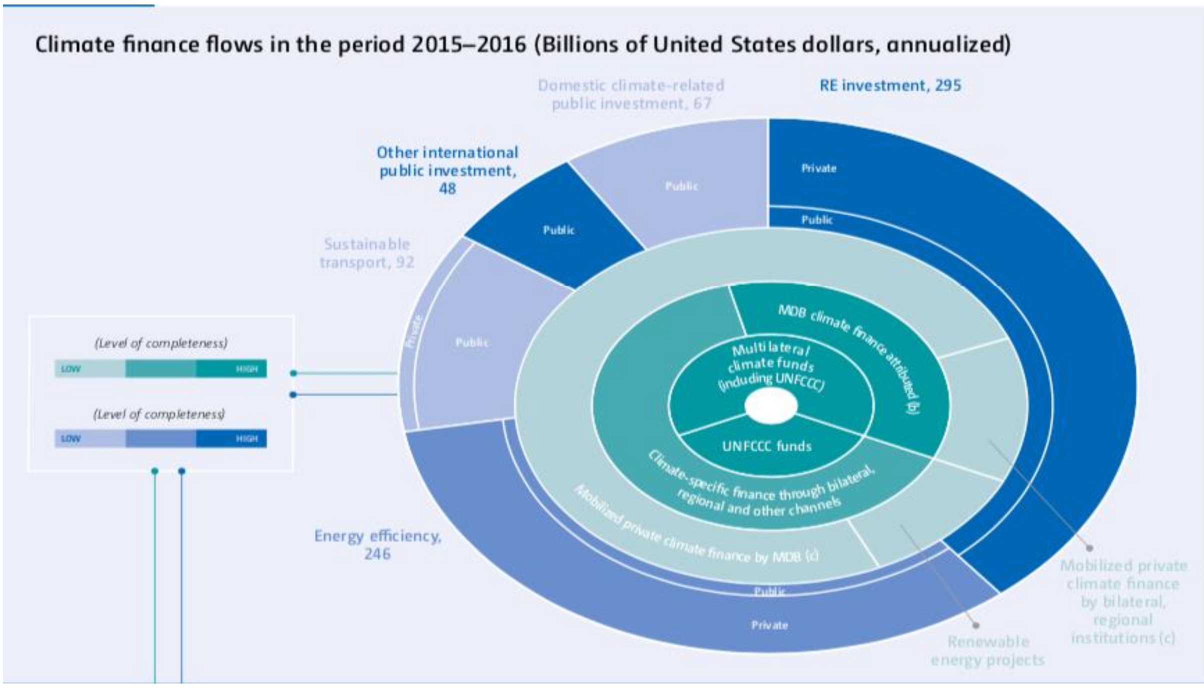


Figure 7.1: Global climate finance flows

7.2.2. Climate Finance—National (India)

The Government of India, as a policy response to address climate change and to realize its goal of low carbon economy to meet the Kyoto protocol , announced National Action Plan on Climate Change (NAPCC) in 2008. The NAPCC focuses on areas or sectors that require interventions to address climate change and articulates India's road map to achieve sustainable development. The NAPCC mainly focuses on energy efficiency, clean technology and resource efficiency. The MoEF&CC serves as the nodal agency for overall formulation, implementation, coordination and supervision of climate policy in India. The main missions of the NAPCC are:

1. National Solar Mission
2. National Mission for Enhanced Energy Efficiency
3. National Mission on Sustainable Habitat
4. National Water Mission
5. National Mission for Sustaining the Himalayan Ecosystem
6. National Mission for a Green India
7. National Mission for Sustainable Agriculture and
8. National Mission on Strategic Knowledge for Climate Change.

Paris Agreement and NDC: In response to the decisions of the Conference of Parties, for post-2020 period, India submitted its NDC to the UNFCCC on 2nd October, 2015, outlining the climate actions intended to be taken under the Paris agreement. The eight goals put forth by India in its NDC are:

1. To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation
2. To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.
3. To reduce the emissions intensity of its GDP by 33 to 35% by 2030 from 2005
4. To achieve about 40% 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 (GCF).
5. To create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030.
6. 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.
7. To mobilize domestic and new & additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap.
8. 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.

The climate finance in India was estimated at Rs. 230,000 crores (approximately USD 30 billion) in 2012-13 and Rs.1,08,000 crore up to the end of 12th FYP period (2011-2017). The financial outlay towards the NAPCC missions during the 12th FYP period was Rs. 256,836 crores. India has accessed USD 327 million as GEF grant since 1991. The public spending on adaptation in 2013-14 was Rs. 2,130 billion i.e. 12% of the budget for the year. The total commitment for 21 schemes (actual expenditure as per revised estimates for 2013-14) was Rs. 740 billion during 2013-14 or 0.7% of the GDP (Figure 7.2).

The funds made available to the above and other CDM projects were from different sources as given in the Figure 7.2. Most of the climate funds available in India are from union and state budgets, and international and private funds are limited to a few CDM projects. The government of India had estimated Rs. 11,31,945 crore as budgetary requirement for implementing State Action Plans on Climate Change over 5 years starting in 2014. As per the estimation, Karnataka state required Rs. 7,120 crores towards implementing SAPCC V.1.

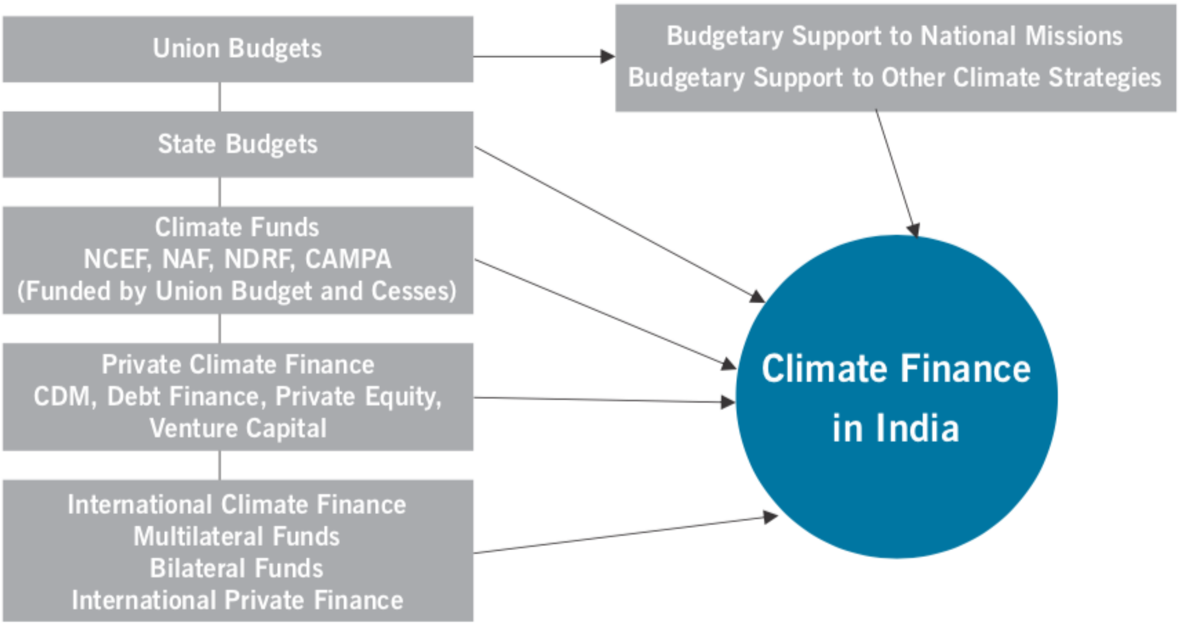


Figure 7.2: Climate fund sources in India

7.2.3. Climate Finance in Karnataka

Mitigation and adaptation to climate change depend on long-term policies and programmes of the State. Climate finance—both public and private will help in reducing climate related vulnerabilities and also in developing coping mechanisms in the affected regions, sectors, social and vulnerable groups in the State. SAPCCs are mainly funded by Union and State budgets through various centrally and state sponsored programmes and schemes. The Central Government approved Rs. 7,000 crores in 2012-13 for Karnataka's State Action Plan on Climate Change.

7.3. The Expenditure Source Analysis

Information provided in Table 7.1 shows that the programmes and schemes implemented in various departments are completely financed by Central and State Governments while World Bank and ADB funded projects are loans. However, a majority of the schemes and programmes are not intended or targeted towards climate mitigation and/or adaptation. There is no official evidence on private finance being available for climate change.

There are no schemes to improve energy efficiency in conventional sources of energy dependent thermal based iron and steel industries, thermal power units, and cement industries. There were no new schemes during 2019-20 to support production of renewable energy such as solar and wind power. Except, BMRCL, promotion of public transport is missing in the sustainable mobility policy. The policy of adaptation such as brining behavioural change in the industry, agriculture, fishing, livestock farming, food processing, and also promoting responsible consumption is absent. The information on use of economic instruments such as carbon markets under CDM, imposing taxes on use of fossil fuels and providing subsidies on electric vehicles and production of renewable energy is not found. Investment on green technologies and innovations, and developing action plans for climate related emergences and vulnerabilities are hardly found in the policy of the State Government.

Table 7.1: Financing climate change in Karnataka during 2019-20

Key sectors	Central and State Schemes	Finance during 2019-20 in Rs.
Forest and Ecology	National Afforestation Programme and Green India Mission with an objective to increase forest cover in five million hectares of forest area and improvement of forest cover quality in five million hectares of forest (Totally 10 Mha) and reducing of 43 million tonnes of CO_2 sinking by 2020.	1000.00 lakh
	Wildlife and National Parks conservation activities	5,993.85 lakh
	Social Forestry Scheme aims at raising of 5227.48 ha of plantation and maintenance of 11560.830 ha of older plantation.	3789.53 lakh.
	Development of Degraded Forests	1478.23 lakh
Agriculture	Sujala Agriculture and Horticulture III sponsored by the World Bank. The project is being implemented in the selected 2531 micro watersheds located in 11 project districts	412.59 crore
	National Adaptation Fund for Climate Change (NAFCC)	24.22 crore
	National Mission on Sustainable Agriculture Sustaining agricultural productivity with availability of natural resources like soil and water	14 82.0 0 lakh
	Krishi Bhagya to improve rainfed agriculture scenario with the efficient management of rain water	2 5000 .00 lakh
	Promotion of Organic Farming	8 7.00 crore
Water Resources	Major & Medium Irrigation Projects:	10420.22 crore
	Minor Irrigation	112728.18 lakh
	Soil and Water Conservation	3 480.0 0 lakh
	Micro Irrigation to promote efficient use of water in the agriculture production.	36818.00 lakh
Rural Development	"Jalamrutha" project as "Water Year-2019", Water literacy, Rejuvenation of Traditional water bodies, water conservation and Greenery. Totally 1362 tanks have been considered for rehabilitation and development.	6904.53 lakh
	Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) with an objective to enhance livelihood security in rural areas by providing	3755.10 crore

Key sectors	Central and State Schemes	Finance during 2019-20 in Rs.
	100 days of guaranteed wage employment in a financial year.	
Urban Development	Water Supply Component of 110 Villages merged to BBMP including improvement in distribution and UFW reduction Component of Core area	1500 crore
	The Solid Waste Management: processing, treatment and disposal facilities are established.	440 crore
Transport	Public Transport System in cities of Karnataka, assistance for construction of Transit Infrastructure in cities, implementation of Cycle Tracks in the neighbourhoods of Bangalore,	441.57 crore
	Bangalore Metro Rail Project Phase-2 The total length of Phase-2 is 72.095 km with 60 stations (48 Elevated and 12 Underground).	30695 crore
Energy	New National Biogas and Organic Manure Programme to provide clean bio-gaseous fuel mainly for cooking purposes and also for other applications for reducing use of LPG and other conventional fuels	1355 lakh
	New and Renewable Energy	515 lakh
Coastal Development	Sustainable Coastal Protection and Management Project by Asian Development Bank to increase incomes and reduce poverty in the coastal communities.	606.50 crore
Health	Swachha Bharat Mission (SBM)	740.00 crore
	National Health Mission: National Vector Borne Disease Control programme	79.84 crore
Revenue	State Disaster Response fund allocated as per the 15th Finance Commission	1054 crore

7.3.1. Scheme wise (Mitigation and Adaptation) Analysis of Climate Finance

In order to understand the financing of climate change for the State Action Plan on Climate Change V.1, an analysis of the provision of department and scheme wise State Budget of public expenditure on mitigation and adaptation of climate change was carried out (Annexure A.10). Under the state intervention through fiscal policies, firstly, climate relevant expenditures were tracked and secondly analysis was done to estimate the extent of expenditure relevant to climate change.

In this regard, an intensive review of Karnataka state Government schemes (2017-18 to 2019-20) was carried out. The total annual budget allocated for direct and indirect actions towards addressing climate change (Table 7.2) was:

- 2017-18: Rs. 9,89,975.10 lakh accounting for 5.31% of the total state budget.
- 2018-19: Rs. 10,71,432.25 lakh accounting for 4.90% of the total state budget.
    - Revised budget of Rs. 11,62,603.13 accounting for 5.35% of the total.
- 2019-20: Rs. 8,25,312.74 lakh accounting for 3.52% of the total state budget.

Table 7.2: Percentage of the annual total budget allocated for climate change actions during 2017-18 to 2019-20 years

Years	Total budget allocation (Rs. Lakh)	Amount allocated for climate change actions (Rs. Lakh)	Percentage of the total budget
2017-18	18651046.81	989975.10	5.31
2018-19	21848812.00	1071432.25	4.90
2018-19*	21745099.37	1162603.13	5.35
2019-20	23415295.77	825312.74	3.52

Source: Authors calculation (for revised budget)

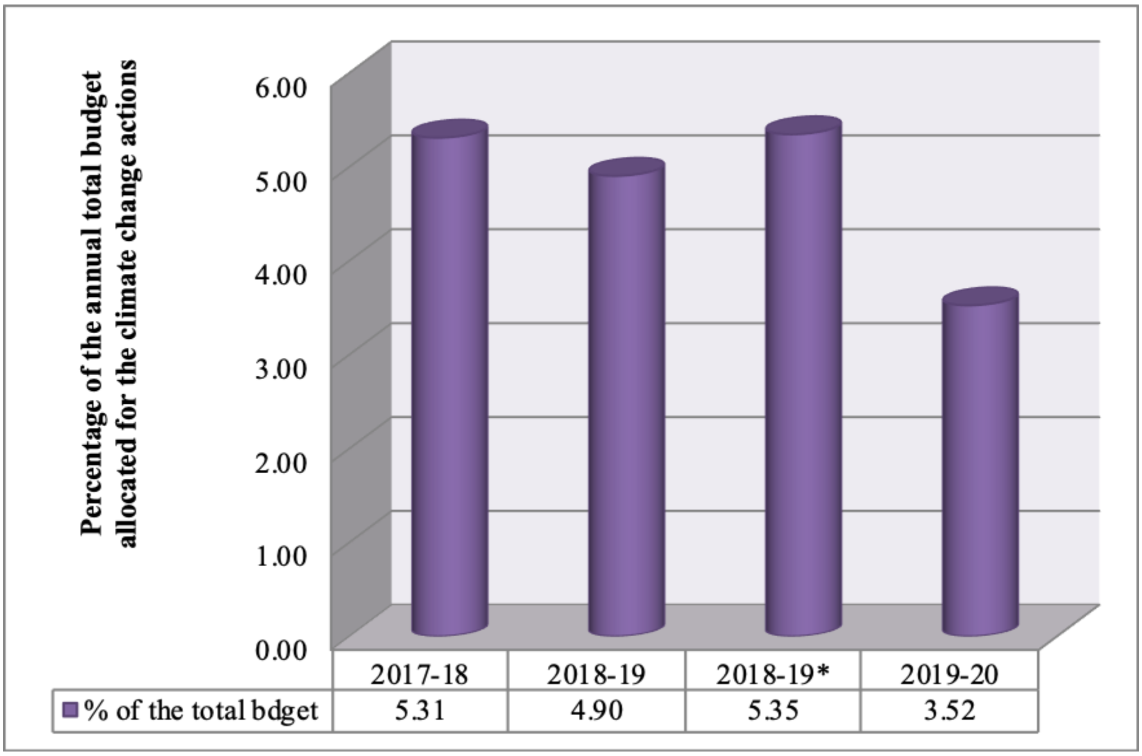


Figure 7.3: Percentage of the annual total budget allocated for the climate change actions

This data clearly shows that the actions set out under SAPCC V.1 were poorly financed. Figure 7.3 shows that the budget allocated for climate change related programmes and schemes was highest in 2018-19 (Revised Budget) and lowest in 2019-20.

A total of 103 schemes have been identified to address climate change and its effects directly (intended) or indirectly (unintended). The information on schemes is extracted from the Schemes 2019-20 Vol II, Department of Planning, Program Monitoring and Statistics, Government of Karnataka. Among the schemes targeted towards climate change adaptation and mitigation, majority of them were from Agriculture, Horticulture and Forestry sectors. Proportion of the total budget allocated to take action against climate change was highest in the agriculture department—1.16% of the total state budget in 2017-18, 1.72% of the total state budget in 2018-19 (BE) and 10.01% of the total state budget in 2019-20. Proportion of the budget allocated by water resource, energy, urban development, finance, revenue and fisheries towards taking climate change actions were very negligible. The proportion of budget allocated for climate action in different departments was also highest in the agriculture department that is to the extent of 30.34% in 2017-2018, 35.11% in 2018-19 (BE) and it was 28.39% in 2019-20. Department of cooperation received highest amount in the revised estimate of 2018-19 under Minimum Floor Price Scheme, Rural Market Improvement and Yashaswini scheme.

Annual growth rates in climate change action budget shows no considerable growth in the fund flow. For some departments like, Agriculture, Debt servicing, Minor Irrigation and RDPR the budget (Table 7.3) flow is seen to be continuously decreasing and in the case of the Horticulture, it is stagnant. An increase in the budget allocated to Water Resource department, to the extent of 499.50% in 2018-19 revised budget is also witnessed.

Table 7.3: Annual growth rate and CAGR (%) in budget allocation for climate action in different departments

Department	2017-18	2018-19 (BE)	2018-19* (RE)	2019-20	CAGR (%) for 2017-18 to 2019-20
Agriculture	-	0.25	-0.21	-0.21	0.09
Horticulture	-	0.00	0.00	0.00	0.02
Animal Husbandry	-	0.42	-0.26	0.58	0.46
Fisheries	-	-0.60	4.74	-0.67	-0.19
Forestry	-	0.94	-0.02	0.08	0.72
Cooperation	-	-0.08	5.54	-0.91	-0.38
Energy	-	0.00	-0.50	0.00	0.00
Water Resources	-	0.00	499.50	-0.90	0.00
Minor Irrigation	-	1.90	0.22	-0.54	0.45
Revenue	-	-0.94	0.17	-0.73	-0.95
Finance	-	0.65	0.00	0.41	0.88
RDPR	-	0.09	-0.34	-0.37	-0.45
Labour	-	-0.27	0.00	-0.09	-0.26
Welfare of STs	-	-0.23	0.00	0.00	-0.18
Urban Development	-	-0.05	0.00	0.14	0.00
Debt Servicing	-	-0.60	-0.50	-1.00	0.06
Total					**-0.13**

Source: Authors' calculation

Compounded annual growth rates of the annual budget allocated for the climate change actions (Table 7.3) has shown that, there is a positive growth in the budget allocation in the departments of Agriculture (0.09%), Horticulture (0.02%), Animal Husbandry (0.46%), Forestry (0.72%), Minor irrigation (0.45%), Finance (0.88%) and Debt Servicing (0.06%). Overall budget flows for schemes helping to take actions against climate change are decreasing at the rate of 0.13%. It shows that there is a need for financial allocation by the Government to combat the adverse impacts of climate change in various sectors of the economy.

From the broad-spectrum of schemes addressing climate change, schemes that are directly addressing the issues of climate change can be classified as ‘intended schemes’, and these are 66 in number. There are other schemes that are indirectly addressing the issue of climate change termed ‘unintended schemes’—25 in number. Agriculture, horticulture, forestry and fisheries account for a majority of the ‘intended schemes’. The proportion of schemes that are ‘intended’ is 72.53% and ‘unintended’ schemes are 27.47% (Figure 7.4). About 51 schemes are oriented towards reducing the negative impact or for coping with climate change or adaptation (Annexure A.11) and 38 schemes are targeted towards reducing emissions or mitigation (Annexure A.12). Figure 7.5 shows that the proportion of Government schemes introduced for climate adaptation is 57.30% and that for mitigation is 42.70%.

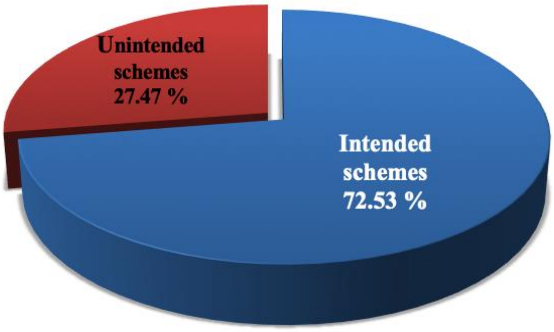


Figure 7.4: Proportion of government schemes with ‘intended’ and ‘unintended’ activities for addressing climate change during 2017-18 to 2019-20

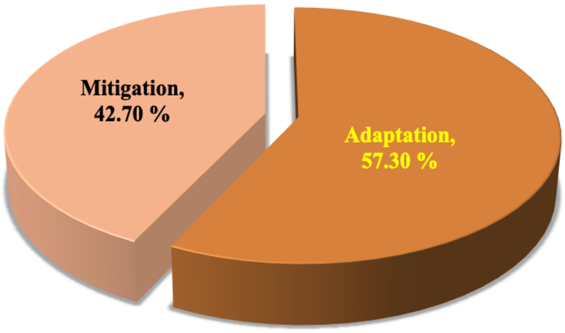


Figure 7.5: Proportion of government schemes introduced for adaptation and/or mitigation of climate change during 2017-18 to 2019-20)

Table 7.4 presents the number of schemes introduced by different departments of the Government of Karnataka.

