Chapter 1

Karnataka – Greenhouse Gas Inventory

Centre for Study of Science, Technology and Policy (CSTEP)

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Karnataka - Greenhouse Gas Inventory

Anthropogenic emissions of carbon dioxide (CO2) weighted by global warming potentials, constitute by far, the largest part of the emissions of greenhouse gases. Of these CO2 emissions, those that are produced from fuel combustion make up the great majority. CO2 emissions from burning biomass that a majority of rural households use for cooking is not considered, as biomass is considered to be carbon neutral.

In this section, we assess Karnataka's emissions of Greenhouse gasses (GHG) namely Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) at the state level. The methodology here used was similar to the 'GHG Emissions 2007', report from Ministry of Environment and Forests (MoEF)[1], which in turn has followed IPCC 1996[2] methodology.

The simplest way to estimate CO2 emission from fossil fuel combustion is assuming that the carbon in the fuel is released into the atmosphere in the short or the long run. Short-term emissions are defined within the *IPCC Guidelines* as those occurring within twenty years of the fuel use and are almost entirely reported in the fuel combustion module. Long-term CO2 emissions result from the final oxidation of long-life materials manufactured from fuel carbon and are usually emissions from waste destruction[3]. This methodology is called the top-down approach. In the more detailed bottom-up approach, the computation of carbon released to the atmosphere is done at the plant level, where combustion takes place taking into account the type of fuel used. The CO2 inventory in this report is calculated using top-down approach.

The sectors considered here are:

- Power Sector
- Transportation
- Residential/Commercial Buildings
- Industry
- Agriculture
- Waste
- Land Use and Land Use Change and Forestry (LULUCF)

[1] India: Greenhouse Gas Emissions 2007, MoEF, May 2010
[2] IPCC 1997
[3] http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/2_1_CO2_Stationary_Combustion.pdf

Roughly, the annual total emissions from Karnataka are around 80.2[4] million tons of CO_2 equivalence (eq). LULUCF constitutes a negligible amount of net emissions at the national level[5], and the same is assumed for the state. Here it should be highlighted that information was not available uniformly across all sectors. Moreover, it was found that the granularity of the information available was not uniform. For some sectors or sub-sectors, due to lack of state level information national statistics had to be used as a proxy. While some data was for 2007-08, others were for 2009-10. Assuming there has not been any major shift in activity in these sectors, the number given is a fairly good estimate. The emissions from the three GHGs can be further broken down into the following:

- CO_2 emissions were 58.8 million tons (corresponding national number is 1221.7 million tons)
- CH_4 emissions were 0.9 million tons (corresponding national number is 20.6 million tons)
- N_2O emissions were 0.01 million tons (corresponding national number is 0.24 million tons)

In each of the cases, Karnataka's emissions are around 4% of the national emissions.

High speed diesel (HSD) is used for road transportation, diesel based electricity generation, irrigation pumps and industries. While the total diesel sold in the state is known, the allocation between the sectors is not known. Certain approximations are made and at times the national statistic is used as a proxy. As there are very few diesel based irrigation pumps in the state, emissions from this source are assumed to be zero. Around 55% of the HSD sold in the country is used for transportation[6] and the same percentage is assumed for the state. The rest, 45% of the HSD sold is assumed to be used by industry, although we recognize that this may not be the true picture. For example, the amount of HSD used by diesel generators in commercial and residential buildings is ignored. Furthermore, the use of petroleum products by transportation might be different than the national statistic. The allocation of the emissions from each sector can be seen in the figure below. Details of the emissions and the methodology adopted are described after.

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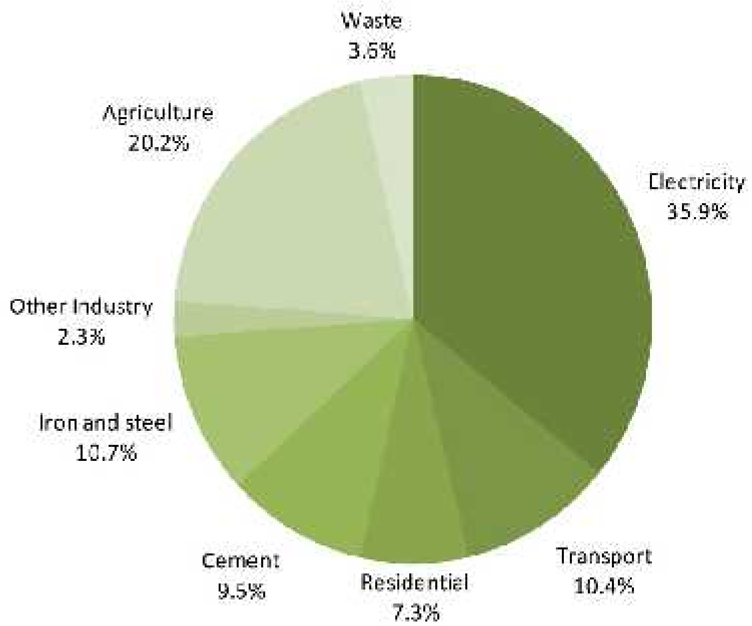
[4] Take a look at the notes under table 3

[5] Per 2004 NATCOM report, this is true for India, and the same is assumed for Karnataka

[6] TEDDY 2010, TERI Energy Data Directory

FIGURE 1.1 / KARNATAKA: GHG EMISSIONS BY SECTOR



*See notes for Table 1.4 / Karnataka: Summary of GHG Inventory

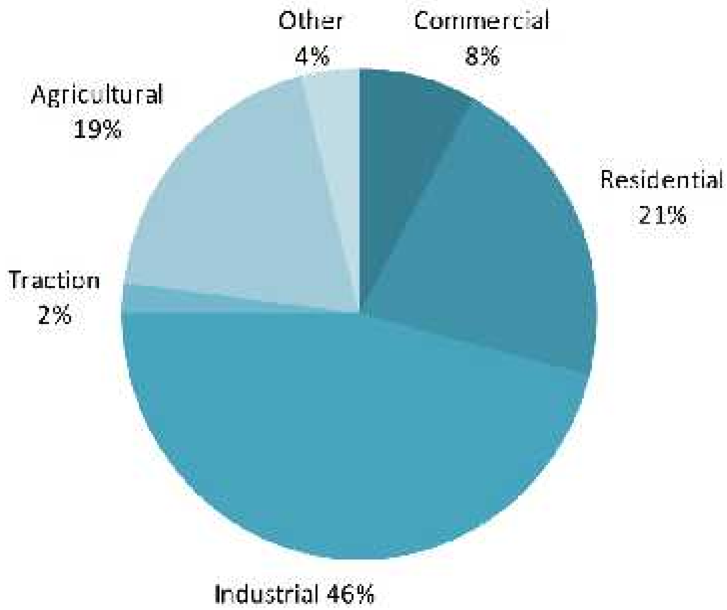
Power sector

In the power sector, the net generation after factoring auxiliary consumption can be accurately calculated within a small margin of error. From the Central Electricity Authority's[7] CO2 inventory of coal, gas and diesel based plants, the specific CO2 emissions due to net generation[8] from these sources was obtained. This was used to calculate the CO2 emissions in this sector. The total CO2 emissions from this sector were around 28.7 million tons for the year 2009-10[9]. Almost the entire emissions here can be attributed to coal based generation. Emissions due to methane and nitrous oxide are less than 0.5% (marginal) of the total emissions in terms of CO_2 equivalence; and therefore have not taken into account. Figure 1.2 gives the all India sectoral breakup of the electricity usage.

[7] Central Electricity Authority, CO2 Baseline Database, Version 5, November 2009
The specific emissions assumed are: 1.1 kg/ net kWh for coal, 0.45 kg/net kWh for gas and 0.74 kg/net kWh for diesel based generation

[8] Auxiliary power consumption used to obtain net generation: coal 8%, gas and diesel 3.1%.
[9] Installed capacity data from the Ministry of Power, Annual report 2010

Figure 1.2 / India: Electricity Consumption by Sector



Source: International Energy Association, 2008

Transport

Here the emissions due to road, aviation and shipping are included. The total petroleum products sold by fuel type are known and from this the total emissions due to this sector is obtained by using the emission factors. While petrol sold in the state is exclusively used for transportation, aviation turbine fuel (ATF) is used by only airlines. However high speed diesel (HSD), is used for transportation, electricity generation by diesel generators and running irrigation pumps. A total of 2.9 million tons of HSD was sold in the state[10] and it was assumed that about 55%[11] of this went towards transportation. Light diesel oil (LDO) and furnace oil (FO) are used for transportation and by industry. A total of 8.35 million tons of CO_2[12] were emitted by the sector as a whole in 2007-08. Here again CH_4 and N_2O are not taken into account.

Residential and Commercial Buildings

This sector is a major consumer of electricity, accounting for over 29% of the total consumption in the country as can be seen in figure 1.2. However, as the emissions from power generation

[10] Consumption of major petroleum products in the state of Karnataka from India Stat.
[11] This is the percentage of HSD that was used in the transportation sector for all India (data from Petroleum planning and analysis cell, MoPNG.
[12] The emission factors were obtained from, India: Greenhouse Gas Emissions 2007, MoEF, May 2010

have been taken into account in the power sector, it will be not considered here to avoid double counting. However, the emissions due to cooking with liquid petroleum gas (LPG), kerosene and biomass are considered. Over 75% of the households in India use biomass. While biomass is considered carbon neutral, their CH_4 and N_2O emissions are taken into account. As per the national statistic, it is assumed that 27.7 kgs of biomass is used per person per month. The total population in the state using biomass is assumed to be 5.95 crores[13]. This implies roughly 20 million tons of biomass is used annually, resulting in CH_4 emissions of 0.09 million tons and N_2O emissions of 0.0012 million tons. The CO_2 emissions due to the use of LPG and kerosene are around 3.57 million tons. The total emissions due to the non-electric energy usage in this sector are 5.84 million tons of CO_2 equivalence.

Industry

Here the production volumes of the resource were obtained from various sources[14]. The total emissions were then computed using the emission factors given in the IPCC guidelines. Cement and Iron and steel are some of the most energy intensive industries of which Karnataka has a large manufacturing base. The total CO_2 emissions due to the same are high, at around 8 million tons each.

Five of the larger iron and steel plants, for which data was readily available, were examined in the state of Karnataka. In 2009-10, these companies were responsible for producing 0.74 and 10.2 Million tons (Mt) of pig iron and steel respectively. The corresponding figures for 2008-09 accorded to 0.69 and 6.64 Mt respectively. The CO_2 emissions generated by these five companies were then calculated by multiplying the production capacity (in tons) with the specific emissions (in t CO_2/t of production)[14]. The emission factors considered correspond to the different processes employed in these companies. In general, Basic Oxide Furnace (BOF), Electric Arc Furnace (EAF), Open Hearth Furnace (OHF) and Direct Reduced Iron (DRI) are the four different processes engaged by the different iron and steel producing companies to produce pig iron and steel.

[13] *Population projection for India and states 2001-2026, Census of India 2001* http://nrhm-mis.nic.in/UI/Public%20Periodic/Population_Projection_Report_2006.pdf

[14] Directorate of Economics, Government of Karnataka, India Stat, Ministry of Petroleum and Natural Gas, Federation of Indian Mineral Industries (FIMI)

The afore-mentioned methodology yielded 5.62 and 8.59 Mt of CO_2 in FY 2008-09 and FY 2009-10 respectively. The production capacity and the different processes employed were obtained from the annual reports of the respective companies[15].

In FY 2007-08 and 2008-09, Karnataka produced 10.5 and 12.1 Million tons (Mt) of cement. To calculate the CO_2 emission, IPCC's Tier 2 approach was employed . The CO_2 emissions generated were calculated by multiplying the production capacity (in tons) with the country emission factor (in t CO_2/t of production). The emission factor is assumed to be 0.537 tons of CO2 per ton of clinker produced[16], with the clinker to cement ratio of 0.85; the specific emission for cement production will then be 0.63 tons of CO_2 per ton of cement production. Hence the total CO_2 emissions for 2008-09 work out to be 7.64 million tons from cement production in the state. The state also produces silk yarn and has gold mines. The emissions due to these two industries are not taken into account due to lack of availability of data.

TABLE 1.1 / KARNATAKA: INDUSTRIAL EMISSIONS, 2008-2009

Industry		Production (million tons)	CO_2 Emissions (tons/tons)	Total CO_2 Emissions (Million Tons)
Aluminium		0.11	1.65	0.180
Iron & Steel	Pig Iron	0.23	1.46	0.330
	Saleable Steel	0.14	0.70	0.098
	Steel ingots	0.15	0.08	0.012
Paper		0.37	1.05	0.384
Sugar		3.40	0.241	0.819
Ammonia		0.24	0.82	0.197
Cement		12.10	0.63	7.642
Iron ore*		36.39	0.008	0.291
TOTAL				9.954

[15] JSW Steel Limited, 2010, Annual report 2009-10, p.25, Retrieved on March 3rd 2011 from http://www.jsw.in/investor_zone/pdf/Annual_Results/JSW%20Steel%20Full%202010.pdf
Kalyani Steels 2010, Annual Report 2009-10, p.40, Retrieved on March 3rd, 2011 from http://www.kalyanisteels.com/annual_reports/Kalyani%20Steel%20AR%202010.pdf
KIOCL, 2010, Annual Report 2009-10, p.12, Retrieved on March 3rd, 2011 from http://www.kioclltd.com/annual_report.shtml

[16] India: Greenhouse Gas Emissions 2007, MoEF, May 2010 and www.cmaindia.org

Agriculture

Emissions due to this sector result from livestock management and paddy cultivation. Livestock enteric fermentation is a dominant source of CH_4 emission and accounts for over 60% of the total GHG emissions in terms of CO_2 eq. Table 1.2 summarizes emissions from this sector.

TABLE 1.2 / KARNATAKA: GHG EMISSIONS FROM AGRICULTURAL SECTOR, 2003

	CH_4 EMISSIONS (IN MILLION TONS)	N_2O EMISSIONS (IN MILLION TONS)	CO_2 EQUIVALENCE (IN MILLION TONS)
ENTERIC FERMENTATION	0.50	-	10.54
LIVESTOCK MANURE MANAGEMENT	0.04	0.0065	2.93
RICE CULTIVATION	0.13		2.75
TOTAL	0.68	0.0065	16.23

Emissions from Livestock

The total livestock population in Karnataka in the year 2003 was 25.6 million as per the 17th livestock census[17]. This includes cattle, buffaloes, sheep, goat and pigs. Emissions here are due to two factors – enteric fermentation and manure management, and tier II approach of IPCC methodology was used in computing the actual emissions here.
It has to be noted that the Indian feeding standard of livestock is vastly different from the underlying assumption made in the calculation of the IPCC default emission factors. Hence, emissions factor arrived at for India specific Indian feeding standard was used in this analysis. The factors used here were developed by Central Leather Research Institute (CLRI)[18]. It should be noted here that this methodology might be different than what was adopted by MoEF. The MoEF report has used the NATCOM report[19].

The drawback in this analysis is that more recent data was unavailable. Livestock population for more recent years was not extrapolated due to lack of data and time constraint.

[17] 2003 all India 17th livestock census
[18] *Budgeting Anthropogenic GHG emission from Indian livestock using country-specific emission coefficients*, Current Science, Mahadeswara Swamy and Sumana Bhattacharya, Vol 19. No.10, Nov 25, 2006
[19] NATCOM, 2004. India's Initial National Communication to the UNFCC. MoEF, GoI.

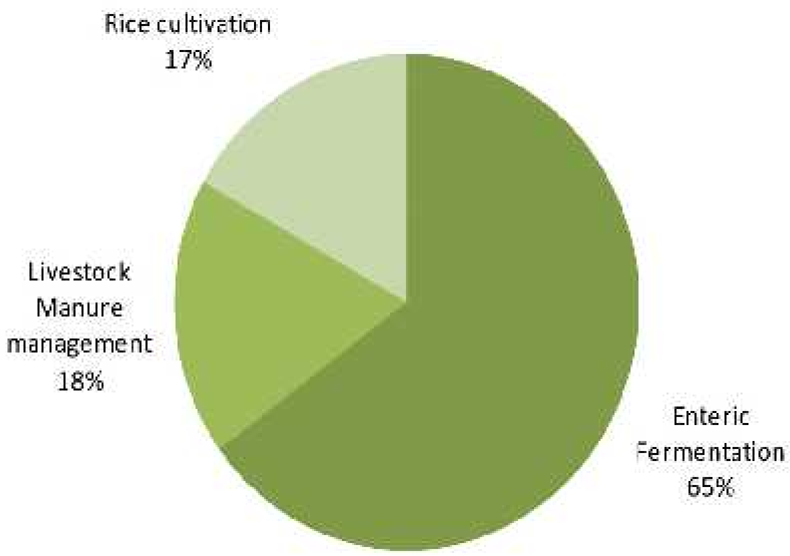
Rice Cultivation

Approximately 1.4 million hectares of land was under rice cultivation in the year 2007. However, the breakup of the land under different water management practices (or irrigation) was not available. Hence, the national statistic was used as a proxy to arrive at a number for the state. Continuously flooded water management practice results in high methane emissions, while multiple aeration of paddy fields proves to be the most efficient. Rice cultivation in Karnataka resulted in a total emission of 0.131 million tons of CH_4 or 2.75 million tons of CO_2 equivalence. Here emissions from agricultural soil and field burning of crop residue have not been done so far.

TABLE 1.3 / KARNATAKA: SUMMARY OF CH4 EMISSIONS FROM RICE CULTIVATION, 2003

ECOSYSTEM	WATER REGIME	RICE AREA 2007 (000' HA)	METHANE EMISSION ('000 TONS)
IRRIGATED	Continuously Flooded	206	33
	Single Aeration	273	18
	Multiple Aeration	285	5
RAINFED	Drought Prone	115	8
	Flood Prone	309	59
DEEP WATER		42	8
UPLAND		168	0
TOTAL		1,396	131

Figure 1.3 / Karnataka: Break up of GHG emissions in Agricultural sector, 2003



Land Use Land Use Change and Forestry (LULUCF)

As per NATCOM 2004 report, the emission from LULUCF is considered to be negligible. Hence, it is assumed to be negligible for Karnataka as well and thus not included in the study.

Waste

The three main sources of GHG emissions are municipal solid waste, domestic and industrial waste water. The CH_4 emissions are due to the decomposition of waste in anaerobic condition and N_2O emissions from domestic waste water is due to its protein content.

While calculating CH_4 emissions from municipal solid waste management, only waste from urban areas is included, whereas the waste in the rural areas is scattered and does not contribute to anaerobic fermentation. IPCC (1996) revised methodology is adopted to calculate CH4 emission from municipal solid waste.

The urban population in Karnataka is considered to be 37% of the state population[20]. The total municipal waste generation rate from urban areas is estimated to be 0.55kg/capita/day on an

[20] Mckinsey Report and population projection- Census India

average. 70% of this is considered to reach the land fill site[21]. These assumptions are used in the calculation of CH_4 emission from total waste which is found to be 70 thousand tonnes.

The waste water produced in Karnataka is estimated to 1,036 million liters per day[22]. From the adopted IPCC 2006 guideline, it is calculated that 19 thousand tonnes of CH_4 is emitted. However, the N_2O emissions are negligible.

Since there is a dearth in data on industrial waste water, the emissions from this source was not obtained.

Finally the total emissions due to this sector could not be calculated due to the unavailability of emissions due to industrial waste water. More data is needed to arrive at a complete estimate. In absence of this, the emissions from this sector were approximated to be 5% of the national emissions which accounts for 2.9 million tons of CO2 equivalence for Karnataka.

[21] National Environmental Engineering Research Institute, NEERI, 2005. Assessment of status of Municipal Solid Waste Management in metro cities, state capitals, class -I cities and class – II towns.

[22] Housing condition in India NSS report July-December 2002, http://moef.nic.in/modules/others/?f=event

TABLE 1.4 / KARNATAKA: SUMMARY OF GREENHOUSE GAS (GHG) INVENTORY*

	Particulars	Quantity/ Production/ Area	Production (units)	CO_2 emissions (in million tons)	CH_4 emissions (in million tons)	N_2O emissions (in million tons)	CO_2 equivalence (in million tons)
Energy	Electricity Generation (2009-2010)	11,495	*MW*	28.76			28.76
	Transport (2007-08)	-	-	8.35	-	-	8.35
	Residential (2007-08)	-	-	3.57	0.0900	0.0012	5.84
Industry (2008-2009)	Cement Production	120.97	*Lakh tonnes*	7.64	-	-	7.64
	Iron & Steel Production	115.4	*Lakh tonnes*	8.59	-	-	8.59
	Ammonia Production	2.36	*Lakh tonnes*	0.19	-	-	0.19
	Aluminium Production	1.09	*Lakh tonnes*	0.180			0.18
	Iron Ore	423.14	*Lakh tonnes*	0.291	-	-	0.29
	Pulp and Paper	3.65	*Lakh tonnes*	0.38	-	-	0.38
	Sugar	33.97	*Lakh tonnes*	0.82	-	-	0.82
Agriculture	Enteric Fermentation (2003)	2,56,17,000	*Animals*	-	0.50	-	10.54
	Livestock Manure Management (2003)	2,56,17,000	*Animals*	-	0.04	0.00654	2.93
	Rice Cultivation(2007)	1.40	*Million hectare*	-	0.13	-	2.75
Waste		-	-	-	0.126	0.00079	2.89
TOTAL							80.15

* It has to be pointed out again that the data for the same period was unavailable for all sectors. All attempts were made to get the most recent data for each of the sector. Hence it is likely that the total emissions will be higher than the 80 million tons given above. One could have fixed a particular year and projected the emissions of sectors where data was unavailable. However, this would introduce more errors as several assumptions had to be made in the projection. Going forward the government should take concerted efforts to collect annual data.

Chapter 2

Climate variability and climate change projections - Karnataka Region

Indian Institute of Science, Bangalore

2011

Climate variability and climate change projections – Karnataka region

Introduction

Climate change is one of the biggest environmental threats to food production, water availability, forest biodiversity and livelihoods. It is widely believed that developing countries such as India will be impacted more severely than developed countries (e.g. UK and USA).

IPCC definition of climate change: Climate change in IPCC usage refers to "*a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity*" (IPCC, 2007).

Climate in a narrow sense is usually 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 thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant climate parameters include temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

In this report, we first discuss the current climate variability in Karnataka using the IMD daily rainfall data for the period of 1971 – 2005 and CRU data for the temperature for the period 1901-2002. Then we discuss the climate projections for the midterm period 2021 to 2050. The State of Karnataka is confined within 11.5 degree North to 18.5 degree North latitudes and 74 degree East and 78.5 degree East longitude. It accounts for 5.83 percent of the total area of the country and ranks eighth among major States of the country in terms of size.

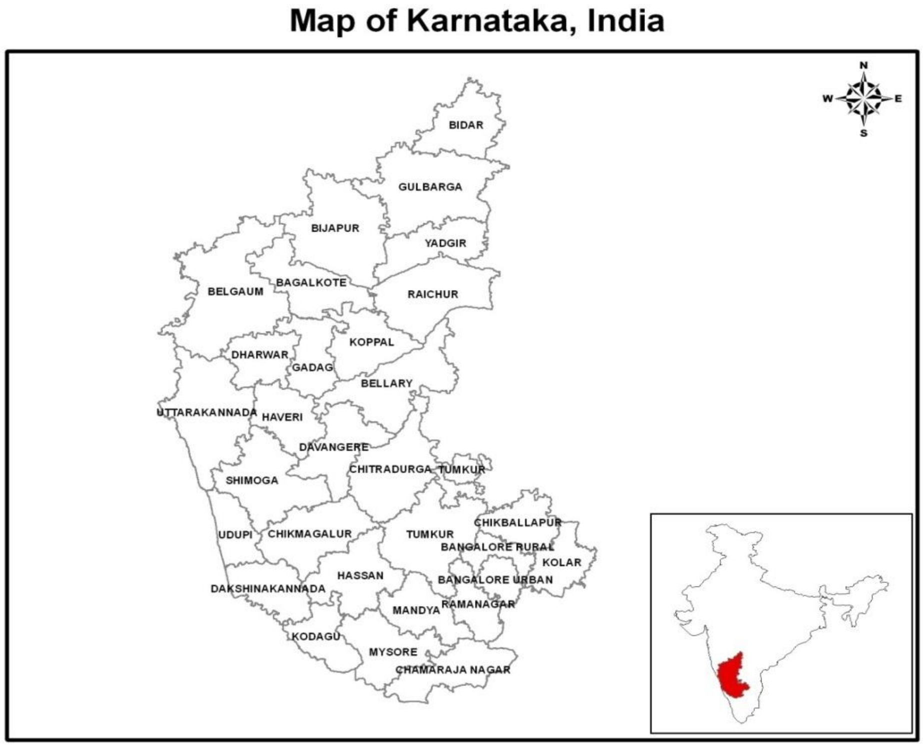


Figure 2.1: Map of India highlighting Karnataka State & District Map of Karnataka.

The annual rainfall in the State varies roughly from 50 to 350 cm. In the districts of Bijapur, Raichur, Bellary and southern half of Gulbarga, the rainfall is lowest varying from 50 to 60 cm. The rainfall increases significantly in the western part of the State and reaches its maximum over the coastal belt. The south-west monsoon is the principal rainy season during which the State receives 80% of its rainfall. Rainfall in the winter season (January to February) is less than one per cent of the annual total, in the hot pre-monsoon season (March to May) about 7% and in the post-monsoon season about 12%.

Tropical monsoon climate covers the entire coastal belt and adjoining areas. The climate in this region is hot with excessive rainfall during the monsoon season i.e., June to September. The southern half of the State experiences hot and seasonally dry tropical savana climate while most of the northern half experiences hot, semi-arid and tropical steppe type of climate. The climate of the State varies with the seasons. The mild winter season from January to February is followed by relative warmer summer season from March to May. The period from October to December forms the post-monsoon or northeast monsoon season. The period from October to March, covering the post-monsoon and winter seasons, is generally pleasant over the entire

State except during a few spells of rain associated with north-east monsoon which affects the south-eastern parts of the State during October to December.

The months April and May are hot, very dry and generally uncomfortable. Weather tends to be oppressive during June due to high humidity and temperature. The next three months (July, August and September) are comfortable due to reduced day temperature although the humidity continues to be very high.

Current Climate Variability in Karnataka

The starting point for an investigation of adaptation to future climate change is to develop an understanding on the adaptation to current climate variability. This means that the focus for the investigation of adaptation to climate change should not be based only on scenarios of the future but also on the analysis of present vulnerability in the face of current climate variability. Rainfall and Temperature are subjected to variability on all time scales: intra-seasonal, inter-annual, decadal, centennial, etc. Food production system, water availability, water resources etc. are sensitive to intra-seasonal, inter-annual, decadal variability in these two important climate variables. Global warming and Climate Change is projected to increase the number of extreme temperature and rainfall events, and hence climate variability is expected to show an upward trend. It is very important to understand the past trends and variability in rainfall, minimum and maximum temperature in Karnataka since the knowledge on the past could provide guidance for the future.

Climate variability refers to variations in the mean state (of temperature, monthly rainfall, etc.) and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural (e.g. solar and volcanic) external forcing (external variability).

In this section, we focus on the current mean climate and climate variability in Karnataka at district level and investigate how changes in them will alter Karnataka's vulnerability to climate change. Precipitation and temperature are used as the key climate variables in this analysis.

Data and Methodology

In order to study the climate variability, 3 meteorological sub-divisions in Karnataka were selected.

- Coastal Karnataka (Dakshina Kannada and Uttara Kannada districts),
- North Interior Karnataka (Belgaum, Bidar, Bijapur, Dharwad, Gulbarga and Raichur districts) and
- South Interior Karnataka (the remaining districts of Bangalore Rural, Bangalore, Bellary, Chikmagalur, Chitradurga, Kodagu, Hassan, Kolar, Mysore, Mandya, Shimoga and Tumkur districts)

The study considers the climate variability only for southwest monsoon (rainy) season. The high resolution (0.5° x 0.5° lat. and long.) daily gridded rainfall dataset for a period of 35 years (1971–2005) provided by Indian Meteorological Department (IMD) for precipitation and the Climatic Research Unit Time Series (CRU TS) version 2.10 on a 0.5° x 0.5° lat. and long. resolution monthly dataset spanning 102 years (1901-2002) for temperature are used. District-wise data is obtained by re-gridding the dataset to 0.1° lat. x 0.1° long, and re-aggregating by districts to study the climate variability at district level.

Rainfall Variability

Information on spatial and temporal variations of rainfall is important in understanding the hydrological balance on a global/regional scale. The distribution of precipitation is also important for water management in agriculture, power generation and drought-monitoring. In India, rainfall received during the southwest monsoon season (June–September) is crucial for its economy. Real-time monitoring of rainfall distribution on a daily basis is required to evaluate the progress and status of monsoon and to initiate necessary action to control drought/flood situations.