Table 7.4: Department wise number of schemes introduced for climate change adaptation and mitigation

Department	Adaptation		Mitigation		Total	
	Number	%	Number	%	Number	%
Agriculture	17	33.33	4	10.53	21	23.60
Horticulture	15	29.41	6	15.79	21	23.60
Fisheries	4	7.84	2	5.26	6	6.74

Forestry	1	1.96	15	39.47	16	17.98
Co-operation	3	5.88	0	0.00	3	3.37
Energy	0	0.00	1	2.63	1	1.12
Water resources	2	3.92	0	0.00	2	2.25
Minor irrigation	2	3.92	1	2.63	3	3.37
Revenue	3	5.88	1	2.63	4	4.49
Finance	2	3.92	2	5.26	4	4.49
Rural development and Panchayat Raj	0	0.00	4	10.53	4	4.49
Labour	1	1.96	0	0.00	1	1.12
Welfare of STs	0	0.00	1	2.63	1	1.12
Urban development	0	0.00	1	2.63	1	1.12
Debt servicing	1	1.96	0	0.00	1	1.12
Total	**51**	**100.00**	**38**	**100.00**	**89**	**100.00**

Source: Authors' calculation

The State Government has implemented a majority of adaptation schemes for climate change under Agriculture (33.33%), Horticulture (29.41%) and Fisheries (7.84%) departments. Whereas climate change mitigation schemes are primarily seen under Forestry (39.47%), Horticulture (15.79%) and Agriculture (10.53%) departments. Forest, energy, transportation, waste management, and horticulture departments have higher potential to mitigate climate change and hence higher Government budget has been channelised. Irrespective of adaptation and mitigation strategies, Agriculture, Horticulture, Forestry, Fishery, Revenue, Finance and RDPR departments are sharing considerably higher percentage of schemes with budget for addressing overall issues of climate change.

India's private sector has been a major engine of growth and employment generation from the period of liberalisation (1990s). In the era of climate change and global warming, several private sector enterprises are putting efforts to materialize the dream of Green India concept. Table 7.5 gives some examples of private enterprises working in various areas of environmental and sustainable growth in Karnataka, highlighting the importance of public private partnership (PPP) in addressing the issue of climate change.

Table 7.5: Eco-friendly private initiatives in Karnataka

	Green initiatives	**Area of work**
1	Greenko (Karnataka) Solar Projects Private Limited	Electricity, Gas & Water
2	The Karnataka Bank Limited	Green initiative to maintain ecological balance in Karnataka and Delhi respectively
3	The South India Paper Mills Limited	Ensuring environmental sustainability, ecological balance, protection of flora and fauna, conservation of natural resources and maintaining the quality of soil, air and water
4	Hoosier Environmental Council	Reduce barriers to sustainable energy use, cut down on pollution and greenhouse gas emissions associated with

		factory farms, strengthen drinking water protections and safe guard wild areas
5	Green India Developers Private Limited	Real Estate and Renting business
6	EnviGreen	Production of 100% biodegradable substitute to plastics

7.4. Budget Requirement for Climate Change Action Plans

The departments of Forestry, Agriculture, Horticulture, Fisheries, Revenue, Finance and RDPR have greater scope for implementing climate change adaptation and mitigation schemes. Therefore, the magnitude of budget allocated for these sectors can be increased gradually. Further, since the forest sector has the highest potential to mitigate climate change, there is a need to increase the budget by 25% by 2025 and further 25% by 2030. Similarly, in the Agriculture and Horticulture sectors the annual budget for climate change action can be increased by 20% by 2025 and further 25% by 2030. Annual budget for climate change action in the Fisheries sector can be increased by 15%. Annual budget amount for the departments of Co-operation, Energy, Minor Irrigation, Finance and RDPR can be increased by 8%. Departments of Water Resources, Labour, Welfare to STs, Urban Development and Debt Servicing can be increased by 5%. This increment in the annual budget allocation for taking climate change actions may help in the integrated development of the environment quality.

Table 7.6: Budget requirement for climate change action plan of Karnataka State in 2025 and 2030 (Rs. lakh)

Department	Budget allocated in 2019 for climate change adaptation and mitigation	Budget requirement for climate change action plans in 2025	Budget requirement for climate change action plans in 2030
Agriculture	234299.46	281159.35	337391.22
Horticulture	88919.63	106703.56	128044.27
Fisheries	3444.00	3960.60	4554.69
Forestry	66716.96	83396.20	104245.25
Co-operation	27906.47	30138.99	32550.11
Energy	500.00	540.00	583.20
Water resources	101.00	106.05	111.35
Micro irrigation	2571.00	2776.68	2998.81
Revenue	1836.00	1982.88	2141.51
Finance	8591.00	9278.28	10020.54
RDPR	76129.00	82219.32	88796.87
Labour	20000.00	21000.00	22050.00
Welfare of STs	10000.00	10500.00	11025.00
Debt Servicing	78229.00	82140.45	86247.47
Total	**825312.74**	**2088041.23**	**5282744.32**

Source: Authors' Calculation

Currently, climate change finance is predominantly from the Government. The private and multilateral finance options are not accessed by the State. Climate financing in Karnataka is highly scattered and based on central and state level schemes and programmes, with no fixed percentage of assured finance allocated or earmarked in the state budget for mitigation and adaptation programmes. The financing of climate change in the State is dominated by central finance and State finance is not targeted towards climate change mitigation. Further, state climate finances are not sector-specific, region or zone-specific or social group-specific, taking into consideration current vulnerabilities, to address climate change.

Specific budget requirement for mitigation action across sectors are presented below:

Power

The total investment required for solar ground-mounted installations is INR 37,434 crores (estimated at INR 3.4 crore/MW at current price). The total investment required for RTPV installation of 2.8 GW is INR 12,600 crores (estimated at INR 4.5 crores/MW) (KERC, 2019a). The future cost decline as well as the O&M cost during the operational years are not considered.

In the Policy scenario, 5.4% reduction in T&D loss from 2021 level is proposed and INR 9,368 crore is required for the same (for five DISCOMs). The state also needs to schedule and allocate funds for improving the energy efficiency in state-owned plants as it could reduce coal consumption. Units 5-7 of Raichur plant, commissioned between 1994 and 2002, need INR 1 crore/MW (cost for R&M activity as per CERC), totalling around INR 630 crore for R&M activities (CERC, 2009). Improvement in its efficiency helps in avoiding 0.4 Mt of coal consumption in RTPS in 2030.

These investments for decarbonising the power sector need to be devised via increasing private sector partnership, adopting finding mechanism similar to Clean Development Mechanism (CDM) benefits, disbursing fund collected as Green Energy Cess (INR 0.05/kWh) from 2016 for activities to decarbonise energy sectors and availing funds from central budgets such as Climate Change Action Programme (CCAP), DDUGJY, IPDS scheme (KREDL, 2009).

Transport

An increased uptake of EVs would entail investments of about INR 89,978 crore to electrify almost 50% of newly-registered vehicles by 2030. Additionally, the charging-infrastructure requirement for increased uptake of EV in the state would require an investment of about INR 716 crore for a total of 2,423 charging stations spread across Karnataka. The FAME II policy under the National Electric Mobility Mission Plan 2020 provides demand incentive for purchase of EVs (DHI, 2019). Under a scenario where the incentive scheme is extended until 2030 to achieve at least 50% electrification in newly-registered EVs in the state, the total demand incentive requirement would be about INR 24,501 crore.

Further, the measures to improve the public transport across the state, particularly for integration of operation of bus services with that of Namma Metro and provision of bus stops at metro stations through bus-fleet augmentation would require an addition of about 37,100 units, resulting in total investments of about INR 7,420 crore by 2030.

Industry

The total investment requirement in the steel and refineries' sectors is estimated to be about INR 64,046 crore, with the steel sector requiring a major portion of the investments (about INR 47,015 crore).

Agriculture

As per the KUSUM subsidy scheme, 60% of the cost is paid for by the government, 30% by banks, and 10% by the farmers (Shah, 2018). Applying the same scheme to the total cost of mitigation with solar pumps, the total cost to be incurred by the government (both central and state) during the period 2021-2030 will be approximately INR 40,010 crore.

Additionally, assuming full implementation of demand side management from 2021 onwards without any barriers, along with replacement of old pumps (beyond 10 years of operation) with EE pump sets can result in carbon-mitigation potential of up to 707 ktCO_2. Assuming a price of INR 50,000 per pump, the total cost for this mitigation activity is INR 16,614 crore.

The existing state power infrastructure has spare capacity to support dedicated agriculture feeders powered by solar panels of capacity up to 2 GW[29]. We estimate an emissions mitigation potential of ~620 kTCO_{2e} for 2.6 lakh EE pumps connected to dedicated agriculture feeder powered by 1.75 GW of solar power. Given this, the solar-feeder connected to EE pumps can be considered as a prioritized mitigation activity for the agriculture sector. The total cost of this mitigation activity, including the cost of EE pump and the solar capacity addition is INR 7,242 crore.

Additional investments are required for enabling energy-efficiency measures. Figure 7.6 shows the relation of emission savings and investments normalised between 10 (low emission, low investment) to 100 (high emission, high investment) for various interventions suggested earlier. LED lighting, energy-efficiency measures in cement industries, energy-efficient irrigation pumps, and irrigation pumps with solar dedicated feeder are some of the immediate interventions that the state could consider taking up.

[29] Based on expert consultation (Annexure 13)

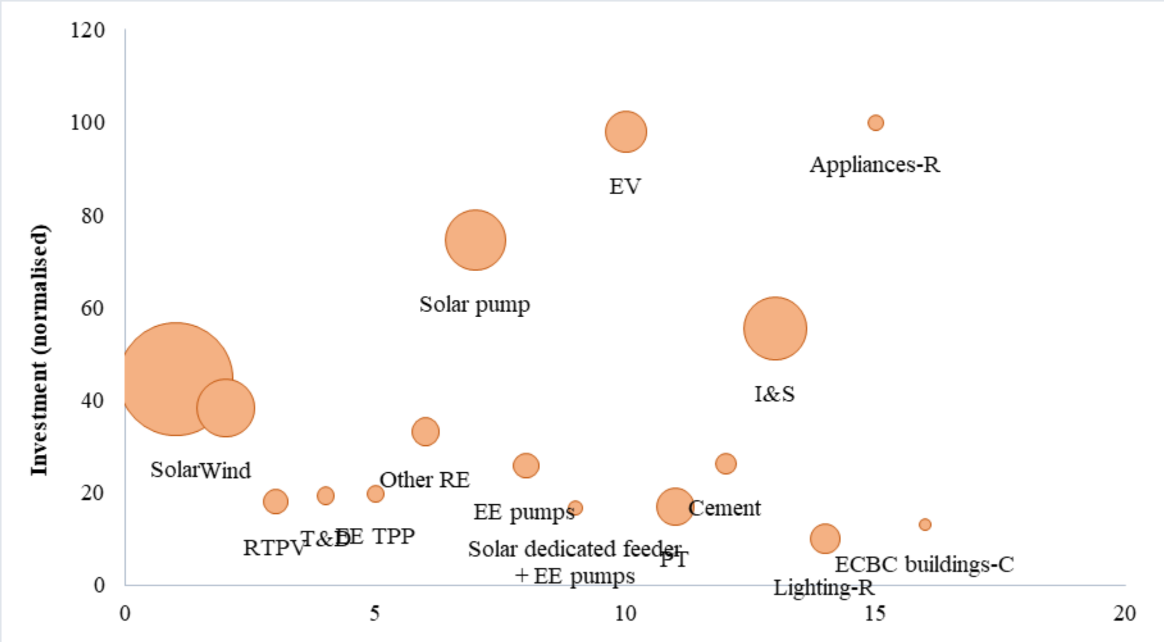


Figure 7.6: Investment vs GHG emission savings[30] in 2030

7.5. Policy Suggestions

1. Diversification to climate change finances such as Global Environment Facility, Special climate change fund, Least developed countries fund, Bilateral and multilateral sources and other sources for climate action in the State.
2. The state should explore more funds towards carbon trading under clean development mechanism for afforestation programmes, developing clean technology, and adaptation programmes.
3. The State needs to allocate budget exclusively for climate change mitigation and adaptation with allocation of at least 5% or Rs. 90,000 crore of State budget of Rs 18,05742 crore.
4. The State specific climate change mitigation and adaptation programmes should be prioritised over department wise schemes and programmes of forest, watershed and agriculture departments, and so on.
5. The circular economy principles of reduce, reuse and recycle should be given importance with financial allocation.
6. There should be a separate chapter on " Sustainable Development and Climate change" in Economic Survey of Karnataka as is in case of Economic Survey of India to clearly focus and review policies and budgetary allocations for climate mitigation and adaptation.

[30] GHG emission savings between policy and base scenario

Apart from implementing the mitigation actions, it is necessary to monitor the progress of these activities and verify the consequent savings. Robust mechanisms—to monitor and verify mitigation efforts, and to report and manage the data—should be implemented parallel to these activities by the state.

Prioritised mitigation actions and potential sources of finance

Sector	Prioritised Activity/ Programme/ Project	Potential source of finance
Power	Additional solar ground-mounted projects by 2030	• Increase private-sector partnership • Adopt funding mechanism similar to CDM[1] benefits • Disburse funds collected as Green Energy Cess (INR 0.05/kWh) from 2016 for activities to decarbonise the energy sector • Use funds from Central budget
	Additional solar rooftop PV (RTPV) projects	
	Additional wind power–based projects by 2030	
	Reduction in T&D loss	• Funds from central budget • UDAY bond scheme
	Renovation and modernisation of Raichur thermal power plant (units 4-7)	• KPCL funds • TPP recovers R&M cost in tariff
Transport	Enhancing charging infrastructure across the state	• Department of Heavy Industries, GoI • State budget allocation under the State EV Policy
	Enhancing public-transport mode share by: • Improving planning and scheduling • Improving and managing fleet size	• State budget allocation
Industry	• Improving energy efficiency across industries, including those not covered under the PAT scheme	• Department of Industries and Commerce, Karnataka
Agriculture	• Mapping of non-functional agricultural pumps • Strict monitoring on implementation of energy-efficient pumps for new connections • Installing smart panel EE pumps to measure the electricity consumption • Continuing the subsidy scheme to promote solar-pump installation	MNRE KUSUM funds allocated to the state
Forestry	• Afforestation • Agroforestry	Karnataka Forest Department through bilateral funding and REDD+ projects

Chapter 8: Institutional Mechanism for SAPCC Implementation

8.1. Context

The Global Climate Change Arrangement, as committed by the Nation-States, under the Paris Agreement, 2015, is expected to limit the increase in the global temperature to well below 2°C preferably to 1.5°C above pre-industrial level. Several strategies for mitigation and of adaptation to Climate Change are put in place to operationalize the commitments. Under this agreement, India has committed to reduce Green House Gas (CHG) emissions intensity of its GDP by 30-35%, increase non-fossil fuel power capacity to 40% from 28% and add carbon sink of 2.5 – 3 billion tonne CO_2 by increasing the forest cover, all by 2030. In pursuit of the goals so set, the undertaking by all the Parties is to develop their own National Action Plans. India, being a Party to all climate agreements has evolved its own National Action Plan on Climate Change (NAPCC), comprising eight missions dealing with different aspects of Natural Resources Governance and activities of Development. Following this, the States have developed their Action Plans. Karnataka State Action Plan on Climate Change (KSAPCC) is one among them. This serves as the primary policy document and strategic Action Plan, at the sub-national level, to address vulnerabilities and increase resilience.

Alongside this development, India has taken the leadership in stitching a Global Solar Alliance among Nations, the working of which would significantly contribute to achievement of the goals of the Climate Change Agreement. With the industrialised and the Developed world demonstrating greater reluctance in owning up responsibility for historic emissions and also not being very enthusiastic in conforming to the spirit of Climate Justice and Equity under the UNFCCC, the much-needed support, cooperation, technical and economic assistance for the Developing world have become a chimera. Under the circumstances, by developing green technological options and evolving clear strategies for systematic reduction in the reliance on fossil fuels over time, India has emerged as a shining example and Global Leader for the Developing World, in their march towards achieving the goals of the Paris Agreement.

8.2. Need for an Organised Governance Structure

As contemplated in the national and state action plans, both the Centre and the States have to carry out the sector-wise Implementation of the action plans through their respective Ministries and Departments. Without doubt, this is the logical way of going about the task. However, in actual performance and achievements in different sectors, the approaches adopted at present have not been able to have the same focus and intensity to match the expectations. The real challenge to this wonderfully designed and painstakingly developed action plan has been that the cumulative outcome and impact of the efforts of all the Missions have so far not been able to lead to the goals in a structured manner. In most of the States, SAPCCs have functioned as stand-alone documents with limited recognition of the activities of other line departments. The need for integration is being increasingly felt to bring forth collective climate action. Need for greater clarity of vision at further de-centralised governance system is also experienced. Districts and cities still largely remain unconcerned with climate action. Capacity building, therefore, needs a greater focus. Building institutions and structures are crucial components of capacity building. The problems and the resultant need for evolving an institutional mechanism to act as driver to achieve the goals may be summed up as below:

(a) *Coordination*: Absence of organic coordination in the working, both within each unit in a sector and among different sectors, has often resulted in repetitions, overlaps and even conflicts. There is thus the need for creating an enabling environment for bringing in harmony, unity of purpose, exchange of information and cooperation, besides integration in functioning among all the players.

(b) *Information Gap*: Authentic, reliable, usable, updated information, about possible adverse impacts of climate change at local level and the measures taken/contemplated for mitigation, adaptation etc. are either absent or available in bits and pieces in an unorganised manner. Need remains for evolving a mechanism and facility for generation, collection, collation, consolidation and dissemination of the required information and its integration in the existing system of governance at all levels.

(c) *Resilience and Capacity-Enhancement*: The requirement of a clearly focussed and professionally equipped arrangement that can address, ameliorate and effectively respond to the cataclysmic impacts of climate change cannot be overstated. This is in addition to absence of either the focus or the wherewithal in the existing system to prepare and enhance the capacity of communities of people, who get directly affected by the phenomenon. Obviously, there is an imperative need for the internalisation of this important component of Climate Action within the existing system, and as an aspect of the lives of communities of people, most vulnerable to the adverse impact of Climate Change. Further, tying up with Academic and Research Institutions and to collaborate with them to build and enhance the capacity of enforcement of both the communities and the institutions should be the integral part of such an endeavour.

(d) *Policy Oversight and an Institutional Arrangement*: Excepting the Action Plan, the overarch of guidance in the working or in monitoring performances is very thin. It requires, besides lending a helping hand in every conceivable way, to support, strengthen and to ensure that the sectoral units reach the targets set for them. Need exists for having a Steering Body at the apex level to guide, aid, enable, enhance capacity, monitor performance, effect midcourse corrections and for conflict resolution. Every new initiative, as a rule, results in creation of a new bureaucracy. Innovative approach is the need of the hour that would integrate the KSAPCC objectives into the working of the current system and the schemes of governance and infuse the spirit of cooperation among the components, in information gathering, sharing, and in putting them into application in a concerted way.

8.3. Design, Content, Structure and Functions of The Proposed System of Climate Governance

In the design for the proposed architecture of climate governance, the following ideas form the basis of recommendations.

Executive Guidance: 'Institutional mechanism' or 'Institutional arrangement' for implementation of SAPCC has necessarily to be Government centric and is to be driven by Government functionaries. However, the nature and magnitude of the problems arising due to changing climate encompasses every aspect of human life and its endeavours. Hence, it should be appropriate that Adaptation and Mitigation actions that internalize every conceivable human intervention impacting the environment gather mass and momentum over time to become a mass movement in which every segment of society and each individual participates with full commitment, preparation and preparedness.

Participation of people's representatives: It would be necessary and appropriate to include and induct the people's representatives both as collaborators and responsible owners of the enterprise. Their involvement with full understanding of the issues involved will remove many misunderstandings and misgivings leading to cooperation and support at various levels of society and government. This participation should be ensured at all levels with the Chief Minister taking lead at the State Level. At district level and city civil bodies, all directly elected people's representatives should participate.

Village level participation: The villagers need to be educated about the impacts of changing climate and need to be educated as how they can not only counter ill effect but can also convert this into an opportunity. Their input in decision making and participation in programmes would be of utmost importance. Panchayat Raj System should be geared up, over a period of time to play a big role in this endeavour.

8.4. Blue-Print of the Architecture of Climate Governance

On the basis of the set of recommendations that emerged from the assessment of need for evolving a mechanism of governance and the consultations that followed, a function-driven five tier governance mechanism is suggested as below:

Figure 8.1: Governance structure

8.5. The Levels of Governance

The following are the proposed details of the composition, functions, roles and responsibilities, at each level of governance (Figure 8.2):

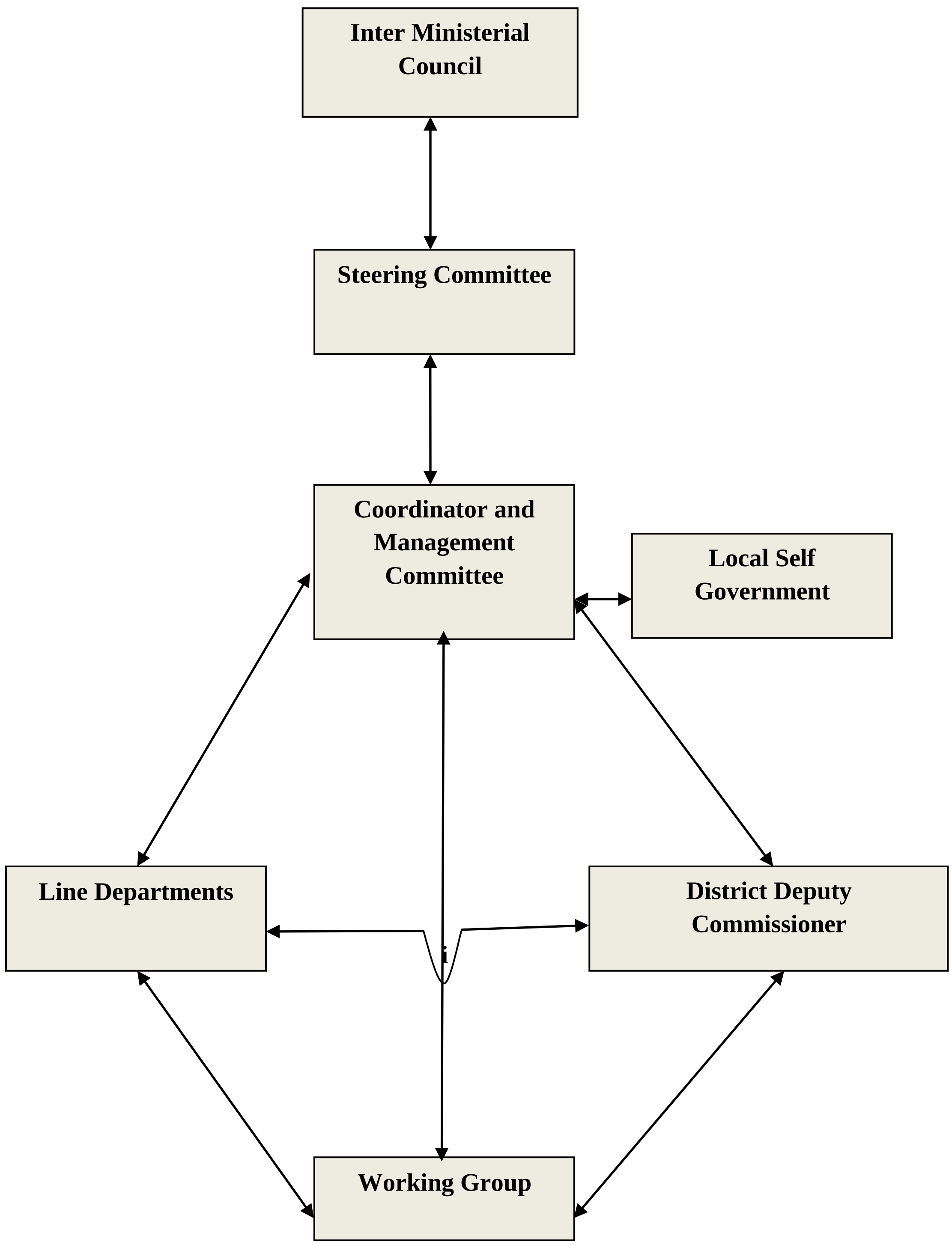


Figure 8.2: Architecture of governance and working mechanism

Apex Level: Interministerial Council

This council is headed by the Chief Minister as its Chairperson and comprising the ministers of related subjects like, Forests Environment & Climate Change, Agriculture; Science & Technology, Information Technology, Energy, Transport, Industries, Water Resources and Urban Development as its members with Addl. Chief Secretary, (Forests, Environment & Climate Change) as Secretary to the Council. The Chief Minister may invite and include as many Ministers as he considers appropriate. It should provide Policy guidance, support and outreach, give approvals for the annual budget, take stock of the progress and decide upon future courses of action. The Council should evolve its own procedures for the meetings and, at its discretion, meet as many times as deemed necessary but at least once a year.

> **Apex Level Interministerial Council**
>
> (The Guardian Angels)
>
> 1. Chief Minister of Karnataka :: Chairperson
> 2. Minister for Forests, Environment & Climate change
> 3. Minister of Agriculture
> 4. Minister for Science & Technology (including Information Technology)
> 5. Minister for Energy
> 6. Minister for Transport
> 7. Minister for Industries
> 8. Minister for water Resources
> 9. Minister for Urban Development
> 10. Any other Minister to be included by the Chief Minister

Top Level: Steering Committee

This is the Brain-Trust and the primary driver of the entire Climate Action Plan. It steers and guides all the concerned institutional arrangements and activities. It sets the vision, mission and direction for action and compliance.

i) Composition: A Thirteen -member body that would have seven representatives from the government, five expert members and a Member Secretary.

- From the Government: The highest in the Bureaucracy representing the government i.e., Chief-

> **Top Level – The Steering Committee**
>
> (The Brain trust & Primary drivers)
>
> 1. Chief Secretary / ACS/Development Commissioner: Chairperson
> 2. Six Additional Chief Secretaries (or Principal Secretaries) of the relevant Departments to be nominated by the Chief Secretary.
> 3. Five Expert Members :
>   a. Expert in Climatology/Meteorology/Sustainable Technologies
>   b. Environmental Economist
>   c. Ecologist
>   d. Law Expert
> 4. Director General, EMPRI :: Member Secretary

Secretary/Development Commissioner/Additional Chief Secretary, as the Chairperson along with 6 Additional Chief Secretaries, (or Principal Secretaries, as the case may be) of the relevant departments.

- Five Expert Members, drawn from the following fields :
  a) Expert in Climatology/Meteorology/ Sustainable Technologies;
  b) Environmental Economist;
  c) Ecologist:- who has experience and expertise in eco-system conservation and management, Research and Extension;
  d) Law Expert- on environment, natural resources, climate, energy and the like. He should also have expertise of international and comparative law.
  e) Member Secretary: Director General, EMPRI
    - The Committee may co-opt as many members at their discretion for their aid and advice. The participation of the Heads of the Departments, whose programmes are listed for discussion in the agenda, can be extremely useful.

ii) Functions: The committee will perform multiple functions encompassing:

a) *Policy-making*: frame policies and issue guidelines.
b) *Decision-making*: making financial allocations; making policy-choices about introduction/employment/initiation/continuation of a particular course of action/strategy/plan of action/device/technology etc.
c) *Approves Action Plans*: By perusing those submitted by the Coordination and Monitoring Committee. Reviews, revises and refines them, and takes a call on approvals, following which the obligation of implementation and compliance rests with those engaged in related activities; it may also commission consultants to carry out appraisal of an action plan.
d) *Administrative directions & Instructions for compliance*: Issues instructions and directions for implementation and compliance.
e) *Control:* Fixing administrative accountability and liability, for administrative lapses/over-reach/poor implementation etc., or for non-compliance/evasion by those respondents having such an obligation.
f) The Steering Committee will have two additional functions to perform, namely, Coordination and Reporting to Government of India and aligning Climate Change actions with Sustainable Development Goals (SDGs).

Middle Level: Coordination and Management Committee

The cacophony that exists in the compartmentalized functioning with each department operating in isolation is sought to be overcome with this arrangement at the middle level so as to bring in the much-desired alignment and coordination in the working of different agencies of the State.

i) Composition: This is proposed to be a eighteen-member body drawn from Government, autonomous institutions, Civil Society organisations, industry and service sector.

1-10: Addl. Chief Secretary/Principal Secretaries of : Revenue Administration; Urban Development, Rural Development and Panchayat Raj; Water Resources; Agriculture

(including Horticulture and Animal Husbandry), Environment and Forests(including Wildlife & Biodiversity), Industry, Science & Technology (including Information Technology), Energy and Law.

(Senior most Additional Chief Secretary shall be the Chairperson of the committee)

11. Transport Commissioner

12. Chairman Pollution Control Board

13. Chairman, Biodiversity Board

14. Planning & Development Expert

15. An expert on Environment, Ecology, Sustainable Development, Environment-friendly Industrial Applications/Service Provider

16. An expert representative from Civil Society Organisation

17. A Management Guru, having expertise in a wide range of sectors. They can be drawn from Management Institute of national eminence, or Administrative training institutions or the like.

18. Director General, EMPRI: Member Secretary

Coordination and Management Committee:

1. Senior most Addl. Chief Secretary from among those listed in para 2 below - Chairperson
2. Addl. Chief Secretary/Principal Secretary of
   a. Revenue
   b. Urban Development
   c. RD & PR
   d. Water Resources
   e. Agriculture (including Horticulture & Animal Husbandry)
   f. Environment & Forests & Climate Change
   g. Industry
   h. Science & Technology
   i. Energy
   j. Law
3. Transport Commissioner
4. Chairman Pollution Control Board
5. Chairman – Biodiversity Board
6. Planning & Development Expert
7. Expert on Ecology, Environment & Sustainable Development
8. Expert from Civil Society Organization
9. A Management Guru
10. Director General, EMPRI – Member Secretary

The non-official members of the Committee will be nominated by the chairperson of the Committee, who at their discretion may associate domain experts of repute, for their aid and advice. Association of Departmental heads, when their plans are being discussed would be of great value.

ii) Functions: This is the Executive Body that gives the oversight, guidance and assistance, besides monitoring compliance. The following are its primary functions:

a) *Coordination:* irons out points of conflict, overlaps and handles jurisdictional questions;

b) *Facilitates* cooperation and collaboration: among different agencies of State to ensure Climate change mitigation, adaptation and resilience, in each of the sectors of governance;
c) *Promotes* civil society and community participation and partnership with the concerned departments and administrative units;
d) *Capacity* enhancement- in the understanding and skills of application of proposed and strategic plans of activities and implementation by organising and conducting Training Programmes, at periodic intervals and by providing the needed technical assistance and support;
e) *Monitoring:* provides the oversight and carries out functions of vigilance over the planning, implementation and reporting of the programmes of action, by the concerned departments and compliance by those who have the obligation of conforming to the regulations and periodic reporting about the progress made by them;
f) *Receives* complaints and attempts to resolve potential conflicts by adopting alternate dispute resolution mechanisms. This is the first level of addressing grievances, resolving conflicts and evolving consensus;
g) *Enables* the concerned departments and agencies to get equipped with the information base, its retrieval, use and application;
h) *Carries* out networking activity with research institutions, service providers, experts and consultants and acts as a conduit between the State agencies and the above mentioned ones;
i) Constitutes Working Groups for preparation of action plan in the areas of concern;
j) *Receives* reports and action plans for different sectors and also from the working groups, constituted for the purpose by it, peruses the same and accords approval. The Committee at its discretion may submit some of the action plans to the Steering Committee for taking appropriate decisions under this arrangement;
k) Irons out conflicts in inter-district programmes;
l) Associates districts through district Deputy Commissioners in overall coordination at district level and in carrying out sensitization programmes on climate issues. The Deputy Commissioner should ensure participation of people's representatives and Panchayat Raj Institutions at district and village level. The targets for each district are to be set and reports reviewed.

Working Groups

Three working groups are envisaged, and they include:

(a) Adaptation Working Group: This should look into every aspect of adaptation which may include development of policies and preparation of action plans for promoting adaptation. It should suggest measures to ongoing programmes (if any) to cope with a changing climate. The sectoral programmes on adaptation should be properly formulated by this working group.

(b) Mitigation Working Group: The should look into all aspects of mitigation and may include development of policies and programmes for mitigation. Like the working group on

Adaptation, this group should also examine ongoing programmes that may be going contrary to the principles of mitigation. The sectoral programmes on mitigation should also be stitched properly before obtaining final approval.

(c) Research Training & Extension Working Group: This Group will develop programmes of need-based research and training in coordination with other research and training institutes and international bodies. The programme for extension activities will also be developed by this working group and it will also suggest linkages with already existing extension wing of various departments and the Government agencies.

The working groups should remain in regular dialogue with respective departments who implement the programmes.

Functions of Working Groups

a) These working groups would require a lot of institutional support in 'Advance forecast and early warning of extreme events' and its communication to department and farmers. A lot of research at global level is going on in this regard. In order to take advantage of all such research and also to strengthen and upgrade their own research capabilities, the working groups will envisage every leading research institution in the state viz. the agricultural universities, Indian Institute of Science, Engineering and Medical universities etc. which should be encouraged to establish a multi-disciplinary cell in their Institution. These cells should identify and collate the emerging information at global level and tailor it to Indian and State requirements. They should also initiate research to fill the gaps and also take up the demand driven research besides encouraging fundamental research according to their own wisdom. The outcome of their efforts should feed on to the activities of the Working Groups.

b) All the three working groups will submit their programmes and reports to Coordination and Management Committee for approval and further action. They may also seek advice and guidance from the Committee, wherever needed.

c) These working Groups would carry out their activities under the aegis of EMPRI, with secretarial and logistic assistance by it and one of its officers to act as the Member Secretary. Their composition, on behalf and with the approval of the Coordination and Management Committee, would be determined by EMPRI. The officers from EMPRI may brief the working groups about the thought process and understanding which has gone into making of SAPCC so that the working groups do not deviate from the central theme of SAPCC.

d) The Coordination and Management Committee may constitute more working groups depending upon the need and may discontinue them when the requirement is met.

Implementation Level: Sectoral Units

A cell in each implementing organisation will be constituted by the Chief Executive of the Department (CEO) with the existing manpower for this purpose, the units of local self-Government like City Corporation or Municipalities should be treated as a department. The principal cell would function directly under the CEO and will report to him. The suggested departments may include sectors like, Revenue Administration; Urban Development, Rural Development and Panchayat Raj; Water Resources; Agriculture, Horticulture, Animal Husbandry, Environment and Forests, Industry, Science & Technology (including Information Technology), Energy, Transport, etc. This is the Unit that ensures implementation of the Approved Action Plans and programmes by the related sectors. These action plans can be developed by sectoral units themselves or may come from the working groups. They would consistently ensure that policy-decisions, programmes and action plans are implemented and periodical reports are placed before the CEO about the status of implementation and compliance. This cell within each sector would collect from each section their proposed Plans of climate action, consolidate them and submit, as the proposed Action-Plan including those suggested by the working group of the concerned sector, to the Coordination and Management Committee for its consideration and approval. It shall act as the repository of everything concerning Climate Policy and action pertaining to the sector and make the same available to the higher level of governance, whenever required. Besides collecting data and preparation of action plan for their respective departments, they should also analyse the extent up to which their various regular activities and programmes affect the climate change issues directly or indirectly. They may also keep on finding the ways and means to reduce any short- or long-term adverse impact of their programme on climate. If the adverse impacts cannot be mitigated within their departmental programme itself, they may have to find other means to offset the same.

The formulation of the annual action plan for Climate change should begin one year in advance and the whole year should be devoted on collection of data, processing the same and arriving at programmes. The departments should also look for agencies of implementation and fixing a system for monitoring, evaluation and mid-term course correction during implementation of the programme. The programmes which are likely to run for more than a year should also be properly reviewed and milestone for the year should be fixed.

District Level Implementation (Figure 8.3)

Many or rather most of the programmes are implemented at district level. Hence, a proper arrangement in every department in the district with a coordination committee at district level needs to be set in place. It is therefore suggested as follows:

a) The Head of Department and departmental climate change cell, in consultation with their District Level officer should arrive at the annual programme for the district. They should also fix quarterly mile stones and subject the same to a review at appropriate intervals.
b) The annual programme with quarterly mile stones of each department should also be communicated to the Deputy Commissioner of each district who should discuss the matter as one of the subjects in the District Coordination Committee meetings and resolve any issue which requires inter departmental coordination or needs support from the district administration. The cross sectoral programmes may also be discussed

in this meeting and necessary instructions can be issued to the District Level Officers and their subordinates.

c) Every year one or more workshops should be organized, in the beginning of the year, inviting people's representatives at various levels and the district level officers including those from Zilla Panchayat to brief them about climate issues and the proposed measures to combat them. Their views should be heard and incorporated to the extent feasible.

d) The involvement of the Zilla Panchayats and Gram Panchayat is very much necessary for implementation of certain measures like optimum use of fertilizers, prevention of unnecessary burning of organic matter, excessive use of irrigation, prevention of open air defecation etc. Therefore, a training cum sensitization programme needs to be undertaken for Zilla and Village Panchayat members sensitising them on the long and short term consequences of possible changes in climatic condition and how communities can gear up to the challenge. The district administration led by the Deputy Commissioner should have this responsibility who at his discretion may enlist support of district officers and experts for the purpose. The Deputy Commissioner will be advised appropriately by the C & M Committee in this regard.

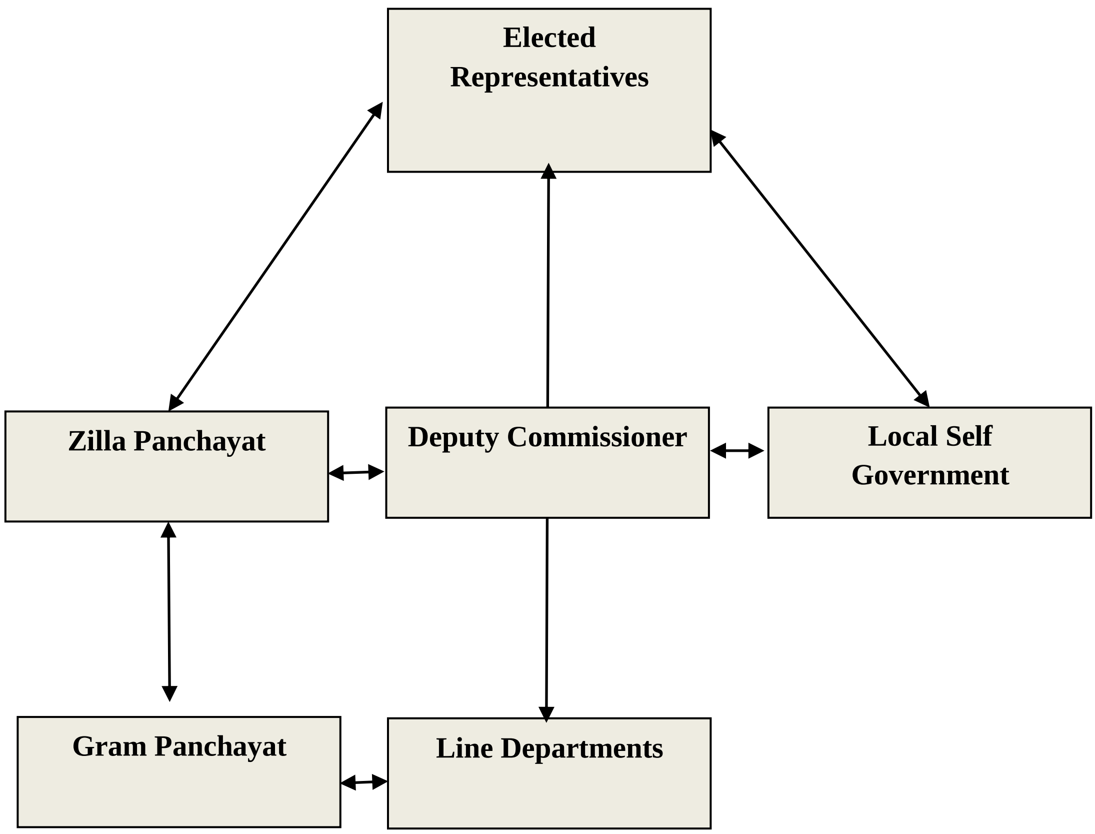


Figure 8.3: District level implementation arrangement

8.6. The Future Arrangement

The present proposal is to accommodate the concerns of a wide range of population and interest groups. The arrangement is strong enough to withstand the changes which will be taking place with the onset of future Action Plans. At the same time, its flexibility allows changes with ease with new learnings and experiences coming in. The arrangement will be required to be fine-tuned at regular intervals so that it works as an organic entity.

8.6.1. Implementation plan for energy and transport sector mitigation plans

In this section, an implementation plan for mitigation actions in the energy and transport sectors is presented.

Power

To increase RE-based electricity generation in the power sector via solar (ground-mounted and RTPV) and wind, the state should focus on addressing regulatory uncertainties, lack of grid infrastructure in wind-energy zones, and land availability issues. To reduce regulatory uncertainties, KERC and DISCOMs need to conduct a detailed impact assessment before making significant regulatory changes. Fixing the wheeling charges and other transmission cost from the beginning till the end of useful life of the project would help in reducing regulatory uncertainties. The grid infrastructure in wind-energy zones has to be developed to promote wind-based electricity generation. Activities similar to the current power-evacuation programme in Koppal need to be developed in other wind-energy zones (CEA, 2018).

The land-availability issues in RE installation can be managed by leasing/buying land from farmers under the Karnataka Land Reforms (Amendment) Ordinance, 2020. Mapping wind zones and solar potential of undulating topography, semi-arid regions, poor cultivation, and uncultivable land will help in identifying the potential land for RE installations.

Re-powering of existing wind projects will facilitate the optimal utilisation of wind-energy zones. As per the Indian Wind Power Directory 2017, the state has repowering potential of nearly 534 MW (Idaminfra, 2018). Repowering of existing wind projects will allow optimal utilisation of wind-energy zones.

For promoting RTPV, we need wide promotion of third-party investment models, which do not negatively impact DISCOM finances. Apart from this, city-level resource-potential assessments (similar to CSTEP's study on LIDAR-based RTPV potential estimation) in Bengaluru can be expanded to cover other cities.

Meanwhile, T&D loss reduction necessitates regular maintenance and accuracy checks of feeders and DT meters, and energy audit of DT centres. Regarding the financial barrier to improve energy efficiency, KPCL should continue allocating funds for their TPPS activities to improve energy efficiency in its plants. Securing new coal-supply linkages would help in reducing coal-availability issues.

Transport

To improve the uptake of EVs (both public and private), the state government needs to overcome key barriers on both demand and supply fronts. The Karnataka State EV and Energy Storage Policy has created a favourable environment to stimulate investment in EV production. Low-interest loans and SGST reimbursement, discounts on registration charges, stamp-duty exemption, and electricity-tariff discounts are some of the measures leading to this favourable policy climate. These measures could be combined with mandates to produce and sell a certain number of EVs, based on the manufacturers' share of conventional-vehicle sales in the state. Additionally, creation of expert working groups and consortiums with industry leaders and veterans would help in the expansion and improvement of EV manufacturing infrastructure. This would play an important role in supporting the EV industry.

On the demand front, to accelerate EV deployment, demand-incentive schemes and tax breaks can be complemented with vehicle-replacement subsidies and low-interest finance mechanisms. Such measures will encourage early retirement of old inefficient vehicles and a transition to EVs. Additional measures such as enhanced taxes for purchase of conventional vehicles can also nudge buyers towards EVs.

In the public-transport fleet, EV buses should be procured and deployed in stages; it will help mitigate the risks associated with implementing a niche technology and provide public transport utilities flexibility to absorb future technology and policy breakthroughs. To enhance the development of charging-infrastructure network, policy regulations such as amending building codes to integrate charging infrastructure and authorising utilities to install charging stations at state-owned facilities with targets would be needed.

Industry

The implementation of subsector-wise SEC reduction targets would be feasible when implemented in a phased manner (as followed in the PAT scheme). The plan for incorporating the SEC-reduction targets at the state level would first require the establishment of sector-wise energy consumption baselines based on the energy consumed in each industrial unit. This would require an energy audit of all manufacturing plants in each sector, and their technical and financial feasibility needs to be determined. Based on the various parameters, the SEC-reduction targets will then be set after consultation with Department of Industries and Commerce and KREDL.

Agriculture

There needs to be a monitoring mechanism to ensure adoption of EE pump sets and enforcement of the Ganga Kalyana scheme, to avoid re-winding of old pumps resulting in inefficiency and high costs to the government in the form of power subsidy. An implementation mechanism similar to the Domestic Efficient Lighting Programme (DELP) can help in greater market integration of EE pumps (FICCI, 2017).

For the successful and widespread implementation of solar pumps, awareness drives can apprise farmers of the benefits (such as longer lifetime, lower maintenance cost, and possible remuneration through feed-in tariff), encouraging them to make the switch (FAO, 2018).

The existing state power infrastructure has spare capacity to support dedicated agriculture feeders powered by solar panels of capacity up to 2 GW[31]. Given this, the solar-feeder connected to EE pumps can be considered a prioritised mitigation activity for the agriculture sector.