Figure 2.2(a) shows the spatial distribution of the mean monsoon (June–September) rainfall averaged for the period 1971–2005 derived from the IMD gridded rainfall dataset.

- The highest climatological rainfall is seen over Costal Karnataka districts (Dakshina Kannada, Udupi and Uttara Kannada) (>25 mm/day) and parts of South Interior Karnataka districts (Kodagu, Hassan and Shimoga) (>12 mm/day).
- Most of the South Interior Karnataka districts and North Interior Karnataka districts of this region experience lowest (<5mm/day) seasonal mean rainfall in a climatological sense.

A normal monsoon with an evenly distributed rainfall throughout the region is desirable, while an extreme event of flood or drought over the region constitutes a natural hazard. Variation in seasonal monsoon rainfall may be considered as a metric to examine climate variability/change over the Karnataka monsoon domain. The year-to-year variability in monsoon rainfall (Figure 2.2(b)) shows extreme hydrological events (large-scale droughts and floods) that could be resulting in reduction in agricultural output and affecting the vast population and economy.

- The dotted lines (Figure 2.2(b)) indicate the value of the percent of rainfall corresponding to one standard deviation, which is 14.1% of the mean. Drought (Flood) years can be defined as the years when the precipitation is lower (higher) than 14.1% of the mean.

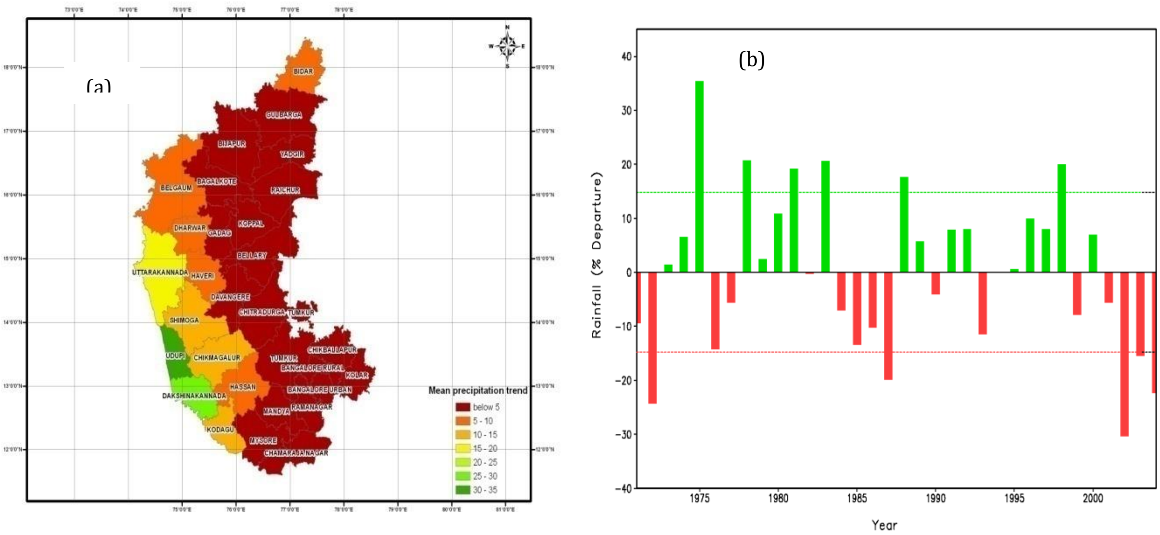


Figure 2.2(a): Spatial pattern of mean southwest monsoon seasonal (June-September) mean rainfall (mm/day). **(b):** Southwest monsoon rainfall of Karnataka for the period 1971-2005 expressed as percentage departure from long term mean.

Coefficient of Variation (C.V.; Figure 2.3) is defined as the inter-annual variability (estimated as the standard deviation) of rainfall over the region as a fraction of mean. Higher values of C.V. indicate larger inter-annual variability and vice versa.

- The coefficient of variation of rainfall is higher over South Interior districts (>55%) of Karnataka.
- The variability is very high in a couple of districts (Chikballapur, Chitradurga, Gadag, Kolar, Mandya and Tumkur) of Karnataka, where the highest C.V. (>85%) is observed.

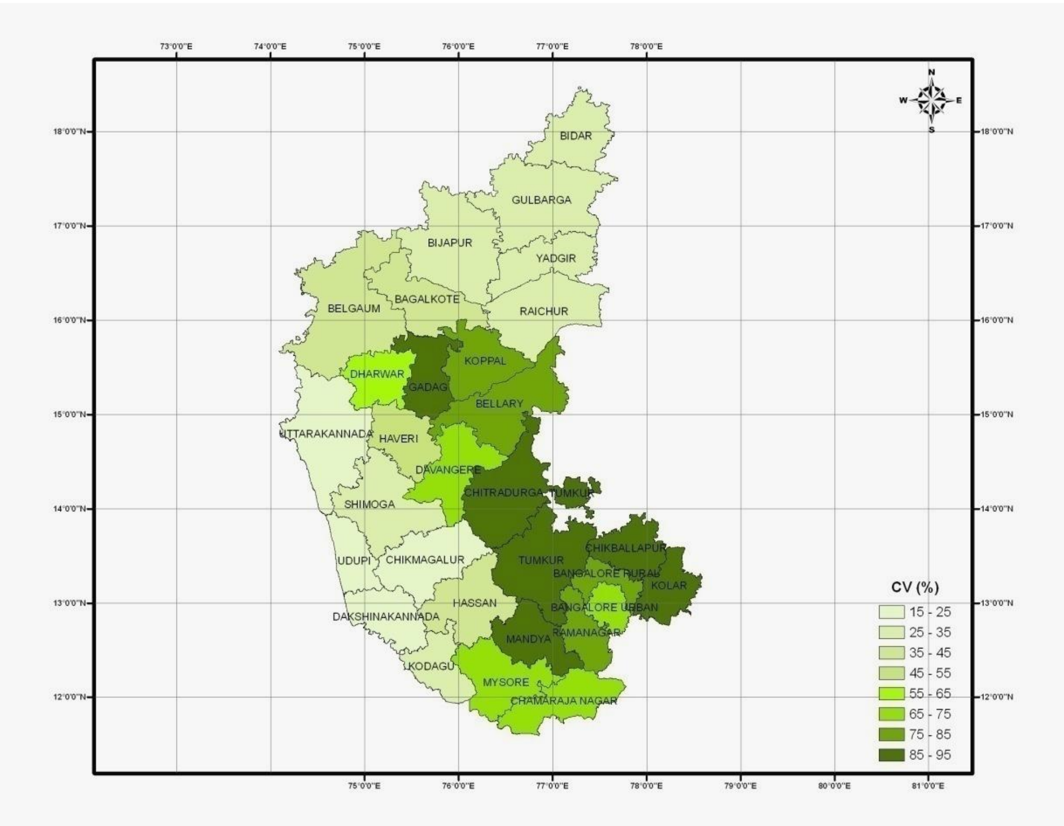


Figure 2.3: District-wise Coefficient of Variation (C.V.) of southwest monsoon season (June-September) rainfall computed using the data for the period 1971-2005. Units are in percentage.

Standard deviations of rainfall for the districts are given in Table 2.1. We have also prepared a time series of precipitation rate averaged over the area 11.5–18.5° N, 74–78.5° E (Karnataka Region) for a period of 54 years (1951-2004) using the IMD gridded data to examine any significant trends (Figure 2.4(a) and (b)) . The linear trend in the dataset, calculated using a least mean square method is shown by the straight line. The slope of the straight line is -1.0 mm/day per 100 yr (about 6% decline in 50 years) which clearly indicates a decrease in the precipitation rate over Karnataka. Figure 2.3 (b) clearly reflects a decrease in precipitation trend in Coastal Karnataka and North Interior Karnataka meteorological subdivisions.

Table 2.1 District-wise standard deviation (mm/day) of rainfall, precipitation trend, minimum and maximum temperature trend.

District	Mean Rainfall (mm/day)	Standard Deviation (mm/day)	Coefficient of Variation (%)	Precipitation Trend (mm/day/100yr)	Minimum Temperature Trend (°C/100yr)	Maximum Temperature Trend (°C/100yr)
Bagalkote	3.11	1.31	42	1.30	0.536	0.537
Bangalore Rural	3.9	3.01	77	7.83	0.400	0.396
Bangalore Urban	4.09	3.02	74	7.89	0.323	0.320
Belgaum	6.37	2.32	36	7.76	0.444	0.332
Bellary	3.41	2.76	81	5.44	0.471	0.575
Bidar	5.29	1,48	28	-0.54	0.610	0.0572
Bijapur	3.25	1.10	34	-0.96	0.632	0.611
Chamarajanagar	4.27	2.84	66	5.01	0.265	0.365
Chikballapur	3.37	3.06	91	7.72	0.321	0.401
Chikmagalur	12.96	2.92	23	-2.85	0.253	0.257
Chitradurga	3.21	2.94	91	8.73	0.334	0.335
Dakshinakannada	26.75	5.18	19	-17.69	0.141	0.148
Davangere	4.52	3.02	67	8.52	0.364	0.366
Dharwad	5.67	3.51	62	6.12	0.415	0.324
Gadag	3.38	3.12	92	6.06	0.492	0.393
Gulbarga	4.61	1.42	31	-1.91	0.644	0.641
Hassan	6.51	2.75	42	2.03	0.265	0.265

Haveri	7.05	3.74	53	6.54	0.408	0.317
Kodagu	13.29	3.41	26	-1.75	0.161	0.262
Kolar	3.49	3.03	87	9.34	0.361	0.258
Koppal	3.21	2.47	77	4.58	0.482	0.588
Mandya	3.5	3.03	87	7.43	0.311	0.498
Mysore	4.39	3.14	72	5.92	0.262	0.463
Raichur	3.62	1.23	34	0.15	0.602	0.615
Ramanagar	3.92	3.03	77	6.64	0.362	0.358
Shimoga	14.26	4.81	34	-10.59	0.250	0.352
Tumkur	3.33	3.06	92	7.55	0.321	0.403
Udupi	33.36	6.14	18	-22.38	0.111	0.113
Uttarakannada	19.35	3.58	18	-1.87	0.146	0.146
Yadgir	4.09	1.38	34	-0.39	0.650	0.551

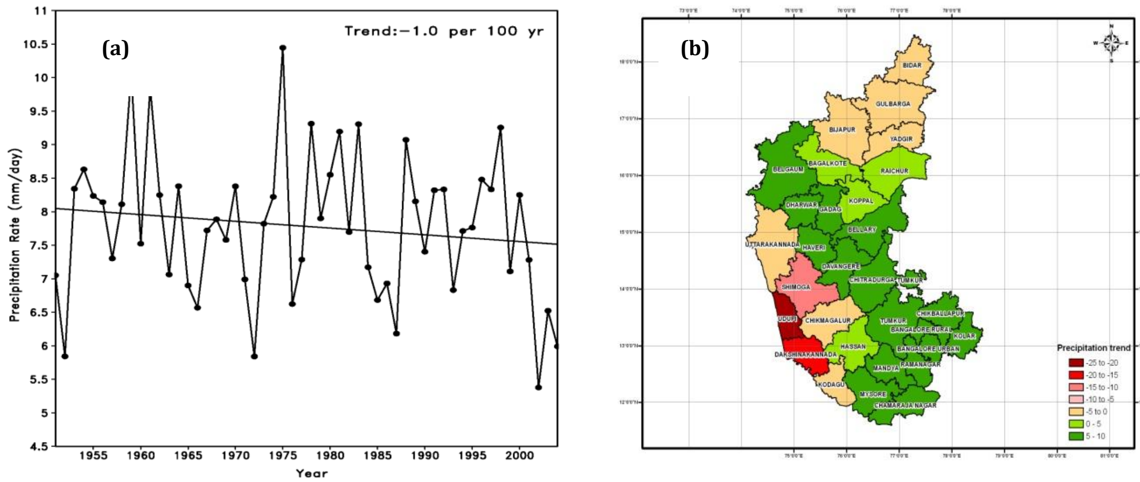


Figure 2.4(a): Time series of precipitation rate during monsoon season (June-September) over the box 11.5-18.5° N, 74–78.5° E in the IMD gridded rainfall analysis. **Figure 2.4(b):** District-

wise precipitation trend (mm/day per 100 yr) of southwest monsoon season (June-September) for the period 1971-2005.

Temperature Variability

In this section, the meteorological measurements of temperature for Karnataka are analyzed.

Figure 2.5(a) and 2.5(b) shows the district-wise variation of the annual mean minimum and maximum temperature averaged for the period 1901–2002 derived from CRU-TS dataset.

- The highest annual mean minimum temperature (>=21 °C) is observed over Raichur, Udupi, Gulbarga and Yadgir district.
- Maximum temperature (>33 °C) is noticed in most of the North Interior Karnataka districts - Raichur, Bijapur, Gulbarga and Yadgir.

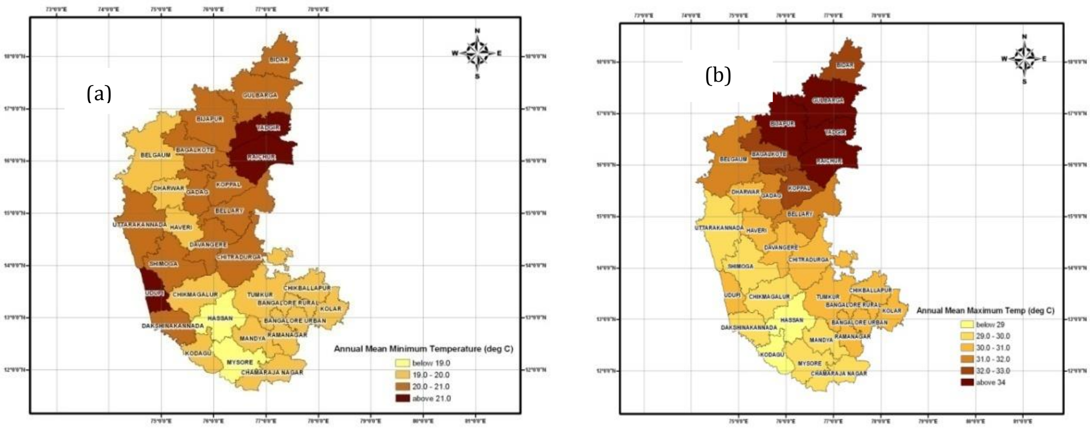


Figure 2.5(a): Spatial pattern of annual mean minimum temperature (°C). **Figure 2.5(b):** Spatial pattern of annual mean maximum temperature (°C).

District-wise Coefficient of Variation (C.V) for annual mean minimum and maximum temperature are shown in Figure 2.6(a) and (b). Higher values of C.V. indicate larger inter-annual variability and vice versa. C.V of annual mean minimum and maximum temperature for districts is listed in Table 2.2 and Table 2.3 respectively.

Table 2.2 District-wise Annual mean minimum temperature, C.V and seasonal mean minimum temperature for 1901-2002.

District	Annual Mean Minimum Temperature (°C)	Coefficient of Variation (%)	Seasonal Mean Minimum Temperature (°C)			
			JF	MAM	JJAS	OND
Bagalkote	20.63	13.43	17.19	23.06	22.17	18.43
Bangalore Rural	19.09	11.53	16.14	21.03	20.26	17.55
Bangalore Urban	19.15	11.29	16.17	20.95	20.38	17.70
Belgaum	19.86	13.25	16.35	21.96	21.47	17.96
Bellary	20.63	12.74	17.41	22.91	22.14	18.51
Bidar	20.53	15.93	16.80	23.75	22.06	17.74
Bijapur	20.91	14.10	17.41	23.66	22.43	18.46
Chamarajanagar	19.03	9.17	16.68	20.69	19.79	17.93
Chikballapur	19.32	12.17	16.23	21.35	20.64	17.60
Chikmagalur	19.38	8.96	17.06	20.94	20.25	18.21
Chitradurga	20.15	10.95	17.50	22.19	21.29	18.34
Dakshinakannada	20.98	6.74	19.12	22.48	21.44	20.11
Davangere	20.12	10.89	17.39	22.10	21.28	18.40
Dharwad	19.85	12.38	16.51	21.82	21.34	18.13
Gadag	20.14	12.72	16.89	22.33	21.62	18.16
Gulbarga	20.97	14.76	17.55	24.03	22.41	18.27
Hassan	18.59	9.31	16.24	20.07	19.51	17.46
Haveri	19.98	11.14	17.01	21.85	21.26	18.39

Kodagu	19.03	7.50	17.14	20.46	19.56	18.14
Kolar	19.25	12.39	15.95	21.09	20.73	17.61
Koppal	20.63	12.98	17.25	23.01	22.12	18.52
Mandya	19.01	9.48	16.60	20.60	19.91	17.81
Mysore	18.99	8.41	16.88	20.48	19.72	17.95
Raichur	21.11	13.53	17.77	23.86	22.50	18.74
Ramanagar	19.15	10.35	16.48	20.92	20.15	17.82
Shimoga	20.18	9.32	17.61	21.85	21.16	18.94
Tumkur	19.38	10.92	16.68	21.28	20.48	17.81
Udupi	21.87	7.18	19.68	23.44	22.47	20.95
Uttarakannada	20.37	10.74	17.21	22.08	21.66	19.04
Yadgir	21.10	14.05	17.70	24.03	22.47	18.62

Table 2.3 District-wise Annual mean maximum temperature, C.V and seasonal mean maximum temperature for 1901-2002.

District	**Annual Mean Maximum Temperature (°C)**	**Coefficient of Variation (%)**	**Seasonal Mean Maximum Temperature (°C)**			
			JF	**MAM**	**JJAS**	**OND**
Bagalkote	32.48	9.95	31.84	37.46	30.77	30.21
Bangalore Rural	30.09	9.34	29.32	34.34	29.19	27.56
Bangalore Urban	30.08	8.90	29.24	34.11	29.33	27.62
Belgaum	31.28	9.73	31.25	35.91	28.97	29.75
Bellary	31.93	9.97	31.27	36.80	30.52	29.38

Bidar	32.50	11.46	30.86	37.97	31.41	29.57
Bijapur	33.20	10.30	32.07	38.39	31.87	30.54
Chamarajanagar	29.49	7.79	29.25	33.00	28.30	27.72
Chikballapur	30.41	9.70	29.48	34.82	29.65	27.64
Chikmagalur	29.14	8.09	29.64	32.58	27.10	28.08
Chitradurga	30.88	9.61	30.63	35.41	29.35	28.55
Dakshinakannada	29.68	6.77	30.41	32.39	27.59	29.28
Davangere	30.63	9.08	30.59	34.88	28.87	28.77
Dharwad	30.69	9.08	30.79	34.90	28.48	29.35
Gadag	31.41	9.67	31.16	36.08	29.54	29.40
Gulbarga	33.07	10.93	31.46	38.42	32.04	30.16
Hassan	28.81	8.81	29.21	32.57	26.81	27.46
Haveri	30.34	8.44	30.50	34.21	28.35	29.03
Kodagu	28.53	10.26	29.07	32.56	26.00	27.50
Kolar	30.31	9.40	28.98	34.39	30.08	27.42
Koppal	32.25	10.16	31.47	37.27	30.80	29.67
Mandya	29.67	8.46	29.49	33.50	28.28	27.79
Mysore	29.08	8.21	29.30	32.66	27.35	27.67
Raichur	33.03	10.57	31.70	38.27	31.99	30.08
Ramanagar	30.04	8.72	29.52	34.04	28.99	27.78
Shimoga	29.68	7.27	30.13	32.79	27.67	28.93
Tumkur	30.32	9.51	30.26	34.62	28.89	27.95

Udupi	30.26	5.62	30.86	32.46	28.38	30.17
Uttarakannada	29.97	7.06	30.29	33.00	27.91	29.47
Yadgir	33.12	10.72	31.61	38.40	32.14	30.16

- The coefficient of variation of annual mean minimum temperature is very low over Coastal Karnataka districts (< 8.5%).
- The variability is very high in a couple of districts (Bidar and Gulbarga) of North Interior Karnataka, where the highest C.V. (>14.5%) is observed.
- Majority of the districts in South-east Karnataka as well as that of North Interior Karnataka show a high variability (>9.0%) for the annual mean maximum temperature (Figure 2.5(b)).

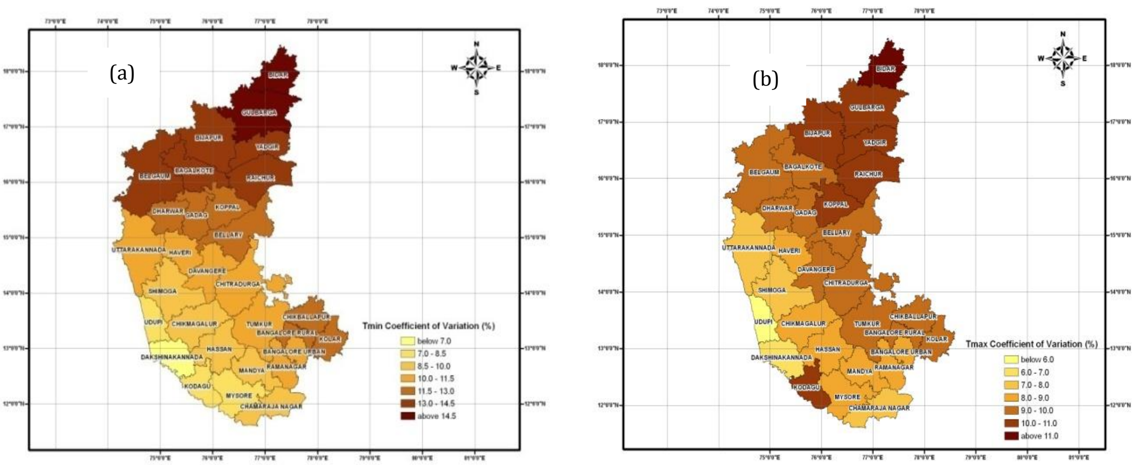


Figure 2.5(a): District-wise Coefficient of Variation (C.V.) of annual mean minimum temperature computed using the data for the period 1901-2002. Units are in percentage.
Figure 2.5(b): District-wise Coefficient of Variation (C.V.) of annual mean maximum temperature computed using the data for the period 1901-2002. Units are in percentage.

District-wise Trend Analysis of Minimum and Maximum Temperature

The analysis of the meteorological measurements of temperature for Karnataka shows a steady warming trend in both the minimum and maximum temperatures (Fig.2.6 (a) and (b)). Both day and night temperatures are more or less uniform over the State, except at the coastal region and high elevated plateau.

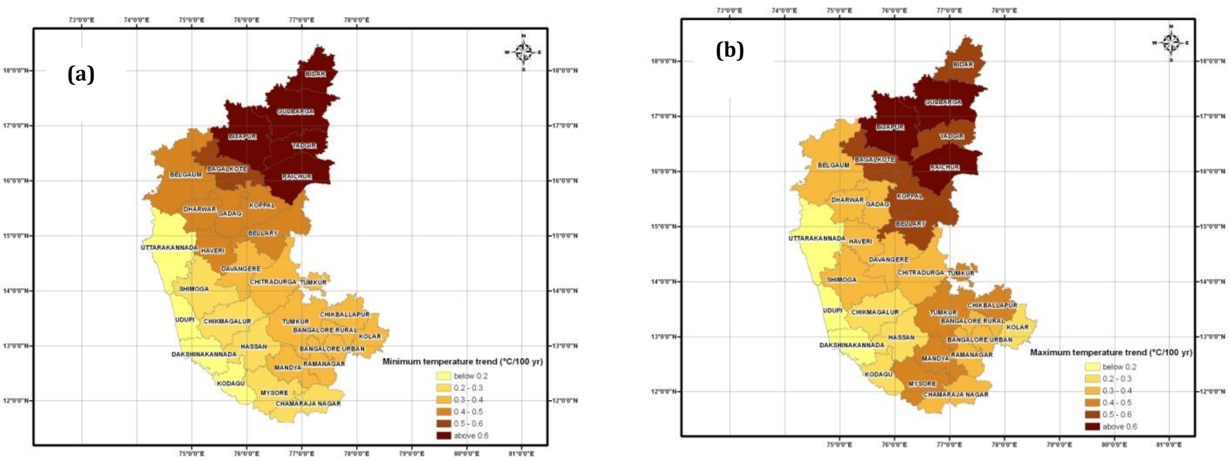


Figure 2.6(a) and (b): Spatial pattern of Minimum and Maximum Temperature trends (°C per 100 yr) over Karnataka for the period 1901-2002.

- The spatial pattern of minimum temperature trend (Figure 2.6(a)) shows an increase all over the region. Districts of North Interior Karnataka (Bidar, Bijapur, Gulbarga, Yadgir and Raichur) experience an increase in minimum temperature of ≥ 0.6°C in the last 100 years.

- The maximum temperature trend (Figure 2.6(b)) indicates an increase of ≥ 0.6°C in the last 100 years over Gulbarga, Bijapur, Gulbarga, Bidar, Raichur and Yadgir.

Future climate projections for Karnataka

Climate change projections for any geographic region are obtained using GCMs (global circulation models) and RCMs (regional climate models). Normally, climate change projections are made for variables such as:

- Surface air temperature (height of 1.5m) – Average, maximum and minimum

- Precipitation (both snow and rainfall)

- Relative humidity

- Radiation (both shortwave and longwave)

- Wind speed (height of 1.5m)

Model and Methods

For climate change projections, we have used simulation data from the global climate model, HadCM3 from the Hadley Centre, UK (Collins et al., 2001). HadCM3 has been used recently for generating climate change projections for various parts of the Indian subcontinent (Kumar et al., 2006). According to that study, the Indian subcontinent could be subjected to an average of over 4° C increase in temperature by 2085 for SRES A2 scenario.

GCM and SRES scenario used: In this report, data from the HadCM3 global climate model downscaled by PRECIS model, a regional climate model for downscaling climate projections (see Kumar et al., 2006), is used. The combination of HadCM3 and PRECIS models is known as the HadRM3 model. The pathways for atmospheric greenhouse gases (e.g. CO_2, CH_4, N_2O, CFCs) are prescribed from the SRES A1B mid-term (2021-2050) projections. Climate change projections were made:

- For daily values of temperature (average, maximum, minimum)
- For daily values of precipitation
- At grid-spacing of 0.44250 latitude by 0.44250 longitude
- For periods of 2021-2050 relative to the baseline period 1961-1990 (also referred to as either 1975 or 1970s)

Derivation of district-wise data: Data derived from the PRECIS model outputs (which had a grid spacing of 0.4425° latitude by 0.4425° longitude) was regridded to 0.2° in latitude and 0.2° in longitude. This ensures that enough grids fall inside each district. Then, the data was re-aggregated (as averages) at the district-level.