Table 8.1. provides the broad implementation plan for the state for the various mitigation actions discussed above.

Table 8.1: Sector-specific (programme/project-specific) implementation plan and arrangements

Sector	Prioritised activity/programme/ Project	Implementation department/agency	Enabling arrangements to promote implementation of proposed activities
Power	Additional solar ground-mounted projects by 2030	Energy Department and KREDL	Addressing regulatory uncertainties, lack of grid infrastructure in wind-energy zones, land-availability issues, and re-powering wind projects
	Additional solar rooftop PV (RTPV) projects		
	Additional wind power–based projects by 2030		
	Reduction in T&D loss	KPTCL, DISCOMs	
	Renovation and modernisation of Raichur thermal power plant (units 4-7)	KPCL, KREDL	
Transport	Enhancing charging infrastructure across the state	DISCOMs	• Tariff rationalisation for EV charging • Updating building codes to integrate EV charging infrastructure
	Enhancing public-transport mode share by: • Improving planning and scheduling • Improving and managing fleet size	Transport Department, State Road Transport Corporations	• Review and adopt best practices implemented in other transport corporations • Streamline key operational processes using technology-enabled solutions
Industry	• Improving energy efficiency across industries, including those not covered under the PAT scheme	KREDL, Karnataka State Small Industries Development Corporation Ltd. (KSSIDCL)	• Monitoring of EE measures and key indicators in industries (large and MSMEs) • Capacity building for creating and maintaining a data repository of production and energy consumption in industries

[31] Based on expert consultation

Agriculture	• Mapping of non-functional agricultural pumps • Strict monitoring on implementation of energy-efficient pumps for new connections • Installing smart panel EE pumps to measure the electricity consumption • Continuing the subsidy scheme to promote solar-pump installation	KREDL, Department of Agriculture	• Awareness campaigns for farmers

Chapter 9: Monitoring and Evaluation

Climate change is a problem in so far as it is deeply complex, intractable and resistant to solution. It threatens to reverse the gains made towards sustainable development. India's GDP being closely associated with climate sensitive activities is very vulnerable to climate change. Climate change poses an unprecedented threat to the life and livelihoods of billions of people. Huge investments are made worldwide on adaptation and mitigation strategies. It is necessary to ensure that the measures taken work well. Proactive plan for future climatic conditions is the need of the hour. It is essential to understand where to focus investments, what is working, what is not and how to minimise the change and maximise the impact of adaptation and mitigation.

Climate change has created positive and negative socio-economic impacts at the global level. However, in the Indian context, climate change has always had negative impacts on all sectors including agriculture, forests & biodiversity, fisheries etc. Socio-economic vulnerability components, which are important, are the determining factors of the ability to adaptation to climate change impacts across various sectors. Climate change impacts are inter- sectoral and call for interdisciplinary action.

The Ministry of Environment, Forest and Climate Change (MoEF&CC) had directed all the states in India to prepare their State Action Plan on Climate Change (SAPCC). The first Karnataka SAPCC was prepared in 2015. Since India announced its nationally determined contributions (NDCs) at United Nation Framework Convention on Climate Change (UNFCCC) in 2015, all Indian states have been asked to revise their SAPCCs in line with India's NDCs.

The state action plan is drawn incorporating climate change interventions without compromising on the state developmental goals so as to derive co-benefits as envisaged by the NAPCC. The scope and nature of actions are chiefly confined to mitigation options. As the state is already experiencing increased occurrence of floods and droughts, some adaptations are proposed. Intervention areas include renewable energy, energy efficiency, water management, agricultural resilience, afforestation, waste management and public transport. The state departments, institutions and other agencies so far have monitored and evaluated adequately many developmental projects of mitigating and adopting nature in the context of climate change.

The state of Karnataka is ranked 10th in its contribution to the national gross development product (GDP) in 2017-18. Bengaluru, Mysuru, and Mangaluru are few of the key cities in the state. Karnataka is one of the leaders in the Information Technology and Biotechnology industries. In 2015-16, service sector contributed 66% of the state GDP, followed by manufacturing (23%), and agriculture sector (11%). The energy demand in the state has been increasing due to increasing population, urbanisation, and industrialisation. The greenhouse gas (GHG) emissions in the state increased from 64 MtCO2e in 2005 to 98 $MtCO_{2e}$ in 2015 at a cumulative annual growth rate (CAGR) of 4.4%. (http://www.ghgplatform-india.org/)

Monitoring and evaluation (M&E) is an evolving system. There are challenges and difficulties in M&E starting with definition of a successful project. Due to the long-term nature of climate change, assessment of progress of a project over a relatively shorter period of time is rather difficult. Besides, adaptation interventions occur against the background of evolving climate. Traditional approaches to M&E need to be modified to meet the needs of adaptation programs. Adaptation is a form of risk management mostly local or regional like dealing with extreme weather events, natural disasters, habitat conservation, agricultural policy etc; Monitoring and evaluation are key stages in adaptation process to demonstrate effectiveness and accountability. Selecting specific, measurable, attainable, relevant and time bound indicators and linking them to objectives is important as time-frames associated with climate change are likely to be longer. Continually changing climate means traditional approaches to measuring change like comparing to static baseline conditions is not possible. Mitigation of climate change impact refers to dealing with causes.

In natural systems, adaptability depends largely on the rate and extent of change besides natural/inherent resilience of the system. Vulnerability is degree to which a system is susceptible to and unable to cope with adverse effects of climate change including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and its adaptive capacity. Adaptation actions are needed to estimate or reduce the vulnerability of systems to impacts of climate change.

Monitoring generally refers to the systematic and continuous/periodic collection of data, quantitative and qualitative, about progress of project over time. Indicators are markers of progress towards intended results.

Indicators for monitoring can be physical, environmental, social or economic. At various levels and stages, adopting indicators that reflect the process of adaptation is important. It is necessary to set targets/goals. Targets/Goals can be absolute (specific numerical targets) or relative (relative change that is independent of the initial value of starting point).

Reporting along-side monitoring at chosen intervals serves to take stock of the progress. Evaluation involves additional independent data collection and analysis: what results/ outcomes and impact have been achieved, what worked well, what did not, what lessons can be learnt from implementation and how can the design be improved. Evaluation is systematic and objective feedback of a completed or ongoing action aimed at providing information about design implementation and performance, and evaluation methods are determined by the focus, which in turn will determine the approach and is based on assumptions (Table 9.1).

Table 9.1: Types of evaluation

<table>
<tr><th>Methodology</th><th>Focus</th><th>Approach</th><th>Assumption</th></tr>
<tr><td>Input – output outcome evaluation</td><td rowspan="3">Effectiveness</td><td rowspan="3">Elements of adaptive capacity / risk are pre-determined and evaluated against a set of indicators.</td><td rowspan="3">Increased adaptive capacity will ultimately lead to reduced vulnerability / risk.</td></tr>
<tr><td>Process based evaluation</td></tr>
<tr><td>Evaluation of behavioural change</td></tr>
</table>

Economic evaluation	Efficiency	Benefits of adaptation are measured in terms of economic gain / loss.	Ability to determine a baseline of projected benefits or losses.

9.1. Existing Monitoring and Evaluation Strategies and Institutions

In this section, the key programmes and institutions involved in monitoring and evaluation are presented to stocktake existing capabilities and institutions.

1) Energy Sector

In line with NDCs, GHG emission reduction is aimed at in the current efforts by the state. The Department of Energy, Agriculture and agencies such as KREDL have been implementing and monitoring these programmes.

2) Agriculture Sector

Adaptation strategies are under implementation under centrally sponsored schemes like NFSM with improved production technologies including irrigation aspects. Krishi Bhagya scheme is being implemented in Karnataka since the year 2014-15, covering 132 taluks of 25 districts in dry land areas with an average rainfall less than 850 mm from the past 25 years. The main aim of Krishi Bhagya scheme is improving rainfed agriculture with efficient management of rain water and enhancing the farm productivity.

Department of Agriculture, Department of Horticulture and Agriculture universities are the agencies that are implementing and monitoring the programmes.

3) Animal Husbandry

Department of Animal Husbandry is projecting significant livestock vulnerabilities to climate change. It expects the emergence of new diseases. There is a need to conduct in-depth studies.

Climate change is likely to cause loss of 1.6 million tons of milk production by the end of 2020 and 15 million tons by 2050 from current levels in India (moef.gov.in/wp-content/uploads/2017/08/AndhraPradesh-DPR.pdf).

Identification of biomarkers for thermal tolerance and drought tolerance in ruminating animals is a current subject of research. Also, milk yield is highly dependent on the quality and quantity of the feed apart from climate change. Traditional methods of animal feed for obtaining higher milk production are also being explored.

4) Coastal Zone and Fisheries

Both mitigation and adaptation actions are underway in the coastal areas of Karnataka. Decrease in ground water resources due to salinity incursion from sea is of common occurrence. This aspect is monitored by state ground water board and local bodies.

Due to change in the coastal micro climate, increase in vector borne diseases like malaria, dengue, and chikungunya etc. are likely to occur frequently and the State Department of Health and Department of Fisheries are entrusted with researching on this aspect.

Instances of toxic algal blooms and changing/deteriorating coastal water quality consequent on discharge of untreated sewage and effluents in to coastal waters is controlled by establishing STPs and CETPs. Monitoring and evaluating their functional efficiency are entrusted to state PCBs, Coastal Zone Authorities, local NGOs and state fisheries colleges.

Erosion due to sea action, protection of mangroves and sedimentation due to heavy rains in hinterland are the challenges dealt by the CZMA and Forest Department from time to time.

5) Forest and Biodiversity

The INDC target is set for creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030.

The Karnataka Forest Department has been working successfully for raising forest plantations in non-forest lands, farm forestry and raising seedlings. Monitoring carbon stocks is in progress in collaboration with Indian Institute of Science. The Department is also devising strategies for market linked development of carbon sinks. Carrying capacity study of Western Ghats is the need of the hour and is treated as priority. Adequate control measures to minimise forest fires are put in place.

Carbon sink potential by increasing forest and tree cover in Karnataka under the baseline scenario, considering current trends and rates of afforestation in forestlands and agroforestry in 10% of area under rainfed croplands is about 41 $MtCO_2$ by 2030. afforestation and agroforestry promotion, covering all the areas under wastelands as well as rainfed croplands may be needed and this could create a sink of about 218 $MtCO_2$ as against the target assumed at 150 to 180 $MtCO_{2.}$

Karnataka Biodiversity Board, Western Ghats Task Force, Department of Mines and Geology and research institutes are adequately equipped for the task.

Under the purview of Karnataka Biodiversity Board, 3,542 Biodiversity management committees are actively working in conservation, sustainable use and documentation of biological diversity at local levels. A comprehensive bio-resources inventory was developed. In Karnataka 198 pharmaceuticals and 82 cosmetics industries are reported to use bio-resources.

6) Health Sector

Climate change presents risks for human health. Projected increases in temperature may increase the frequency of heat waves, thermal stress, dehydration and influenza. Measuring the health effects from climate change can only be very approximate. Long term strategy in the field is yet to be drawn.

Health of population is also related to socio-economic status. Kodagu, Udupi, Bangalore rural, Ramnagara and Uttara Kannada are socio-economically the most vulnerable districts among all the districts of Karnataka. Belgaum, Tumkur, Mysore, Bellary and Raichur districts are low socio-economic vulnerable in Karnataka. (A Case Study of Karnataka, Monograph 63, Institute for Social and Economic Change, Bangalore. ISBN ISBN 81-7791-161-9.)

Department of Health is monitoring the various programmes and projects in the state.

7) Urban Projects

Any urban project/program is designed with the intention of achieving a number of specific requirements/targets like accessible health care, rainwater harvesting, artificial ground water recharge, drainage, etc. Sewage treatment is monitored by KSPCB. Inadequately maintained storm water drains coupled with heavy rain in short spells causing flooding of urban areas is a concern. All the above aspects are being addressed by the Government of Karnataka.

Urban greening: Under this scheme, flowering and fruit bearing trees are planted in urban areas. Tree parks and avenue plantations are established in cities and towns of the state. Supply of seedlings to the residents of urban areas by the Forest Department, urban local bodies and NGOs is also one of the activities under this scheme.

8) Ground Water

Karnataka has approximately 6% of the country's total surface water resources with total catchment area of 191,773 sq. km. However, it is the second most arid state after Rajasthan with 19 out of 30 districts considered drought prone. Ground water sources provide for about 45% of the state's irrigation.

Groundwater systems are critical to climate-change adaptation and require appropriate structural and non-structural management if they need to sustain a growing population. BWSSB has made rain water harvesting (RWH) structures mandatory for new buildings on sites measuring 1200 sq ft and above and existing sites of 2400 sq ft. Within a time span of two years, 25,000 RWH structures have been established which is 43% compliance. The Department of Panchayat Raj and Rural Development has created close to 56,000 ground water recharge structures, and around 1,000 roof top rain water harvesting structures. Watershed Development Department is also implementing some projects. The Department of Mines and Geology has established 1200 ground water recharge structures.

Ramthal Project is one of the largest drip irrigation projects in the world located in Hundgund Taluk of Bagalkote District. This community drip irrigation project, apart from addressing socio-agronomical aspects, providing capacity building and agronomic support in the region, also seeks to link farmers with markets under the Drip-to-Market Agro Corridor (DMAC) executed by Megha Engineering and Infrastructures Limited (MEIL).

Shiggaon Lift Irrigation Scheme is a state commissioned sprinkler irrigation system in Savanur Taluk where 1.5 tmcft of water is diverted from a diversion weir constructed across the Varada, a tributary of the Tungabhadra River to irrigate 9,900 hectares of land. The project aims at improving yields through reduced crop loss due to erratic, unreliable or insufficient rainwater supply and the possibility of multiple-cropping, which results in a higher annual output. A number of water conservation/harvesting works have been completed under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS). The state has successfully implemented several projects and is continuously monitoring and evaluating costs and benefits.

9.2 Proposed Monitoring and Evaluation Strategy and Institutions

Several new programmes and strategies have been proposed for the different sectors, and the institutional arrangement for the same have also been proposed in this Action Plan. Here broad monitoring and evaluation strategy and institutions for monitoring are detailed for each sector.

Energy Sector

INDC includes the following goals for energy sector.

1. To reduce the emissions intensity of GDP (Gross Domestic Product) by 33% to 35% by 2030 from 2005 level through mitigation efforts across various sectors".
2. To achieve about 40% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030".

In line with NDCs, GHG emission reduction is aimed at in the current efforts by the state. Solar ground-mounted capacity is to be augmented by 7.4 GW and Solar roof-top-mounted capacity by 3.2 GW. Besides, wind power is to be augmented by 3.3 GW. Saving T & D losses to possible extent is also projected. To lower the agricultural consumption, energy efficient pump-sets, setting up of biogas plants, solar photo voltaic cells for IP sets are proposed. KREDL will be the implementing and monitoring agency, and evaluation is undertaken by the Department of Energy and the Department of Agriculture, GOK. Encouraging the use of electric vehicles and providing necessary infrastructure of charging stations will be implemented and monitored by the State Transport Department.

Agriculture Sector

Projections of climate change at the district level are available now. But agriculture planning may require block level projections. The same has also been prepared by Indian Institute of Science. This however will have to be incorporated into programmes and policies. Also, the information on spread of pests in agro climatic zones is to be gathered to protect crops. Protecting indigenous climate change resistant varieties by finding suitable market mechanisms are also to be researched. Dry land farming and agroforestry are under research and implementation using biotechnology. Department of Agriculture, Department of Horticulture and Agriculture universities are the agencies that will have to continue implementing and monitoring the programmes.

Animal Husbandry

Establishment of Centre for climate resilient animal adaptation studies is much needed. Initiatives and incentives for preserving indigenous variety will go a long way. Formulating livestock insurance policy and Research on improving stock to reduce GHG from native species are also on state priority list. All these activities are to be implemented and monitored by the state-owned animal breeding and research centres and State Animal Husbandry Department.

Conclusion

The ongoing initiatives in the various sectors in the state are in line with the state's climate change response. Besides, the state has also selected emerging intervention areas in the sectors like Energy efficiency, Renewable energy, Agriculture, Biomass and other areas. Rapid assessment of sectoral actions by 22 state departments preceded the existing action plans. The scope and nature of actions are chiefly confined to mitigation options. There are 13 ongoing actions in agriculture and allied sectors, 10 in water resources sector, 4 in forestry & biodiversity sector, 12 in energy sector, 10 in urban sector and 8 in health sector.

The present knowledge on how climate change is anticipated to impact Karnataka is limited. It is not known exactly where, when and to what degree climate change affects Karnataka. Indicative projections on the range of possibilities are drawn and discussed in various scientific and technical forums and continuous efforts are made to identify required immediate and long-term actions

A comprehensive and coordinated action plan with identified and accepted indicators/parameters is the need of the hour. Integration of impacts, vulnerabilities and mitigation/adaptation strategies is necessary to assess and prioritise the actions in consultation with stake holders. No specific targets or time frames were set forth for many of the actions/plans and were only envisaged because of non-availability of funds. Long term plans/adaptation strategies require further research on data collection, policy formulation and steady flow of funds.

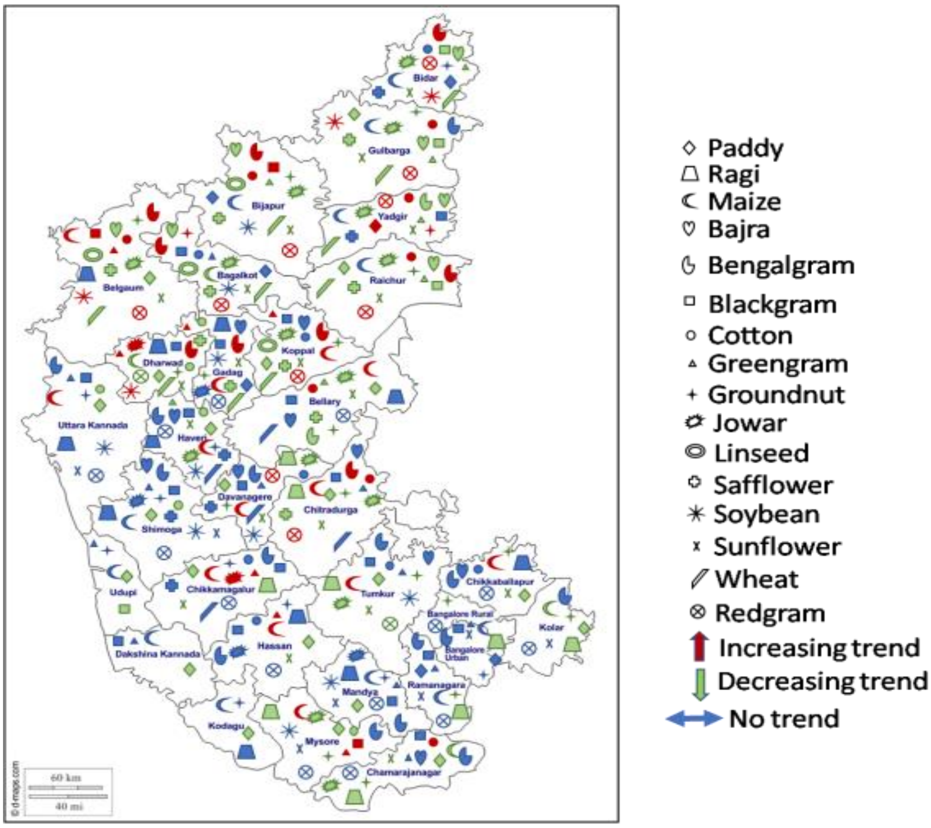
Annexures

Annexure A.1: Major agricultural crops of Karnataka

.	District	Kharif	Rabi	Summer
1	Bangalore (U)	Ragi, Paddy, Avare, Maize	Horsegram	Paddy, Ragi, Maize
2	Bangalore (R)	Ragi, Paddy, Avare, Maize, G.nut, Castor, Niger, H.gram	Horsegram	Paddy, Ragi, Maize,
3	Kolar	Ragi, G.nut, Avare, Maize, Paddy, Castor, Niger, H.gram	Horsegram	Paddy, Ragi, Maize, G.nut
4	Tumkur	Ragi, G.nut, Avare, Maize, Tur, Paddy, Castor, Niger, H.gram, Greengram, Sunflower	Paddy, H.gram, Sunflower	Paddy, Ragi, G.nut
5	Shimoga	Paddy, Ragi, Maize, G.nut, Cotton, Sugarcane	Horsegram	Paddy, G.nut, Balckgram, Greengram, Cowpea
6	Chitradurga	G.nut, Ragi, Maize, Jowar, Sunflower, Tur, Avare, Paddy, Sesamum, Horsegram, Cotton	Jowar, Sunflower, Horsegram	Paddy, G.nut, Sunflower, Ragi
7	Davanagere	Maize,Paddy, Jowar, Ragi, G.nut, Sunflower, Tur, Cotton	Jowar, H.gram, Sunflower	Paddy, G.nut, Sunflower
8	Mysore	Paddy, Ragi, Jowar, Maize, Tur, H.gram, Cowpea, Avare, G.nut, Sesamum, Sunflower, Castor, Niger, Cotton, Tobacco, S.cane	Ragi, Maize,H.gram, Cowpea	Paddy, Ragi,
9	Chamarajanagar	Jowar, Paddy, Ragi,Maize, Tur, H.gram, Cowpea, Avare, G.nut, Sesamum, Sunflower, Castor, Niger, Cotton, Sugarcane	Ragi, Maize,H.gram, Cowpea	Paddy, Ragi,
10	Mandya	Ragi, Paddy, H.gram, G.nut, Sesamum,Castor, Niger, Cowpea, Avare, Sugarcane	Horsegram, Ragi	Paddy, Ragi
11	Kodagu	Paddy, Maize	-	Paddy
12	Hassan	Ragi, Paddy, Maize, Jowar, Tur, H.gram, Cowpea, Avare, Castor, Niger, Sunflower, Sesamum, G.nut, Cotton, Tobacco, S.cane	Ragi, H.Gram, Paddy, Sunflower, Bengalgram,	Paddy,G.nut,
13	Chickmagalur	Ragi, Paddy, Jowar, Avare, Sunflower, G.nut, Sesamum, Cotton, Sugarcane	Jowar, Bengalgram, Horsegram	Paddy,G.nut,
14	D.Kannada	Paddy	Paddy, Blackgram,	Paddy
15	Udupi	Paddy	Paddy, Blackgram, Horsegram	Paddy, G.nut
16	Dharwad	Paddy, Jowar, Maize, Greengram, G.nut, Soyabean, Tur, Cotton	Jowar, Wheat, Bengalgram, Sunflower, Safflower	G.nut
17	Gadag	G.nut, Maize, Jowar, Sunflower, Greengram, Cotton	Jowar, Wheat, Bengalgram, Sunflower, Safflower	G.nut, Sunflower
18	Haveri	Maize, Paddy, Jowar, G.nut, Cotton, Greengram, Tur,Cowpea, Sunflower, M.Millets	Jowar, Cotton, Horsegram, Sunflower, Safflower, Wheat	G.nut, Sunflower, Paddy, Sugarcane, Cowpea
19	U.Kannada	Paddy, Cotton, Sugarcane	Paddy, Blackgram, Greengra,	Paddy, G.nut, Cowpea
20	Belgaum	G.nut, Jowar, Maize, Paddy, Cotton, Sugarcane, Tobacco, Bajra, Tur, Sunflower, Soyabean, Greengram,	Jowar, Wheat, Maize,Bengalgram,Sunflower , Safflower,Linseed, Horsegram	G.nut, Maize, Sunflower

		Horsegram, Avare, M.Millets, Cowpea		
21	Bijapur	Bajra, Sunflower, G.nut, Maize, Horsegram, Tur, Cotton, S.cane	Jowar, Sunflower, Wheat, Bengalgram. Safflower, Linseed, Cotton,	G.nut, Sunflower, Maize
22	Bagalkote	Bajra, Maize, Sunflower, Jowar, G.nut, Sesamum, Soyabean, G.gram, H.gram, Cotton, S.cane	Jowar, Sunflower, Wheat, Ben.gram, Maize, Safflower, Linseed, Horsegram	G.nut, Sunflower, Maize
23	Raichur	Bajra, Paddy, Sunflower, Tur, G.nut, G.gram, Sesamum,Cotton, Jowar, M.Millets	Jowar, Sunflower, Bengalgram, Safflower, Cotton,Wheat, H.gram	Paddy, G.nut, Sunflower
24	Koppal	Bajra, Paddy, G.nut, Sunflower, Jowar, Sesamum, G.gram, H.gram, Cowpea, M.Millets, Cotton, Tur, Castor, Niger	Jowar, Wheat, Sunflower, Bengalgram, Cotton, Safflower,Linseed	Paddy, G.nut, Sunflower
25	Bellary	G.nut, Sunflower, Jowar, Maize, Bajra, Ragi, Cotton, Tur,H.gram, M.Millets, Niger, Sesamum,	Jowar, Sunflower, Bengalgram, Wheat, H.gram, Cotton, Safflower	Paddy, G.nut, Sunflower,Sugarcane, Cowpea, Jowar
26	Gulbarga	Tur, Sunflower, G.nut, Bajra, G.gram, Blackgram, Sesamum, Jowar, Cotton, Sugarcane	Jowar, Bengalgram, Sunflower, Wheat, Safflower, Linseed	G.nut, Sunflower, Paddy Jowar
27	Bidar	Jowar, Blackgram, Greengram, Tur, Bajra, Sunflower, Sesamum, Niger, Paddy, M.Millets, S.cane	Bengalgram, Jowar, WheatSunflower, Safflower, Linseed	G.nut, Sunflower

Source: KSDA, GOK, Bangalore



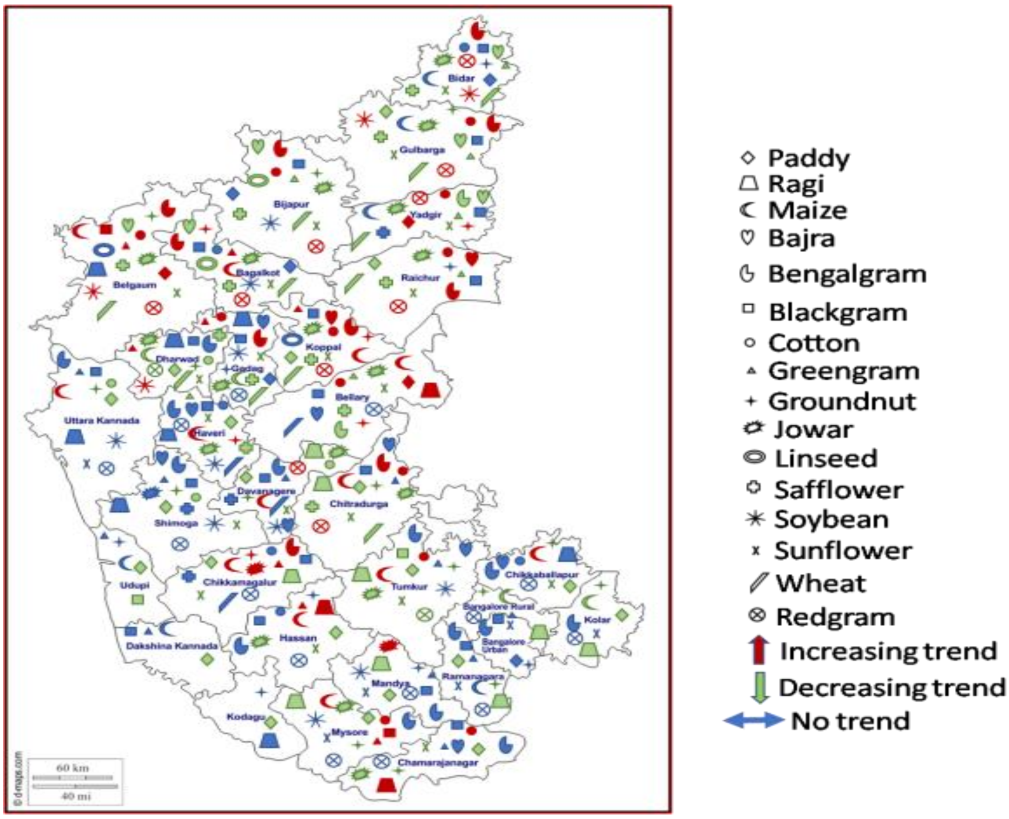
Annexure A.2: Trends in area under irrigation in Karnataka

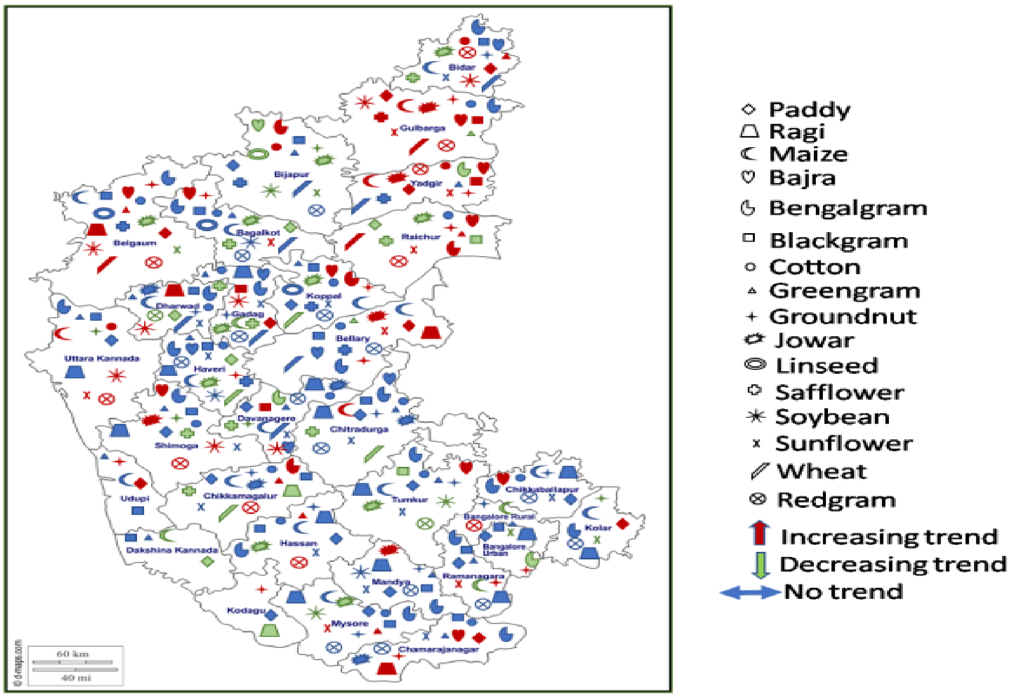
Trends in area under irrigation in Karnataka (Unit: Area in lakh hectares)				
Year	**Gross Cultivated Area**	**Gross Irrigated Area**	**Net Irrigated Area**	**Gross Irrigated Area as a % of Gross Cultivated Area**
2000-01	122.84	32.71	26.43	27
2005-06	130.27	36.32	29.7	28
2010-11	130.62	42.79	34.90	33
2011-12	120.59	41.37	34.40	34
2012-13	117.48	40.07	34.20	34
2013-14	122.67	41.12	35.56	34
2014-15	122.47	41.86	35.89	34
2015-16	120.09	37.42	32.43	31
2016-17	117.79	35.48	31.04	30
2017-18	119.94	36.39	31.55	30
Source: Directorate of Economics & Statistics, GOK				

Annexure A.3: Source-wise area under irrigation in Karnataka

Source-wise area under Irrigation in Karnataka (Unit: Area in Lakh hectares)								
Source		**Canals**	**Tanks**	**Wells**	**Tube/ Bore wells**	**Lift Irrigation**	**Other Sources ***	**Total**
2000-01	**Net**	9.66	2.61	4.79	5.39	0.95	3.03	26.43
	Gross	12.54	3.04	5.73	6.81	1.20	3.39	32.71
2010-11	**Net**	11.57	1.97	4.37	12.81	1.06	3.12	34.90
	Gross	15.22	2.23	4.99	15.55	1.33	3.47	42.79
2011-12	**Net**	11.78	1.78	4.23	12.78	0.90	2.93	34.40
	Gross	14.73	1.96	4.75	15.40	1.17	3.36	41.37
2012-13	**Net**	11.36	1.38	4.07	13.21	1.02	3.16	34.21
	Gross	13.35	1.58	4.63	15.88	1.15	3.48	40.07
2013-14	**Net**	12.53	1.54	4.11	13.22	0.93	3.22	35.56
	Gross	14.69	1.66	4.61	15.59	1.05	3.52	41.12
2014-15	**Net**	12.31	1.58	3.85	14.10	0.99	3.76	36.59
	Gross	14.22	1.70	4.21	16.45	1.16	4.11	41.86
2015-16	**Net**	10.68	1.6	4.33	16.33	-	4.48	37.42
	Gross	9.28	1.46	3.76	13.99	-	3.94	32.43
2016-17	**Net**	9.13	1.16	3.26	13.71	-	3.78	31.48
	Gross	10.10	1.25	3.81	16.05	-	4.27	35.48
2017-18	**Net**	9.45	1.26	2.89	14.14	-	3.81	36.39
	Gross	10.55	1.35	3.35	16.66	-	4.48	31.55
% share to Net Irrigated Area		28.6	4.5	11.6	43.1	-	12	100.00

Annexure A.4: Trends in productivity of crops in Karnataka





Annexure A.5: Livestock and poultry statistics of Karnataka

Number of livestock and poultry (No. in crores)		
Year	**Total Livestock**	**Total Poultry**
1997	3.07	2.14
2003	2.83	2.44
2007	3.29	4.24
2012	2.90	5.34
Source: Livestock Census, DES, Bangalore		

Annexure A.6: Production of the major livestock products in Karnataka

Livestock and Poultry Production									
Item	Unit	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Milk	Tonnes	5488	5718	5997	6123	6344	6562	7137	7901
Meat *	Tonnes	139553	166059	169894	181312	196600	209012	228232	253604
Wool	Tonnes	7779	8020	7755	8821	8191	6588	4304	3058
Eggs	No. in Cr	347	368	412	439	476	506.72	556.61	599.94
* Includes Poultry Meat. Source: DE&S, Bangalore									

Annexure A.7: Installed capacity and electricity generation in Karnataka

Progress in Power Sector

Source	Units	2014-15	2015-16	2016-17	2017-18	2018-19 (UptoNov-18)
A. Installed Capacity						
1. Public Sector						
Hydel	MW	3,652.00	3,667.00	3,667.00	3,680.00	3,680.00
Wind energy	MW	5 .00	5 .00	5 .00	5 .00	5.00
Thermal	MW	2,720.00	2,720.00	4,220.00	5,020.00	5,020.00
Diesel plants	MW	108.00	108.00	0.00	0.00	0.00
Solar PV plant	MW	14.00	24.00	24.00	34.00	34.00
Total	**MW**	**6,499.00**	**6,524.00**	**7,916.00**	**8,739.00**	**8,739.00**
Jurala Hydro	**MW**	**117.00**	**117.00**	**117.00**	**117.00**	**117.00**
2. Private Sector						
IPP Thermal	MW	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00
Mini Hydel	MW	7 96.41	835.46	843.46	851.96	853.46
Wind energy	MW	2,680.44	2,911.34	3,793.66	4,668.66	4,732.56
Co-generation & Biomass	MW	1,285.08	1,379.58	1,519.58	1,777.19	1,807.19
Solar (including solar rooftop)	MW	74.38	134.06	1,092.50	4,988.32	5,231.62
Total	**MW**	**6,036.31**	**6,460.44**	**8 ,449.20**	**13,486.13**	**1 3,824.83**
3.Central Generating Station	**MW**	**2,169.00**	**2,677.00**	**2,898.00**	**3,693.00**	**4,163.00**

Allocation						
Total Installed Capacity	**MW**	**14,821.31**	**15,778.44**	**19,380.20**	**26,035.13**	**2 6,843.83**
B. Electricity Supply						
1. Electricity Generation (Net)						
Hydel (KPCL)	MU	12,775.61	6,972.66	6,564.42	7,012.61	7,338.22
Thermal (KPCL)	MU	15,428.83	15,443.51	16,491.36	14,855.69	7,125.94
Wind	MU	-	3,550.56	4,213.10	7,402.00	7,338.73
Solar PV plant	MU		202.08	469.12	2,524.00	3,683.33
Mini Hydel	MU		1,009.12	847.46	1,390.00	1,378.69
Co-gen and Bio-Mass	MU		279.73	501.23	2,098.00	377.31
Private sector	MU	17,999.75	18,940.59	8,158.59	8,264.00	3,121.91
Total	**M U**	**46,204.19**	**46,398.25**	**37,245.28**	**43,546.30**	**30,364.13**

Annexure A.8: The bird's eye view of the distribution system in the state

	Particulars		BESCOM	MESCOM	CESC	HESCOM	GESCOM	Hukkeri RECS
1.	Area	Sq. km.	41092	26222	27773	54513	43861	991.49
2.	Districts	Nos.	8	4	5	7	6	-
3.	Taluks	Nos.	46	22	29	49	31	1
4.	Population	lakhs	207	61.55	81.55	148	121	3.571
5.	Consumers	lakhs	106.96	22.22	28.50	44.11	28.42	1.20
6.	Energy consumption	MU	26239.30	4713.21	6260.28	10092.02	6358.35	265.63
7.	Zone	Nos.	3	1	1	2	2	-
8.	DTCs	Nos.	266186	59170	106280	167117	89436*	2204
9.	Assets	Rs. In Crores	20160.09	4517.60	6543.21	8846.61	7231.68	190.00
10.	HT lines	Ckt. kms	93527.49	34159.96	51457	71788.94	59367.23*	1291
11.	LT lines	Ckt. kms	165246.52	78222.12	81571	119300.83	85607.90*	3970

Annexure A.9: Projected monthly rainfall data for different districts of Karnataka under RCP 4.5 and RCP 8.5 scenarios

	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**October**	**November**	**December**	**Sept**	Grand Total
Bagalkot	0.0	4.8	0.0	0.0	111.5	4.9	283.5	58.2	38.1	0.1	0.0	378.8	**879.9**
Bangalore Rural	0.0	1.3	0.0	5.2	82.6	100.0	63.9	372.4	309.6	107.5	38.5	355.5	**1436.6**
Bangalore Urban	0.0	4.8	0.0	0.0	111.5	4.9	283.5	58.2	38.1	0.1	0.0	378.8	**879.9**
Belgaum	0.0	0.0	0.0	0.0	52.9	182.3	101.6	127.1	67.1	0.6	0.0	20.4	**552.0**
Bellary	0.0	5.7	0.0	0.0	44.3	61.5	32.7	194.3	182.2	68.0	0.4	174.9	**764.0**
Bidar	0.0	0.3	0.0	5.2	13.6	191.6	121.8	194.3	88.3	1.8	0.0	256.7	**873.6**
Bijapur	0.0	3.6	0.0	0.0	2.8	152.5	23.1	11.5	176.9	88.7	0.0	31.1	**490.2**
Chamarajanagar	0.0	0.0	0.0	18.0	92.0	205.3	36.7	66.3	198.5	148.0	0.0	231.2	**995.9**
Chikballapur	0.0	0.0	0.0	7.3	88.8	98.0	54.8	281.1	133.0	51.4	24.8	214.4	**953.5**
Chikmagaluru	0.0	0.3	0.0	26.7	215.3	186.7	72.8	442.5	307.2	77.8	3.2	712.7	**2045.2**
Chitradurga	0.0	0.0	0.0	0.0	72.0	469.1	37.5	103.6	197.1	26.1	12.9	105.4	**1023.6**
Dakshin Kannada	0.0	0.0	0.0	45.7	209.5	508.9	566.5	388.8	365.4	356.6	1.1	160.0	**2602.6**
Davanagere	0.0	0.0	0.0	12.1	98.7	50.4	69.6	141.8	276.3	60.1	6.6	229.7	**945.2**
Dharwad	0.0	0.0	0.0	0.0	61.0	126.1	276.1	309.1	257.2	19.4	0.0	131.7	**1180.6**
Gadag	0.0	13.3	0.0	2.5	29.4	68.6	45.9	341.4	192.0	11.0	0.0	6.2	**710.3**
Hassan	0.0	0.0	0.0	21.0	178.5	54.1	37.0	204.4	171.0	110.2	0.0	85.7	**861.9**
Gulbarga	0.0	0.0	0.0	0.0	3.7	62.4	148.6	381.3	192.3	4.3	0.0	257.6	**1050.2**
Haveri	0.0	0.0	0.0	13.3	102.5	339.9	118.7	418.8	86.8	27.9	0.0	181.2	**1289.0**
Kodagu	0.0	17.5	0.0	13.8	135.1	197.2	171.5	1094.7	159.3	130.8	43.6	116.1	**2079.5**
Kolar	0.0	3.2	0.0	0.2	39.3	124.4	38.9	77.4	88.8	57.3	0.0	218.3	**647.8**
Koppal	0.0	8.4	0.0	0.0	0.0	198.0	40.3	236.9	209.1	41.4	0.0	192.3	**926.5**
Mandya	0.0	0.9	0.0	5.4	107.3	292.2	4.3	9.6	71.8	150.4	0.0	314.1	**955.9**
Mysore	0.0	49.6	0.0	27.1	17.2	332.7	133.9	327.9	70.1	134.1	146.9	371.6	**1611.3**
Raichur	0.0	0.4	0.0	0.2	42.2	206.7	82.8	229.6	56.4	2.8	0.0	103.6	**724.6**
Ramnagara	0.0	7.0	0.0	0.0	0.0	374.8	66.6	21.6	312.7	92.1	0.0	245.3	**1120.2**
Shimoga	0.0	0.0	0.0	12.4	76.5	276.6	161.7	587.3	170.4	48.6	0.3	65.6	**1399.4**
Tumkur	0.0	0.0	0.0	4.4	226.9	52.2	46.8	72.7	316.3	54.7	41.2	136.1	**951.3**
Udupi	0.0	0.0	0.0	4.1	234.5	383.1	704.9	2433.8	475.3	294.8	5.8	98.7	**4635.1**
Uttar Kannada	0.0	0.0	0.0	1.7	86.6	451.7	332.6	1316.5	161.8	25.5	0.0	85.4	**2461.7**
Yadgir	0.0	1.9	0.0	0.0	16.6	197.8	76.8	239.1	85.0	3.3	0.0	140.7	**761.2**

Annexure A.10: Data, assumptions and methodology for energy and transport sector mitigation assessment

Power sector - ***Methodology to estimate the emission mitigation (2012-18)***

Emissions mitigated with increased RE-based electricity generation

CO_2 avoided from RE electricity generation to meet demand = $\sum_{2012\text{-}2018}$ Annual RE-based electricity generation to meet demand (GWh) * Coal emission factor (kg/kWh)

Where, Coal emission factor (kg/kWh) = Average coal emission factor of plants in Karnataka between 2012-18 =0.9 kg/kWh[32]

In the case of RTPV, historical electricity generation data was not available. Hence, CUF of 19% (mentioned in tariff order) was used for estimating electricity generation from installed capacity.

Emissions mitigated with T&D loss improvement

CO_2 avoided with T&D loss improvement = $\sum_{2012\text{-}2018}$ Annual electricity generation avoided with T&D loss improvement w.r.t 2012 * State emission factor[33] (kg/kWh)

Where, State emission factor for a given year (kg/kWh) =Emissions due to electricity generation to meet demand in the state (excluding exports)/ (Annual electricity demand in the state)

Emissions mitigated with energy efficiency improvement

CO_2 avoided with efficiency improvement in fossil-based plants= $\sum_{2012\text{-}2018}$ CO_2 emission factor fuel (tCO_2/TJ)* Annual energy savings (TJ) w.r.t 2012 heat rate

CO_2 emission factor (coal) = 96.7 tCO_2/TJ (IPCC fuel emission factor)

Cumulative installed capacity (MW)	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Wind	1980	2182	2365	2685	2916	3798	4673	4695
Small Hydro	662	713	753	796	836	844	852	1255
Biomass/Bagasse/Cogeneration/ Waste-to-Energy	1023	1215	1244	1285	1380	1520	1777	1784
Solar Ground-Mounted	9	14	31	88	147	1039	4887	5936
Solar RTPV	0	0	0	0	11	78	136	160
Large Hydro	3656	3656	3656	3773	3788	3788	3798	3798
Nuclear	880	880	880	880	880	880	880	880
Gas	220	220	220	220	220	220	220	220
Diesel/Oil	234	234	234	106	106	106	81	81
Coal	4780	4780	4780	4780	6280	8680	9480	9480
Total	13444	13894	14163	14614	16563	20952	26784	28289

Year-wise gross electricity generation (GWh)	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Wind	3279	3596	4548	7642	4798	6058	7410	9778
Small Hydro	2998	2352	2002		1463	1374	1604	1803
Biomass/Bagasse/ Cogeneration					3264	2036	2058	2500
Solar Ground-Mounted					199	513	2392	7576
Solar RTPV	0	0	0	1	18	129	226	266
Large Hydro	14276	10166	12948	13321	7482	6774	7146	11857
Nuclear	5106	5348	6578	6384	7632	6470	7446	7446
Gas	1149	377	0	0	0	0	0	0
Diesel/Oil	624	317	23	0	0	0	0	0
Coal	23288	27759	29658	30446	32268	30324	29186	29186
Total	**50721**	**49915**	**55757**	**57794**	**57124**	**53679**	**57469**	**70413**

[32] CEA CO2 baseline
[33] Details provided in Annexure B

Methodology to estimate the mitigation potential of existing policies (2021-30)

Emissions mitigated with increased RE-based electricity generation

CO_2 avoided from RE electricity generation to meet demand = $\sum_{2021\text{-}2030}$ Annual RE-based electricity generation to meet demand (GWh) * Coal emission factor (kg/kWh)

Where, Coal emission factor (kg/kWh) = Average coal emission factor of plants in Karnataka between 2018 =0.9 kg/kWh[34]

The coal emission factor is decreased to 0.85 kg/kWh in 2030 linearly from 0.9 kg/kWh in 2018 to represent new efficient plant.