Projected increase in average, minimum and maximum temperature

Table 2.4: Projected change in annual average temperature, minimum and maximum temperature for all districts of karnataka, for 2021-2050 (A1B) relative compared to baseline (1961-1990)

Sl. Num.	District	Increase projected in T_{avg}(in ^{0}C)	Increase projected in T_{min}(in ^{0}C)	Increase projected in T_{max} (in ^{0}C)
1	Yadgir	2.21	2.34	2.10
2	Bijapur	2.20	2.32	2.11
3	Raichur	2.20	2.31	2.12
4	Gulbarga	2.19	2.33	2.04
5	Bagalkote	2.15	2.25	2.10
6	Koppal	2.14	2.21	2.09
7	Bidar	2.12	2.30	1.93
8	Bellary	2.08	2.16	2.03
9	Gadag	2.08	2.15	2.05
10	Belgaum	2.01	2.11	1.98
11	Chitradurga	2.00	2.07	1.97
12	Dharwar	2.00	2.08	1.97
13	Mandya	1.99	2.03	2.00
14	Tumkur	1.99	2.06	1.96
15	Chikballapur	1.98	2.06	1.91
16	Davangere	1.98	2.05	1.98
17	Bangalore rural	1.97	2.06	1.91
18	Haveri	1.97	2.04	1.97
19	Ramanagar	1.97	2.05	1.92
20	Bangalore urban	1.96	2.06	1.88
21	Chamaraja nagar	1.96	2.03	1.94
22	Kolar	1.96	2.06	1.87
23	Mysore	1.95	1.99	1.98
24	Hassan	1.92	1.96	1.95
25	Shimoga	1.88	1.95	1.91
26	Uttarakannada	1.87	1.96	1.86
27	Chikmagalur	1.86	1.93	1.89
28	Kodagu	1.79	1.86	1.81
29	Dakshinakannada	1.72	1.81	1.71
30	Udupi	1.71	1.78	1.72

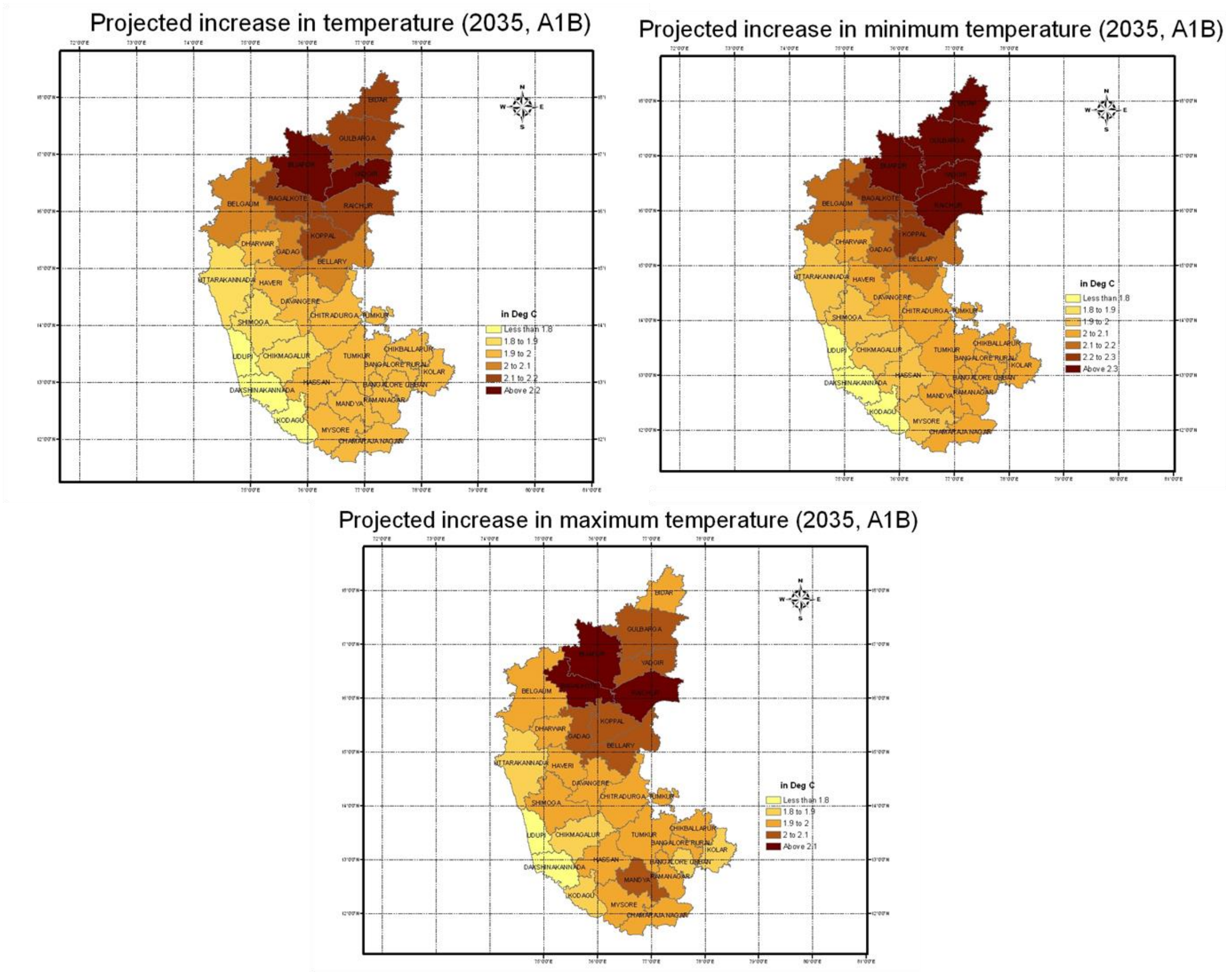


Figure 2.7: District-wise projected change in annual average temperature (°C), minimum and maximum temperatures for the period 2021-2050 (A1B SRES scenario) compared to baseline (1961-1990), projected by the HadRM3 model. The solid black lines show the district boundaries.

Figure 2.7 shows the projected increase in temperatures in the state.

We note that:

- The projected increase for annual average temperatures for the northern districts is higher than the southern districts. These regions are expected to experience a warming above 2^0 C by 2030s.
- Most of the state is projected to experience a warming of 1.8 to 2.2 ^{0}C.

- The northern part of the state is also projected to experience higher increases in minimum and maximum temperatures.
- The increase in the minimum temperature projected is slightly more than that of the average and the maximum temperatures.

Projected changes in rainfall

Table 2.5: Projected change in annual and seasonal rainfall for all districts of Karnataka, for 2021-2050 (A1B), compared to baseline (1961-1990)

Sl. Num.	District	Change projected for JF months (%)	Change projected for MAM months (%)	Change projected for JJAS months (%)	Change projected for OND months (%)	Change in annual-mean projected (%)
1	Bagalkote	-35.42	43.65	-10.47	16.87	1.38
2	Bangalore rural	3.05	36.30	-2.31	9.61	3.56
3	Bangalore urban	-15.11	29.92	-2.89	10.14	3.66
4	Belgaum	-6.25	20.34	-1.32	20.00	6.15
5	Bellary	-14.47	36.16	-8.11	6.87	0.52
6	Bidar	-71.30	22.29	6.89	50.76	27.03
7	Bijapur	-50.81	39.41	-9.81	12.54	0.60
8	Chamaraja nagar	-8.51	16.55	-8.40	1.56	-1.85
9	Chikballapur	50.17	17.40	-2.40	3.21	0.97
10	Chikmagalur	-44.13	2.86	0.14	11.63	3.62
11	Chitradurga	0.94	22.76	-3.98	14.46	6.50
12	Dakshinakannada	-34.37	2.08	-0.43	8.28	0.87
13	Davangere	0.00	24.07	-1.84	14.20	6.57
14	Dharwar	0.00	30.55	0.06	9.94	3.71
15	Gadag	0.00	37.48	-6.79	12.42	1.93
16	Gulbarga	-63.11	12.77	-1.44	9.49	4.26
17	Hassan	-53.02	-3.39	-3.72	11.94	2.45
18	Haveri	0.00	12.28	1.91	10.87	5.80
19	Kodagu	-30.65	-7.33	0.97	6.61	2.53
20	Kolar	4.80	22.75	-3.57	4.90	1.08
21	Koppal	-2.08	45.19	-12.35	8.81	-1.56
22	Mandya	-20.00	4.57	-7.00	10.40	1.40
23	Mysore	-22.93	-2.68	-4.91	2.90	-0.78
24	Raichur	-4.17	20.50	-10.99	-7.59	-6.79
25	Ramanagar	-21.75	22.77	-4.87	10.27	2.85
26	Shimoga	-12.50	10.55	4.31	8.03	5.27
27	Tumkur	13.76	21.77	-3.95	14.26	5.22

28	Udupi	-10.71	25.93	2.43	9.51	4.07
29	Uttarakannada	0.00	10.62	4.87	6.80	5.40
30	Yadgir	-65.04	19.32	-7.14	-5.22	-4.07

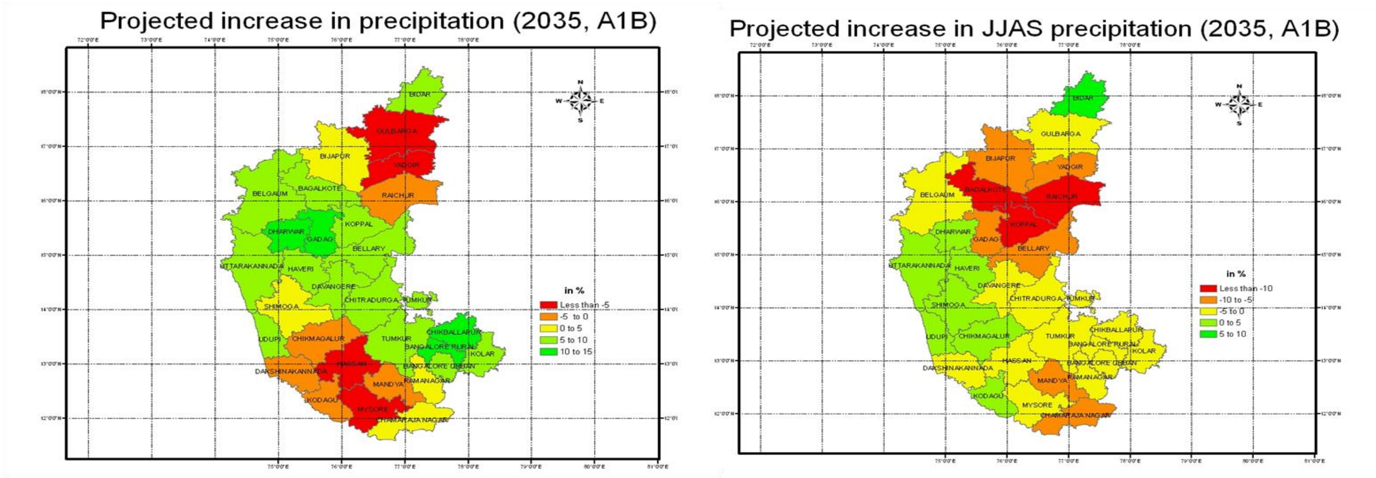


Figure 2.8: District-wise projected change in annual rainfall (%) and JJAS rainfall for the period 2021-2050 (A1B SRES scenario) compared to baseline (1961-1990) projected by the HadRM3 model. The solid black lines show the district boundaries.

Figure 2.8 shows the projected change in total annual rainfall and for the summer monsoon season (June, July, August and September months abbreviated as or JJAS).

It can be seen that:

- The north-eastern and south-western parts of the state are projected to experience decrease in the quantum of rainfall, annually. This roughly correlates with observed trends over the last 30 years.
- Over the JJAS season too, north-eastern and south-western parts of the state are projected to experience reduced amounts of rainfall

Monthly temperature increases for Bijapur

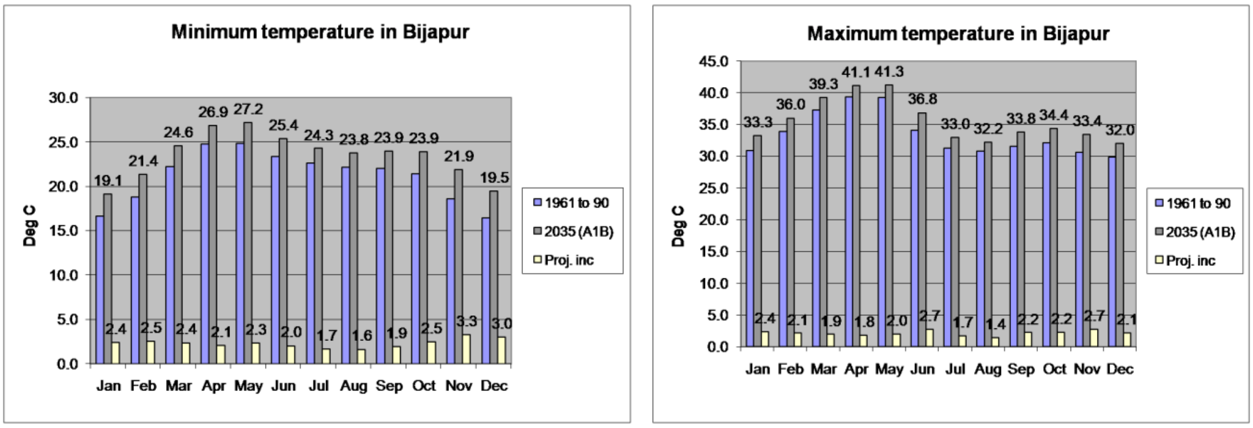


Figure 2.9: Projected increases in the maximum and minimum temperatures in Bjiapur.

We analyzed the projected increases on a monthly scale for all the districts. An example is given in Fig. 2.9 for Bijapur (a large and important district in the northern part of the state).

Main observations are:

- The minimum temperature goes up by as much as 2.4 to 3.3 ^{0}C in the winter months (November to February)
- The maximum temperature goes up by as much as 2.7 ^{0}C in June and November.
- The average daily maximum temperature is projected to go up to as much as 41.3 ^{0}C in the month of May. This may be detrimental to various crop systems and natural ecosystems.

Projections for the frequency of droughts

We define a period of absence of rainfall (daily rainfall < 2.5 mm) for 40 or more contiguous days as "an incidence of severe drought". This agrees with the FAO definition of droughts. Further, we identify two major growing seasons in Karnataka: *Kharif* (July 2nd week to October

2nd week) and *Rabi* (September 1st week to February 4th week). The number of incidences of severe droughts are estimated for 2021-2050 for each grid point and compared to the baseline. The percentage increase is calculated; this increase gives an indication of possible increases in drought instances for that grid-point. Grids that are not drought-prone (number of severe drought instances less than 20 in the 30-year baseline) are excluded. The result of the analysis is shown in figure 2.10.

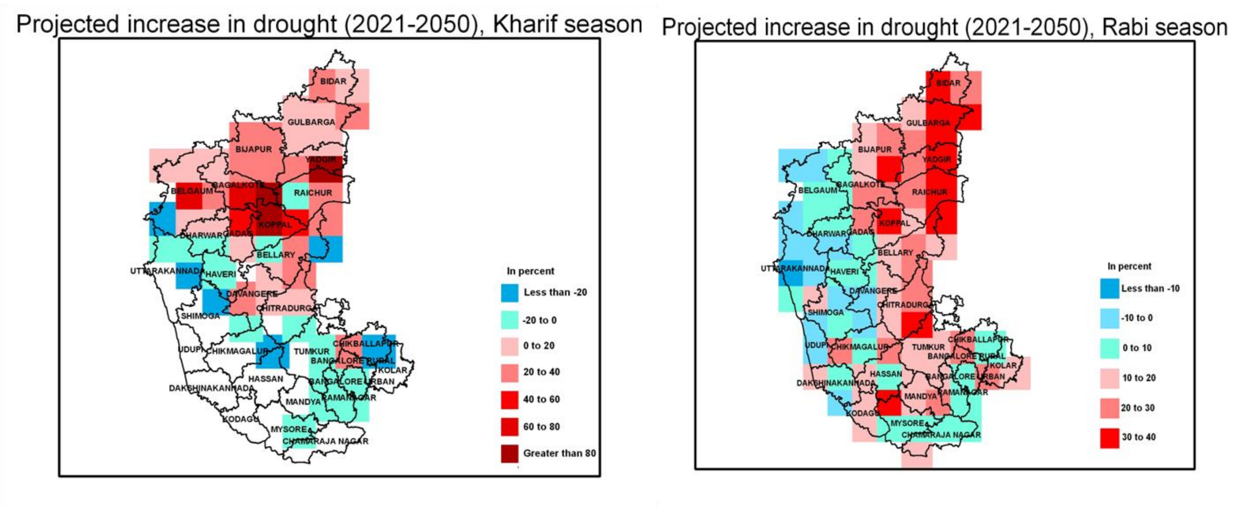


Figure 2.10: Projected increase in drought incidences in the future, compared to the baseline (1961-1990). The percentage increases in drought incidences in Kharif and Rabi season are shown. The blue colors indicate that drought instances are projected to decrease, while the red colors indicate that such instances may increase.

We find that:

- In the Kharif season, most northern districts are projected to have an increase in drought incidences by10-80%
- Districts of Koppal and Yadgir are projected to have almost a doubling of drought frequency in the Kharif season
- In the Rabi season, drought frequency is projected to increase in most of the eastern districts of the state.

- The western parts of the state are projected to have more rainfall and hence less number of droughts in the Rabi season.

Multi-GCM analysis of temperature and rainfall projections

Method: To ensure reliability of projections, analyses of multiple models are often used to build confidence. We also use a similar multi-model methodology; that is, we analyze how much the projection from other GCMs agree with that of HadRM3 (from which all our district-wise projections have been derived) for A1B scenario. All GCM grids falling in the general rectangular region containing Karnataka (latitude between 11.0 ° N and 18.0 ° N and longitude between 74.0 ° E to 78.0 ° E) were analyzed.

Temperature: Figure 2.11 and 2.13 show the increase in temperature projected by different GCMs. Mean of all GCMs is indicated by the dotted lines. One can observe that the increases projected by HadCM3 are quite near the mean projections.

- Rainfall: Figures 2.12 and 2.14 show a similar comparison, but for annual increase in rainfall predicted by various models. HadCM3 projections are quite near the average projections except for the period of 2065-2080.

Hence, we find that HadRM3 temperature and rainfall projections (which are based on HadCM3) are nearly representative of the mean of IPCC models, especially in the near future (2021-2050). Also, the high degree of agreement among GCMs with respect to temperature projections and less agreement with respect to rainfall projections can be observed. However, we caution that the spatial pattern of projection from other GCMs could be different. The signal to noise ratio is also usually higher at local scales. To address the uncertainty at local district levels, downscaled data from multiple GCMs will have to be analyzed in the future.

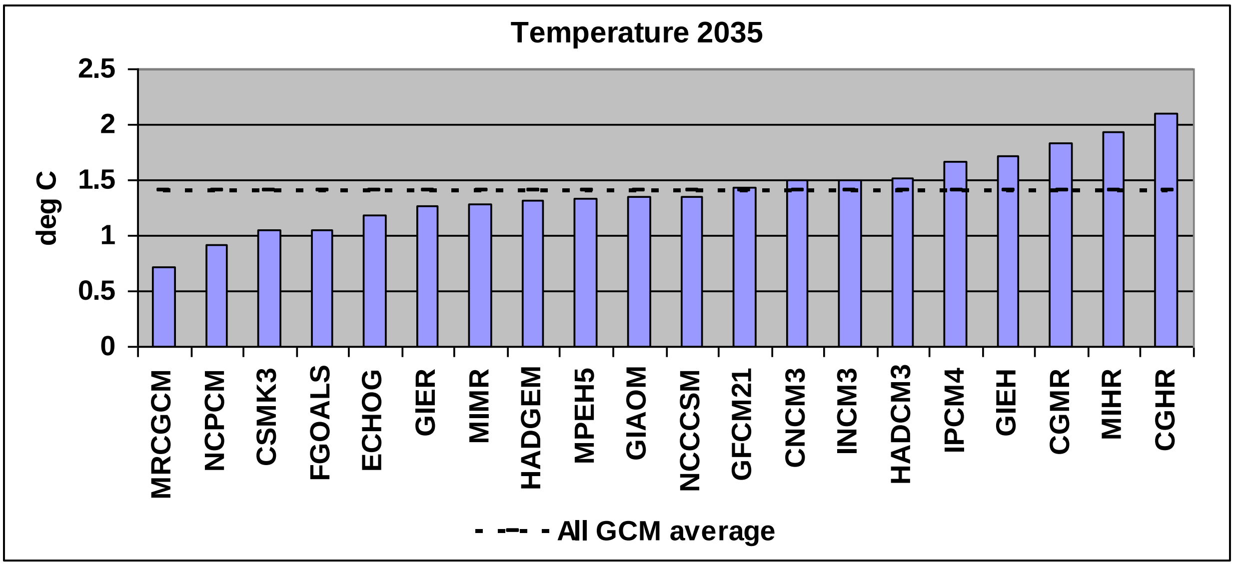


Figure 2.11: The change in temperature projected for the Karnataka region by various IPCC GCMs for the period of 2021-2050 relative to the period of 1961-1990. The dash-dotted line shows the mean from all models.

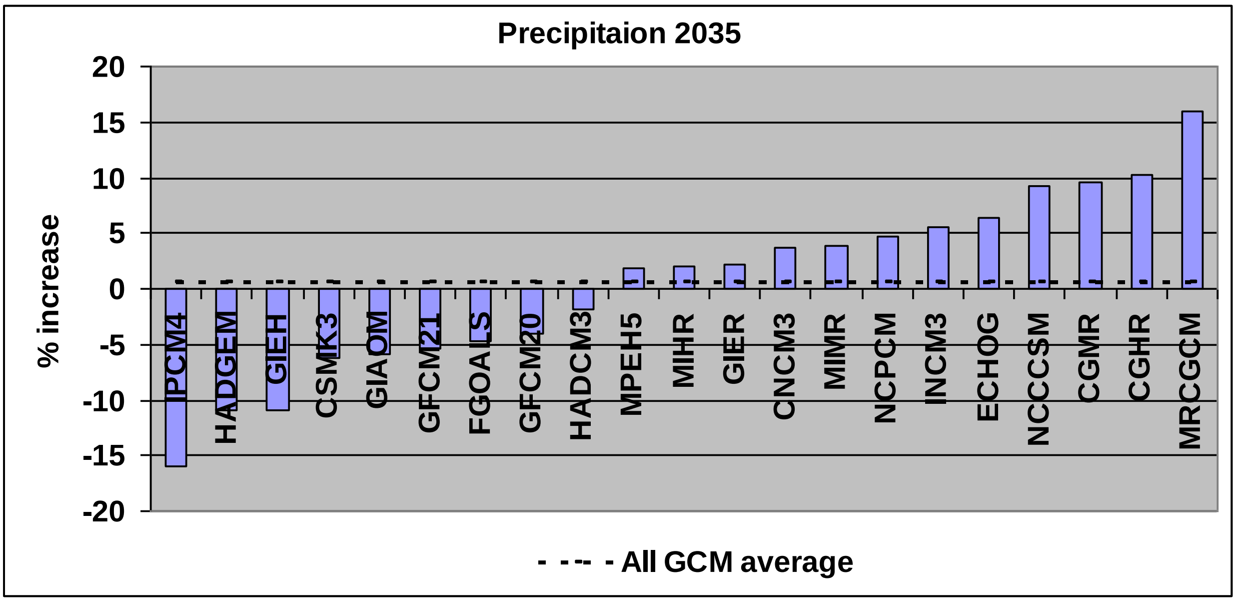


Figure 2.12: The change in precipitation projected for the Karnataka region by various IPCC GCMs for the period of 2021-2050 relative to the period of 1961-1990. The dash-dotted line shows the mean from all models.

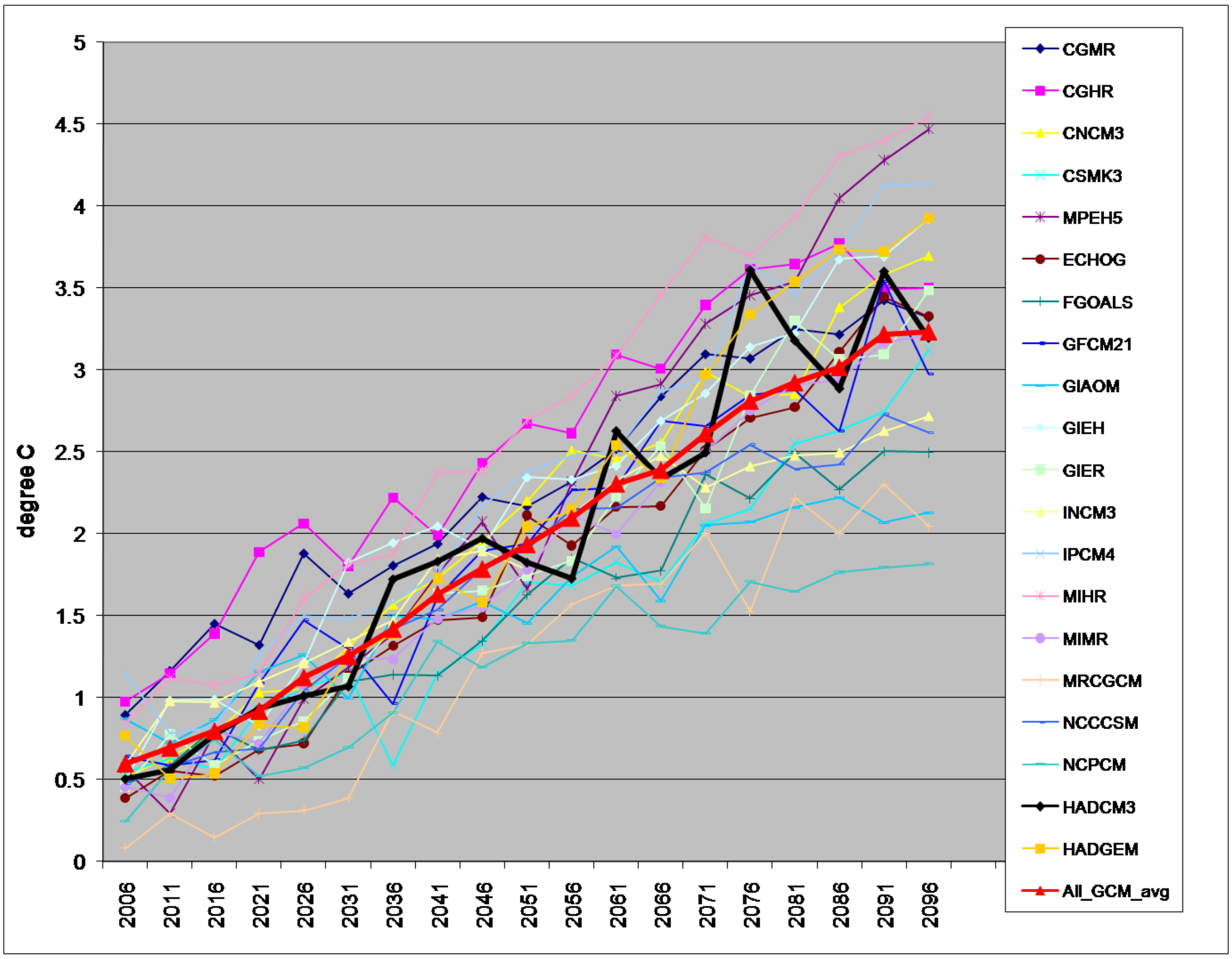


Figure 2.13: Projected change in temperature (°C) relative to baseline (1975) for Karnataka region under A1B scenario. The HadCM3 result is shown by thick black line and the multi-model average is shown in red.

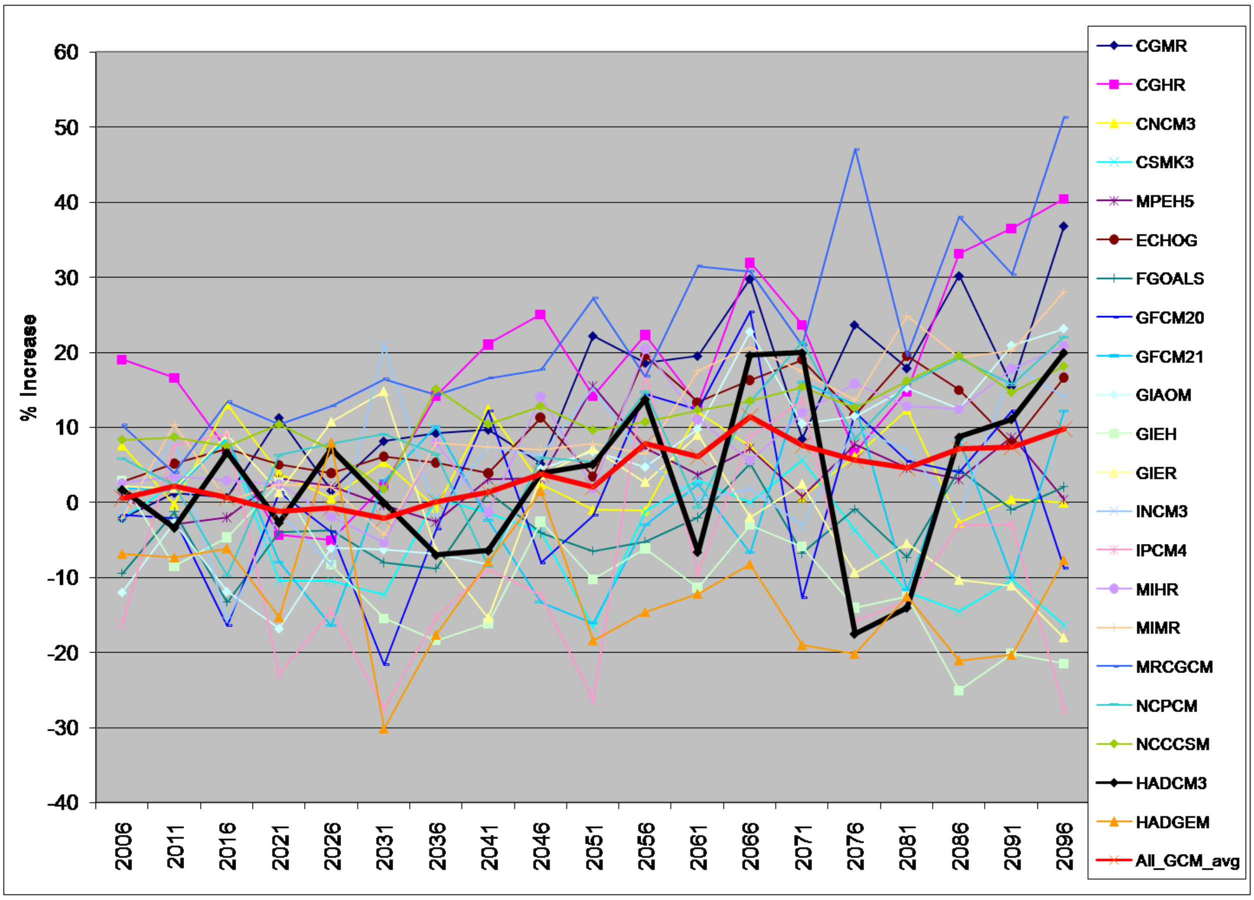


Figure 2.14: Projected change in rainfall (%) relative to baseline (1975) for Karnataka region under A1B scenario. The HadCM3 result is shown by thick black line and the multi-model average is shown in red.

Comparison of projected changes in rainfall with observed changes

In this section, we compare the changes in rainfall (quantum of increase/decrease) that is projected by the HadCM3 model (over the period of 1975 to 2035) against trends that are already observed over the period of 1971-2005. For example, HadCM3 could be projecting that the annual rainfall would increase at a rate of 3% per decade (from 1975 to 2035) for a particular district. The question is: what is the actual observed increase seen for that district? To address this question, we compare the projected trend and the observed trend for the districts. The method used for these is briefly outlined below.

Method

Projected trend: (a) The average rainfall for the baseline period of 1961-1990 (A1B) is obtained from the HadCM3 model; (b) The average rainfall for the period of 2021-2050 (A1B) was obtained from the HadCM3 model; c) The percentage increase between (a) and (b) are computed. The data was then scaled so that the percent increase is over a 10-year period.

Observed trend: a) The climatological mean rainfall for the period of 1971-1991 was obtained from 0.5 degree x 0.5 degree IMD data; b) The climatological mean rainfall for the period of 1985-2005 was obtained from 0.5 degree x 0.5 degree IMD data; c) The percentage increase between (a) and (b) were computed. The data was then scaled so that the percent increase is over a 10-year period.

Correlation between projected and observed rainfall

- Correlation is high between model projections and actual observed rainfall trends for the annual-mean and the post monsoon (OND) period (Figs. 2.15 and 2.17). Therefore, we may conclude that projections by the model for annual and OND rainfall are quite robust. Hence, it can be stated with some confidence that: 1) Annual rainfall would generally decrease in the North-east and South-west parts of the state; 2) The OND rainfall would decrease in the South-west part of the state.
- Correlations are weak for the summer monsoon (JJAS) period (Fig. 2.16)
- Observed trends mostly have a much higher magnitude (of the order of 10-20%) than projections (of the order of 0-5%). Therefore, our projections may be underestimating the trends.

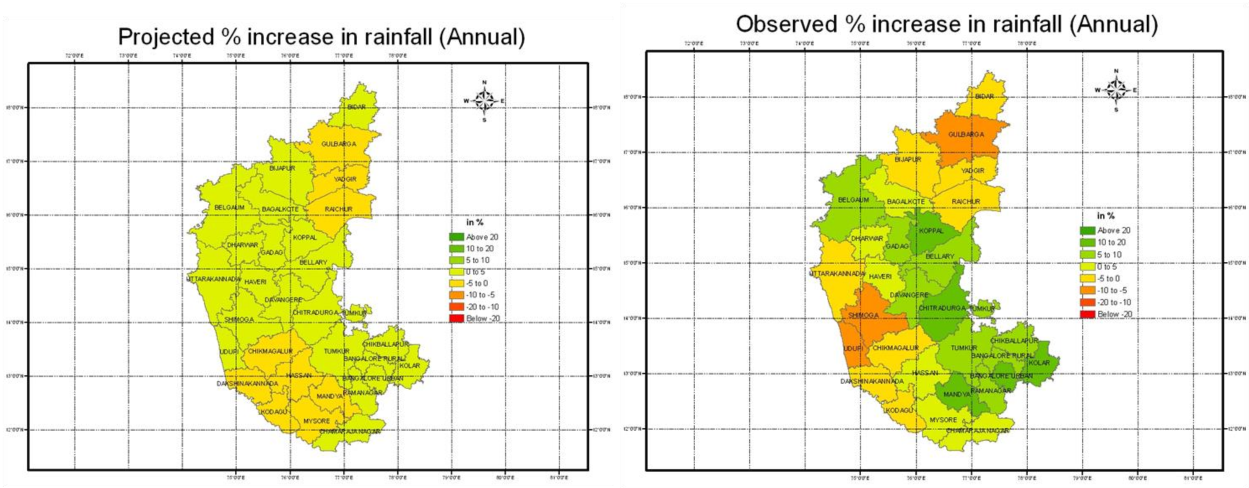


Figure 2.15: Change in annual-mean rainfall (projected vs observed) for the periods between 1961-1990 and 2021-2050 in the model projections and between1971-1991 and 1985-2005 in the observed records. A decrease in rainfall is projected for the north-eastern and south-western parts of the state. A similar trend is seen in the observed rainfall. But the magnitude of the trends is much higher in the observed case. For example, there are districts where the rainfall has decreased in the range of 10 to 20% (per 10 years) in the past but this magnitude of trend is not seen in the projections. Therefore, our model may be underestimating the drying trend in these regions.

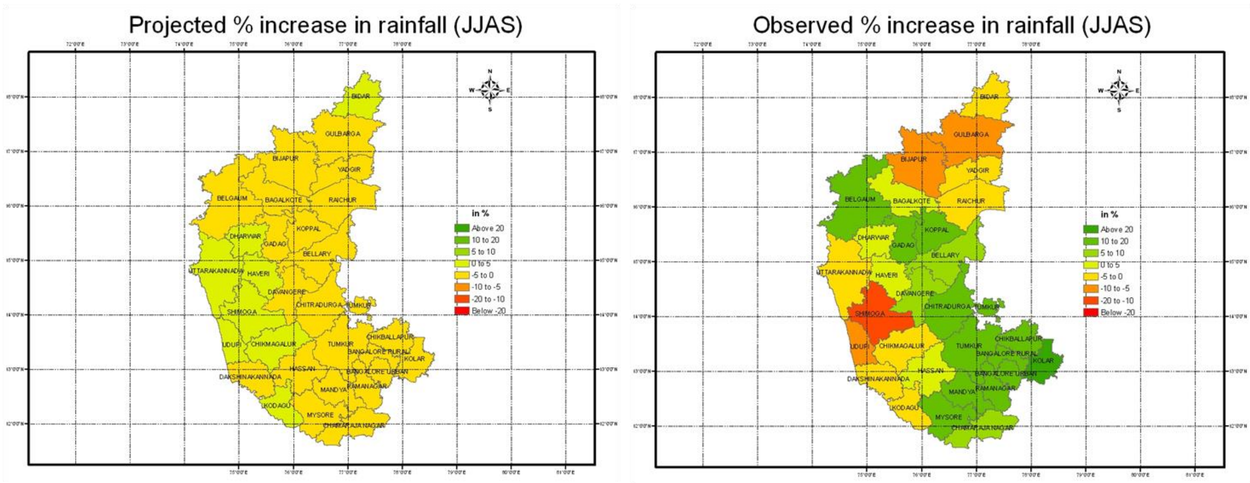


Figure 2.16: Change in rainfall (projected vs observed) during the monsoon season (JJAS) for the periods between 1961-1990 and 2021-2050 in the model projections and between1971-1991 and 1985-2005 in the observed records. In this comparison, rainfall is projected to slightly increase in the north-eastern tip of the state, and the western parts. But a different pattern is seen in the observed data: rainfall has significantly decreased in these parts especially in the western parts of the state (district of Shimoga).

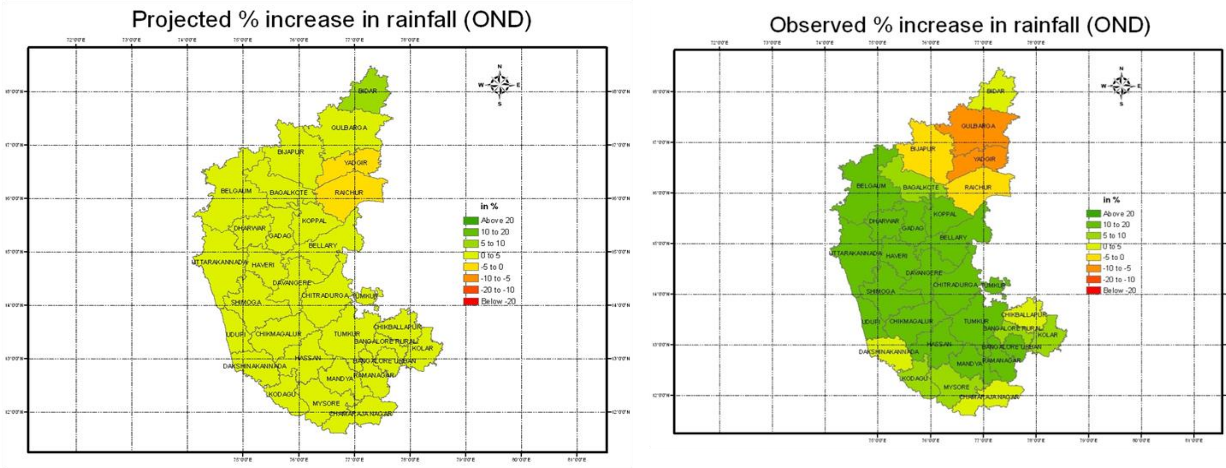


Figure 2.17: Change in post monsoon season (OND) rainfall (projected vs observed) for the periods between 1961-1990 and 2021-2050 in the model projections and between1971-1991 and 1985-2005 in the observed records. In this case, rainfall is projected to slightly decrease in the north-eastern parts of the state. This pattern is also seen in the observed data. But the observed magnitude is much higher (particularly in the districts of Gulbarha and Yagdir).

Summary:

- The rainfall analysis IMD gridded data shows that there is a long-term negative trend of about 6% in precipitation over Karnataka for the period 1951-2004.
- The rainfall variability is very high in Chikballapur, Chitradurga, Gadag, Kolar, Mandya and Tumkur districts.
- There is considerable decrease in precipitation over the Coastal and North Interior Karnataka districts during the period 1951-2004.
- Annual mean minimum and maximum temperatures are highest in Raichur, Gulbarga and Yadgir districts of North Interior Karnataka.
- Bidar and Gulbarga districts indicate a larger inter-annual variability with respect to annual mean minimum and maximum temperature.
- A steady warming trend is observed in both the minimum and maximum temperature over Bijapur, Gulbarga and Raichur.
- Most of the areas in the state is projected to experience a warming of 1.8 to 2.2 ^{0}C

- The north-eastern and south-western parts of the state are projected to experience decrease in the quantum of rainfall, annually and during JJAS season.
- The OND rainfall is projected to decrease in the South-west part of the state.

Acknowledgment:

We thank the World Bank for supporting this study. We also thank BCCI-K for coordinating the project activities.

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Chapter 3

Impacts of Forests in Karnataka Region

Indian Institute of Science, Bangalore

2011

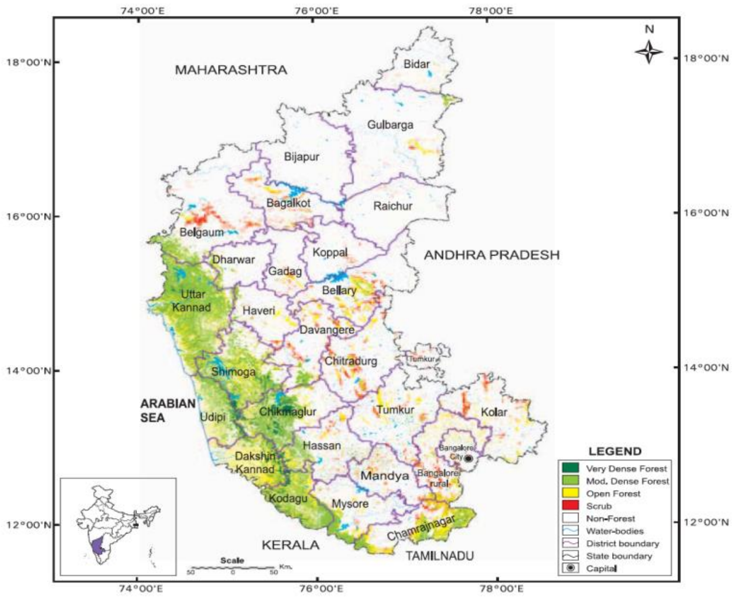
Impacts of forests in Karnataka Region

Introduction

Forest sector is important in the context of climate change due to three reasons namely; i) deforestation and land degradation contributes to about 20% of global CO_2 emissions, ii) forest sector provides a large opportunity to mitigate climate change, particularly the REDD (Reducing Emissions from Deforestation and Degradation) mechanism, and iii) forest ecosystems are projected to be adversely impacted by climate change, affecting biodiversity, biomass growth and forest regeneration. Climate is one of the most important determinants of vegetation patterns globally and has significant influence on the distribution, structure and ecology of forests. It is therefore logical to assume that changes in climate would alter the configuration of forest ecosystems. Based on a range of vegetation modeling studies, IPCC (2007) concluded that a-third of biodiversity is under the threat of extinction and further, significant impacts of climate change are projected on forest biodiversity and regeneration, especially in tropics and mountain areas. Studies at Indian Institute of Science (IISc) concluded that under the climate projections for the year 2085, 77% and 68% of the forested grids in India are likely to experience shift in forest types under A2 and B2 scenarios, respectively. A recent study from IISc using a dynamic global vegetation model showed that at the national level, about 45% of the forest areas are projected to undergo change by 2030s under A1B climate change scenario. Thus, Government of India has formulated a National Greening India Mission in the context of climate change adaptation and mitigation and to sustain the ecosystem services of forests.

State of forests in Karnataka

The distribution of forests along with crown densities in Karnataka is given in Figure 3.1a. The area under forests in Karnataka is estimated by Forest Survey of India at 3.62 million hectares, and it accounts for about 19% of the geographic area. Moderate dense forests account for about 56 % of the forest area followed by very dense forests accounting for only about 5%. Among the forest types (Figure 3.1b)) tropical dry deciduous and tropical moist deciduous forests account for about 25% each and tropical evergreen + semi evergreen forests together account for about 35%.



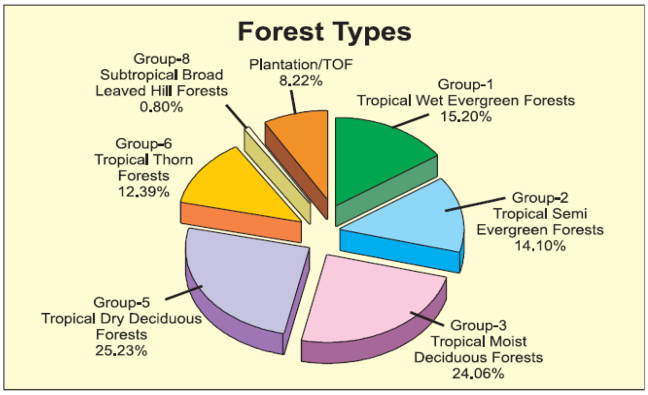


Figure 3.1(a and b): Karnataka Forest Cover Map (left) and Forest types of Karnataka (right) (FSI, 2009)

Trends in area under forests are given in Table 3.1. According to Forest Survey of India, area under forests seems to have marginally declined during the period 2001 to 2007. The dense forest has declined significantly during this period and consequently the area under open forest has increased.

Table 3.1: Trends in area under different types of forest in Karnataka (sq km)

Forest type	2001 assessment	2003 assessment	2005 assessment	2007 assessment
Dense forest	26156	22461	21968	21958
Open forest	10835	13988	14232	14232
Scrub forest	3245	3141	3173	3176
Total	**40236**	**39590**	**39373**	**39366**

Afforestation and forest conservation programmes in Karnataka:

- Karnataka has implemented a large afforestation programme. Around 1.2 million hectares of degraded forest and non forest lands have been afforested in the past 25 years. Karnataka has adopted multiple models under the afforestation programme including; Ecological restoration through Natural regeneration, Assisted Natural Regeneration, Plantations for Timber production, Plantation for fuelwood and small timber production, NTFP Plantations, School forest, farm forestry and Restoration of Mangroves.
- More than 700 million seedlings have been distributed to the farmers, institutions and people for agro-forestry, farm forestry and homestead gardens in the last 25 years.

- Karnataka has adopted Joint Forest Program to involve local people in protection, planning and management of forests. Under the national afforestation program, FDAs, have been constituted in the forests and the wildlife divisions.
- As part of Biodiversity protection and conservation initiative, around 17% of the forest area has been brought under protected area network (5 national parks and 21 Wildlife Sanctuaries).

Impact of climate change on forests of Karnataka

Objectives

Forest sector is important in the context of climate change due to three reasons namely; i) deforestation and land degradation contributes to about 20% of global CO_2 emissions, ii) forest sector provides a large opportunity to mitigate climate change, particularly the REDD (Reducing Emissions from Deforestation and Degradation) mechanism, and iii) forest ecosystems are projected to be adversely impacted by climate change, affecting biodiversity, biomass growth and forest regeneration. Climate is one of the most important determinants of vegetation patterns globally and has significant influence on the distribution, structure and ecology of forests. It is therefore logical to assume that changes in climate would alter the configuration of forest ecosystems. Based on a range of vegetation modeling studies, IPCC (2007) concluded that a-third of biodiversity is under the threat of extinction and further, significant impacts of climate change are projected on forest biodiversity and regeneration, especially in tropics and mountain areas). A recent study (Ravindranath et al., 2006) concludes that 77% and 68% of the forested grids in India are likely to experience shift in forest types for climate change under A2 and B2 scenarios, respectively. In addition there have been two regional studies, the first focusing on potential climate change impacts on forests in the northern state of Himachal Pradesh (Deshingkar, 1997) and the second in the Western Ghats (Ravindranath et al., 1997). These studies indicated moderate to large-scale shifts in vegetation types with implications for forest dieback and biodiversity. A recent study from IISc using a dynamic global vegetation model showed that at the national level, about 45% of the forested grids are projected to undergo change by 2030s under A1B climate change scenario. Thus, Government of India has formulated a National Greening India Mission in the context of climate change adaptation and mitigation and to sustain the ecosystem services of forests.

Forests account for about 19% of the geographic area of Karnataka. Karnataka is also home to bulk of the biodiversity rich Western Ghats. Western Ghats, though a bio-diversity hotspot, has fragmented forests in its northern parts. This makes these forests additionally vulnerable to climate change as well as to increased risk of fire and pest attack.

Thus the impact of climate change in Karnataka is of great significance and adaptation measures may be required to enable forests to cope with the climate change.

Methods and Models:

An assessment of the impact of projected climate change on forest ecosystems in Karnataka is made using the following:

- ***Climate model***; Regional Climate Model of the Hadley Centre (HadRM3)
- ***Climate change scenario***; A1B scenario
- ***Climate impact model;*** global dynamic vegetation model IBIS
- ***Period of assessment***; short-term (2021-2050) periods.
- ***Baseline period***: 1961-1990, also referred to as either 1975 or 1970s
- ***Input data***; monthly mean cloudiness (%), monthly mean precipitation rate (mm/day), monthly mean relative humidity (%), monthly minimum, maximum and mean temperature (C) and wind speed (m/s), soil parameter (percentage of sand, silt and clay) and topography.

Impacts of climate change:

The dynamic global vegetation model has been validated by Indian Institute of Science for its suitability for Indian conditions. The impacts are assessed at regional climate grid scales (about 50kmx50km). It can be observed that during the short term period of 2030s (atmospheric CO_2 concentration reaches 490ppm), out of the 1946 forested grids in Karnataka 747 (38%) will be impacted by climate change. This means that the projected climate is not suitable for the existing forest types and the species present. The distributions of the forested grids which are projected to be impacted by climate change are presented in Figure 3.2 for 2030s. Forested grids mainly in the central and northern parts of Western Ghats and South-east are projected to be impacted by climate change.

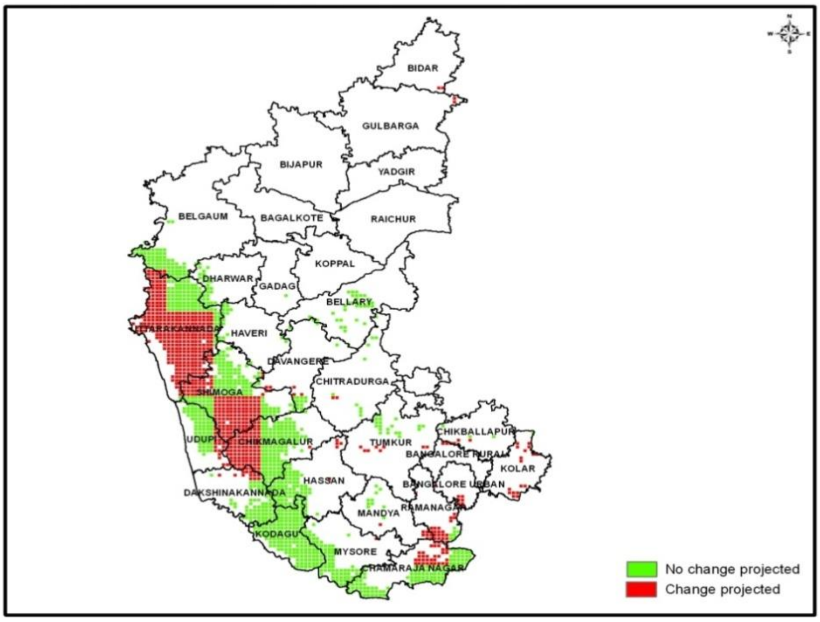


Figure 3.2: Forest vegetation change projected by 2035 under A1B scenario in Karnataka

Climate change and Western Ghats:

Western Ghats is one of the biodiversity hotspots. According the dynamic global vegetation model projections, the forests of Uttar Kannada, Chikkamagalur and Shimoga districts are particularly vulnerable to the projected climate change even by as early as 2030s. Thus the biodiversity rich Western Ghats region of Karnataka is projected to be adversely impacted by climate change threatening the biodiversity.

Greening India Mission; Mitigation and adaptation

Government of India has formulated a large Greening India Mission aimed at mitigation and adaptation. Greening is meant to enhance ecosystem services such as carbon sequestration and storage, biodiversity conservation and provision of biomass and NTFPs (Non Timber Forest Products). The mission aims at responding to climate change by combination of adaptation and mitigation measures which would aim at;

- Enhancing carbon sinks in sustainably managed forests and other ecosystems
- Adaptation of vulnerable species/ecosystems to the changing climate and
- Adaptation of forest dependent communities.

Thus under the state action plan both adaptation and mitigation projects are proposed for addressing climate change impacts on forest ecosystems as well as to mitigate the climate change through enhancing the carbon sinks**.**

Adaptation programme under the Greening India Mission:

It was shown earlier in Figure 3.2 that significant proportion of the forests in Karnataka is vulnerable to climate change risks. There are no scientific studies to recommend specific adaptation measures suitable for different vulnerable forest types and regions. Studies by Indian Institute of Science have suggested some of the *win-win* adaptation strategies and practices to promote adaptation to projected climate risks. Table 3 presents a preliminary list of potential adaptation interventions and project ideas, particularly focused on the Western Ghats. There is a need for conducting preliminary studies to identify locations for implementing the adaptation measures. The cost of each of the adaptation interventions is not readily available. Many of the **adaptation interventions such as anticipatory planting, promotion of natural regeneration, mixed species forestry, and prevention of fire can become an integral part of the mitigation projects proposed under the greening India Mission**, listed in Table 3.2. Linking Protected Areas should be one of one priority projects under the adaptation programmes.

Table 3.2: Adaptation projects proposed for Karnataka under the Greening India Mission (GIM)

Category of Adaptation interventions	***Proposed adaptation Activities / Projects in Karnataka***
Anticipatory planting of species across latitudinal and longitudinal gradient	This will be a component of all mitigation programs / projects proposed under the Mitigation component of GIM (Table 3.3)
Promotion of natural regeneration and mixed species planting	This will be a component of all mitigation programs / projects proposed under the Mitigation component of GIM (Table 3.3)
Adoption of short rotation species	For all afforestation projects in the western ghats region
Effective fire prevention and fire management	For implementation in all the current fire prone areas of the state
Linking Protected Areas (PAs) management (for securing corridors for species migration)	Identify locations for linking existing PAs As a pilot project linking two PAs is proposed linking – Kuduremukh National Park and Krishnagiri Sanctuary
Reduced forest fragmentation by conserving contiguous forest patches	Identify locations for linking forest fragments in the western ghat region and a pilot project is proposed

Mitigation projects under the Greening India Mission:

Forest sector provides a large opportunity for mitigation of climate change, in particular through reducing CO_2 emissions by reducing deforestation and forest degradation as well as increasing carbon sinks in the existing forests and creating new sinks in degraded lands through afforestation. The GIM has identified five sub-missions and several activities or interventions. The proposed mitigation programs and projects under the GIM are presented in Table 3.3, along with area proposed and the investment cost required.

Table 3.3: Mitigation projects proposed under the Greening India Mission (GIM)

GIM activities	***Categories under sub-missions***	***Regions of state***	***Total Area***		***Investment cost per hectare (in Rs.)***	***Total investment cost (in crores of Rs.)***
			Total Potential Area (in Mha)	***Extent of Proposed Area (in Mha)***		
1	2	3	4	5		
Sub-mission 1: Enhancing quality of forest cover and improving eco-system services	Moderately dense forest cover, but showing degradation	Western Ghats	2	0.2	15,000	300
	Eco-restoration of degraded open forests	Western Ghats and other areas	1.4	0.4	30,000	1200
	Restoration of grasslands	Outside forests	0.94	0.1	35,000	350
	Total		**4.34**	**0.7**		**1850**
Sub-mission 2: Eco-system restoration and increase in forest cover	Restoring scrublands		0.32	0.1	50,000	500
	Restoration of mangroves		0.001	0.001	70,000	7
	Restoration of abandoned mining areas		-	0.005	100,000	50
	Total		**0.32**	**0.106**		**557**
Sub-mission 3: Enhancing tree cover in Urban areas	Avenue, city forests, municipal parks, gardens, households, institutional lands, etc.,		-	0.02	10,000	20

Sub-mission 4: Agro-forestry and Social Forestry	Shelterbelt plantations		0.015	0.01	8000	8
	Private lands		5	0.5	20,000	100
	Highways/ rural roads/canals/tank bunds (ha)		0.045	0.03	70,000	210
	Total		**5.06**	**0.56**		**2745**

Mitigation potential of the proposed projects under greening India mission:

Mitigation potential of proposed activities (Table 3.3) is estimated using COMAP model and Carbon sequestration rates used in the Greening India Mission. **The annual incremental mitigation potential (Table 3.4) is estimated to be 15.5 million tonnes of Carbon or about 57 million tonnes of CO_2 by 2020.**

Table 3.4: Incremental annual mitigation potential of proposed activities different options

Options	Area (Mha)	Incremental annual mitigation potential 2020 (MtC)	Incremental cumulative mitigation potential 2010-2020 (MtC)	Incremental cumulative mitigation potential 2010-2030 (MtC)
Moderately dense forests	0.2	1.8	13.7	32.0
Degraded/open forests	0.4	7.4	55.4	129.2
Scrub/grassland ecosystems	0.205	2.2	16.3	38.1
Mangroves	0.001	0.0	0.1	0.2
Agroforestry & social forestry incl. urban forestry	0.56	4.1	30.7	71.7
	1.366	**15.5**	**116.2**	**271.2**

Institutional arrangements for mitigation and adaptation programs

The **institutional arrangement** proposed for mitigation and adaptation programmes to address climate change proposed under the State climate change action plan is given in the box below.

Activities		**Institution**
Research	Carbon mitigation projects	Research wing of Karnataka Forest Department (KFD) and Indian Institute of Science (IISc)
	Impact and vulnerability modeling	Research wing of KFD and IISc
	Adaptation projects	Research wing of KFD, IISc, Institute of Social and Economic Change (ISEC) and Forestry College at Sirsi and Ponampet
	Long term monitoring	Research wing of KFD and Forestry Colleges at Sirsi and Ponampet
Monitoring	Carbon stocks	Research wing of KFD, IISc and Forestry Colleges at Sirsi and Ponampet
	Biodiversity	Research wing of KFD and Forestry College at Sirsi and Ponampet
	Growth rates	Research wing of KFD and Forestry Colleges at Sirsi and Ponampet
	Socio-economic aspects	Research wing of KFD and ISEC
Implementation	Overall the implementation of the mitigation and adaptation programmes under the Green India Mission would constitute an additional programme implementation responsibility along with the regulatory and developmental responsibilities that the KFD discharges at present. Forest Department does not have enough staff strength especially at lower levels to shoulder enhanced targets. Neither is the present set of staff adequately trained for a qualitative and people oriented Joint working. However keeping in view the above mentioned limitation, it is proposed to set up a special purpose vehicle totally different in composition and culture for effective implementation of Greening India Mission. At the department level, the works in the notified forest areas will be taken up through the territorial wing of the	

	department while those outside notified forests would be implemented through a separate *Directorate of Social Forestry* that will be assisted at Circle/Division level by subject matters specialist like Sociologist, Economist, Extension and Training Experts, etc for enhanced effectiveness. While the overall programme implementation will be facilitated, supervised and monitored by the KFD, the Village Forest Committees (VFCs) and Eco-development Committees (EDCs) will have a greater role in implementation of works at field level with the involvement of Non-Government Organization (NGOs) and other village level thematic groups like Self Help Groups (SHGs) under linkage with Gram Panchayaths. Research, modeling, GIS and Monitoring personnel need to be outsourced or engaged on contract basis or on deputation to have continuity of term so as to enable running of these facilities on professional lines. Such professional support is very essential to assist the Research, Working Plan and Evaluation Wings in the department.