The CUF of RE-sources were very less in historic years compared to those in KERC tariff order. The CUF of RE-based plants is increased linearly to reach the KERC approved CUF in 2025. Further, the CUF is kept constant till 2030.

Emissions mitigated with T&D loss improvement

CO_2 avoided with T&D loss improvement = $\sum_{2021\text{-}2030}$ Annual electricity generation avoided with T&D loss improvement w.r.t 2018 * State emission factor (kg/kWh)

Where, State emission factor for a given year (kg/kWh) =Emissions due to electricity generation to meet demand in the state (excluding exports)/ (Annual electricity demand in the state)

Emissions mitigated with energy efficiency improvement

CO_2 avoided with efficiency improvement in fossil-based plants= $\sum_{2021\text{-}2030}$ CO_2 emission factor fuel (tCO_2/TJ)* Annual energy savings (TJ) w.r.t 2018

CO_2 emission factor (coal) = 96.7 tCO_2/TJ (IPCC fuel emission factor)

List of planned conventional plants and plants that are likely to come up by 2030 are given below.

Coal plants	Status	Installed c apacity (MW)	Anticipated commissioning year
Edlapura Power Station	Cancelled		
Hassan Power Station	Cancelled		
Kadechur Power Station	Cancelled		
Kudgi Super Thermal Power Project (Second stage)	Yet to be approved	1,600	
Vadlur Power Station	Cancelled		
Gulburga Power Plant	Cancelled	1,320	before 2027-28
Udupi TPP	On hold	1,600	2020

Hydro Plants	Status	Installed Capacity (MW)	Anticipated Commissioning year
Gundia Hydro Project	Ecologically not viable	200	Not available

Gas Plants	Status	Installed Capacity (MW)	Anticipated Commissioning Year
Bidadi 2nd Stage	Stopped due to litigation, lack of gas supply contract	1,400	Not available
Yelahanka Gas	Under construction	370	2020-21
Tadadi Gas Power Plant	No update since 2014. Not considered in analysis. The plant is still in its initial stages and the exact commissioning date is unknown.	2,100	Not available

List of plants and their share of installed capacity to state from central generating stations

[34] CEA CO_2 baseline

Plants	Installed capacity (MW)	Anticipated commissioning year
NLC New thermal	71	2021
Bhavani Kalpakam		2024
Cheyyur coal	800	2029

Heat rate data received from line department (kcal/kWh)

Plant name	2012-13	2014-15	2018-19
Raichur	2807	2844	2771
Torangallu IMP	2515	2423	2413
Torangallu EXT	2422	2417	2411
Bellary TPS	3123	2952	2554
Udupi TPP	2378	2333	2333

Emission mitigation potential in Policy scenario without retirement of RTPS units

Based on the discussion with KPCL and RTPS official, there is no retirement plan for RTPS units. However, KPCL official added that retirement of old units is the decision from state and has to be left to them to decide. Therefore, we have estimated the installed capacity mix, generation mix and resultant emission mitigation potential in Policy scenario without considering the retirement of RTPS units.

Installed capacity and generation mix in 2030 without RTPS retirement and coal TPPs operate at PLF of at least 55%:

Energy source	Installed capacity (MW)	Generation (GWh)
Wind	6,236	14,262
Small hydro	2,496	5,977
Biomass/Bagasse/Cogeneration/Waste to Energy	2,674	9,370
Solar Ground mounted	12,711	21,278
Solar RTPV	3,200	5,053
Large Hydro	3,726	10,324
Nuclear	975	6,336
Gas	1,770	5,360
Diesel/Oil	58	167
Coal	10,351	65,811
Total	44,196	1,43,938

GHG mitigation potential in policy scenario then will be 13,423 ktCO_2 and -2,407 ktCO_2[35] w.r.t base and BAU scenario.

Transport sector

Calculation method for CO_2 emissions savings from mitigation action of implementing metro and public transport improvement in Bengaluru:

The savings in emissions were calculated by estimating the difference in emissions with change in mode share due to implementation of metro and improvement in public transport in Bengaluru.

To estimate the emissions, the following equation has been used.

$$Emissions\ CO_2 = \sum_{i=1}^{n} P * T * S_i * L_i * \eta_i * F_i$$ Where

i – Represents the modes 1 to n

P – Population

T – Per capita trip rate

[35] Since the overall generation requirement is lesser in policy scenario as compared to BAU, the resultant electricity generation from RE sources will also be less. This leads to higher GHG emissions in policy scenario (with RTPS not retiring) w.r.t BAU.

S – Modal structure/share (%)

L – Average trip length for a given mode (km)

η - Fuel efficiency of a given mode (l/km)

F – Emissions factor of a given fuel (tCO_2/l)

To estimate the emissions saving due to improvement of public transport in rest of Karnataka, the total transport demand in PKM based on Karnataka state energy calculator and secondary literature was used. The total passenger transport demand was multiplied by the mode share in the state, which was again multiplied by the fuel efficiency and emission factor to estimate the emissions. The difference in emissions due to change in mode share in Karnataka was used to estimate the emission savings.

To estimate the emissions, key data such as the population of Bengaluru, per capita trip rate, modal structure, average trip length, and emission factors were sourced from various published government statistical reports, studies, and other literature.

Agriculture sector

- Historical GHG mitigation achievement
    - Energy-efficient pumps:
        - Base case: Assuming zero EE pumps; all electric pumps of regular efficiency
        - BAU case: WENEXA project energy savings, being the only project implemented in the 2008-12 period
        - Actual/Policy case: Energy savings based on MRV reported by EESL and approved by Energy Department for all the pilot projects
    - Solar pumps:
        - Base and BAU case: 0 solar pumps
        - Actual/Policy case: Number of solar pumps as per the data reported by Energy Department
- GHG mitigation future projections
    - Number of electric pumps' historical data (2012-18) as per Energy Department
    - Fuel share of the pump data (2012-15) as per Karnataka State Directorate of Economics and Statistics
    - Combining the two, total number of pumps was calculated for 2012-15. Annual average growth rate was calculated to be 5.25%. Total number of pumps projected @ 5.25% till 2030. Total number of pumps by 2030 was validated with the projections in Karnataka State Energy Calculator.
    - Assumptions made for the three broad scenarios are provided in Annexure 2.
- For regular electric pumps' efficiency assumptions:
    - Overall efficiency = Pump efficiency x Motor efficiency
    - Pump efficiency = 50%; Motor efficiency = 60%; Overall efficiency =30%
    - A mild overall improvement at the rate of 0.33% (consistent with Karnataka State Energy Calculator, trajectory 2) is assumed for motor efficiency.
- For energy-efficient electric pumps' efficiency assumptions:
    - Pump efficiency = 60%; Motor efficiency = 75%; Overall efficiency = 45%;
    - An annual degradation at the rate of 1.19% is assumed for motor efficiency—until it reaches 35% overall efficiency
- For energy-efficient electric pumps' HP requirement:

- HP Rating = Water HP/pump efficiency – Since the water levels to be pumped by regular and EE pumps are the same – the Water HP will be the same for both, the HP rating required will be lesser for EE pumps. (Equivalently, this can be worked out to be the reduction in operational hours required to pump with an EE pump set with same HP rating)
- HP rating for EE pump = HP rating of regular pump x (regular pump efficiency / EE pump efficiency) = 0.83 HP rating of regular pump.

- Solar feeder lever:
  - Solar power capacity required for dedicated feeders:
    - Electricity generation required = (# of EE pumps connected*hours of operation*average capacity)/(1-feeder loss%)*(Efficiency) - where feeder loss is 3.5%

*Corresponding solar capacity = Electricity generation required/(CUF*8760)- where CUF = 19%*

Industrial Sector

<u>Methodology to estimate the mitigation potential of existing policies</u>

The following equations were used to estimate the emissions from the industries sector

Cement sector:

Energy Emissions/T of Cement = Total Cement Production (Mt) * SEC of Cement (GJ/t) * Fuel Share (%) * Emission Factor of Fuel Used (t CO_2/GJ)

Where

Mt = Million tonnes

GJ/t = Gigajoules per tonne

t CO_2/GJ = Tonne of CO_2 emitted per GJ of fuel used

Iron & Steel Sector:

Energy Emissions/T of crude steel = Total crude steel Production (Mt) * SEC of crude steel (GJ/t) * Fuel Share (%) * Emission Factor of Fuel Used (t CO_2/GJ)

Where

Mt = Million tonnes

GJ/t = Gigajoules per tonne

t CO_2/GJ = Tonne of CO_2 emitted per GJ of fuel used

Refineries Sector:

Data on crude throughput (2012-18) and energy consumption and fuel share (2012-14) were sourced from MRPL annual reports. The energy-consumption data was not available on MRPL annual reports from 2015 onwards, so the specific energy consumption data was taken from Karnataka State Energy Calculator.

For current polices' mitigation potential:

- Base case: SEC remains constant at 2015 value
- BAU case: SEC trajectory 2015-18 as per Karnataka State Energy Calculator
- Policy case: SEC trajectory 2015-18 as per Karnataka State Energy Calculator

For projections:

- Base case: SEC reduces by 2%; grid electricity share remains at current level (2%)
- BAU case: SEC reduces by 4%; grid electricity share remains at current level (2%)
- Policy case: SEC reduces by 5%; grid electricity share is 0 from 2021 onwards

The energy share of fuel oil has remained constant at 96%. The subsequent emissions was calculated for all three cases using GCV (10,500 kcal/k) and emission factor (77.4 tCO_2e/TJ). The energy share of grid electricity has remained constant at 2%, associated emissions were calculated using supply emission factor for BAU and Base cases.

Annexure A.11: Detailed mitigation scenario definitions

Agriculture Sector

Assumptions:

- Total number of pumps are growing at CAGR 5.2%, based on historical growth rate (2012-2015)

(*Source: Energy Department, Karnataka Directorate of Economics and Statistics*)

- All pumps in the state are in working mode.
- For energy-efficient (EE) pumps, annual degradation of motor efficiency @1.19%[1] is considered until overall efficiency reaches 35%; then, remains at that number (assuming even after degradation, they will not be as inefficient as regular pumps).
- Average HP of solar pumps and regular electric pumps are assumed to be 5 HP in 2012–2019, and linearly increasing from 5 HP to 7.5 HP from 2020 to 2030 to accommodate the higher pumping demand due to water stress.
- Average operational hours: 300 days x 5 hours per day (*Source: Discussion with KREDL official*)
- Average efficiency of conventional and EE pumps are 35% and 45%, respectively.

Existing Policy Analysis (2012-2018)

Lever	Base Case	BAU Case	Actuals
Fuel share	Fuel share of pumps: **2012:** 98% electric and 2% diesel **2018:** 98.33% electric and 1.67% diesel	Fuel share of pumps: **2012:** solar (0%); electric (98%); diesel (2%) **2018:** solar (0%); electric (98.5%); diesel (1.5%) *Source: Karnataka Directorate of Economics and Statistics (data 2012-14)*	Fuel share of pumps: **2012:** solar (0%); diesel (2%); electric (98%) **2018:** solar (0%); electric (98.5%); diesel (1.5%) *Source: Karnataka Directorate of Economics and Statistics (data 2012-14)*
Energy-efficient electric pumps	All electric pumps are of regular efficiency—no EE pumps	214 EE pump sets installed in 2009 as part of BESCOM pilot project *Source: Energy savings as reported by the ESCOMS*	2,204 EE pump sets (BESCOM, CESC, and HESCOM pilot projects) *Source: Energy savings as reported by the ESCOMs*
Solar pumps	No solar pumps; all pumps in the Base case assumed to be electric pumps	No solar pumps	1,300 solar pump sets (2015-18) *Source: Energy Department*

Projections (2021-2030)

Lever	Base case	BAU Case	Policy case
Fuel share	Fuel share of pumps: **2012:** 98% electric and 2% diesel **2018:** 98.33% electric and 1.67% diesel **2030:** 99% electric and 1% diesel	Fuel share of pumps: **2012:** solar (0%); electric (98%); diesel (2%) **2018:** solar (0%); electric (98.5%); diesel (1.5%) **2030:** solar (6%); electric (93.4%); diesel (0.4%) *Source: Karnataka State Energy Calculator Level 2*	Fuel share of pumps: **2012:** solar (0%); diesel (2%); electric (98%) **2018:** solar (0%); electric (98.5%); diesel (1.5%) **2030:** solar (33%); diesel (0.4%); electric (66.6%) *Source: Based on information from KREDL*
Energy-efficient electric pumps	All electric pumps are of regular efficiency—no EE pumps	From 2021 onwards, all new electric pump sets installed are assumed to be EE – as per this assumption, ~37% of all electric pumps will be EE by 2030. *Source: Ganga Kalyana scheme, Energy Department*	From 2021 onwards, all new electric pump sets installed, as well as old pump sets (assuming a lifetime of 10 years) are assumed to be EE; as per this assumption ~57% of all electric pumps will be EE by 2030. *Source: Energy Department*

Lever	Base case	BAU Case	Policy case
	No stock-turnover/ageing considered because there is no replacement of old pumps with EE pumps.	No stock-turnover considered because there is no replacement of old pumps with EE pumps.	Stock-turnover considered. Assuming an average age of 10 years for pumps, one-tenth of the total stock is assumed to be retiring every year. This way, every 10 years, the original stock would have completed lifetime.
Solar pumps	No solar pumps; All pumps in the Base case would be conventional electric pumps.	~3 lakh (of the 50 lakh pumps in 2030) will be solar pumps; installation is assumed to be following an exponential trend. *Source: Karnataka State Energy Calculator Level 2*	Assuming 28% of total pumps were set to be solar pumps by 2030 (approx. 13.7 lakh out of 50 lakh pumps); target is set to be achieved following an exponential trend. *Source: Based on information from KREDL*
Dedicated solar-powered agricultural feeder connected to EE pumps	No EE pumps connected to solar feeder All pumps in the Base case would be conventional electric pumps.	No EE pumps connected to solar feeder Equivalent pumps in the BAU case would be conventional electric pumps.	Assuming 5% (2.6 lakhs) of total pumps to be EE pumps connected to dedicated solar-powered feeders by 2030 – requiring a solar PV capacity of 1.75 GW *Source: Based on expert consultation*

Buildings Sector

Assumptions

- Population in the state will grow at a CAGR of 1.74% from 2011 to 2030. Data was provided by UDD.
- Household size reduces from 4.5 in 2015 to 4.3 in 2030. (Data sourced from Karnataka State Energy Calculator)
- Hours of usage per annum:

Description	2015	2020	2025	2030
Lighting	1,410	1,468	1,523	1,578
Ceiling fans	3,600	3,756	3,918	4,087
Televisions	2,190	2,190	2,190	2,190
Room air conditioners	890	1,051	1,213	1,375

Source: State Energy Calculator, BEE

- Data on wattage of various appliances, stock of appliances, and percentage share of penetration are sourced from Karnataka State Energy Calculator.

Existing Policy Analysis (2012-2018)

Lever	Base case	BAU Case	Actuals
Residential: LED lighting	**2012:** Mix of incandescent bulbs (65%) and fluorescent tube lights (35%) **2018:** Mix of incandescent bulbs (67%) and fluorescent tube lights (33%)	• Same as Base case • No UJALA scheme	Hosa Belaku (UJALA Scheme) implemented **2012:**0% of lighting points are LEDs **2018:** 2.2 crore LED bulbs and 4 lakh LED tube lights (based on actuals) *Source: UJALA Dashboard*
Residential: Energy-efficient appliances	Conventional fan of 75W	• No UJALA scheme • 0% EE fans sold	UJALA Scheme implemented **2012:** 0% of EE fans **2018:** 0.6 lakh EE fans sold (based on actuals) *No data/estimates available on star-rated appliances*
Street Lighting National Programme (SLNP)	Data unavailable	No LED streetlights	9,882 LED streetlights installed in the state by 2018-19 Energy saving per LED tube light= 670 kWh/annum *Source: BEE; SLNP dashboard*

ECBC-compliant buildings	No data available

Projections (2021-30)

Lever	Base Case	BAU Case	Policy Case
Residential: lighting	Mix of incandescent bulbs (67%) and fluorescent tube lights (33%)	Continuation of UJALA scheme **2012:** 0% of lighting points are LEDs **2018:** 2.2 crore LED bulbs and 4 lakh LED tube lights (based on actuals) **2030:** 3.8 crore LED bulbs to be used in 2030 (i.e., 39% of the lighting points to be LED) *Source: Level 2 of State Energy Calculator*	**2012:** 0% of lighting points are LEDs **2018:** 2.2 crore LED bulbs and 4 lakh LED tube lights (based on actuals) **2030:** 7.4 crore LED bulbs to be used in 2030 (i.e., 75% of the lighting points to be LED) *Source: Level 3 of State Energy Calculator with higher EE measures*
Residential: appliances	**2015:** Low: Medium: High = 78:15:7 **2018:** Low: Medium: High = 72:19:9 **2030:** Low: Medium: High = 70:20:10 *Source: Applying half the growth rate in Level 2 of State Energy Calculator*	Continuation of standards and labelling programme **2015:** Low: Medium: High = 78:15:7 **2018:** Low: Medium: High = 72:19:9 **2030:** Low: Medium: High = 62:26:12 *Source: Level 2 of State Energy Calculator with EE measures*	**2015:** Low: Medium: High = 78:15:7 **2018:** Low: Medium: High = 72:19:9 **2030:** Low: Medium: High = 49:26:25 *Source: Level 3 of State Energy Calculator with higher EE measures*
Commercial: lighting, HVAC, and others	**2015:** Low: Medium: High = 44:50:6 **2020:** Low: Medium: High = 43:50:7 **2030:** Low: Medium: High = 40:50:10 *Source: Level 1 of State Energy Calculator (modified)*	**2015:** Low: Medium: High = 44:50:6 **2020:** Low: Medium: High = 40:50:10 **2030:** Low: Medium: High = 33:50:17 *Source: Level 2 of State Energy Calculator with EE measures*	2015: Low: Medium: High = 44:50:6 2020: Low: Medium: High = 40:50:10 2030: Low: Medium: High = 29:46:25 *Source: Level 3 of State Energy Calculator with higher EE measures*
Commercial: Building envelope	No ECBC-compliant buildings	% floor area to be ECBC-compliant **2015:** 10% **2020:**12% **2030:**16% *Source: Level 1 of State Energy Calculator*	% floor area to be ECBC-compliant **2015:** 10% **2020:** 19% **2030:** 38% *Source: Level 3 of State Energy Calculator*

Power Sector

Assumptions

- Power sector analysis is consumption-based
- Actual CUF of RE-based electricity generation in historical years is lower than the CUF specified by KERC
- CUF is linearly increased from 2019 level to the CUF mentioned in recent KERC tariff orders by 2025 and kept constant till 2030 (*Source: KERC tariff orders 2018*)
- No large utility-scale solar-capacity addition is considered between 2020 and 2022 (*Based on discussion with Energy Department*)

- Average auxiliary power consumption of 6% is considered to estimate the electricity-generation requirements from demand[1]
- Demand projections (2019-30) for key sectors (industries, agriculture, buildings, and transport) were taken from demand-side sectoral analysis. Electricity demand from other sectors (e.g., public lighting, water pumping, etc) was taken from CEA's 19th EPS Report.

Existing Policy Analysis (2012-18)

Lever	Base Case	BAU Case	Actuals
RE-based electricity generation	• Marginal increase in RE-based electricity generation (CAGR of 2%) • Actual electricity generation from non-fossil fuel-based sources is also considered • Remaining demand is met with coal-based power plants **Electricity generation share of RE:** **2012:** 8.5% **2018:** 8.7%	• Historic growth of RE generation between 2008 and 12 continues till 2018 (CAGR of 9.7%) • Actual electricity generation from non-fossil fuel-based sources is also considered • Remaining demand is met with coal-based power plants. **Electricity generation share of RE:** **2012:** 8.5% **2018:** 15% *Source: Karnataka Energy Department, CEA-CO_2 Baseline database*	• Actual generation share is considered • RE-based generation grew at CAGR of 25% **Electricity generation share of RE:** 2012: 8.5% 2018: 29% Source: *Karnataka Energy Department, CEA-CO2 Baseline database, National Power Portal (MoP)*
T&D loss reduction	• Marginal reduction in T&D loss % (CAGR of -1%) **T&D loss %:** **2012:** 19.7% **2018:** 18.5% *Source: PAT scheme targets (target for T&D loss was to reduce it at a CAGR of -2% reduction, therefore a lower reduction trend is used for Base case)*	• Historical T&D loss% reduction trend (2012-15) continues (CAGR of -1.4%) **T&D loss %:** **2012:** 19.7% **2018:** 18.1% *Source: KERC annual reports, Energy department*	• Actual T&D loss % is considered (CAGR of -3%) **T&D loss%:** **2012:** 19.7% **2018:** 16.3% *Source: KERC annual reports, Energy Department*
Energy efficiency of power plants	Slight improvement in plant efficiency considering the nominal annual degradation (0.2%) and nominal annual improvement with annual maintenance (0.33%) **Net annual reduction% of heat rate:** 0.13% Source: *CEA reports, best practices reports for a few plants*	Improvement in plant efficiency considering the nominal annual degradation (0.2%) and nominal annual improvement with annual maintenance (0.5%) **Net annual reduction% of heat rate:** 0.3% Source: *CEA reports, best practices reports for a few plants*	Actual improvement in plant efficiency is considered **Annual reduction % of heat rate:** 0.16% (for Raichur plant) to 2.2% (for Bellary plant) *Source: PCKL, KREDL*

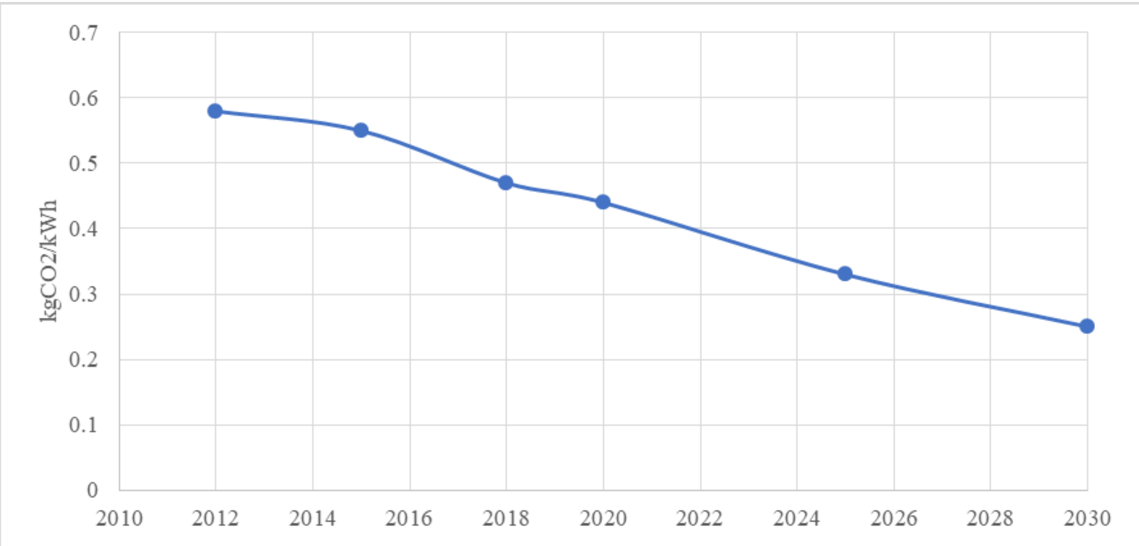
Projections (2021-2030)

Lever	Base case	BAU	Policy
RE-based electricity generation	• Marginal increase in RE-based electricity generation (CAGR of 2%) • Remaining demand is met with coal-based power plants **Electricity generation share of RE:** **2018:** 29% **2030:** 20.5%	• Moderate wind and solar capacity addition; no coal-plant retirement • Coal power plant PLF is first increased to 70% by 2025 • Remaining demand is met with solar and wind new capacity additions, such that the electricity generation from solar and wind is in the ratio 1.5:1 (based on 2015-2019 historical electricity-generation trend of new capacity addition) • Upper bound for solar capacity addition is 12.7 GW in 2030 (estimated	• Aggressive wind and solar capacity addition • 4 units of Raichur plant (1-3) (old units) are considered for retirement in 2025 (10% of the total coal capacity share to the state) • Coal power plant PLF is first increased to 56.5% in 2025 (average annual projected PLF in 2022 as per CEA National Electricity Plan when there is power surplus situation and 175 GW RE target is met in 2022) • Remaining demand is met with solar and wind new capacity additions, such that the electricity generation from solar and wind is in the ratio 1.5:1 (based on 2015-2019 historical electricity-generation trend of new

Lever	Base case	BAU	Policy
		from recent 450 GW target for India) **Electricity generation share of RE:** **2018:** 29% **2030:** 39% *Source: CEA National Electricity Plan, Energy Department*	capacity addition) **Electricity generation share of RE:** **2018:** 29% **2030:** 51% *Source: CEA National Electricity Plan, Energy Department*
T&D loss reduction	Marginal reduction in T&D loss % (CAGR of -1%) **T&D loss%:** **2018:** 16.27% **2030:** 14.42%	Historical T&D loss % reduction till 2018 continues (continuation of UDAY scheme) **T&D loss%:** **2018:** 16.27% **2030:** 11.11% *Source: KERC annual reports, Energy Department*	Aggressive T&D loss reduction **T&D loss %:** **2018:** 16.27% **2030:** 8.2% *Source: Karnataka Energy Calculator Level 3*
Energy efficiency of power plants	Slight improvement in plant efficiency considering the nominal annual degradation (0.2%) and nominal annual improvement with annual maintenance (0.33%) **Net annual reduction% of heat rate:** 0.13% Source: *CEA reports, best practices reports for a few plants*	Improvement in plant efficiency considering the nominal annual degradation (0.2%) and nominal annual improvement with annual maintenance (0.5%) **Net annual reduction% of heat rate:** 0.3% Source: *CEA reports, best practices reports for a few plants*	Significant improvement in overall plant efficiency. The heat rate will be within 7.5% of unit-wise design heat rate in 2030 Plants operating at lower heat rate at present will undergo continuous O&M activities and heat rate in 2030 will be within 5% of the design heat rate

[1] *Auxiliary consumption of coal TPPs: 7-12%, nuclear: 9%, large hydro: 0.5%, solar: <0.5%*

Grid emission factor of Karnataka[36]:



Transport Sector

Assumptions

[36] The grid emission factor was calculated based on the electricity required to meet the consumption in the state. Grid emission factor between 2012 to 2018 was calculated based on the actual data while from 2019 to 2030 was projected using the policy scenario.

- Population growth of Bengaluru (CAGR of 3.8%) is based on the projections from Bengaluru Comprehensive Mobility Plan 2019.
- The requirement of EV charging infrastructure is based on BEE guidelines for setting up charging stations every 25 km on either side of state and national highways.
- Implementation of EV charging infrastructure is considered across state including the already sanctioned charging stations.
- Implementation of metro and improved public transport considered only for Bengaluru

Average VKM	**km**	Source
Car	11,458	(ICCT, 2012), (GoK & NITI Aayog, 2018)
Bus	60000	
2W	7500	
3W	19000	

EV Efficiency	**KWh/km**	Source
2W	0.013	Based on energy and range ratings of popular EV models in the market
3W	0.061	
Cars	0.105	
Buses	0.15	

Vehicle Fuel Efficiency	**l/km**	**Source**
2W Gasoline	0.03	(GoK & NITI Aayog, 2018; IESS, 2015)
3W LPG	0.05	
4W Diesel	0.08	

Mode share assumptions for Bengaluru (BMRCL, 2019; DULT & Wilbur Smith Associatess, 2009; Verma et al., 2018)

Mode	**2012**	**Base 2030**	**BAU 2030**	**Policy 2030**
Bus	42%	25%	25%	39%
Metro	0%	2%	12%	19%
Cycle	2%	2%	2%	5%
Walk	8%	2%	2%	6%
Car	7%	6%	6%	2%
Taxi	1%	8%	5%	2%
Shared Taxi	1%	8%	5%	2%
Two wheeler	29%	29%	29%	13%
Auto	10%	18%	15%	12%

Per capita trip rate for base year was assumed to be 1.28 and for 1.48 for the terminal year.

Average trip length:

Mode	**Bus**	**Metro**	**Cycle**	**Walk**	**Car**	**Taxi**	**Shared Taxi**	**2W**	**3W**
Trip Length (km)	10.7	10	2.6	1	12.8	13.1	15.4	8	3.7

Existing policy analysis (2012-18)

Lever	**Base Case**	**BAU Case**	**Policy Case**
EV sales: FAME & State EV Policy	Based on the assumption that if projected EVs are conventional vehicles; based on actual sales of EVs in Karnataka in 2012-2019 *Source: Karnataka State Road Transport Department*	Actual total EV sales in the state by vehicle type in 2012-2019 *Source: Karnataka State Road Transport Department*	Actual total EV sales in the state by vehicle type in 2012-2019 *Source: Karnataka State Road Transport Department*
Improvement of public transport	Improvement in mode share of	Existing mode share of metro	Existing mode share of metro

in Bengaluru	metro from 0% in 2012 to about 2% in 2018 and decrease in mode share of bus.	of increases to about 4% by 2018.	of increases to about 6 % by 2018.

Projections (2021-30)

Lever	Base Case	BAU Case	Policy Case
EV Sales: FAME	Based on the assumption that if projected EVs are conventional vehicles; Projections of EVs after 2019 are based on historical growth in EV sales from 2012-2019	Projection of EV sales based on historic growth in EV sales 2W: 19% 3W: 51% 4W: 22%	Projection of EV sales based on national-level FAME targets apportioned to Karnataka, based on average share of 2W, 3W and 4W (which is about 7%)
EV Sales: State EV Policy	Based on the assumption that if projected EVs are conventional vehicles; Projections of EVs after 2019 are based on historical growth in EV sales from 2012-2019. Share of EVs in total registered vehicles is about 1.5% .	Share of EVs in total newly registered vehicles is assumed to reach 1.5% in 2030, from almost 0% in 2012. This is based on the growth in registered vehicles from 2012 to 2016.	Share of EVs in total newly registered vehicles is assumed to reach 50% in 2030 from almost 0% in 2012. This is based on the growth in registered vehicles from 2012 to 2016.
Improvement of public transport in Bengaluru	Share of metro remains stagnant at 2% along the horizon. Share of bus also declines to 25%.	Mode share of metro improves to 12%, while the share of bus remains 25% by 2030.	Share of metro improves to 19% and the share of bus improves to 39%.
Improvement of public transport in rest of Karnataka	Mode share of buses reduces from 53% in 2012 to 52% in 2030.	Mode share of buses improves from 53% to 55%.	Mode share of buses improves from 53% to 59%.

Industry

Assumptions

- Production of cement and steel 2012-2018: Based on estimates from Indian Bureau of Mines and Karnataka State Energy Calculator
- Projection of production is based on the production growth estimated in the Karnataka State Energy Calculator.
- Base year value for SEC is based on back calculation from 2015 from Karnataka State Energy Calculator and expert consultation.

Sector-wise specific energy consumption values in GJ/t considered under various scenarios:

Sub-sector	Production output in 2012 (Mt)	2012	2030 Base	2030 BAU	2030 Policy	Source
Cement	15.69	4.1	3.92	3.78	3.39	(GoK & NITI Aayog, 2018; Indian Bureau of Mines, 2015)
Steel	8.32	26.01	24.87	23.47	22.02	

Lever	Base case	BAU Case	Policy case
Improvement in energy efficiency	No improvement in energy efficiency assumed.	An average annual efficiency improvement of 0.25% is assumed between 2012-2019 *Source: Expert consultation*	An average annual efficiency improvement of 0.4% and 0.6% in cement, and iron and steel respectively is assumed between 2012-2019. *Source: PAT Cycle-1 achievement and expert consultation*

Existing policy analysis (2012-18)

Lever	Base case	BAU Case	Policy case
Improvement in energy efficiency	No improvement in energy efficiency assumed.	An average annual efficiency improvement of 0.25% is assumed between 2012-2019 Source: Expert consultation	An average annual efficiency improvement of 0.4% and 0.6% in cement, and iron and steel respectively is assumed between 2012-2019. Source: PAT Cycle-1 achievement and expert consultation
Fuel and process	Remains same in 2012-2018	Remains same in 2012-2018	**In 2012**

switch	Share of Coal: 82% Share of Electricity: 6%	Share of Coal: 82% Share of Electricity: 6%	Share of Coal: 82% Share of Electricity: 6% **In 2018** Share of Coal: 79.6% Share of Electricity: 8.4%

Projections (2021-30)

Lever	**Base Case**	**BAU Case**	**Policy Case**
Improvement in energy efficiency	No improvement in energy efficiency assumed	An average annual efficiency improvement of 0.25% is assumed from 2018 to 2030	An average annual efficiency improvement of 0.4% and 0.6% in cement, and iron and steel is assumed from 2018 to 2030.
Fuel and process switch	Share of Coal: 82% Share of Electricity: 6%	Share of Coal: 82% Share of Electricity: 6%	**In 2018** Share of Coal: 79.6% Share of Electricity: 8.4% **In 2030** Share of Coal: 73% Share of Electricity: 15%

Annexure A.12: Inputs and assumptions

Power

In the power sector, the key levers are defined for three scenarios (similar to the existing policy analysis): Base, BAU and Policy for the projection period. The Policy scenario considers more aggressive mitigation activities (compared with the current activities/schemes) to decarbonise the sector. Further, the mitigation potential in the Policy scenario is estimated with respect to Base and BAU scenarios.

To estimate the GHG-mitigation potential, source-wise installed capacity and the corresponding electricity generation are required. Source-wise installed capacity and electricity generation between 2021 and 2030 were estimated for three scenarios by developing a Microsoft Excel–based power-projection framework.

Key inputs to the power-sector framework are: (1) year-wise electricity demand projections for three scenarios; (2) new conventional power-plant capacity share to the state of coal, large hydro, gas, and nuclear power plants; and (3) source-wise RE potential and allotted capacity[37]. The total projected electricity demand in Base, BAU and Policy scenarios in 2030 are 155 TWh, 142 TWh, and 126 TWh, respectively. New installed capacity was: 871 MW of coal, 84 MW of nuclear, and 1,770 MW of gas, which is expected to be operational between 2021 and 2030. The state also sanctioned and allotted funds to install 11.5 MW of waste-to-energy plants in 2021-2023. In addition, 87.5 MW of total installed capacity of waste-to-energy plants in Kannahalli, Chikkamangala, and Dodabidarikallu are at various stages of approval. Karnataka Power Corporation Limited (KPCL) has proposed to install 2,000 MW of pumped hydro in Sharavati river (Mongabay, 2020). Meanwhile, KERC and KREDL have decided to pause capacity addition of large utility-scale solar-power projects for a few years—given the power-surplus situation, grid-balancing issues, and perceived increase in financial burden for DISCOMs (MERCOM, India, 2019). Moreover, the state has enough solar capacity to meet the solar RPO targets of 2021-22. The coal power plants in Karnataka are also facing a huge financial crisis due to their backing down post 2015-16. Therefore, in our projections, utility-scale solar-capacity addition is not considered till 2022, in any of the scenarios. However, as a mid-term activity, till 2021-22, the state would focus on increasing RTPV installation, decentralised RE electricity generation (as part of Smart City Mission projects), solar-based irrigation, and RE-based electricity generation in industrial clusters, without affecting the grid balance. Further, between 2022 and 2030, utility-scale as well as decentralised RE electricity generating sources are added in all scenarios. Details of other input data are provided in Annexure B.

The broad definitions for the three scenarios for different policy levers in the power sector are provided below:

Increased RE-based electricity generation:

Base scenario: The scenario is same as the Base case in existing Policy analysis.

BAU scenario**:** Moderate wind and solar capacity additions are made in 2021-30. The status of various thermal-power and large-hydro projects was assessed in the global energy monitor. As mentioned above, the large solar-power projects are stalled for the next few years. An upper limit of 12.4 GW on solar capacity is considered in line with the new national target of 450 GW of RE by 2030. Plant load factors (PLFs) of different supply options are based on current PLFs. The deficit in electricity demand is met with coal TPPs. PLF of coal TPPs in Karnataka was assumed to linearly increase from 38% (based on average PLF of all coal installed capacity) in 2018 to 70% in 2025 and then kept constant till 2030.

Policy scenario: Considering the high renewable potential in the state, aggressive installation of renewables (wind and solar)-based capacity addition is proposed till 2030. Four units of RTPS (1 to 4 units) are considered

[37] Based on KREDL's data

to retire in 2025[38], and PLF of coal power plant will increase from 38% in 2018 to 55% in 2025, thereafter remaining constant. The remaining demand is met with new solar and wind capacity additions. The rationale for fixing the coal PLFs under various scenarios is provided in Annexure B.

Improvement in T&D infrastructure:

Base scenario: Marginal reduction in T&D loss percentage (CAGR of -1%), lower than current PAT scheme targets for DISCOMs) reaching 14.4% in 2030.

BAU scenario: Historical T&D loss percentage-reduction trend in 2012-18 is continued, reaching a T&D loss of 11.1% in 2030.

Policy scenario: Aggressive T&D loss reduction is considered, targeting to limit T&D loss at 8.2% in 2030 (based on level 3 T&D loss trajectory in Karnataka Energy Calculator 2050)(GoK & NITI Aayog, 2018).

Energy-efficiency improvement of coal-based TPP:

Base and BAU scenario: **The annual energy efficiency improvement is same** as that of the existing policy analysis. In the Base scenario, a slight annual reduction in GHR of 0.13%[39] is considered. In the BAU scenario, annual reduction in GHR of 0.33% is considered with improved maintenance activities.

Policy scenario: Significant improvement in GHR is considered. The operating GHR reaches a level within 7.5% of the unit-wise design heat rate (CEA, 2010). Plants currently operating at lower GHR (higher efficiency) will undergo continuous O&M activities, thereby reducing their GHR in 2030 to within a 5% deviation from the design heat rate (CEA, 2010). Those plants operating at higher GHR at present reach a level within 7.5% of the unit-wise design heat rate (CEA, 2010).

Based on the electricity demand and T&D loss trajectories of the three scenarios, the total generation requirement between 2021 and 2030 is estimated. The total electricity generation requirement to meet the demand is estimated to be 178 TWh, 154 TWh, and 138 TWh for Base, BAU, and Policy scenarios, respectively. In Base scenario, the share of RE-based installed capacity increased from 50% in 2021 to 51% in 2030 and electricity generation share decreased from 24% in 2021 to 21.3% in 2030. In the BAU scenario, the share of RE-based installed capacity would increase from 54% in 2021 to 62% in 2030. The resulting increase in RE electricity generation share is 29% in 2021 and 39% in 2030. With the implementation of aggressive policies/schemes, the share of RE-based installed capacity will increase from 49% in 2018 to 55% and 68% in 2021 and 2030, respectively, in the Policy scenario. Along these lines, the share of RE-based electricity generation would increase from 30% in 2021 to 54% in 2030. Solar-based electricity generation (including RTPV) would make the highest contribution to RE-based electricity generation in 2030 and about 25% of the total electricity generated. The source-wise generation trajectories for the three scenarios are provided in Figure below.

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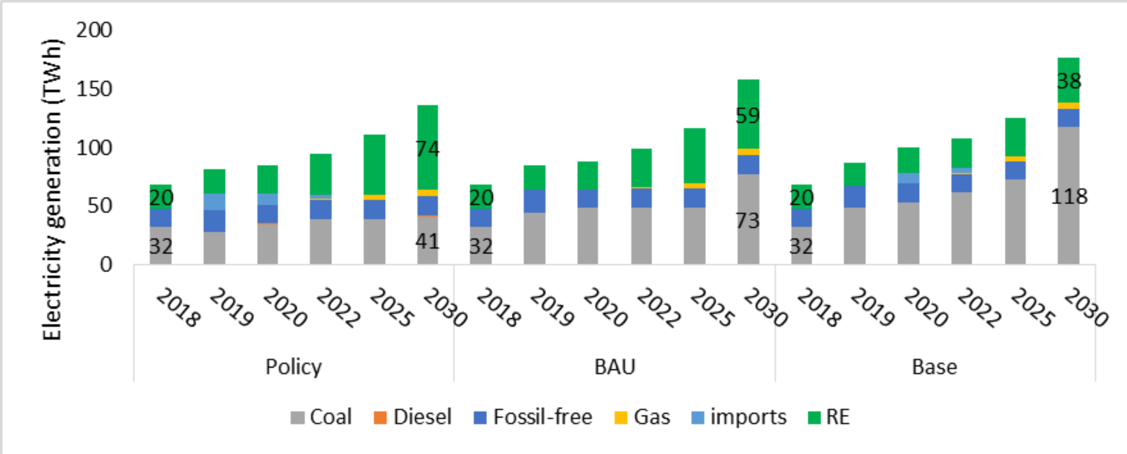
[38] A policy scenario with RTPS not retiring is provided in Annexure A

[39] This is based on a nominal annual increase in GHR of 0.2% (due to aging) and nominal annual decrease in GHR of 0.33% (due to maintenance activities) (CERC, 2013; Korellis, 2014).



Source-wise electricity generation till 2030 for various scenarios

The mitigation potential for each scenario is estimated for the key levers. Since the electricity demand of each scenario is inputted to the power sector model, the emission reduction due to reduced electricity demand (from various scenarios due to efficiency improvement) also gets accounted in power sector. Therefore, there is the possibility of double counting the emission mitigation potential. To avoid double counting, the estimated emission mitigation from reduced electricity demand is subtracted from power sector emission mitigation.

Transport

The key lever considered for future emissions mitigation in the transport sector, as described earlier, is the increased uptake of EVs (under both the national FAME scheme and the Karnataka State EV and Energy Storage Policy). Improvement in the share of public transport modes, such as metro and buses in Bengaluru is considered as the second lever and increased use of public transport in rest of Karnataka is the third lever.

In **the increased uptake of EVs scenario**, the registered EV stock in the future has a direct bearing on the emissions mitigated.

Base scenario: The Base scenario is assumed to be the same as that considered in the existing Policy scenario between 2012 and 2018.

BAU scenario: The future increase in EV stock in the BAU was estimated based on historical CAGR of EVs between 2012 and 2018. It is assumed that the EVS would continue to grow at a historic CAGR of about 18% from 2019 to 2030.

Policy scenario: In the Policy scenario projection, it is assumed that FAME targets of 6-7 million EVs in India could be achieved by 2030, taking into account the existing charging infrastructure scenario and nascent EV manufacturing industry in India. The share of Karnataka in the total EV sales target was apportioned based on Karnataka's historical share in India's registered vehicles (two-wheelers, three-wheelers, and four-wheelers) from 2009 to 2016. In the Policy scenario, under the state EV policy, it was assumed that only 50% of the newly-registered stock would be electric by 2030.

Under the **improved public transport scenario for Bengaluru** using metro as well as buses, Base scenario: The passenger transport demand is assumed to continue a shift towards private transport with the share of buses decreasing from 42% in 2012 to about 25% in 2030. The share of metro in total passenger trips is assumed to remain stagnant at about 2% through 2030.

BAU scenario: In the BAU scenario we assumed that, the existing trend of shift towards personal vehicle use for urban mobility continues, thus decreasing the share of buses in total trips (from 42% in 2012 to 25% in 2030)(BMRCL, 2019). However, with the expected operationalisation of the second phase of metro, the share of metro in total trips is assumed to increase from 2% in 2018 to 12% by 2030. Further increase in metro share in the BAU scenario is constrained due to the lack of first- and last- mile connectivity to metro stations.