Conclusion:

- There are around 3.62 Mha of forests in Karnataka. The area under forests is marginally declining in the state, while the area under dense forests has declined significantly (more than 8% from 2001 to 2007).
- It is projected that the forests of Uttar Kannada, Chikkamagalur and Shimoga districts are particularly vulnerable to the projected climate change even by as early as 2030s. Overall, around 38% of the forest area is projected to be impacted by climate change by the 2030s.
- The annual incremental mitigation potential of forestry in the state is estimated to be 15.5 million tonnes of Carbon or about 57 million tonnes of CO_2 by 2020.

Acknowledgment:

We thank the World Bank for supporting this study. We also thank BCCI-K for coordinating the project activities.

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Chapter 4

Impact on Agricultural Sector

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2011

The climate projections over India indicate that temperature rise is likely to be around 3°C and rainfall increase is expected by 10-20 per cent over Central part of India by the end of this century. Whether the projections would become real or not, the occurrences of weather extremes like floods and droughts, cold and heat waves will not be uncommon across the Country. The cold wave during 2008 was even extended to Gujarat and Maharashtra. Both the States experienced a record low of night temperatures during the winter 2008. Similar was the cold wave in 2002-03 over the northern States of India, in particular Himachal Pradesh, which led to the estimated crop loss up to 100% depending upon the type of crops.

The wheat production in the Country during the previous years was not encouraging due to increase in temperature across the wheat growing regions during the reproductive phase of the crop. As per the FAD report, the wheat stocks have declined to their lowest levels since 1980. Less understood but an obviously potent factor is the effect of global warming? Probably, the stagnation in Indian food grains production since last one decade may be due to occurrence of extreme weather events. Also, the increase in temperature during the rabi season in north India has affected the country's wheat production and forced us to import to maintain the buffer stock. Hence, there is a need to address the whole issue of climate change and its ill-effects on Indian agriculture in totality so as to mitigate the same through adaptive techniques against the global warming on war-footing.

Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are still playing key role in Indian agricultural productivity there by national prosperity. Southwest monsoon, the source of about three fourths of India's annual rainfall is deciding the crop harvest and economy. The recent trend in climate variability alters the timing and intensity of the monsoon from year to year causing floods or droughts. Increasing evidence over the past few decades indicate that significant changes in climate are taking place worldwide due to enhanced human activities. Climate change and global warming also affect the abundance, spawning and availability of commercially important marine fisheries.

Impact of climate change on agriculture will be one of the major deciding factors influencing the future food security of mankind on the earth. The crop losses may increase if the predicted climate change increases the climate variability. Different crops respond differently as the global warming will have a complex impact. Some of the mitigation and adaptation measures suggested in vulnerable area would be helpful to overcome the production loss in the State. We hope this report will be of immense use for planners at the national/state level to chalk out various adaptive techniques against the ill-effects of climate change/variability/weather extremes.

Status of Annual, Seasonal and Monthly Normal and actual weather available parameters of different agro climatic zones/Districts of Karnataka State

Agriculture is a way of life for our people. In material terms, it provides sustenance for the vast majority of our population and accounts for nearly half of our national produce. On the success which attends our efforts here, depends also the success of our entire economic growth. Even now, much of our industry depends on agriculture for its raw material, exports emanate directly or otherwise from the agricultural sector and the growth of rural incomes will constitute an expanding market for the domestic industry.

Karnataka state forms the South Western part of the Deccan Peninsula and lies between 11.5°and 18.6° North latitude and 74.0° and 78.4° East longitudes. It is the 8th largest state in the country having an area of 191,791 Sq. Kms (6.25% of India's total area of 3,065,027 Sq.Kms.). The State has 30 districts, 176 taluks, 745 hoblies, 29,483 Villages. As per the census of 2001, the State has a total population of 5.27 crores accounting for 5.13 per cent of the country's total population of 102.70 crores. Sixty six per cent of the total population resides in rural areas, whose main occupation is Agriculture and allied activities. Out of the total population, 44.6 per cent is working population, of which 69.36 lakh are cultivators and 62.09 lakh are agricultural labourers. As per the Agricultural Census of 2000-01, the State has about 123.07 lakh hectares of cultivable.

Rainfall trend in the State:

Rainfall situation of the State (1901-2008) and projected for 2035: The daily weather data has been obtained from IMD Pune and DES, GOK has been analysed. The analysis revealed that State receives normal rainfall of 1152 mm (190-2008) of which monsoon receives 850 mm. The State mean annual rainfall was 1204 mm for the period 1901 to 1950 (Ref.1). Analysis indicated that the gradual declining in the south-west monsoon rainfall and decreased portion of rainfall is partly shared by Pre-monsoon and N-E monsoon. Hence there is a change in the rainfall pattern and amount of rainfall received during different months. The mean rainfall of the State for the period from 1951 to 2008 is found to be reduced to 1140 mm (Ref. 2). The mean monthly, seasonal and annual rainfall of all the districts is given table 1. The other weather parameters are given in tables 2-5. In addition to this some part of the State likely to receive the s-w monsoon rains required for agriculture beyond July month (Ref. 3). The mean temperature is also having the increasing tendency.

Table 1. Mean monthly, seasonal and annual Rainfall (A) and number of rainy days (B) of different districts of the Karnataka state up to 2008(1951 to 2008).

District	Rainfall	Jan	Feb	Mar	Apr	May	Pre. Mon	Jun	Jul	Aug	Sep	SWM	Oct	Nov	Dec	NEM	Annual
BENGALURU RURAL	A	2	3	10	32	94	141	71	87	115	154	427	145	63	14	222	790
	B	0.5	0.5	0.6	2.9	6.5	11	4.9	7	8.1	8.3	28.3	8.1	4.3	1	13.4	52.7
BENGALURU URBAN	A	1	8	9	37	113	168	73	103	132	158	466	166	65	10	241	875
	B	0.5	0.5	0.6	2.9	6.5	11	4.9	7	8.1	8.3	28.3	8.1	4.3	1	13.4	52.7
BAGALKOTE	A	1	2	4	24	57	88	68	75	74	143	360	93	35	8	136	584
	B	0.2	0.3	0.5	1.8	3.1	5.9	5	5.7	5.1	8	23.8	5	2	0.5	7.5	37.2
BELGAM	A	1	2	7	29	76	115	114	208	128	110	560	101	38	9	148	823
	B	0.2	0.1	0.6	2.4	3.8	7.1	7.4	11.8	9	7.5	35.7	6.4	2.4	0.6	9.4	52.2
BELLARY	A	1	1	3	27	71	103	69	88	99	132	388	101	34	10	145	636
	B	0.2	0.3	0.3	1.8	3.6	6.2	4.3	6.2	6.3	7.3	24.1	5.4	2.4	0.5	8.3	38.6
BIDAR	A	3	5	13	23	31	75	134	192	184	195	705	75	24	6	105	885
	B	0.5	0.8	1.1	2.1	2.4	6.9	7.4	11.6	10.1	10.7	39.8	3.6	1.6	0.4	5.6	52.3
BIJAPUR	A	1	2	6	20	44	73	78	89	103	157	427	95	28	8	131	631
	B	0.2	0.3	0.5	1.8	3.1	5.9	5	5.7	5.1	8	23.8	5	2	0.5	7.5	37.2
CHAMARAJANAGAR	A	4	6	15	68	146	239	58	64	82	112	316	163	79	19	261	816
	B	0.5	0.5	0.6	2.9	6.5	11	4.9	7	8.1	8.3	28.3	8.1	4.3	1	13.4	52.7
CHIKKABALAPURA	A	1	4	8	26	74	113	59	92	107	154	412	147	54	16	217	742
	B	0.5	0.5	0.6	2.9	6.5	11	4.9	7	8.1	8.3	28.3	8.1	4.3	1	13.4	52.7
CHIKMAGALUR	A	1	3	12	58	105	179	301	662	382	160	1505	145	59	16	220	1904
	B	0.3	0.3	0.8	3.9	6.1	11.4	15	21.4	18.5	11.6	66.5	9.1	4.1	1	14.2	92.1
CHITRADURGA	A	5	7	11	27	94	144	69	74	92	128	363	142	60	10	212	719
	B	0.3	0.3	0.3	1.8	4.3	7	4.2	6.9	6.1	6.2	23.4	6	2.9	0.6	9.5	39.9
DAKSHIN KANNADA	A	1	4	10	47	171	233	921	1301	796	320	3338	214	101	25	340	3911
	B	0.3	0.1	0.4	2.2	6.4	9.4	24.8	28.6	26.3	17.2	96.9	11	4.8	1.1	16.9	123.2
DAVANAGERE	A	1	2	4	39	84	130	63	92	98	108	361	91	66	9	166	657
	B	0.3	0.3	0.3	1.8	4.3	7	4.2	6.9	6.1	6.2	23.4	6	2.9	0.6	9.5	39.9
DHARWAD	A	1	3	8	47	88	147	105	152	100	123	480	106	43	10	159	786
	B	0.2	0.2	0.5	2.6	4.4	7.9	7.5	12	9.2	7.3	36	6.6	2.5	0.6	9.7	53.6

GADAG	A	1	3	5	30	76	115	62	67	108	128	365	101	40	9	150	630
	B	0.2	0.2	0.5	2.6	4.4	7.9	7.5	12	9.2	7.3	36	6.6	2.5	0.6	9.7	53.6
GULBARGA	A	2	3	8	20	38	71	108	163	175	194	640	107	16	5	128	839
	B	0.2	0.5	0.7	1.7	2.2	5.3	7.3	10.5	8.7	9.7	36.2	3.8	1.4	0.2	5.4	46.9
HASSAN	A	1	3	12	58	107	181	118	172	196	98	584	172	39	11	222	987
	B	0.4	0.4	0.7	3.6	7.1	12.2	8.9	13.8	10.6	7.7	41	8.9	4.6	1.1	14.6	67.8
HAVERI	A	1	3	5	41	82	132	96	201	103	85	485	80	65	15	160	777
	B	0.2	0.2	0.5	2.6	4.4	7.9	7.5	12	9.2	7.3	36	6.6	2.5	0.6	9.7	53.6
KODAGU	A	2	5	18	71	151	247	486	938	426	270	2120	150	95	20	265	2632
	B	0.5	0.4	1.4	5.9	8.9	17.1	19.6	25.6	21.5	14.4	81.1	12.4	6	1.4	19.8	118
KOLAR	A	8	12	13	25	75	133	55	79	87	142	363	119	81	27	227	723
	B	0.7	0.5	0.6	3.1	4.9	9.8	4.3	6.4	7.2	7.6	25.5	7.2	4.7	1.3	13.2	47.5
KOPPAL	A	1	1	2	20	50	74	65	91	96	133	385	93	24	7	124	583
	B	0.2	0.3	0.5	1.5	2.9	5.4	5.9	7.4	7.2	8.1	7.15	4.9	1.9	0.3	7.1	41.1
MANDYA	A	3	5	10	50	123	191	48	51	85	112	296	152	66	17	235	722
	B	0.3	0.4	0.6	3.6	7.2	12.1	3.6	3.9	5.1	6.2	18.8	8.5	4.2	1	13.7	44.6
MYSORE	A	3	4	13	65	135	220	65	100	81	89	335	150	51	10	211	766
	B	0.4	0.4	0.9	4.4	7.8	13.9	5.2	7.3	6.5	6.2	25.2	8.7	4.3	1	14	53.1
RAICHUR	A	1	1	2	16	45	65	85	101	126	168	480	101	28	7	136	681
	B	0.2	0.3	0.5	1.5	2.9	5.4	5.9	7.4	7.2	8.1	7.15	4.9	1.9	0.3	7.1	41.1
RAMANAGARA	B	1	6	12	45	127	191	63	82	102	178	425	168	53	15	236	852
	A	0.5	0.5	0.6	2.9	6.5	11	4.9	7	8.1	8.3	28.3	8.1	4.3	1	13.4	52.7
SHIMOGA	A	1	3	7	45	92	148	307	681	352	144	1484	136	41	10	187	1819
	B	0.2	0.2	0.6	2.7	4.5	8.2	13.2	20.5	16.9	9.8	60.4	7.6	3	0.7	11.3	79.9
TUMKUR	A	5	7	11	27	94	144	69	74	92	128	363	142	60	10	212	719
	B	0.3	0.4	0.5	2.3	5.5	9	4.3	6	6.6	7.2	24.1	7.3	3.8	0.8	11.9	45
UDUPI	A	1	3	4	30	170	208	1105	1341	840	383	3669	208	78	19	305	4182
	B	0.3	0.1	0.4	2.2	6.4	9.4	24.8	28.6	26.3	17.2	96.9	11	4.8	1.1	16.9	123.2
UTTARKANNADA	A	1	3	3	25	116	148	681	1006	602	248	2537	139	49	12	200	2885
	B	0.1	0.1	0.4	1.9	4.1	6.6	20.6	27.1	23.8	14.3	85.8	7.7	2.9	0.5	11.1	103.5
STATE	A	**2**	**3**	**8**	**37**	**91**		**189**	**272**	**199**	**159**		**136**	**45**	**11**		**1152**

Table 2.Mean monthly Maximum and Minimum Temperature (Deg. Cel) in different districts of the State

STATION	*TEMP.*	*JAN*	*FEB*	*MAR*	*APR*	*MAY*	*JUN*	*JUL*	*AUG*	*SEP*	*OCT*	*NOV*	*DEC*	*ANNUAL*
BANGALORE	*MAX*	*26.9*	*29.7*	*32.3*	*33.4*	*32.7*	*28.9*	*27.2*	*27.3*	*27.6*	*27.5*	*26.3*	*25.7*	*28.8*
	MIN	*15*	*16.5*	*19*	*21.2*	*21.1*	*19.7*	*19.2*	*19.2*	*18.9*	*18.9*	*17.2*	*15.3*	*18.4*
BELLARY	*MAX*	*30.3*	*33.3*	*36.4*	*38.1*	*37.9*	*33.7*	*31.5*	*31.4*	*31.5*	*31.3*	*29.9*	*29.3*	*32.9*
	MIN	*17.6*	*19.9*	*22.9*	*25.5*	*25.8*	*24.7*	*24*	*23.5*	*23*	*22.3*	*19.6*	*17.4*	*22.2*
BALEHONNUR	*MAX*	*27.3*	*29.3*	*31.3*	*30.9*	*29.4*	*25.1*	*22.7*	*23.2*	*24.5*	*26.1*	*26.2*	*26.2*	*26.9*
	MIN	*14.8*	*15.8*	*17.5*	*19*	*19.5*	*18.8*	*18.5*	*18.6*	*18.1*	*17.9*	*16.4*	*14.9*	*17.5*
CHITRADURGA	*MAX*	*28.9*	*32*	*34.9*	*36.3*	*35.1*	*30.6*	*28.1*	*28.1*	*29.1*	*29.6*	*28.4*	*28*	*30.8*
	MIN	*17.1*	*19.2*	*21.5*	*22.7*	*22.3*	*21.4*	*20.8*	*20.5*	*20.3*	*20.3*	*18.4*	*16.7*	*20.1*
MERCARA	*MAX*	*24.6*	*26.8*	*28.5*	*27.9*	*26.3*	*21.9*	*20.2*	*20.7*	*22*	*23.7*	*23.6*	*23.5*	*24.1*
	MIN	*14.2*	*15.1*	*16.6*	*17.9*	*18.3*	*17.4*	*17.1*	*17.1*	*16.9*	*17*	*16.1*	*14.6*	*16.5*
HASSAN	*MAX*	*28.1*	*30.5*	*32.9*	*33.2*	*31.5*	*26.8*	*24.8*	*25.5*	*26.7*	*27.6*	*27*	*26.8*	*28.5*
	MIN	*14.7*	*16.1*	*18.2*	*20.1*	*20.3*	*19.4*	*18.9*	*18.8*	*18.4*	*18.6*	*16.9*	*15*	*17.9*
MYSORE	*MAX*	*28.3*	*31.2*	*33.5*	*34*	*32.6*	*28.9*	*27.3*	*27.9*	*28.7*	*28.4*	*27.4*	*27*	*29.6*
	MIN	*16.4*	*18.2*	*20.2*	*21.4*	*21.2*	*20.2*	*19.7*	*19.6*	*19.3*	*19.6*	*18.3*	*16.5*	*19.2*
SHIMOGA	*MAX*	*30.5*	*32.9*	*35.3*	*35.7*	*33.8*	*29*	*26.8*	*27.1*	*28.6*	*29.2*	*29.1*	*28.9*	*30.6*
	MIN	*14.6*	*16.1*	*19.1*	*22.2*	*22.5*	*21.7*	*21.1*	*21*	*20.5*	*20.3*	*17.3*	*14.4*	*19.2*
HONAVAR	*MAX*	*31.9*	*31.3*	*31.9*	*32.4*	*32.3*	*29.3*	*28.2*	*28.3*	*28.8*	*30.6*	*32.5*	*32.7*	*30.9*
	MIN	*20*	*20.5*	*22.7*	*25.2*	*25.8*	*24.1*	*23.5*	*23.5*	*23.2*	*23.2*	*21.9*	*20.9*	*22.9*
MANGALORE	*MAX*	*31.4*	*31.1*	*31.7*	*32.4*	*32.1*	*29.4*	*28.5*	*28.5*	*28.7*	*29.8*	*31.1*	*31.7*	*30.5*
	MIN	*21.7*	*22.8*	*24.5*	*26.1*	*26*	*23.9*	*23.5*	*23.6*	*23.5*	*23.8*	*23.2*	*21.9*	*23.7*
BELGAUM	*MAX*	*30.1*	*32.2*	*35*	*35.7*	*34*	*27.5*	*25.2*	*25.6*	*27*	*30.1*	*29.3*	*29.3*	*30.1*
	MIN	*14*	*15.1*	*18*	*19.5*	*20.6*	*20.6*	*19.8*	*19.4*	*19*	*18.6*	*17.1*	*13.9*	*18*
BIDAR	*MAX*	*28.3*	*31.1*	*34.6*	*36.9*	*38.6*	*33.3*	*29*	*28.7*	*28.8*	*29.5*	*27.9*	*27.1*	*31.1*
	MIN	*16.5*	*18.7*	*21.9*	*24.5*	*26*	*22.9*	*21.3*	*21*	*21*	*20.6*	*18*	*16.2*	*20.7*
BIJAPUR	*MAX*	*30.2*	*32.9*	*36*	*38*	*38.5*	*33.3*	*30.1*	*30.1*	*30.6*	*31*	*29.7*	*29*	*32.5*
	MIN	*16.2*	*18.1*	*21.3*	*23.8*	*23.9*	*22.4*	*21.7*	*21.3*	*21.1*	*20.6*	*17.4*	*15.2*	*20.3*
GADAG	*MAX*	*30.3*	*33*	*36*	*37.3*	*36.5*	*31.1*	*28.5*	*28.9*	*29.7*	*30.8*	*29.8*	*29.1*	*31.7*
	MIN	*16.7*	*18.6*	*21*	*22.5*	*22.6*	*21.9*	*21.2*	*20.9*	*20.5*	*20.2*	*18.4*	*16.5*	*20.1*
GULBARGA	*MAX*	*30.4*	*33.4*	*36.8*	*39.1*	*40.2*	*35*	*31.4*	*31.2*	*31.1*	*31.9*	*30.4*	*29.5*	*33.4*
	MIN	*16*	*18.5*	*21.7*	*25*	*26.3*	*23.8*	*22.5*	*22.2*	*21.9*	*21*	*17.5*	*15.1*	*21*
RAICHUR	*MAX*	*30.2*	*33.2*	*36.6*	*38.7*	*39.6*	*35.1*	*32*	*31.9*	*31.6*	*31.7*	*30.1*	*29.1*	*33.3*
	MIN	*18.5*	*20.5*	*23.7*	*26.2*	*26.5*	*24.1*	*22.9*	*22.8*	*22.7*	*22.5*	*20*	*18*	*22.4*

Table 3. Mean monthly Relative Humidity (%) at two situations.

STATION	*RH*	*JAN*	*FEB*	*MAR*	*APR*	*MAY*	*JUN*	*JUL*	*AUG*	*SEP*	*OCT*	*NOV*	*DEC*	*ANNUAL*
BANGALORE	*Morning*	77	67	63	70	75	82	86	86	85	83	78	78	78
	Evening	40	29	24	34	46	62	68	66	62	64	59	51	50
BELLARY	*Morning*	65	51	45	53	58	67	71	72	73	73	69	69	64
	Evening	31	25	22	28	33	50	59	57	55	53	45	38	41
BALEHONNUR	*Morning*	78	79	81	87	88	92	95	94	93	89	85	79	87
	Evening	-	-	-	-	NA	-	-	-	-	-	-	-	-
CHITRADURGA	*Morning*	65	56	55	67	75	79	83	84	83	79	73	71	73
	Evening	33	24	24	30	39	63	69	69	63	55	50	40	47
MERCARA	*Morning*	79	73	72	82	88	95	97	96	94	89	83	82	86
	Evening	55	53	54	71	80	94	98	95	91	85	73	58	76
HASSAN	*Morning*	74	69	71	76	80	85	88	85	86	83	78	76	79
	Evening	37	31	31	47	64	77	81	79	75	70	58	46	58
MYSORE	*Morning*	75	69	71	75	79	81	84	84	83	85	80	78	79
	Evening	30	25	21	34	51	66	70	67	61	61	54	43	49
SHIMOGA	*Morning*	76	76	77	75	78	83	88	87	85	86	82	76	81
	Evening	33	27	27	44	57	73	81	78	74	70	57	43	55
HONAVAR	*Morning*	68	75	79	78	79	89	92	92	91	85	70	63	80
	Evening	59	64	67	70	72	86	90	88	84	79	66	59	74
MANGALORE	*Morning*	71	75	75	73	77	89	91	91	89	85	77	69	80
	Evening	61	66	67	69	72	85	88	87	83	79	66	62	74
BELGAUM	*Morning*	66	61	62	72	78	85	90	92	89	81	70	67	76
	Evening	30	30	32	46	58	76	92	87	81	64	47	35	57
BIDAR	*Morning*	62	50	44	49	51	76	86	86	84	70	61	61	65
	Evening	35	29	26	31	30	54	67	68	68	54	43	39	45
BIJAPUR	*Morning*	56	47	45	50	58	75	80	80	80	70	60	58	63
	Evening	31	26	24	25	28	52	62	60	59	49	40	34	41
GADAG	*Morning*	61	54	58	71	78	88	84	84	83	75	64	63	72
	Evening	35	31	31	41	49	68	73	70	66	57	46	41	51
GULBARGA	*Morning*	54	43	36	41	47	71	81	81	80	68	57	56	60
	Evening	27	24	20	22	26	47	62	59	61	48	35	31	39
RAICHUR	*Morning*	64	54	50	54	60	73	78	77	78	71	64	63	65
	Evening	32	29	28	30	33	50	59	55	56	49	41	34	41

Table 4. Mean monthly wind speed (Km/hour)

STATION	***JAN***	***FEB***	***MAR***	***APR***	***MAY***	***JUN***	***JUL***	***AUG***	***SEP***	***OCT***	***NOV***	***DEC***	***ANNUAL***
BANGALORE	10.4	9.7	9.4	9	11.8	17.1	17.5	15.2	12.1	8.2	8.5	9.6	11.5
BELLARY	4.9	5.2	5.9	6.9	10.2	13.8	14.8	13.6	11.1	5.5	4.4	4.4	8.4
BALEHONNUR	5.1	4.2	4.2	3.7	3.5	3.9	5.6	4.2	3.5	3.1	3.7	4.3	4.1
CHITRADURGA	7.8	6.9	7.1	7.7	10.6	14.2	14.9	13.1	10.8	6.3	6.2	7.6	9.4
MERCARA	9.6	8.4	8	8.2	10	13.5	16.7	15.5	12.3	8.4	10	11.4	11
HASSAN	5.8	5.7	6.7	8.2	11.5	14.9	15.3	13.6	11.6	6.9	5.5	5.8	9.3
MYSORE	11.3	9.1	8.8	8.4	10.2	13.9	14.1	12.5	10.7	7.9	9.3	11.3	10.6
SHIMOGA	4.1	4.3	4.9	5.3	6.3	7.4	6.7	6.3	5.2	4	4.2	4.5	5.3
HONAVAR	5.0	5.2	5.1	5.4	6.3	6.8	7.2	6.0	4.4	4.2	4.4	5.2	5.4
MANGALORE	8.5	8.8	8.5	8.9	9.6	9.3	9.4	7.9	6.8	7.3	7.2	8.1	8.4
BELGAUM	6.4	6.6	7.2	8.5	10.6	13.0	14.4	13.5	9.9	8.1	6.8	6.5	9.3
BIDAR	10.6	10.6	10.8	11.2	13.7	20.7	22.5	18.5	13.2	8.8	9.3	9.4	13.3
BIJAPUR	5.0	5.4	6.1	7.4	10.5	13.5	15.0	13.5	10.0	5.5	4.0	4.1	8.3
GADAG	7.5	7.1	8.1	10.1	13.8	18.2	19.6	17.5	13.6	7.8	7.0	7.6	11.4
GULBARGA	9.1	9.9	10.4	11.7	14.8	19.2	20.3	17.5	13.0	11.2	11.3	9.8	13.2
RAICHUR	9.6	9.4	10.0	10.3	14.6	20.7	21.7	18.2	13.6	9.4	9.6	9.4	13.0

Table 4a. Mean monthly wind direction

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BANGALORE	M	E	E	SE	SW/W	W	W	W	W	W	W	E	E
	E	E	E	E	E	W/NW	W	W	W	W	NE	E/NE	E
BELLARY	M	C/SE	C/SE	C/SE	NW	NW	W/NW	W/NW	W/NW	NW/N	C/NW	C/SE	C/SE
	E	SE	SE	SE	SE	NW	W/NW	W/NW	W/NW	NW	NW	SE	SE
BALEHONNUR	M	SE	SE	C/SE	C/SE	C/NW	C/W	W	C/W	C/NW	C/SE	SE	SE
	E					NE							
CHITRADURGA	M	E	C/SE	W	W	W	W	W	W	W	W	E	E
	E	E	E	E	E	W	W	W	W	W	E	E	E
MERCARA*	M	E/NE	C/E	C/NE	C/NW	W/NW	W/NW	W/NW	W/NW	W/NW	C/E	NE/E	E/NE
	E	E/NE	E	W	W/NW	W/NW	W/NW	W/NW	W/NW	W/NW	W	E/NE	E/NE
HASSAN	M	E	C/E	C/W	W	W	W	W	W	W	W	E	E
	E	E	E	E	W	W	W	W	W	W	W	E	E
MYSORE	M	NE/E	C/NE	C/W	W	W	W	W	W	W	W	E/NE	NE/E
	E	E	E	E	E	W	W	W	W	W	W	E/NE	E
SHIMOGA	M	C/VAR	C/VAR	C/VAR	C/VAR	SW	SW	SW	SW	C/SW	C/VAR	C/NE	C/E
	E	E	E	E	SW/W	W	SW	W	W	W/SW	SW	NE	E
HONAVAR	M	E	E	E	E	E	W	W	W	E	E	E	E
	E	W	W	W	W	W	W	W	W	W	W	W	W
MANGALORE	M	E	E	E	E	E	E	W	W	E	E	E	E
	E	NW	NW	NW	NW	NW	SW	W	NW	NW	NW	NW	NW
BELGAUM	M	E	C/E	C/N	W	W	W	W	W	W	E/NE	E	E
	E	E	W	W	W	W	W	W	W	W	W	E	E
BIDAR	M	SE	SW	SW	SW/NW	NW	W	W	W	W	NE	E	E
	E	NE	NE	NE	NE/E	NW	W	W	W	W	NE	NE	NE
BIJAPUR	M	S	N	N	N/NW	W	W	W	W	W	N	E	SE
	E	SE	NE	NE	N/NE	NW	W	W	W	W	NE	NE	NE
GADAG	M	SE	SE	NW	NW	NW	NW	NW	NW	NW	SE/NW	SE	SE
	E	SE	SE	SE	SE	NW	NW	NW	NW	NW	SE/NW	E	E
GULBARGA	M	E/NE	NE	NE	N	W	W	W	W	W	NE	NE	E
	E	E	E	E	SE	NW	W	W	W	W	NE	NE	E
RAICHUR	M	SE	SE	SE	SW	NW	SW	SW	SW	NW	NE	NE	SE
	E	SE	SE	SE	SE	NW	SW	W	W	NW	NE	NE	NE

Table 5. Mean Monthly Bright Sun Shine Hours of the available district.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
BABBUR	10.1	10.5	10.2	9.7	8.9	6	4.3	5.4	6.3	7.7	8.5	9.3	**8.1**
HEBBAL (BANGALORE)	9.3	10.1	9.9	9.3	8.6	5.7	4.0	5.0	5.8	6.6	7.7	7.8	**7.5**
MANDYA	9.2	10.1	9.9	9.6	8.3	6.1	4.5	5.4	6.6	7.3	7.9	8.3	**7.7**
BELLARY	10.0	10.5	10	9.9	9.3	6.6	4.8	5.5	6.5	7.8	8.4	9.3	**8.2**
HAGARI	9.6	10.1	9.8	9.4	8.4	5.7	3.8	4.9	5.9	6.9	8.3	8.9	**7.6**
DHARWAD	9.7	10.1	9.4	8.6	7.5	4.1	2.3	3.5	5.1	6.8	8.5	9.1	**7.0**
RAICHUR	9.8	10.2	9.9	9.8	8.9	5.7	4.2	5.3	5.8	7.8	9.0	9.0	**8.2**

The rainfall status

Seasonal Distribution of rainfall in the State: Out of 1140 mm of average annual rainfall of the state (1951 to 2008), about 805 mm (71%) received in the period of June to September (South-West monsoon), 195 mm (17%) in the period of October-December (North-East monsoon) and only 139 mm (12%) during January to May. June receives highest monthly rainfall of 283 mm followed by 190 mm in August. In total, the crop growth period in rainfed areas extends from June to October. Thus, performance of South-West monsoon decides the fate of agriculture in Karnataka. The seasonal distribution of the rainfall is shown in the figure1.