Policy scenario: The Policy scenario provides a push to greater use of public transport—by optimising the frequency of bus services, improving the first- and last-mile connectivity of metro, and rationalising bus transport routes. Consequently, the share of metro and buses in the total passenger trips in Bengaluru is projected to increase to 19% and 39%, respectively, by 2030.

Improved public transport system across Karnataka

Base scenario: With minimum efforts to improve public transport in the state, the share of buses in total transport demand is assumed to decrease from 53% in 2012 to about 52% in 2030.

BAU scenario: It is assumed that measures to improve the share of buses in the total transport will be made by introducing Bus Rapid Transit Systems and intelligent transport systems in tier II cities (such as Davangere, Shimoga, Mangaluru, etc.), leading to a marginal increase in the share of public transport in the BAU scenario to 55% from 52% in the Base case in 2030 (GoK & NITI Aayog, 2018).

Policy Scenario: With increasing urbanisation and growth in private-vehicle ownership and use in Karnataka, the Policy scenario assumes concerted efforts to improve the bus fleet and add new routes and services, along with increasing the network of BRTS. Consequently, the share of buses in the total transport mix is assumed to increase to 59% in 2030.

Industries

In the industries sector, the two key levers of **energy-efficiency improvement and process switch** are considered for both cement, and iron and steel.

Base scenario: The Base scenario assumes the continuation of an annual SEC improvement of 0.25% across both the iron and steel, and cement sectors due to voluntary energy efficiency measures taken up by the industrial units.

BAU scenario: BAU scenario of the energy-efficiency improvement lever assumes the continuation of the PAT scheme until 2030 with the inclusion of more industrial units in these sectors. Consequently, an annual improvement in SEC of 0.4% and 0.5% has been assumed for cement, and iron and steel sectors, respectively. The improvement in SEC is assumed to be achieved by implementing general energy-efficiency measures such as the use of variable-frequency drives across several industrial units (including the many sponge iron plants and cement-grinding units spread across Karnataka) and increased production of blended cement.

Policy scenario: In the Policy scenario, it is assumed that cement and steel units across Karnataka work towards implementing best available standards and benchmarks for energy-efficiency improvement. It is assumed that the MSMEs units in the state also implement aggressive energy-efficiency measures. Under this scenario, an annual SEC improvement of 1% and 0.9% has been considered for the cement, and iron and steel sectors respectively. A detailed set of assumptions considered for each of the sector has been given in Annexure B. The Policy scenario also assumes the implementation of waste-heat recovery measures from DRI process and cement plants to reduce the use of coal.

Agriculture

In the agriculture sector, the three key levers for emission mitigation are increased adoption of energy-efficient (EE) pumps and solar pumps[40]; and a solar-powered dedicated feeder connected to EE pumps. The total number of irrigation pump sets are assumed to be growing at a CAGR of 5.2% annually, resulting in nearly 50 lakh irrigation pumps by 2030. The total number is the same in all three cases. So both in BAU and Policy scenarios, the rate of uptake of solar pumps determines the number of EE pumps. We assume that a small fraction (0.4%) of the total pumps will continue to be diesel powered in 2030, to factor in possible remote areas with no electricity. We have identified three broad scenarios with the key levers:

[40] Considering off-grid stand alone solar pumps (Component A of KUSUM scheme)

- **Solar pump lever:**
    - Base scenario: where we assume there are no solar pumps
    - BAU scenario: where we assume ~3 lakh pumps (6%) to be solar powered by 2030.
    - Policy scenario: where we assume a more aggressive uptake of solar pumps—with 28% of pumps (13.7 lakhs) to be solar by 2030, based on discussions with experts at KREDL.
- **Energy-Efficient pump lever:**
    - Base scenario: where we assume there are no EE pumps
    - BAU scenario: where we assume partial implementation of the Ganga Kalyana Scheme. In our assumption, the new connections are all EE pumps, but the pumps running beyond their lifetimes are not replaced and continue to operate at regular efficiency. By this assumption, 34% of all pumps will be EE in 2030.
    - Policy scenario: where we assume full implementation of the Ganga Kalyana Scheme. New connections, as well as pumps operating beyond 10 years' lifetime in the old stock of electric pumps, are assumed to be replaced with EE pumps in this scenario—resulting in 65% of all pumps being EE by 2030.
- **Dedicated solar feeders with EE pumps:** There are studies that point out that widespread adoption of individual solar pumps could further deplete groundwater aquifers (Brett Walton, 2019). States like Maharashtra have commissioned solar power plants to power dedicated agriculture feeders.
    - Base and BAU scenarios: This lever is not considered for both BAU and Base scenarios.
    - Policy scenario: We assume an additional 2.6 lakh EE pumps will be connected to agriculture feeders connected to off-grid solar panels. We estimate a requirement of 1.75 GW of solar PV capacity to realise this[41].

The detailed methodology and scenario description are provided in Annexure A and B, respectively.

Buildings

In the buildings sector, policies promoting energy efficiency are a clear winner for emission mitigation. The key levers considered in this sector are energy-efficient lighting, energy-efficient appliances, and adoption of ECBC-compliant buildings.

Efficient lighting and appliances

Base case: The Base case of LED bulbs is assumed to be the same as that specified by BEE in its latest document on impact assessment (BEE, 2020). The Base case includes a mix of incandescent bulbs and CFL bulbs. Central government schemes like standards and labelling have mandated the use of energy-efficiency labels on appliances like air conditioners, televisions, and refrigerators as well as voluntary labelling for ceiling fans. Majority of appliances in use (~78%) in 2015 were of the low-efficiency category—which includes 1/2 star-rated devices. This is expected to reduce to 70% by 2030 with a slight increase in the medium and high-efficiency categories.

BAU scenario: Recently, there has been a strong push in policies for the lighting sector, especially via UJALA scheme. The share of LED bulbs is expected to increase to 60% by 2030. In the case of efficient appliances, it has been recently seen that the sales of medium (3-star rated) and high (4/5-star rated) efficient appliances

[41] Based on expert consultation, the existing infrastructure in the state has enough spare capacity to support up to 2 GW of solar power for dedicated agriculture feeders

have increased in India. In the BAU scenario, the share of efficient appliances was assumed to increase to 26% (medium) and 12% (high) in 2030.

Policy scenario: Karnataka can push for more aggressive measures in efficient lighting and appliances, as considered in this scenario. The share of LED-based lighting can increase to 75% and high-efficient appliances to 25% by 2030.

ECBC-compliant buildings

Base case: Commercial buildings would include hospitals, hotels, office buildings, retail sector, educational, assembly places, and transit. The EPI of a conventional building is expected to increase from 83 kWh/m^2 to 98 kWh/m^2 from 2017 to 2027, after including a small penetration of green building. In the base case, there are no ECBC-compliant buildings considered.

BAU scenario: Karnataka recently notified the ECBC for the commercial sector and adopted it in the building by-laws. The adoption of the ECBC will be slow in the BAU case and is expected to increase from 10% to 16% of the commercial floor area from 2015 to 2030.

Policy scenario: With aggressive push in existing policy, it is assumed that 38% of the commercial area in 2030 is ECBC-compliant.

Annexure A.13: Expert consultations

Sector	Contacted	Date of discussion
Power	Mr Rajkumar Biradar, Joint Director, Energy Department	29/01/2020
	Mr Ravindra/ Mr Gopal (Finance)	29/01/2020
	Mr Selvaraj	30/01/2020
	Mr Prashanth, KPCL	20/03/2020 – 18/10/2020
	Mr Chetan D, Executive Engineer (Electrical), KPTCL	04/03/2020
	Ms. T.L Padmalatha, Deputy Director (Trading), PCKL	12/03/2020
Agriculture	Mr Rajkumar Biradar, Joint Director, Energy Department	29/01/2020
	Mr Hanumantappa, KREDL	13/03/2020
Buildings	Mr Rajkumar Biradar, Joint Director, Energy Department	29/01/2020
	Mr Hanumantappa, KREDL	13/03/2020
Transport	Mr Shivarj.B.Patil, Additional Commissioner	29/01/2020
	Mr Srinivas, BMRCL	20/02/2020
	Mr Shamanth, DULT	20/02/2020, 03,19/03/2020
	Mr Rajeev, WRI India	15/7/2020
	Ms Harsha, CSTUP-IISc	9/7/2020
Industries	Mr Mayur, Department of Industries and Commerce	17/02/2020,17/03/2020
	Mr Shidling, Asst. General Manager	30/01/2020
	Mr Shashidhar M.R, Deputy Director (Energy)	16/03/2020
	Mr Srinivasappa N, Assistant Director	16/03/2020
	Mr Devaraju N, Assistant Director	16/03/2020
	Mr Hanumanthappa, KREDL	28/01/2020

Annexure A.14: Scheme-wise budget allocation by the Government of Karnataka to prevent climate change and its impacts (Rs. lakh)

Department		Scheme name	2017-18 (Accounts)	2018-19 (BE)	2018-19* (RE)	2019-20 (BE)
Agriculture	1	National Food Security Mission (NFSM)	19778.10	16790.00	16790.00	17477.00
	2	Krishi Bhagya	63300.53	50000.00	50000.00	25000.00
	3	Organic Farming - Agriculture	3932.44	10000.00	10000.00	9700.00
	4	NMSA- Chief Minister's SookshmaNeeravariYojane	42508.87	34617.00	34617.00	36818.00
	5	New Crop Insurance Scheme	84508.20	84511.00	84511.00	84500.00
	6	National Mission for Oil Seeds and Oil Palm	1142.68	687.00	687.00	0.00
	7	Rashtriya Krishi Vikas Yojane - RKVY	34047.00	32167.00	28400.00	19800.00
	8	Income Support to Farmers through DBT	0.00	100000.00	27000.00	0.00
	9	Karnataka Antaraganaga Micro Irrigation Corporation (+C144)	0.00	200.00	200.00	0.00
	10	Agricultural Infrastructure	1442.71	632.00	632.00	5120.00
	11	National Oil seed and Oil Palm Mission	650.49	687.00	687.00	687.00
	12	Organic Fertilizer	0.00	307.20	307.20	335.54
	13	Agricultural Farms and Development Centers	0.00	69.90	69.90	64.90
	14	Soil and water Conservation - Watershed Development Department - Directorate of Watershed Development	641.90	724.00	724.00	1616.00
	15	Soil Conservation in the Catchment of River Valley Projected by Watershed Development Department	374.52	384.00	384.00	0.00
	16	Watershed Development to prevent Drought	0.00	0.00	0.00	10000.00
	17	Sujala Watershed Project - 3 - EAP	4988.15	10000.00	10000.00	5000.00
	18	Pradhana Mantri Krishi SinchayiYojane - Watershed Development	42984.84	32750.00	30776.33	16600.00
	19	Watershed Development	0.00	1566.02	1566.02	1496.02
	20	Soil Conservation on Watershed Basis	70.42	79.00	79.00	85.00
Total (Rs. lakh)			**300370.84**	**376171.12**	**297430.45**	**234299.46**

Department		Scheme name	2017-18 (Accounts)	2018-19	2018-19* (RE)	2019-20
Horticulture (HRT)	1	Assistant to fruit crops farmers	0.00	0.00	0.00	15000.00
	2	Oil palm Cultivation in Potential States	812.62	464.00	782.21	528.00
	3	PMKSY - National Mission on Sustainable Agriculture	28846.65	23400.00	23400.00	26400.00
	4	Integrated farming in Coconut for productivity improvement programme	2094.16	20000.00	20000.00	1596.35
	5	Comprehensive Horticulture Development	13428.68	13500.00	13500.00	13000.00
	6	Development and Maintenance of Farms and Nurseries	1296.30	1300.00	1300.00	1300.00
	7	National Horticulture Mission	11451.85	12802.00	12802.00	12549.00
	8	Implementation of Medicinal Plant component under National Ayush Mission (NAM)	24.27	200.00	0.00	100.00
	9	Scheme for Integrated control of pests and diseases of horticultural crops	336.44	1666.00	1666.00	1215.00
	10	Krishi Bhagya (Horticulture)	12673.07	12917.00	10917.00	6000.00
	11	Karnataka Watershed Development Project - II (Sujala - III) EAP	1092.07	3303.00	3303.00	233.00
	12	Micro-irrigation Installation - Horticulture (NABARD WORKS)	1158.85	448.00	448.00	153.00
	13	Apiculture	0.00	254.26	254.26	228.20
	14	Oil Palm Cultivation in Potential States	0.00	60.10	60.10	55.20
	15	Drip Irrigation - Subsidy for Horticultural Crops	0.00	1161.00	1161.00	1095.09
	16	Maintenance of Horticulture Farms	0.00	287.50	287.50	312.20
	17	Scheme for seed coconut procurement and nursery maintenance	0.00	166.53	166.53	165.27
	18	Cold storage subvention	0.00	66.10	66.10	69.86
	19	Assistance to farmers	0.00	241.10	241.10	255.62
	20	Training farmers	0.00	60.90	60.90	61.82
	21	Assistance to sericulturist	0.00	927.50	297.50	1319.02
	22	New initiatives doe sericulture development and assessment to stake holders	9547.03	4468.00	4468.00	4110.00
	23	PMKY - National Mission for Sustainable Agriculture	3478.62	2110.00	2110.00	2110.00
	24	Construction of Cocoon Markets - NABARD	644.98	818.00	818.00	1063.00
Total (Rs. lakh)			**86885.59**	**100620.99**	**98109.20**	**88919.63**

Department		Scheme name	2017-18 (Accounts)	2018-19 (BE)	2018-19* (RE)	2019-20 (BE)
Forestry (FOR)	1	Forest protection, Regeneration and Cultural Operation	1578.12	1605.00	1605.00	1605.00
	2	Implementation and management action plan for Mangroves	96.00	343.00	99.00	90.00
	3	Afforest ration in other areas	1606.00	1600.00	1600.00	1600.00
	4	National Bamboo Mission	157.12	0.00	1666.66	2455.00
	5	Demarcation and protection of forests	2247.88	5975.00	3975.00	2975.00
	6	Afforest ration on forest and non forest areas	15647.31	12736.00	12736.00	17539.00
	7	Karnataka River Conservation Program	0.00	1000.00	600.00	500.00
	8	Intensification of Forest Management Scheme	168.45	425.00	425.00	425.00
	9	Nature Conservation	0.00	6834.00	6834.00	8610.00
	10	Development of protected areas	378.01	395.00	395.00	180.00
	11	Integrated Development of Wild life Habitats	721.78	713.00	713.00	713.00
	12	Green India Mission	683.75	900.00	900.00	1000.00
	13	Nature Conservation, Wildlife Habitat Management and Man animal Conflict measures	7773.70	12903.00	12903.00	8718.00
	14	Social Forestry	0.00	16497.00	16497.00	18967.96
	15	Sub-Mission Agro forestry	938.03	418.00	418.00	955.00
	16	Protection of Biodiversity in the state	307.50	429.00	429.00	374.00
	17	Eco Clubs	25.00	100.00	100.00	10.00
		Total (Rs. Lakh)	**32328.65**	**62873.00**	**61895.66**	**66716.96**

Department		Scheme name	2017-18 (Accounts)	2018-19 (BE)	2018-19* (RE)	2019-20 (BE)
Co-operation	1	Minimum Floor Price Scheme	30600.00	30600.00	306100.00	27903.47
	2	Improvement of rural market - NABARD	3542.68	5228.00	5228.00	3.00
	3	Yashaswini	19079.14	13300.00	9800.00	0.00
Total (Rs. Lakh)			**53221.82**	**49128.00**	**321128.00**	**27906.47**
Energy (ER)	1	Solar energy project	0.00	1000.00	500.00	500.00
Total (Rs. lakh)			**0.00**	**1000.00**	**500.00**	**500.00**

Water resources (WR)	1	National groundwater management improvement scheme	0.00	1.00	1000.00	100.00
	2	Water user co-operative societies	0.00	1.00	1.00	1.00
Total (Rs. lakh)			**0.00**	**2.00**	**1001.00**	**101.00**
Minor Irrigation	1	Har Kheth Ko Pani - PMKSY	0.00	2667.00	2667.00	1000.00
	2	Ganga Kalyana Schemes	0.00	32.00	32.00	36.00
	3	Other flood control works	1487.97	1590.00	2590.00	1435.00
	4	River Management and Flood Control (FMP)	75.25	250.00	250.00	100.00
Total (Rs. lakh)			**1563.22**	**4539.00**	**5539.00**	**2571.00**
Revenue	1	Disaster management cell	822.23	831.00	831.00	624.00
	2	National Cyclone Risk Mitigation Project	1659.22	4948.00	4948.00	1212.00
	3	National Disaster Response Fund	91304.40	0.00	0.00	0.00
	4	Flood Relief Assistance to Kerala	0.00	0.00	1000.00	0.00
Total (Rs .lakh)			**93785.85**	**5779.00**	**6779.00**	**1836.00**

Department		Scheme name	2017-18 (Accounts)	2018-19 (BE)	2018-19* (RE)	2019-20 (BE)
	1	Soil and Water conservation	147.19	243.00	243.00	200.00
	2	Forestry and Wild Life	1204.09	1987.00	1987.00	2450.00
	3	Major and medium irrigation	1979.49	3267.00	3267.00	4441.00
Finance	4	Minor Irrigation	366.02	604.00	604.00	1500.00
Total (Rs. lakh)			**3696.79**	**6101.00**	**6101.00**	**8591.00**
	1	Swachh Bharata Mission	168026.00	181033.00	119033.00	74000.00
	2	Maintenance of Bore wells	0.00	1614.00	1614.00	1614.00
	3	Bio-gas Development	360.51	470.00	470.00	515.00
RDPR	4	Integrated Development of Western Ghat Region	446.00	300.00	300.00	0.00
Total (Rs. lakh)			**168833.00**	**183417.00**	**121417.00**	**76129.00**
Labour (LBR)	1	Community Irrigation Scheme	**30000.00**	**21888.00**	**21888.00**	**20000.00**
Welfare of STs (WF)	1	Ganga Kalyana for Scheduled Tribe	**13000.00**	**10000.00**	**10000.00**	**10000.00**
Urban Development (UD)	1	Lake Development	**5000.00**	**2000.00**	**1000.00**	**0.00**
Debt Servicing (DS)	1	Major and minor irrigation projects	**71934.61.00**	**68489.00**	**68489.00**	**78229.00**
Total Budget Estimated to implement schemes to combat against climate change and its impact						
Grand Total (Rs. lakh)			**989975.00**	**1071432.00**	**1162603.00**	**825313.00**

Source: Authors' compilation from Schemes of 2019-20, Department of planning, programme monitoring & Statistics. Govt. of Karnataka

Annexure A.15: Schemes oriented towards climate change adaptation in Karnataka

	Schemes		Scheme
1	Krishi Bhagya	27	Maintenance of Horticulture Farms
2	NMSA- Chief Minister's Sookshma Neeravari Yojane	28	Cold storage subvention
3	New Crop Insurance Scheme	29	Assistance to farmers
4	National Mission for Oil Seeds and Oil Palm	30	Training farmers
5	Rashtriya Krishi Vikas Yojane - RKVY	31	Assistance to sericulturist
6	Income Support to Farmers through DBT	32	New initiatives for sericulture development and assessment to stake holders
7	Karnataka Antaraganaga Micro Irrigation Corporation (+C144)	33	Assistant for purchase of fish seed
8	Agricultural Infrastructure	34	Assistant for construction of Fish markets
9	National Oil seed and Oil Palm Mission	35	Construction of fishing harbors - CSS
10	Agricultural Farms and Development Centers	36	Renovation of Fishing Harbors and land centers
11	Soil and water Conservation - Watershed Development Department - Directorate of Watershed Development	37	National Bamboo Mission
12	Soil Conservation in the Catchment of River Valley Projected by Watershed Development Department	38	Minimum Floor Price Scheme
13	Watershed Development to prevent Drought	39	Improvement of rural market - NABARD
14	Sujala Watershed Project - 3 - EAP	40	Yashaswini
15	Pradhana Mantri Krishi SinchayiYojane - Watershed Development	41	National groundwater management improvement scheme
16	Watershed Development	42	Water user co-operative societies
17	Soil Conservation on Watershed Basis	43	Har Kheth Ko Pani - PMKSY
18	Assistant to fruit crops farmers	44	Other flood control works
19	Oil palm Cultivation in Potential States	45	Disaster management cell
20	Scheme for Integrated control of pests and diseases of horticultural crops	46	National Disaster Response Fund
21	Krishi Bhagya (Horticulture)	47	Flood Relief Assistance to Kerala
22	Karnataka Watershed Development Project - II (Sujala - III) EAP	48	Major and medium irrigation
23	Micro-irrigation Installation - Horticulture (NABARD WORKS)	49	Minor Irrigation
24	Apiculture	50	Community Irrigation Scheme
25	Oil Palm Cultivation in Potential States	51	Major and minor irrigation projects
26	Drip Irrigation - Subsidy for Horticultural Crops		

Source: Authors' compilation

Annexure A.16: Karnataka State Government Schemes introduced for climate change mitigation

Sl. No.	Schemes	Sl. No.	Scheme
1	National Food Security Mission (NFSM)	20	Nature Conservation
2	Organic Farming - Agriculture	21	Development of protected areas
3	Organic Fertilizer	22	Integrated Development of Wild life Habitats
4	PMKSY - National Mission on Sustainable Agriculture	23	Green India Mission
5	Integrated farming in Coconut for productivity improvement programme	24	Nature Conservation, Wildlife Habitat Management and Man animal Conflict measures
6	Comprehensive Horticulture Development	25	Social Forestry
7	Development and Maintenance of Farms and Nurseries	26	Sub-Mission Agro forestry
8	National Horticulture Mission	27	Protection of Biodiversity in the state
9	Scheme for seed coconut procurement and nursery maintenance	28	Solar energy project
10	PMKY - National Mission for Sustainable Agriculture	29	Ganga Kalyana Schemes
11	Blue revolution / Integrated development and management of fisheries	30	National Cyclone Risk Mitigation Project
12	Supply of fishery requisite kits	31	Soil and Water conservation
13	Forest protection, Regeneration and Cultural Operation	32	Forestry and Wild Life
14	Implementation and management action plan for Mangroves	33	Swacha Nharata Mission
15	Afforest ration in other areas	34	Maintenance of Borewells
16	Demarcation and protection of forests	35	Bio-gas Development
7	Afforest ration on forest and non forest areas	36	Integrated Development of Western Ghat Region
18	Karnataka River Conservation Program	37	Ganga Kalyana for Scheduled Tribe
19	CSS-Intensification of Forest Management Scheme	38	Lake Development

Source: Authors' compilation