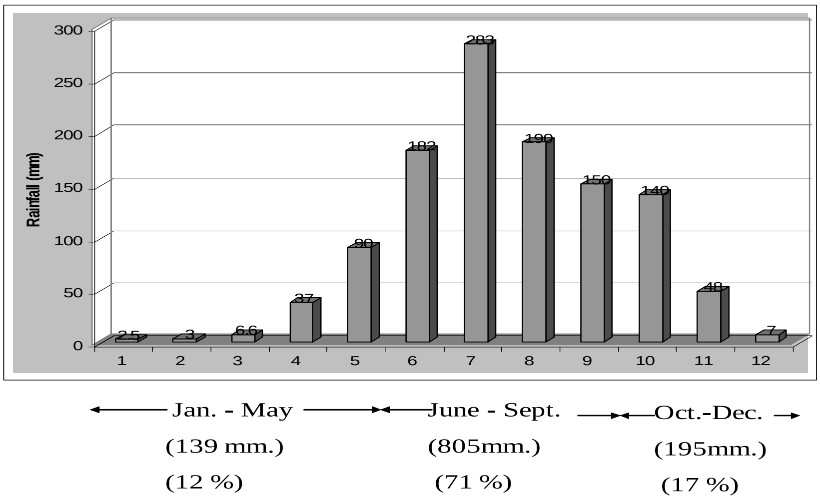


Fig.1. The seasonal distribution of the rainfall In Karnataka state.

Pre-monsoon is purely a local phenomena depending upon the local conventional current. South-West monsoon is a global phenomena influenced by the oscillation in the Indian ocean in the Southern hemisphere of the earth. The rainfall contribution and its distribution during this period (June to September) is depending upon the physical changes taking place in the Southern hemisphere, hence it is not much influenced by the local environment. North-East monsoon rains though is not assured to the State, it is influenced by the Cyclonic winds generated in Bay of Bengal. Eastern part of Karnataka is beneficial from this North-East monsoon. Further the rainfall trends of all the districts from 1901 to 2008 have been analysed and given in table 6.

Table 6: Annual and seasonal rainfall normal (mm) and trends of various districts during period (1901-2008) of Karnataka State.

Region	District	Prem (Jan -May)			SWM(Jun- Sep)			NEM (Oct- Dec)			Annual	
		Trend	**mm**	**(%)**	**Trend**	**mm**	**(%)**	**Trend**	**mm**	**(%)**	**Trend**	
	BENGALURU RURAL	↑	**141**	18	↓	**427**	54	↓	**222**	28	↓	**790**
	BENGALURU URBAN	↑	**168**	19	↑	**466**	53	↑	**241**	28	↑	**875**
	CHAMARAJANAGAR	↓	**239**	29	↓	**316**	39	↑	**261**	32	↓	**816**
	CHITRADURGA	↑	**179**	9	↑	**1505**	79	↑	**220**	12	↑	**1904**
	DAVANAGERE	↑	**233**	6	↑	**3338**	85	↑	**340**	9	↑	**3911**
	KOLAR	↑	**247**	9	↑	**2129**	81	↑	**266**	10	↑	**2642**
	MANDYA	↔	**74**	13	↓	**385**	66	↑	**124**	21	↑	**583**
	MYSORE	↓	**191**	26	↑	**296**	41	↑	**235**	33	↑	**722**
	TUMKUR	↓	**191**	22	↑	**425**	50	↓	**236**	28	↓	**852**
	CHIKKABALLAPURA	↓	**208**	5	↔	**3669**	88	↓	**305**	7	↓	**4182**
	RAMANAGARA	↓	**148**	5	↔	**2537**	88	↑	**200**	7	↓	**2885**
SIK	DAVANAGERE	↑	**233**	6	↑	**3338**	85	↑	**340**	9	↑	**3911**
	BAGALKOTE	↔	**88**	15	↓	**360**	62	↓	**136**	23	↓	**586**
	BELGAM	↓	**115**	14	↑	**560**	68	↔	**148**	18	↔	**823**
	BELLARY	↓	**103**	16	↓	**388**	61	↓	**145**	23	↓	**636**
	BIDAR	↑	**75**	8	↑	**705**	80	↓	**105**	12	↑	**885**
	BIJAPUR	↑	**73**	12	↓	**427**	68	↓	**131**	21	↓	**631**
	DHARWAD	↔	**130**	20	↓	**361**	55	↔	**166**	25	↓	**657**
	GADAG	↓	**147**	19	↑	**480**	61	↓	**159**	20	↓	**786**
	GULBARGA	↑	**115**	18	↓	**365**	58	↓	**150**	24	↓	**630**
	HAVERI	↑	**181**	18	↓	**584**	59	↓	**222**	22	↓	**987**
	KOPPAL	↑	**133**	18	↔	**363**	50	↑	**227**	31	↑	**723**
NIK	RAICHUR	↑	**220**	29	↓	**335**	44	↓	**211**	28	↓	**766**
	CHIKMAGALUR		**113**	15	↑	**412**	56	↑	**217**	29	↑	**742**
	HASSAN	↑	**71**	8	↑	**640**	76	↑	**128**	15	↑	**839**
MR	KODAGU	↑	**132**	17	↓	**485**	62	↑	**160**	21	↔	**777**
	SHIMOGA	↑	**65**	10	↑	**480**	70	↑	**136**	20	↑	**681**
	DAKSHIN KANNADA	↑	**118**	21	↓	**283**	50	↑	**169**	30	↓	**570**
	UDUPI	↑	**148**	8	↓	**1484**	82	↑	**187**	10	↓	**1819**
CR	UTTARKANNADA	↑	**144**	20	↓	**363**	50	↑	**212**	29	↑	**719**
	State		**142**	**12**		**820**	**71**		**190**	**17**		**1152**

↑ : Increasing **↓: Decreasing** **↔: No change**

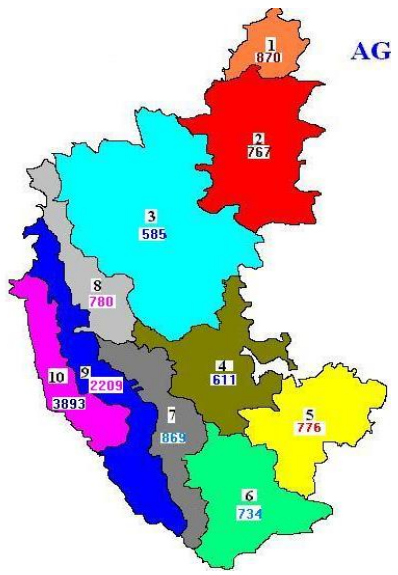
Note : SIK : South interior Karnataka
NIK : North interior Karnataka
MR : Malanad region

CR : Coastal region

Status of the agriculture and horticulture at macro and micro level. This includes area under different crops. Normal, potential and realized yields in the past (based on the available data).

Karnataka is typically an agrarian state. About 66 per cent of the total population lives in rural areas and the main source of income is from farming alone. Out of ten agro-c1imatic zones, five fall under dry zones. A large track of areas falls under semi arid conditions facing severe agro-climatic and resource constraints. Karnataka is one of the few States with lowest proportion of area under irrigation and second only to Rajasthan in the share of drought prone area. Karnataka is a leading producer of Coarse Cereals (Maize, ragi, Jowar, etc.) and Sunflower in the country. Nearly 70% of the total cultivated area is under rainfed farming. In view of limited water source for irrigated agriculture and uncertainty / improper distribution of rainfall, the crop productivity suffers to a great extent. In addition to these natural vagaries, dissemination of technologies with regard to various agricultural practices is also a limiting factor in productivity and production.

The crop data has been obtained from the Department of Agriculture and DES GOK for the available period and analysed. As per the census of 2001, the State has a total population of 5.27 crores accounting for 5.13 per cent of the country's total population of 102.70 crores. The rate of growth of population in the State has declined considerably from 21.12% in 1991 to 17.25% in 2001. Sixty six per cent of the total population resides in rural areas, whose main occupation is Agriculture and allied activities. Out of the total population, 44.6 per cent is working population, of which 69.36 lakh are cultivators and 62.09 lakh are agricultural labourers. One important feature, of agricultural labourers is that the percentage of women (58.19%) overrides the percentage of men (41.81%). The literacy rate of the State is 67.04 per cent, while in rural areas it is 59.68% and that of urban areas it is 81.05 per cent. The State has 27 districts, 176 taluks, 745 hoblies, 29,483 Villages (27,575 inhabited and 1908 uninhabited) and 5692 grama panchayaths. The total number of operational holdings is 70.79 lakhs with 1.74 hectares, as average size operational holding. Small and marginal farmers account for 72.9 per cent of the total holdings, cultivating only 34.4 per cent of the total cultivable area. The number of holdings increased by 8.58 lakhs due to fragmentation of the land in the last five years. The average size of holding has decreased from 1.95 hectares to 1.74 hectares.



The State is divided into 10 Agro-climatic zones on the basis of soil structure, humidity, elevation, topography, vegetation, rainfall and other agro-climatic factors (Fig. 2).

1. North Eastern Transition Zone, 2. North Eastern Dry Zone, 3. Northen Dry Zone, 4. Central Dry Zone, 5. South Eastern Dry Zone 6. Southern Dry Zone, 7. Southern Transition Zone, 8. Northern Transition Zone, 9. Hilly Zone, 10. Coastal Zone

Figure 2. Agro climatic zones of Karnataka State

Panchasutra for Agricultural Development

1. Protect and improve the soil health.
2. Conservation of natural resources, with special emphasis on water and micro irrigation,
3. Timely availability of credit and other inputs to the farmers,
4. Integrate post harvest processing with the production process, and
5. Reduce the distance between 'Lab to Land' in transfer of technology.

The State of Karnataka has total geographical area 190.5 Lakh hectares. Its classification is as indicated in the above table. Total cropped area is about 128.93 Lakhs hectares. In this cropped area, nearly 70 % is depending on rainfall and 30 % is under irrigation. The total food production of the state is about118.35 Lakh tonnes, of which, 108.35 Lakh Tonnes (cereals), 10.0 Lakh Tonnes (Pulses). And the oil seeds production is about 12.159 Lakh Tonnes. Classification of land use and pattern are given in tables 7 & 8 respectively.

Table 7. Classification of land use in Karnataka State

Classification of land	**Area under each sector**
Total Geographical area	190.5
Forest	30.72
Land put to non-agri uses	13.69
Barren & uncultivable land	7.88
Cultivable waste	4.15
Uncultivated land	12.2
Fallow land	17.67
Net area under sown	104.19
Total cropped area	128.93

Table 8. Land use pattern in Karnataka State in different district:

Sl. No.	District	Total Geo-graphical area	Classification of area										
			Forest	Not available for cultivation		Cultivable waste	Uncultivated land excluding fallow land		Fallow land		Net Area Sown	Total Cropped Area	Area Sown more than once
				Land put to non-agri. uses	Barren & uncultivable land		Pmt.pastures & other grazing land	Mics. tree crops, groves	Current fallows	Other Fallow land			
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1	Bagalkote	658877	81126	28832	24810	2035	3429	274	40124	9971	468276	600414	132138
2	Bangalore (Urban)	217410	5055	111436	4911	4444	5674	7498	14434	5074	58884	60814	1930
3	Bangalore (Rural)	229519	11322	39841	11124	3898	3879	12227	28906	14470	103852	134084	30232
4	Belgaum	1344382	190424	69368	44342	12761	24807	3085	159577	6997	833021	1051947	218926
5	Bellary	813196	97017	68623	53477	24839	5472	3606	68296	27805	464061	602438	138377
6	Bidar	541765	27707	22006	19127	19382	13964	10861	56972	41519	330227	411180	80953
7	Bijapur	1053471	1977	35847	29059	5502	9575	1316	85297	5685	879213	1060841	181628
8	Chamarajanagar	569901	275610	24606	21434	7637	22750	4782	7874	19145	186063	218655	32592
9	Chikkaballapur	404501	49704	31933	34302	6143	59510	6482	37025	8703	170699	174212	3513
10	Chikkamagalur	722075	200485	42639	28322	19404	90186	21249	18244	4797	296749	325270	28521
11	Chitradurga	770702	73719	51243	25403	21615	88740	11317	38770	24459	435436	484550	49114
12	Dakshina Kannada	477149	128476	63790	59063	31297	19150	31962	7417	5595	130399	158179	27780
13	Davanagere	597597	89918	38963	20533	8525	19538	4955	19533	5861	389771	422634	32863
14	Dharwad	427329	35235	21747	3985	2669	3571	178	34631	6819	318494	528521	210027
15	Gadag	465715	32614	10481	11628	1010	2592	263	18937	3459	384731	558533	173802
16	Gulbarga	1610208	69089	67952	63155	11802	37610	1845	177990	22995	1157770	1444923	287153
17	Hassan	662602	58775	78681	30365	14142	32943	6957	34784	36300	369655	440719	71064

18	Haveri	485156	47454	31687	5793	2989	12209	2136	12320	5325	365243	429658	64415
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
19	Kodagu	410775	134597	23961	31010	9128	14774	23452	3763	2738	167352	179229	11877
20	Kolar	374966	20620	45677	28870	6397	39418	7009	41301	12813	172861	179355	6494
21	Koppal	552495	29451	38870	16627	2568	14675	210	68440	0	381654	508052	126398
22	Mandya	498244	24765	60906	21519	41955	38049	3382	30724	42999	233945	283928	49983
23	Mysore	676382	62851	67028	45812	21460	55256	6871	35718	40080	341306	579739	238433
24	Raichur	835843	18167	20563	20084	10712	19816	13680	116438	40832	575551	722518	146967
25	Ramanagar	355912	69946	26225	24339	1178	24662	3950	16556	30127	158929	163595	4666
26	Shimoga	847784	276855	88453	13312	16307	163463	26868	11300	30337	220889	256163	35274
27	Tumkur	1064755	45177	84241	67539	62642	76453	21033	69384	30093	608193	664314	56121
28	Udupi	356446	100102	39260	11597	36160	10625	47704	1778	8344	100876	122943	22067
29	Uttara Kannada	1024679	813595	34422	16234	6450	16852	4814	5887	11733	114692	125263	10571
	Karnataka State:	**1.9E+07**	**3071833**	**1369281**	**787776**	**415051**	**929642**	**289966**	**1262420**	**505075**	**1E+07**	**1.3E+07**	**2473879**
	Area in Lakh Hects.	**190.5**	**30.72**	**13.69**	**7.88**	**4.15**	**9.3**	**2.9**	**12.62**	**5.05**	**104.19**	**128.93**	**24.74**

Source: Annual Season & Crop Report 2007-08, DE&S, Bangalore.

Cropping Pattern in the State:

Total Food production of the State. The cropped area under different crops, crop production and productivity in different districts are as shown in the table 9, 10 & 11 respectively. Similarly the total growing area, total crop production and productivity trends for different districts and for major crops are given in table 12.

Table 9. Area of Agricultural Crops in Karnataka - 2000-01 to 2009-10 (Area in lakhs hectares)

Sl. No.	Crops	YEAR									
		2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
1	Rice	14.84	14.18	11.55	10.74	13.08	14.85	13.96	14.16	15.14	14.69
2	Jowar	17.11	17.91	17.86	16.98	16.63	15.20	14.19	13.82	13.82	13.69
3	Ragi	10.22	9.53	7.67	9.98	8.93	9.39	6.06	8.33	8.41	7.64
4	Maize	6.69	5.80	6.50	6.18	8.50	9.36	9.61	11.13	10.68	12.41
5	Bajra	4.62	2.09	3.05	3.19	4.45	4.31	3.88	4.32	2.66	3.05
6	Wheat	2.61	2.60	2.47	2.32	2.42	2.53	2.69	2.76	2.69	2.84
7	M.Miliets	0.71	0.70	0.54	0.68	0.58	0.52	0.40	0.36	0.33	0.26
	Total Cereals:	57.57	52.82	49.64	50.07	54.59	56.16	50.78	54.87	53.73	54.58
1	Tur	5.83	4.82	5.14	5.32	5.62	6.00	5.96	6.81	5.97	6.04
2	Bengalgram	3.6	4.80	4.80	5.10	4.18	4.18	6.51	6.05	7.26	9.34
3	Horsegram	2.9	3.43	3.35	2.74	2.83	2.69	3.24	2.27	2.17	2.28
4	Blackgram	1.4	1.63	1.65	1.41	1.33	1.11	1.45	1.63	1.12	1.18
5	Greengram	4.5	2.58	4.13	2.73	5.23	4.01	4.50	5.30	2.74	3.79
6	Cowpea & others	1.15	0.86	0.89	0.77	1.09	0.94	0.86	1.00	0.82	0.97
7	Avare	0.88	0.81	0.65	0.69	0.80	0.87	0.64	0.79	0.79	0.75
	Total Pulses:	**20.47**	**18.93**	**20.61**	**18.74**	**21.08**	**19.81**	**23.16**	**23.86**	**20.87**	**24.34**
	Total Food grains:	78.04	71.75	70.24	68.82	75.67	75.96	73.94	78.73	74.60	78.92
1	Groundnut	10.6	8.55	8.44	8.17	9.69	10.40	7.64	9.08	8.50	7.99
2	Sesamum	0.93	0.73	0.74	0.58	1.07	1.03	0.85	0.87	0.56	0.77
3	Sunflower	4.71	5.84	8.77	11.35	12.71	14.27	12.31	10.25	10.01	8.07
4	Castor	0.30	0.22	0.17	0.17	0.20	0.25	0.20	0.23	0.20	0.18
5	Niger	0.44	0.36	0.29	0.27	0.33	0.33	0.27	0.31	0.25	0.26
6	Mustard	0.07	0.07	0.04	0.06	0.06	0.07	0.04	0.04	0.05	0.05
7	Soya bean	0.613	0.48	0.58	0.94	1.59	1.33	1.31	1.13	1.34	1.84
8	Safflower	0.9	0.92	0.85	0.99	0.94	0.81	0.81	0.70	0.73	0.68
9	Linseed	0.1	0.20	0.17	0.13	0.14	0.13	0.12	0.14	0.14	0.12
	TotalOil seeds:	**18.94**	**17.37**	**20.05**	**22.67**	**26.73**	**28.63**	**23.55**	**22.76**	**21.78**	**19.97**
	Annual Crops:										
1	Cotton	5.5	6.08	3.93	3.17	5.22	4.13	3.76	4.03	4.09	4.55
2	Sugarcane	4.1	4.07	3.83	3.35	3.05	4.16	5.09	4.80	4.59	5.12
3	Tobacco	0.7	0.72	0.82	0.98	0.91	1.01	1.04	1.13	1.08	1.18
	Total Area under Agrl. Crops	107.38	99.99	98.87	98.99	111.58	113.89	107.37	11.45	106.14	109.74
	Total Cultivated Area	**122.84**	**116.7**	**115.32**	**114.50**	**128.07**	**130.27**	**124.38**	**128.93**	**123.68**	**122.8**

In the kharif season 72 lakhs hectares is cultivated. Of which, 34.8 Lakh hectares Cereals, 13.7 lakhs hectares pulses, 16.5 lakhs hectares oil seeds, 2.7 lakhs hectares cotton, 3.3 lakhs hectares Sugarcane and 1.0 Lakh hectare Tobacco.

Table 10. Production of Agricultural Crops in Karnataka 2000-2001 to 2009-10 (1akh tonnes, Cotton in 1akh bales of 170 Kg lint unit)

SI. No.	Crops	YEAR									
		2000-01	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**
1	Rice	38.47	32.34	23.90	25.50	37.06	39.99	36.46	38.69	38.02	35.12
2	lowar	15.47	13.72	12.25	7.81	13.59	14.79	11.30	16.70	16.29	12.81
3	Ragi	18.35	15.39	7.14	11.25	16.14	16.56	6.65	13.68	13.94	13.14
4	Maize	21.36	14.52	13.43	12.10	25.09	28.07	26.42	32.76	30.29	30.31
5	Bajra	3.42	-1.12	1.20	1.91	2.66	3.91	1.63	3.35	1.87	1.52
6	Wheat	2.50	1.99	1.48	0.96	2.06	2.26	2.24	2.80	2.47	2.51
7	M.Millets	0.47	0.37	0.31	0.39	0.31	0.27	0.21	0.18	0.15	0.12
	Total Cereals:	**100.04**	**79.45**	**59.71**	**59.93**	**96.91**	**105.85**	**84.90**	**108.15**	**103.03**	**95.53**
1	Tur	2.64	1.47	2.41	2.00	2.91	4.08	2.63	4.51	3.15	2.82
2	Benga1gram	2.39	2.82	2.52	1.71	2.31	2.38	2.98	3.64	4.01	5.66
3	Horsegram	1.57	1.49	1.09	0.77	1.22	1.29	1.03	1.11	0.88	1.04
4	B1ackgram	0.56	0.60	0.23	0.39	0.16	0.25	0.24	0.70	0.29	0.14
5	Greengram	1.85	0.67	0.28	0.42	0.83	0.99	0.54	1.20	0.37	0.47
6	Cowpea & others	0.35	0.27	0.26	0.24	0.38	0.32	0.42	0.49	0.34	0.36
7	Avare	0.20	0.19	0.15	0.16	0.19	0.21	0.55	0.68	0.68	0.51
	Total Pulses:	9.56	7.52	6.94	5.69	8.00	9.51	8.39	12.33	9.72	11.00
	Total Food grains:	109.60	86.97	66.64	65.62	104.91	115.35	93.29	120.49	112.75	106.53
1	Groundnut	10.81	5.86	5.39	4.33	6.84	5.96	3.27	6.92	5.01 .	5.32
2	Sesamum	0.40	0.27	0.29	0.26	0.57	0.89	0.50	0.48	0.32	0.31
3	Sunflower	2.31	2.62	3.74	3.65	5.28	6.68	3.84	4.93	4.96	3.16
4	Castor	0.39	0.16	0.16	0.15	0.17	0.26	0.16	0.16	0.18	0.12
5	Niger	0.08	0.07	0.06	0.05	0.06	0.06	0.05	0.12	0.09	0.09
6	Mustard	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.02
7	Sovabean	0.65	0.40	0.48	0.45	1.00	0.75	0.97	0.92	0.91	0.82
8	Safflower	0.72	0.73	0.55	0.42	0.49	0.62	0.60	0.59	0.58	0.50
9	Linseed	0.06	0.07	0.06	0.01	0.03	0.04	0.04	0.05	0.05	0.03
	Total Oilseeds:	15.45	10.20	10.74	9.34	14.46	15.27	9.45	14.19	12.12	10.37
	Annual Crops:										
1	Cotton	8.55	6.12	3.31	2.65	6.25	5.85	5.36	7.05	8.66	8.65
2	Sugarcane	429.23	330.17	324.85	160.02*	139.93*	196.48*	236.42*	260.28*	233.28*	291.12*
3	Tobacco	0.52	0.59	0.59	0.55	0.68	0.64	0.46	0.48	0.52	0.91
* Prodn. for the harvested area.					2.43	1.79	2.21	2.69	3.07	2.81	3.26

Table 11. Yield of Agricultural Crops in Karnataka 2000-2001 to 2009-10 (Yield in Kgs. Per hectare, Sugarcane in Tonnes per hectare unit)

Sl. No.	Crops	YEAR									
		2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
1	Rice	2730	2401	2179	2500	2982	2834	2750	2875	2644	2517
2	Jowar	914	806	722	484	860	1024	838	1272	1241	985
3	Ragi	1889	1699	980	1186	1903	1858	1156	1729	1745	1811
4	Maize	3361	2634	2176	2060	3106	3157	2895	3099	2985	2571
5	Bajra	778	564	415	632	630	954	443	816	740	525
6	Wheat	988	803	630	436	897	943	874	1071	969	930
7	M.Millets	699	554	591	531	552	542	569	503	482	480
	Total Cereals:	**1829**	**1583**	**1266**	**1260**	**1869**	**1984**	**1760**	**2075**	**2019**	**1782**
1	Tur	476	322	493	395	545	716	464	697	556	491
2	Benga1gram	682	618	553	353	582	599	483	634	581	638
3	Horsegram	561	457	343	297	452	505	335	516	426	480
4	B1ackgram	403	387	147	288	129	237	175	451	264	125
5	Greengram	432	273	72	162	166	260	126	238	141	131
6	Cowpea & others	309	330	303	323	358	358	514	515	436	391
7	Avare	228	247	240	241	239	254	907	901	908	716
	Total Pulses:	**492**	**418**	**354**	**320**	**399**	**505**	**381**	**544**	**497**	**476**
	Total Food grains:	**1478**	**1276**	**999**	**1004**	**1459**	**1598**	**1328**	**1611**	**1593**	**1421**
1	Groundnut	1070	721	672	558	743	603	451	802	621	701
2	Sesamum	432	390	414	463	567	912	619	587	593	434
3	Sunfower	509	473	449	338	437	492	329	506	522	412
4	Castor	1347	779	972	944	913	1095	841	706	977	708
5	Niger	193	196	193	190	191	194	191	380	372	344
6	Mustard	266	272	269	285	281	270	267	367	375	393
7	Soyabean	1098	874	874	507	659	590	780	858	714	470
8	Saffower	811	832	685	444	544	800	779	888	831	771
9	Linseed	388	353	370	81	222	351	322	416	376	289
	Total Oilseeds:	**859**	**618**	**564**	**434**	**570**	**562**	**422**	**656**	**586**	**547**
	Annual Crops:										
1	Cotton	277	180	151	149	214	253	255	313	379	340
2	Sugarcane	108	85	89	69	82	93	92	89	87	94
3	Tobacco	778	851	757	592	777	667	469	446	509	810

Source: Fully Revised Estimates of Area, Production and Productivity of Principal Agriculture Crops, published by DE&S (ref. 3)

Table 12. Area Production and Productivity trends in all District of Karnataka (1955-2008)

Districts	Rice			Maize			Jawar			Ragi			Cotton		
	Area	Prdn	Prdty	Area	Prdn	Prdty	Area	Prdn	Prdty	Area	Prdn	Prdty	Area	Prdn	Prdty
Bagalkote	↑	↓	↓	↑	↓	↓	↑	↑	↓	↑	↑	↓	↓	↑	↑
Bangalore - urban	↑	↓	↓	↑	↑	↓	-	-	-	↓	↓	↓	-	-	-
Bangalore - rural	↓	↑	↓	↑	↑	↑	-	-	-	↓	↑	↓	-	-	-
Belgaum	↔	↓	↓	↑	↑	↓	↔	↑	↑	↓	↑	↑	↓	↑	↓
Bellary	↑	↓	↓	↑	↑	↓	↓	↑	↑	↑	↓	↓	↑	↓	↓
Bidar	↓	↓	↓	↑	↑	↑	↓	↑	↑	↓	↑	↑	↓	↑	↑
Bijapur	↓	↓	↑	↑	↑	↑	↓	↑	↑	↑	↑	↑	↓	↓	↑
Chamarajanagar	↔	↓	↓	↑	↑	↓	↑	↑	↓	↑	↑	↑	↓	↓	↑
Chikmagalur	↔	↑	↑	↑	↑	↓	↑	↑	↑	↑	↑	↑	↑	↑	↓
Chitradurga	↓	↑	↔	↑	↑	↑	↔	↑	↑	↓	↑	↑	↓	↑	↑
Davanagere	↑	↓	↔	↑	↑	↑	↔	↑	↑	↓	↑	↑	↓	↑	↑
Dharwad	↑	↓	↓	↑	↓	↑	↑	↑	↑	↓	↑	↑	↓	↑	↑
Gadag	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	↑	↓	↑	↑
Gulbarga	↔	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	↑	↑	↑	↑
Hassan	↓	↓	↓	↑	↑	↑	↑	↑	↓	↓	↑	↑	↓	↓	↓
Haveri	↓	↓	↓	↑	↑	↓	↓	↓	↓	↓	↑	↑	↔	↑	↑
Kodagu	↓	↑	↑	↑	↑	↑	↑	↑	↓	↔	↔	↑	↓	↑	↑
Kolar	↓	↑	↑	↑	↑	↑	↓	↓	↓	↓	↓	↑	↓	↓	↓
Koppal	↑	↓	↓	↑	↑	↑	↓	↓	↓	-	-	-	↓	↓	↓
Mandya	↔	↑	↑	↑	↑	↑	↓	↑	↑	↓	↑	↑	↓	↑	↑
Mysore	↑	↑	↑	↓	↑	↑	↓	↓	↑	↓	↑	↑	↑	↑	↔
Raichur	↑	↑	↑	↑	↑	↑	↓	↔	↔	↓	↓	↑	↑	↑	↑
Shimoga	↓	↑	↑	↑	↑	↑	↓	↓	↑	↓	↓	↑	↑	↑	↑
Tumkur	↓	↓	↓	↑	↑	↑	↑	↓	↓	↓	↑	↑	↓	↑	↑
Udupi	↓	↓	↓	↑	↑	↑	-	-	-	-	-	-	-	-	-
Uttara kannada	↔	↑	↑	↑	↑	↓	↑	↑	↑	↓	↓	↑	↑	↑	↑

Districts	Redgram			Groundnut			Sunflower			Sugarcane		
	Area	Prdn	Prdty	Area	Prdn	Prdty	Area	Prdn	Prdty	Area	Prdn	Prdty
Bagalkote	↑	↓	↑	↓	↑	↓	↓	↑	↑	↓	↑	↓
Bangalore - urban	↑	↓	↓	↓	↓	↓	↑	↓	↓	-	-	-
Bangalore - rural	↔	↔	↑	↑	↓	↑	↑	↓	↓	-	-	-
Belgaum	↓	↓	↔	↓	↓	↑	↑	↔	↔	↑	↓	↓
Bellary	↓	↓	↓	↑	↓	↑	↑	↔	↔	↓	↑	↑
Bidar	↑	↓	↑	↓	↓	↔	↑	↑	↓	↓	↑	↑
Bijapur	↑	↔	↔	↓	↓	↔	↑	↑	↔	↑	↓	↓
Chamarajanagar	↓	↑	↑	↓	↓	↓	↑	↑	↑	↓	↑	↓
Chikmagalur	↔	↔	↔	↔	↔	↔	↑	↓	↓	↓	↑	↑
Chitradurga	↓	↓	↑	↑	↑	↓	↑	↑	↓	↓	↑	↑
Davanagere	↓	↓	↑	↑	↑	↓	↑	↑	↓	↓	↑	↑
Dharwad	↑	↓	↓	↑	↓	↓	↑	↓	↓	↓	↑	↑
Gadag	↑	↑	↑	↓	↓	↑	↓	↓	↓	↑	↑	↑
Gulbarga	↑	↑	↑	↓	↓	↑	↑	↑	↑	↓	↑	↑
Hassan	↓	↔	↔	↔	↔	↔	↑	↑	↑	↓	↑	↑
Haveri	-	-	-	↓	↓	↓	↓	↑	↑	↓	↑	↑
Kodagu	↑	↑	↑	↓	↔	↑	↑	↑	↑	↓	↑	↑
Kolar	↓	↓	↔	↑	↑	↓	↑	↑	↓	↓	↑	↑
Koppal	↓	↑	↑	↓	↓	↓	↑	↑	↑	↓	↑	↑
Mandya	↓	↔	↔	↔	↔	↑	↑	↑	↑	↑	↑	↑
Mysore	↓	↑	↑	↔	↔	↔	↔	↔	↔	↑	↑	↑
Raichur	↔	↔	↔	↓	↓	↑	↑	↑	↑	↑	↑	↑
Shimoga	↓	↓	↓	↑	↑	↓	↔	↔	↔	↑	↑	↑
Tumkur	↑	↓	↓	↑	↑	↓	↑	↑	↔	-	-	-
Udupi	-	-	-	↓	↑	↑	-	-	-	↓	↓	↓
Uttara kannada	↔	↔	↑	↑	↑	↑	↓	↓	↓	↓	↑	↑

The total food production of the state is about118.35 Lakh tonnes, of which, 108.35 Lakh Tonnes (cereals), 10.0 Lakh Tonnes (Pulses). And the oil seeds production is about 12.159 Lakh Tonnes. Finger millet popularly called as Ragi is one of the major food crop of Karnataka in general and Southern Karnataka in particular. Karnataka occupies a premier position in area, production and productivity of ragi crop. In Karnataka,Ragi is being cultivated over an area of a lakh ha with. a production of 15.0 lakh tones and with a productivity of 1650 ka/ha. The major ragi growing areas are Bangalore rural, Bangalore urban, Kolar, Tumkur, Chitradurga, Hassan, Mandya, Mysore, Chamarajanagar and Ramanagar.

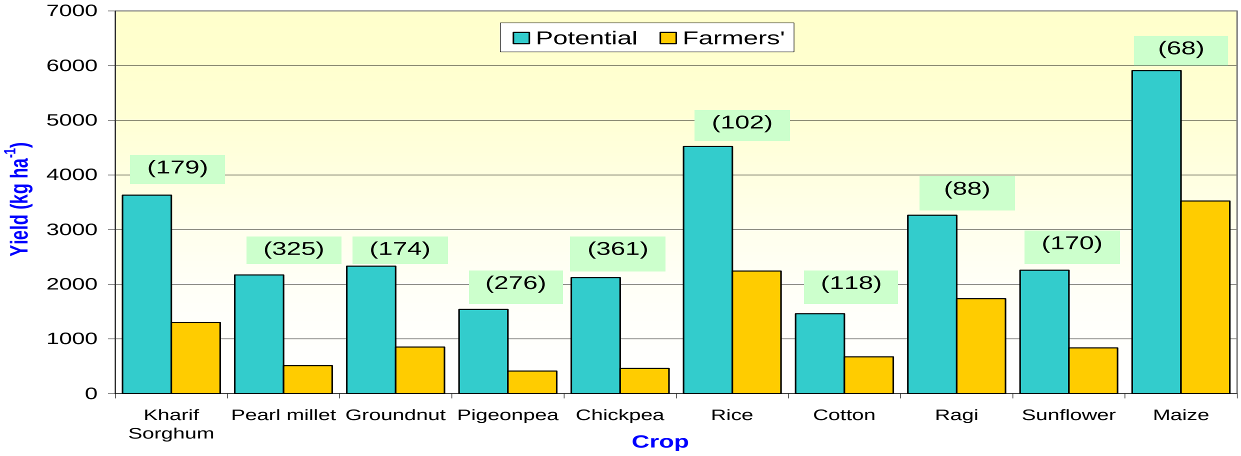


Figure 3. Yield gaps in Karnataka (Source: ICRISAT, 2009)

Relation between yield response and available weather parameters at possible domains. Impact of extreme weather inputs on crop yield.

1. State Food Production variation with the seasonal precipitation.

Annual and monsoon rains have been related with the State food production during the period of study. The dip in food production is directly influenced by the seasonal and as well as annual rainfall situation (ref. 4.) and it is shown in figure 4.

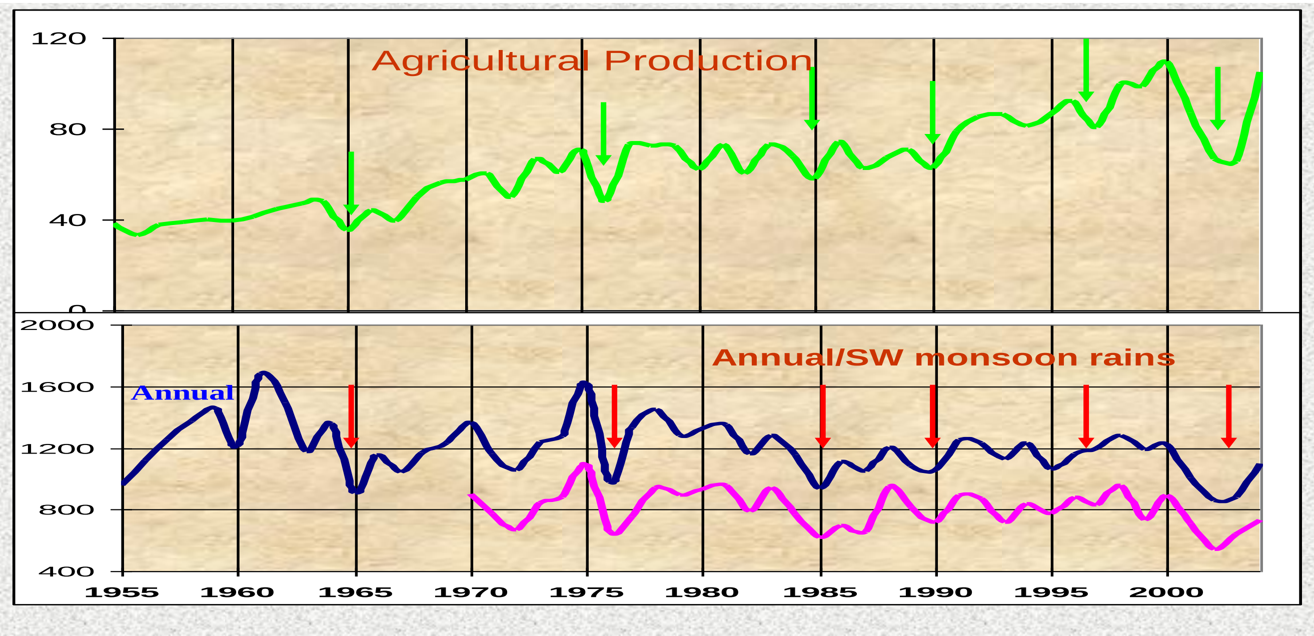


Figure 4. State s-w monsoon and annual rainfall and the total agricultural production.

The state average annual rainfall for the past 50 years indicates a cycle of 16 year, wherein first 8 year it shows above normal trend followed by another 8 years of below normal with exception in 2 to 3 years. According to this, the state of Karnataka received below normal rainfall from 1996 to 2003. Since the crop growth period in rainfed areas is between June and October, The performance of south-west monsoon decides the fate of agriculture in Karnataka. The rainfall shift in many zones during the period 1991 to 2008 compared to its early period showed changes in southwest monsoon rainfall pattern indicating a shift in rainfall pattern from July to August and September to October(peaks extending the period up to end of October month) .

2. Rainfall and Runoff Pattern of Coorg District of Karnataka State:

Coorg District (Coorg District) in Karnataka State has major area on the Western ghats and smaller area on the plateau region to the east of the Western ghat with lateritic soil type. Plantation crops are the major agricultural crops of the region. It contributes the major catchments to the Cauvery river basin in Karnataka. The annual average rainfall ranges from 2185 mm to 3263 mm with normal rainfall of the district 2725 mm. Rainfall pattern is unimodel in nature with a peak of about 878 mm during July month. 77 per cent to 83 per cent of the rainfall is received during South-West monsoon period with very low coefficient of variation of 25 per cent. The recent twenty years of rainfall indicated the declining in annual rainfall compared to the earlier years. The average for the period from1980 to 2002 reduced to 2646 mm from 2725mm. The mean annual Potential Evapotranspiration is about 1201 mm. The rainfall during January to May and December months is lower than the Potential Evapotranspiration and rest of the months higher than the Potential Evapotranspiration. Soil is very shallow in depth and has about 4.5 per cent deep drainage during heavy rainfall months. The available water capacity of the soil is about 150 mm for every 150 Cm of the soil. Because of the land topography and physical properties, the major rainwater goes as runoff. The climatic water balance revealed that about 914 mm of rainwater is available to meet the atmospheric demand i.e., the evapotranspiration during the whole year allowing the rest of about 1611mm rainwater as runoff.

3. Stocheometric crop weather model for sustainable production of Finger millet. A Stocheometric crop weather model developed by the Department of Agrometeorology, University of Agricultural Science, Bangalore (Ref.5 & 6) has been used to predict the biomass as well as the grain yield.. Multiple linear regression equations relating the GDD, SSH and AET with the accumulated dry matter during each growth stage and also the final grain yield were generated using the field experimental data for the period 1992-98. The coefficient of determinants indicated in the model is considered. The initial TDM is used to estimate the final TDM in each stage. Comparison of the observed and the predicted yields indicate the close agreement between them in all the stages. Comparison of the observed and the predicted yields indicate the close agreement between them in all the stages. Hence, this Stocheometric crop weather model was used to predict the ragi yield in many districts taking different sowing dates and assuming the current package of practice.

4**. Stocheometric crop weather model for groundnut yield prediction.** A Stocheometric crop weather model to predict groundnut (variety: JL-24) growth and pod yield based on the dry matter accumulated at the end of each stage developed by the department of Agrometeorology, University of Agricultural Sciences, Bangalore has been used to predict the groundnut yield in different districts for both 1990-2001 climatic situation and 2035 climatic situation. The yields have been tabulated in the yield tables.

5. Rainfall Analysis, Water balance and cropping pattern in different rainfall scenario.

Agroclimatic classification**:**

Precipitation, temperature and soil are the main factors for growth of crop in different approaches. Hence the climatic classification is made based on these factors (Ref. 7).

Temperature (Superimposed by moisture range)
Moisture (Superimposed by temperature)
Indices (thermal or moisture or combined)
IMD Climatic Classification:
MAI = (Rain water/PET)

1. Very arid : If MAI < 0.33 for all months, 2. Arid : If MAI > 0.34 for 1 or 2 months
3. Semi-arid : If MAI > 0.34 for 3 or 4 months consecutive
4. Humid : If MAI > 0.34 for more than 6 months

In India there are 127 Agroclimatic zones classified based on this classification in combination with Koppan's Climatic Classification.

Soil -moisture holding capacity: This is nothing but the available water capacity. This is the difference in moisture content in soil between field capacity and wilting point level of the soil. It depends on soil type and structure and also the rooting pattern of vegetation growing and the land surface. This is also called the maximum available water capacity of the concerned soil. A sandy soil will hold only 2 or 3 cm of moisture per 30 cm of soil depth while a silt on clay soil may hold 10 or more cm of moisture in the same depth. This is defined as the "maximum length of water (in mm) available in one meter depth of a column of the soil when water is not a limiting factor". Water holding capacity and other parameters at various soil depth.

No. of Days	Root length. Cm)	WHC	PW	AWC
0 – 30 days	30	36	12	24
31 – 60 days	60	72	24	48
61 – 90 days	90	108	36	72
91 – 120 days	90	144	48	96

Concept of Water Balance: Water balance technique integrates moisture distribution in space and time are better in dryland conditions because of rainfall is the only important climatic factor affecting plants growth. Studies of water balance of crops and plant communities are of great fundamental importance. They would help in water conservation and better utilization of incident rainfall. These studies not only help in establishing the relationship between the amount and intensity of incident rainfall and the amount that enters into the soil but also are useful to in understanding the relation between the amount of water actually utilized by the crop and amount actually present in the soil. They also help in preparation of supplementary irrigation schedules.

(i) **Thornthwite Water balance**: It was already known that calculation of PET by considering root characteristics and soil physical characteristics is very difficult. Soil moisture changes both vertical and horizontal movements depending on the atmospheric conditions in soil with time. The water balance can be calculated yearly, monthly, weekly and daily using book keeping method. PET and P requirements two parameters.

(ii). **FAO Water Balance**: Crop Coefficient: This is nothing but the efficiency of the crop that absorbs the moisture from the soil when there is no dearth of moisture in the soil. This is defined as

$$Kc = \frac{\text{ET requirement of a crop}}{\text{Potential evapotranspiration}}$$

6. **Estimation of productivity of major crops in different district: Estimating baseline production**: Simulations were done with InfoCrop model (Ref.7) for major crops of the State using the respective crop coefficients and management for each of the 10 years from 1991 to 2000. The actual daily weather data of the respective districts were taken and simulated to get the predicted yield. The mean of 10 years realized yield was taken as the baseline yield. The actual crop yield in each district was compared with the predicted yield and the ratio (constant) of realized and estimated was generated for all the crops and for all the districts. These values were calibrated to district productivity and this was treated as the 'baseline yields'.

Simulating production for 2035 scenario: Using InfoCrop models crop yield (Ref.8) (Based on IPCC and national Climate Change Policies) was studied for major crops in the state. The climate models outputs on temperature (minimum and maximum) and rainfall for A1b-2035 scenario were used. Apart from this, frequency of occurrence of climatic extreme events such as higher/low rainfall events and high temperature events is inherently accounted for. The projected carbon dioxide levels as per Bern CC model for scenario was also included in the model for simulations. Based on the simulated yields in changed scenarios, productivity was estimated as in case of baseline production taking the changed climatic scenario and enhanced CO2. Then the simulation outputs are multiplied with the ratio constants (generated using the baseline yields) to get the estimated yields. To express the impacts on productivity, the net change in productivity in climate change scenario was calculated and expressed as the percentage change from baseline mean productivity. The infocrop model was used for Maize, Sorghum, Rice, Redgram, Cotton, Potato, Soyabean and Wheat crops.

The Stocheometric crop weather model:

A Simple crop weather relationship to predict groundnut (variety: JL-24) growth and pod yield based on the dry matter accumulated at the end of each stage has been developed. Multiple linear regression equations relating the GDD, SSH and AET with the accumulated dry matter during each growth stage and also the final pod yield were generated using the field experimental data for the period 2000-2009.

$T_1 = (A_1X_1+B_1Y_1+C_1Z_1)$ ... (1)
$T_2 = T_1S_2 + (A_2X_2+B_2Y_2+C_2Z_2)$ ... (2)
$T_3 = T_2S_3 + (A_3X_3+B_1Y_3+C_3Z_3)$ ... (2)
$T_4 = T_3S_4 + (A_4X_4+B_4Y_4+C_4Z_4)$ ... (4)
$T_5 = T_4S_5 + (A_5X_5+B_5Y_5+C_5Z_5)$ ... (5)

Subscript indicates the respective stages, T_1 … T_5 are the accumulated bio-mass or Total Dry Matter at the end of respective stage. A, B and C are the Coefficient of determinants of the variables. X, Y and Z (GDD, SHH and AET), S is the coefficients of determinants of input accumulated bio-mass. The pod yield as influenced by the accumulated bio-mass at the end of each stage is related in the equation of the type

$Yg = IT_1(O) + JT_2(O) + KT3(O) + LT_4(O) + MT_5(P)$

Where, $T_1(O)$, $T_2(O)$, T_3 (O) and $T_4(O)$ are the observed total dry-matter at the end of first four stages and T_5 (P) is the predicted total dry-matter for 5^{th} stage. I, J, K, L, M and N are the coefficients. Pod yield prediction equation was developed using observed total dry-matter at the end of first four stages and predicted total dry-matter for 5^{th} stage as independent variables and observed pod yield as dependent variable to predict the pod yield, the model is as fallows

$$Yg = 1.4275\ T_1(O) - 0.0307\ T_2(O) - 0.4205\ T3(O) - 0.0276\ T_4(O) + 0.6358\ T_5(P)$$

This model was found to be significant, and about 87.74% variation in the pod yield can be explained by the independent variables. Coefficients of variable and coefficient of determination (R^2) of fitted models for different stages were shown in Table-13.

Table 13: Coefficients of variable and coefficient of determination (R^2) of fitted models for different stages

Stages of crops		Initial TDM	GDD	SSH	AET	R^2	Result
30 DAS			0.0065	0.0119	-0.0284	0.7724	*
50% flowering stage		1.8585*	0.0013	-0.0112	0.0668	0.9608	*
Pod initiation stage		1.6820*	0.0633	0.0066	-0.1461	0.9353	*
Pod filling stage		0.9036*	-0.0133	0.0561	0.0056	0.9433	*
Harvesting stage		1.0541*	0.0196	-0.0515	0.0189	0.9795	*
Pod yield	TDM 1	TDM 2	TDM 3	TDM 4	PREDICTED TDM 5	R^2	Result
	1.4275	-0.0307	-0.4205	-0.0276	0.6358*	0.8774	*

*: significant at 5% significance level

The coefficient of determinants indicate that the climatic parameters considered and the initial TDM used to estimate the final TDM in each stage could be able to predict the final to an extent of 77 per cent to 98 per cent (coefficients of determinants) in different stages. There is a very good agreement between the observed and the predicted yield, which is revealed by the coefficient of determination of 88 per cent. The Considering the observed Total Dry Matter up to the first four stages and the predicted Total Dry Matter at the end of the harvesting stage, the model has been validated for the year 2009, and there is very good agreement between the observed and the predicted yield.

This type of crop weather models were used for the generation of productivity in the case of Ragi and groundnut in the State. Similar procedure was adopted to generate the baseline yields and also to estimate the yield for the changed scenario of 2035.

Limitations of the Models: Both the models have been statistically tested with the observed and predicted productivities. The model is able to predict the yield up to 89 % (R^2) accurately.

Current / ongoing policies, programs, plans, initiatives and practices in Karnataka, and to examine the implications of these in the context of climate change.

Government of Karnataka has **Agricultural Policy 2006 and adopted in total.** The present policy (Ref.9) document has the stressed the need to implement a workable strategy for water management in rain fed areas and also adopting the watershed approach in drought prone and water land areas. The management and effective equitable utilization of our shared water resources is the key element in improving agricultural performance. The policy document has drawn attention to the need to promote water efficient technologies and crops. Other critical requirements for agricultural dynamism, according to the present policy include new generation technologies and effective attention machinery for delivering technological products to farmers. The policy has recognized the need to have a sharper focus on strategic research for evolving the needed technologies, a task that should be assigned to the two agricultural universities in the State. Field extension activity has been clearly assigned to the State Machinery. Karnataka Agriculture Policy in future envisages a move from the traditional grain based strategy followed in the past towards diversification, emphasizing horticulture, poultry and live stock. This transition poses new challenges including new institutional arrangements. In addition to having more efficient markets and improved delivery channels from farmers to consumers, the policy has underlined the importance of the concerted efforts to increase value addition to agricultural produce. Karnataka Agriculture Policy has the ambition to double agricultural production in ten years. We are aiming to be a significant player in global agricultural trade. Increased productivity, higher efficiency and greater value addition have been identified as factors for this to happen.

Panchasutra for Agricultural Development

1. Protect and improve the soil health.
2. Conservation of natural resources, with special emphasis on water and micro irrigation,
3. Timely availability of credit and other inputs to the farmers,
4. Integrate post harvest processing with the production process, and
5. Reduce the distance between 'Lab to Land' in transfer of technology.

Karnataka has a typical composition of having regions with most of the agro-climatic condition in the country, except the snow-clad mountainous region. A large portion of the land falls under semi-arid conditions facing severe agro-climatic and resource constraints. Interestingly, coexisting with this are a few patches of high value - high-tech agriculture. This emerged only during last two decades and has a sporadic presence in the State. Consequently, Karnataka's agriculture is at the same time diversified and segmented in many ways. Karnataka is one of the few States with the lowest proportion of their area under irrigation. Majority of farmers here have no other option but to grow low value crops. Under such speckled situation, agricultural sector of the State is growing moderately despite severe climatic and strong resource constraints. The credit for this goes to the untiring efforts of the farmers in the state. Undoubtedly, the State has the potential to emerge as one of the leading states in this sector too. However, it is a matter of deep concern that even though agriculture directly impacts the overall growth and distribution performance in the State economy, it has not been attracting investments in the recent past. Farmers are expressing the grievous situation picturesquely. It is rightly feared that the sector may confront another strong lingering of stagnation. Realizing this, the State Government is seized of this problem and has decided to give a close policy look to deal with it. Now, with this Policy document, the State is venturing into the domain of a dynamic Agricultural Policy that has a **'Farmer –Centric'** approach. This policy envisages achieving a growth rate of 4.5 per cent per annum during the next decade. It is expected that this growth rate will help to increase the net income of the farmer. It will also help to bridge the income differentials between the agricultural sector and the non agricultural sectors.

Goals of this Farmer Centric Policy

- *Soil Health*
- *Conservation of Natural Resources mainly land and water*
- *Availability of Credit*
- *Integrated Post Harvest Management*
- *Lab to Land at quick pace*
- *Double the agricultural production in a decade and net income of the farmer*
- *Growth rate of 4.5 percent per annum*
- *Shift to 'demand driven' technology from the 'supply pushed'*

Macro Initiatives

- *Growth rate in GSDP from agriculture at 4.5 per cent per annum.*
- *Budgetary plan expenditure on agriculture should be 10 per cent of total plan.*
- *Developmental expenditure on agriculture out of total development expenditure to double.*
- *Growth in Capital formation at 5 per cent per annum. Investment in Agriculture for food security.*
- *Investment in rural farm and non-farm enterprises to increase.*
- *Issue 'Raitha Mitra Pustaka' (RMP) a small coded pass book with all information of the farm family.*

A farmer information book scheme called as **'*Raithamitra Pusthaka' (RMP)*'** will be issued to each farmer. This will have information about the farmer, coded in a barcode and numerical code. The information will include particulars like name, address, land holdings, irrigation, membership of banks, societies, credit, soil type and crops grown etc.

Land Issues

- *Second phase of land reforms is called for.*
- *Cultivable land is declining and land for non-agricultural uses is increasing.*
- *Low cropping and irrigation intensity.*
- *Large steppe of Wastelands*
- *About 51 lakh marginal and small holdings*
- *Unrecorded and reverse tenancy*
- *Incomplete land records*
- *Increased fallow lands and absentee landlordism.*

Classification and maintenance of Record of Rights of land will be given high priority and land records will be fully prepared before any field level investment planning is taken up in the micro-watersheds. **'Bhoomi Project'** of the State has covered a significant ground in this direction.

Policy Steps

- *Farmers' groups at Panchayat level will manage wasteland.*
- *Public debate on next phase of land reforms*
- *Wasteland to be used for biofuels, medicinal trees and trees with economic value Biofuel development through mission mode.*

- *Land use Board will be strengthened*
- *PRIs to involve in land use management*
- *Bhoomi project to be strengthened*
- *Diversification of Agriculture into other allied activities.*

Presently, soil erosion is noted in 60 per cent of the area under crops. Water logging, salinity and alkalinity are also major problems. The Tungabhadra project area, Upper Krishna project area and the Malaprabha-Ghataprabha project regions have large area, either degraded or problematic. A planned programme of conjuring soil health will be taken up by covering 35,000 hectares per year. This will be called **"Bhumi-Tayiya Arogya"** programme and its operational core will be public private partnership. This will be achieved with the help of 20 percent contribution from the land owner and 80 percent of the expenditure coming from the State. In addition to manual intervention to restore soil health, agronomic conservation (reduced tillage, residue management and crop cover), integrated plant nutrient system, bio inoculums and application of green manure will be encouraged.

It is proposed that **'Soil Health Card'** will be a component of **'Raitha Mitra Pusthaka'** with each individual farmer, whoever seeks the card at a nominal price. The **'Soil Health Card'** will depict the present soil nutrient content, deficiencies as well as the requirement of various nutrients for the soil in order to bring it back to optimum fertility level. Integrated farming approach will be demonstrated and popularized in the rainfed areas. Post-harvest treatment, processing and contract farming will be encouraged in selected crops.

There were more than 25,000 tanks scattered over the erstwhile Mysore State, but in the Bombay-Karnataka and Hyderabad –Karnataka areas, the number of such minor irrigation works was less.

Irrigation Development:

Planned ultimate irrigation potential 35 lakh ha. from major and medium irrigation.
Potential of 21.97 lakh has. has been created under major and medium irrigation projects
Ongoing projects : 55. Investment required Rs. 10543 crores

According to master plans, the likely total utilization under major medium and minor irrigation projects using surface water is 1690.30 TMC

Department is implementing altogether 108 schemes which comprise 67 plan schemes and 41 non-plan schemes. Plan scheme funds are provided mainly for implementing programmes and non-plan schemes funds are provided for meeting expenditure towards staff and salary. Majority of the staff of the Department are working under Zilla Panchayats.

1. **National Agricultural Extension Project(NAEP)-** All Agricultural Development Programmes are channelized through the system of NAEP.

2. **Production and distribution of quality seeds -**It is a State scheme which envisages production and distribution of quality seeds to farmers.

3. **Popularization of Bio-fertilisers-** Scheme envisages to encourage farmers to use bio-fertilisers to control increase in prices of fertilisers and also pollution of atmosphere. Production of bio-fertilisers in Agricultural Universities, distribution to farmers on subsidy, quality control are some of the strategies adopted. It is a State sector scheme.

4. Scheme for plant protection measures- It is a State scheme and the main objective is to distribute Plant Protection Chemicals to farmers at subsidy in the event of outbreak of endemic and epidemic pests and diseases.

5.Natural farming-It is a State sector scheme which aims at reducing excess use of fertiliser and plant protection chemicals by farmers,through promotion of natural farming practices.

6. Study tour of farmers within the State and country- A Scheme sponsored by State and main objective of the Scheme is to expose farmers to new Agril.technologies developed within and outside state by Agricultural Universities and other institutions, and to enable farmers to adopt them for their benefit.

7. Special component and Tribal sub-It aims at increasing per acre yield in the lands of Schedule Caste and Schedule Tribe farm families, to uplift the two categories. Strategy envisages distribution of inputs, PP equipments, power tillers, pumpsets, storage bins ,land development, etc.

8. Supply of power tillers and tractors as an incentive to farmers- It is a State sector scheme and envisages promotion of farm mechanisation in the State. Power tillers are distributed to farmers on subsidy.

9. Distribution of Rice planter/weeder, sugar planter etc.,- It is a State sector scheme and aims at promotion and use of improved agricultural implements. Improved implements are distributed on subsidy.

10. Krishi Prashasthi: Scheme aims to recognize and award farmers doing outstanding work in increasing agricultural production and inculcate healthy competitive spirit among the farmers. Awards are given to farmers who achieve record yields in the crops offered for competition at State, District and Taluk levels, each year.

11. Farm Management Studies: Department of Agriculture undertakes farm management studies regularly. Objectives of the studies are:

a) To estimate the cost of cultivation per hectare and cost of production per quintal of produce of different agricultural crops.

b) To study the physical inputs, output and cost relationship.

c) To estimate the efficiency factors and net returns for various crops.

d) This data is used by the Government for making policy decisions and also benefit farmers in selecting profitable crop alternatives.

The studies are conducted in 68 centres from selected 40 farmers with additional 20 farmers in each centre. The studies are undertaken in all the 10 agro climatic zones. The studies are conducted on cost accounting method where, variable cost like human and bullock labour, seeds, farm yard manure, fertilisers, plant protection chemicals, irrigation charges, repair charges and miscellaneous charges and fixed cost like interest on investment, land revenue and taxes, interest on working capital, depreciation charges, risk premium, managerial cost and rental value on land are considered.

II. Centrally sponsored schemes

1. **Integrated Cereals Development Programme (ICDP – coarse cereals)-** It is a Centrally Sponsored Scheme which aims at a holistic improvement in production and productivity of cereals based cropping system. Under the Scheme, distribution of certified seeds, field and IPM demonstrations, distribution of farm implements and extending productivity awards to Gram Panchayats are some of the important strategies followed.

2. National Pulses Development Programme-Objective is to boost production of pulses and stabilize yield levels by providing incentive to farmers and institutions. It is a Centrally Sponsored scheme. Package approach for higher yields, adoption of technologies, integrated pest management, double cropping, inter-cropping etc., are some of the strategies followed under the programme.

3. Oil Seeds Production Programme-It is a Centrally Sponsored Scheme implemented to accelerate production, processing and management technologies to achieve self-reliance in oil seeds. Increasing area, intensification of oil seed cultivation, Hybrid sunflower cultivation, cultivation under irrigation, promotional programmes, inter-cropping, double cropping, quality seeds, IPM concept, post harvest support for processing storage and marketing are the strategies adopted.

4. Sustainable Development of Sugarcane based cropping system(SUBACS) - This is a Centrally sponsored scheme and aims at higher production and productivity in the districts which have productivity below state/national average. Strategies envisage use of quality seeds, planting, popularisation of weedicide and drip irrigation, use of parasites, soyabean inter-cropping, management of ratoon crop and post harvest technology, fertiliser application and irrigation schedules as recommended.

5. Accelerated Maize Development under technology Mission on Maize - It is a Centrally Sponsored scheme which focuses on needs relating to production, research, post-harvest, marketing etc., of Maize. Strategies adopted include use of quality seeds and improved technology, intensive cultivation, training, use of improved implements, etc.

6. Balanced and Integrated use of fertiliser- It is a Centrally sponsored scheme which aims at balanced and integrated use of fertilisers in farmers' fields, and encourages use of organic manures. Strategies envisage training, demonstrations, etc.

7. Rashtriya Krishi Bima Yojana (RKBY)- Government of India communicated to all the State/U.T. Governments the discontinuation of the implementation of the existing CCIS from Rabi 1999-2000 and has taken a decision to implement a new insurance scheme entitled "National Agricultural Insurance Scheme(Rashtriya Krishi bima Yojana)" in the country from Rabi 1999-2000. This new insurance scheme covers all cereals, pulses, oilseeds and commercial crops/horticultural crops viz., sugarcane, cotton and potato.

III. Central sector schemes:-

1. Central sector scheme of wheat minikit trials- Scheme aims at conducting mini-kit trials in farmers fields to encourage them to use varieties released in the preceeding five years.

2. Central Sector rice seed minikit and state level training-

Scheme envisages organising of minikit trials in farmers fields to encourage them to use varieties released in the preceeding five years.

3. Supply of small tractors-It is a Central Sector scheme. It aims at popularisation of Agricultural mechanisation in the farms. Small tractors are distributed to farmers on subsidy.

IV. Externally aided projects:-

1. Project for Agricultural Training of farm women with DANIDA Assistance- It is a Danish assisted project. Its emphasis is on farm women's participation in agriculture development and promoting their capability as they are the decision makers on farm operations. Training of farm women in the latest technology in Agriculture and allied fields is the strategy adopted.

In order to strengthen the Agricultural Extension and Training programmes for the Farm Women and Farm Youth in Karnataka, a project called the WYTEP with the assistance of DANIDA was approved by the Government of Karnataka, Government of India and DANIDA Mission and the scheme phase-I was started during the year 1982-83 in the 11 districts by covering 107 taluks in the State.

The **DANIDA** Mission on the review of the WYTEP Phase-I of the Project were satisfied with the progress achieved and approved the extension of the project in the State for another 11 years under phase-II from 1-7-1989. Project was operated throughtout the State except in Bidar District. Total cost of Phase-II was Rs.28.40 Crores from 1-7-89 to 31-5-2000. Project Component consisted of conducting training for Farm Women(10 days) and Farm Youth (14 days) in the latest technology of Agriculture and allied subjects like Animal Husbandry/Horticulture/Sericulture etc. In addition to the above, Institutional Courses like link workers training, village based training camps, specilised courses for Farm Women conferences were organised. It is proposed to take up Phase of WYTEP from 1st June-2000. Project has been proposed for a period of five years with a total outlay of Rs.4593.00 lakhs, out of which DANIDA share will be Rs.1574.00 lakhs and State share will be Rs.3019.00 lakhs. Phase-III of the project will be a transition phase to develop Farm Women Extension as a sustainable system in the Department of Agriculture. Project has been submitted to Government of India/DANIDA/GOK for clearance.

Gearing the General Extension System (GES) : To provide effective extension service to farm women. Develop and strengthen farm women to enable them tomanage their own resources and take decisions on their needs for training and extension services thereby increasing their agricultural knowledge and skills. The GES of the department will assume responsibilities for providing extension services to Farm Women Groups(FWGs). Extension activities to be centered around FWGs so that the other farm women are also motivated to form groups and seek help. Providing facilities and support to the FWGs to make them sustainable and seek help. Continuing the focus of attention on farm women through the Assistant Agriculture Officer(Farm Women) in the newer areas within the taluk. Training Link Workers on current thrust technologies as a means to help the members learn. Providing need based and location specific training support to FWGs. Integrating the modules developed under WYTEP in the GES. Providing wider exposure to the group members to see places of technical interest. Establishment of model farms at the group level as a centre for transfer of technologies to the village. Organising need based training to the groups members both at the Training Centres (TCs) as well as the cluster level utilising the TCs for both officials training programmes and for the farm women training on selected thrust technologies.

KARNATAKA WATERSHED DEVELOPMENT PROJECT:

The objectives of the project are to improve the productive potentials of selected watersheds and their associated natural resource base. Sustainable alleviation of Poverty, Develop and strengthen community based institutional arrangements for sustainable natural resource management and Involvement of village communities in participatory planning, implementation, social and environmental management, maintenance of assets and to operate in a more socially inclusive manner.

Land users in selected watersheds enabled to practice sustainable management of natural reasources in private and common land, Revelant authorities involved in project planning and implementation able to support farmers and villagers in the project area in dentification, prioritization, planning and implementation of sustainable land use systems. Implementation of sustainable land use systems. Holistic land use system aimed at suistainable and increased production developed by the project and applied by a majority of farmers. Short and long term employment opportunities and household income increased in the project area, A sustainable organisational frame work and financial bases involvement of disadvantaged groups in watershed management established in project

Comprehensive Crop Insurance Scheme. (CCIS)

It was implemented in the State from Kharif 1985, till Khariff 1999 to provide a measure of financial support to farmers in the event of crop failure as a result of flood etc., All farmers who availed crop loans for notified crops/taluks from Co-operative Banks, commercial banks and Regional Rural Banks were compulsorily covered under the scheme. Sum insured was 100% of crop loans disbursed with a maximum of Rs.10,000/- per farmer per season. Taluk was the notified area. Altogether 11 crops were covered. Paddy, Jowar, Ragi, Bajra, Maize, G.nut, Sunflower and Tur were covered in Kharif season, Wheat, Jowar, Bengalgram, Safflower, Sunflower and Paddy were covered during Rabi season and Paddy, Ragi and G.nut were covered during summer season. Premium was 2% of the sum insured for cereals and 1% of the sum insured for pulses and oil seeds. Fifty percent of premium of small and marginal farmers were subsidized. A sum of Rs.5738.44 lakhs was paid as claims from 1985 to 1998-99, against a premium collection of Rs.1720.09 lakhs from the insured farmers. Government of India have approved a claim of Rs.963.07 lakhs for kharif 1999. Action is being initiated to disburse this amount to farmers early. Including kharif 1999 claims, the total claim amount works out to Rs.6701.51 lakhs.

Weather Based Crop Insurance Scheme (ECIS)

Centrally sponsored Experimental Crop Insurance Scheme was implemented in 5 taluks namely Bijapur, Basavana Bagewadi, Sindhagi, Indi and Muddebihal of Bijapur district in Karnataka State during Rabi 1997-98 crop season vide Government order No.AHD.101.ANS.97, Bangalore, dated:16-1-1998. All Small and marginal farmers, (loanee or non-loanee) were covered under the scheme. Crops covered for Rabi 1997 season were Jowar, Wheat, Bengalgram, Safflower and Sunflower. Farmers in the five taluks who had grown the 5 notified crops were eligible to participate in the scheme by opening a bank account in Nationalized Banks/Commercial

Banks/Regional Rural Banks. Sum insured was equal to the scale of finance for non-loanee farmers and upto crop loan taken by loanee-farmers for growing the insured crop during the season, subject to a ceiling of Rs.10,000/- per farmer for all insured crops. Premium rate was 2% of sum insured for Cereals and Millets and 1% of sum insured for pulses and oilseed crops. One hundred per cent of the premium towards crops insured by small and marginal farmers was subsidised and the same was shared by the Central Government and State Government in the ratio of 1:1.

A total number of 50540 small and marginal farmers have participated in the scheme during Rabi 1997. Government of India have approved for a total claim amount of Rs.799.82 lakhs. Government of Karnataka's share of contribution will be 20% of the claim amount. Action is being taken to disburse the claims shortly.

RASHTRIYA KRISHI BIMA YOJANA (RKBY)

" National Agricultural Insurance Scheme (Rashtriya Krishi Bima Yojana-RKBY)"has been introduced with State from kharif 2000. Objectives of the RKBY are as under:

1. To provide insurance coverage and financial support to farmers in the event of failure of any of the notified crops as a result of natural calamities, pests and diseases.
2. To encourage the farmers to adopt progressive farming practices, high value inputs and higher technology in Agriculture.
3. To stabilize farm incomes, particularly in disaster years.

The scheme is compulsory for loanee farmers, who avail crop loans from financial institutions, for the notified crops. All other farmers growing notified crops can opt for the scheme on a voluntary basis.

Crops notified: The following crops are notified for the kharif 2000 in Karnataka.

a. Food crops: 1) Cereals- Paddy, Jowar, Ragi, Bajra and Maize.

    2) Pulses – Tur, Greengram, Blackgram, Soyabean

b. Oil seeds : Sunflower and Groundnut.

KARNATAKA AGRICULTURE COMMISSION: Farming community in Karnataka has made sizable contribution to the economy in achieving milestones in agricultural production. This was possible due to concerted efforts in implementing development strategies that comprise technological breakthrough and their applications, hard and dedicated work of farmers and supportive policies of the Government. However, forward linkages and some of the backward linkages need strengthening. This linkages have become all the more relevant in view of the challenges and opportunities thrown open, in the content of liberalisation and opening of the Indian economy.

Government had identified following important areas where in further scope exists for improvement.

i. Agriculture research and adoption of improved technology.
ii. Protection of yield levels already attained and bridging the yield gap between potential and actual yields to attain higher productivity in all the ten agro- climatic regions.
iii. Pace of Integrated Watershed Development.

iv. Cost effective land development, water management techniques etc.,
v. Extension services.
vi. Input supply and farm mechanisation .
vii. Rural credit.
viii. Horticulture including floriculture, dairying, poultrying, meat,wool, fisheries and sericulture.
ix. Agricultural marketing, infrastructure, processing etc.
x. Organic farming.
xi. Trade polices with particular reference to input and output.

Assessment of climate change scenario for 2035. This includes rainfall and temperature trends and variables.

The long-range climate change has been observed worldwide and also the changes in the food production and productivity of the individual crop. This change is slow in nature and caused some area to loose their traditional crops and to go for alternate crops. This change in climate results either in increasing/decreasing the soil moisture during the crop growing period, decreasing/increasing the length of the adequate moisture availability period, increases/decreases the yield of the particular crop in the same area grown for several years and so on. Consequence to this some less water required crops have come in to existence, some area have acquired new crops of high water required. The production/productivity of an individual crop has been changed resulting variation in total production of the food grains. This total production of food grains in the Nation/State is altogether changing the food habits, economy of the grower or the state. The analysis of the impact of climate change on crop productivity and total production in a given area helps to know how much crop replacement taken place in a that area, the climatic component caused for the replacement of the crops, future trend in the production etc.. The economy of the given region and arrangements for transportation of the food from the high production area to the low production area or preparedness to cope up with the expected trend in the food production. In view of this, using the available GCM data (Ref. 10), the rainfall and other parameters have been down scaled for the Karnataka region following the methodology indicated below.

Model, SRES scenario, variables extracted
GCM used is HadCM3, Hadley center, UK (Collins et al, 2001)
Downscaling by IITM, Pune
SRES scenario used is A1B
Near-term of 2021-2050 is considered
Monthly anomaly values for the following variables were extracted from the model:
Average temperature, at 1.5m above ground level
Maximum temperature, at 1.5m above ground level
Minimum temperature, 1.5 m above ground level
Total precipitation

Rainfall percentages deviations projection for 2035 (figure 5) revealed the following results and is given in table 14. The total monthly rainfall of all the districts are given in table 15.

District	JAN	FEB	MAR	APR	MAY	**Pre**	JUN	JUL	AUG	SEP	**SWM**	OCT	NOV	DEC	**NEM**	Annual
BANGALORE RURAL	-66.7	72.8	126.7	-26.6	8.8	23.0	-15.4	-1.8	7.0	0.9	-2.3	2.8	-12.1	38.2	9.6	10.1
BANGALORE URBAN	-87.5	57.3	94.2	-14.9	10.4	11.9	-13.6	-3.2	4.5	0.8	-2.9	3.9	-9.7	36.2	10.1	6.4
BAGALKOTE	0.0	-70.8	149.4	-20.8	2.3	12.0	-27.3	-17.6	9.8	-6.7	-10.5	-0.8	-16.6	68.1	16.9	6.1
BELGAUM	0.0	-12.5	81.2	-14.7	-5.5	9.7	-23.7	4.2	12.3	1.8	-1.3	-1.6	-6.7	68.3	20.0	9.5
BELLARY	-28.9	0.0	121.0	-28.5	16.0	15.9	-29.2	-26.2	23.7	-0.7	-8.1	1.3	-19.5	38.8	6.9	4.9
BIDAR	-51.7	-90.9	42.0	-11.5	36.4	-15.1	-6.1	14.5	24.7	-5.6	6.9	3.6	-55.9	204.6	50.8	14.2
BIJAPUR	-6.4	-95.2	135.4	-23.6	6.4	3.3	-24.8	-21.7	14.7	-7.4	-9.8	-0.6	-36.1	74.4	12.5	2.0
CHAMARAJA NAGAR	-99.2	82.2	47.6	-12.1	14.1	6.5	-23.0	-8.0	-1.8	-0.8	-8.4	1.9	-9.1	11.9	1.6	-0.1
CHIKBALLAPUR	-16.7	117.0	77.2	-32.7	7.7	30.5	-17.9	-4.5	12.4	0.5	-2.4	2.4	-15.8	23.1	3.2	10.4
CHIKMAGALUR	-21.6	-66.7	33.6	-18.5	-6.5	-15.9	-19.7	14.9	3.6	1.8	0.1	7.5	-4.7	32.1	11.6	-1.4
CHITRADURGA	0.0	1.9	73.1	-29.3	24.5	14.0	-33.2	0.4	19.1	-2.1	-4.0	3.6	-7.1	46.8	14.5	8.2
DAKSHINAKANNA DA	5.9	-74.6	40.1	-17.7	-16.2	-12.5	-6.8	8.1	-3.2	0.2	-0.4	9.5	-2.9	18.2	8.3	-1.6
DAVANGERE	0.0	0.0	76.2	-21.3	17.4	14.4	-28.0	3.4	19.0	-1.7	-1.8	4.8	-1.5	39.3	14.2	8.9
DHARWAR	0.0	0.0	106.7	-14.7	-0.4	18.3	-21.7	4.9	12.8	4.2	0.1	-2.3	-1.3	33.5	9.9	9.4
GADAG	0.0	0.0	127.0	-19.9	5.4	22.5	-31.0	-10.3	14.6	-0.5	-6.8	-0.7	-4.9	42.8	12.4	9.4
GULBARGA	-41.5	-84.7	48.2	-21.3	11.4	-17.6	-15.1	-6.9	22.3	-6.1	-1.4	-2.4	-53.1	83.9	9.5	-3.2
HASSAN	-14.0	-92.0	14.5	-23.4	-1.3	-23.2	-24.8	8.9	1.0	0.1	-3.7	4.3	-10.8	42.3	11.9	-5.0
HAVERI	0.0	0.0	47.3	-16.6	6.2	7.4	-16.8	7.1	14.4	3.0	1.9	3.3	0.6	28.8	10.9	6.7
KODAGU	-0.6	-60.7	7.0	-25.5	-3.5	-16.7	-8.0	8.7	1.4	1.8	1.0	5.8	-7.6	21.7	6.6	-3.0
KOLAR	-40.6	50.2	68.1	-8.0	8.2	15.6	-10.2	-5.1	2.1	-1.0	-3.6	2.1	-13.0	25.5	4.9	5.6
KOPPAL	0.0	-4.2	149.4	-24.3	10.5	26.3	-35.0	-30.9	18.0	-1.5	-12.3	-0.8	-20.6	47.8	8.8	7.6
MANDYA	-37.5	-2.5	24.6	-18.9	8.0	-5.3	-25.0	-3.7	0.7	0.1	-7.0	2.8	-11.6	40.0	10.4	-0.6
MYSORE	-44.4	-1.5	7.0	-19.7	4.7	-10.8	-18.8	1.6	-2.0	-0.3	-4.9	1.8	-9.8	16.7	2.9	-4.3
RAICHUR	0.0	-8.3	66.0	-16.9	12.4	10.6	-27.1	-31.7	19.2	-4.3	-11.0	-2.4	-69.2	48.8	-7.6	-2.6
RAMANAGAR	-92.4	48.9	71.9	-15.0	11.4	5.0	-19.3	-5.9	4.5	1.2	-4.9	4.0	-9.8	36.6	10.3	3.5
SHIMOGA	0.0	-25.0	45.4	-14.6	0.9	1.3	-10.4	14.2	8.3	5.1	4.3	7.5	-0.7	17.3	8.0	4.6
TUMKUR	-3.6	31.1	85.7	-35.1	14.8	18.6	-27.6	0.0	11.6	0.2	-3.9	2.7	-11.5	51.6	14.3	9.6
UDUPI	0.0	-21.4	98.8	-15.3	-5.7	11.3	-2.5	10.3	-1.2	3.1	2.4	14.0	3.6	10.9	9.5	7.7
UTTARAKANNADA	0.0	0.0	41.7	-13.2	3.3	6.4	-6.2	8.3	7.7	9.8	4.9	4.8	3.6	11.9	6.8	6.0
	-22.3	-8.6	72.7	-19.8	7.0	5.8	-19.6	-2.3	9.7	-0.2	-3.1	2.9	-14.3	43.4	10.7	4.5

Table 14.Per Cent age Deviation in mean monthly rainfall in Karnataka seasonal shift growing period.

Table 15. Mean monthly Rainfall in Karnataka during 2035

District	JAN	FEB	MAR	APR	MAY	PM	JUN	JUL	AUG	SEP	SWM	OCT	NOV	DEC	NEM	Annual
BANGALORE RURAL	0.7	5.2	22.7	23.5	102.3	173.4	60.1	85.4	123.1	155.4	417.1	149.1	55.3	19.3	28.8	869.8
BANGALORE URBAN	1.9	12.6	17.5	31.5	124.8	188.0	63.1	99.7	137.9	159.2	452.5	172.5	58.7	13.6	30.4	930.9
BAGALKOTE	1.0	0.6	10.0	19.0	58.3	98.6	49.4	61.8	81.2	133.3	322.3	92.2	29.2	13.4	50.6	619.9
BELGAUM	1.0	1.8	12.7	24.7	71.8	126.2	87.0	216.8	143.8	112.0	552.6	99.4	35.5	15.1	60.0	900.9
BELLARY	0.7	1.0	6.6	19.3	82.4	119.4	48.8	65.0	122.4	131.1	356.5	102.3	27.4	13.9	20.6	667.1
BIDAR	1.4	0.5	18.5	20.4	42.3	63.6	125.8	219.8	229.5	184.1	753.6	77.7	10.6	18.3	152.3	1010.4
BIJAPUR	0.9	0.1	14.1	15.3	46.8	75.4	58.6	69.7	118.1	145.3	385.1	94.4	17.9	13.9	37.6	643.7
CHAMARAJA NAGAR	0.0	10.9	22.1	59.7	166.7	254.6	44.7	58.9	80.5	111.1	289.4	166.1	71.8	21.3	4.7	815.1
CHIKBALLAPUR	0.8	8.7	14.2	17.5	79.7	147.5	48.4	87.9	120.2	154.7	402.1	150.5	45.4	19.7	9.6	819.5
CHIKMAGALUR	0.8	1.0	16.0	47.3	98.2	150.5	241.6	760.8	395.6	162.9	1507.1	155.9	56.2	21.1	34.9	1877.5
CHITRADURGA	5.0	7.1	19.0	19.1	117.0	164.2	46.1	74.3	109.5	125.3	348.6	147.2	55.7	14.7	43.4	777.8
DAKSHINAKANNADA	1.1	1.0	14.0	38.7	143.4	203.9	858.5	1405.8	770.9	320.5	3323.6	234.3	98.1	29.6	24.8	3850.3
DAVANGERE	1.0	2.0	7.0	30.7	98.6	148.8	45.4	95.1	116.6	106.2	354.4	95.4	65.0	12.5	42.6	715.7
DHARWAD	1.0	3.0	16.5	40.1	87.7	173.9	82.2	159.5	112.8	128.2	480.3	103.5	42.4	13.3	29.8	860.2
GADAG	1.0	3.0	11.4	24.0	80.1	140.9	42.8	60.1	123.8	127.3	340.2	100.3	38.0	12.9	37.3	689.0
GULBARGA	1.2	0.5	11.9	15.7	42.3	58.5	91.7	151.8	214.0	182.2	630.8	104.5	7.5	9.2	28.5	812.3
HASSAN	0.9	0.2	13.7	44.4	105.6	138.9	88.7	187.3	197.9	98.1	562.3	179.5	34.8	15.7	35.8	937.6
HAVERI	1.0	3.0	7.4	34.2	87.1	141.7	79.9	215.2	117.8	87.5	494.3	82.6	65.4	19.3	32.6	829.2
KODAGU	2.0	2.0	19.3	52.9	145.7	205.9	447.2	1019.7	431.8	274.9	2140.6	158.7	87.8	24.3	19.8	2552.4
KOLAR	4.7	18.0	21.8	23.0	81.1	153.7	49.4	75.0	88.8	140.6	350.1	121.6	70.5	33.9	14.7	763.7
KOPPAL	1.0	1.0	5.0	15.1	55.2	93.4	42.2	62.9	113.3	131.0	337.5	92.2	19.1	10.3	26.4	627.2
MANDYA	1.9	4.9	12.5	40.5	132.9	181.0	36.0	49.1	85.6	112.1	275.3	156.2	58.4	23.8	31.2	717.5
MYSORE	1.7	3.9	13.9	52.2	141.3	196.3	52.8	101.6	79.4	88.7	318.6	152.7	46.0	11.7	8.7	733.4
RAICHUR	1.0	0.9	3.3	13.3	50.6	71.9	61.9	68.9	150.2	160.8	427.3	98.6	8.6	10.4	-22.8	663.0
RAMANAGAR	0.1	8.9	20.6	38.3	141.5	200.5	50.8	77.2	106.6	180.2	404.3	174.7	47.8	20.5	30.8	881.4
SHIMOGA	1.0	2.2	10.2	38.4	92.8	150.0	275.1	777.8	381.3	151.4	1548.0	146.2	40.7	11.7	24.1	1901.9
TUMKUR	4.8	9.2	20.4	17.5	107.9	170.7	50.0	74.0	102.6	128.3	348.7	145.9	53.1	15.2	42.8	788.2
UDUPI	1.0	2.4	8.0	25.4	160.4	231.4	1076.9	1479.0	830.3	394.9	3758.0	237.2	80.8	21.1	28.5	4505.5
UTTARAKANNADA	1.0	3.0	4.3	21.7	119.9	157.4	638.6	1089.2	648.2	272.2	2660.6	145.7	50.8	13.4	20.4	3058.5
State mean	1.6	2.7	13.8	29.7	97.3	0.0	152.0	265.6	218.3	158.8	0.0	139.9	38.6	15.8	0.0	1235.2

Spatial and temporal variations (figure 6) exist for temperatures in coastal region. During Kharif season, the middle west coastal region has a temperature regime of 18/27 °C. In west coast, kharif rainfall ranged from 2000-4000 mm The projected increase in seasonal mean minimum temperature during Kharif is about 1 °C in west coast.

Inferences:

Gradual declining in the south-west monsoon rainfall and decreased portion of rainfall is partly shared by Pre-monsoon and N-E monsoon. Hence there is a change in the rainfall pattern and amount of rainfall received during different months is also varied. In addition to this some part of the State likely to receive the s-w monsoon rains required for agriculture beyond July month. Hence the following observations are made.

Raichure, Koppal, Bellary, Bangalore, Bijapur, Chamarajanagar, Gadag and Mandya districts are likely to loose their s-w monsoon rains up to 12.5 %. Hence, in these districts only low water required crops like millets can be grown in rainfed agriculture. In other irrigated area regular irrigated crops can be grown. Bidar, Bijapur, Bellary, Belgaum, Davanagere, Gadag and Gulbarga are the comfortable growing districts during s-w monsoon. DK, Udupi, UK districts from early June to early October. Davanagere, Haveri and Chamarajanagar districts from early July to late October. Gadag and Gulbarga districts from early August to early October. Bellary receives good rains only during August. Bidar to receive from early August to mid September. Chikamagalure and Shimoga districts from mid July to early October, Hassan district from mod early mid to late October. Gulbarga and Raichur districts from Early August to early October. Koppal district from early August to early October. Kolar, Bangalore, Ramanagar Mandya and Mysore districts from late July to late October. Tumkur and Chitradurga districts from mid July to late October.

In addition to this rainfall changes, the per cent age changes with respect to the baseline data (1961-1990) of few other climatic parameters have been generated and listed in tables 16 to 20.

Table 16. Deviation in mean monthly air Temperature in Karnataka in different districts

NO	District Name	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1	BAGALKOTE	2.4	2.3	2.1	1.9	2.1	2.2	1.7	1.6	2.0	2.3	2.9	2.5	2.2
2	BANGALORE RURAL	2.1	2.2	1.8	2.1	2.1	2.1	1.8	1.6	1.8	1.8	2.2	2.2	2.0
3	BANGALORE URBAN	2.0	2.3	1.7	2.1	2.0	2.1	1.8	1.6	1.8	1.7	2.1	2.1	2.0
4	BELGAUM	2.3	2.1	2.0	1.7	2.0	2.0	1.5	1.5	1.7	2.1	2.8	2.3	2.0
5	BELLARY	2.4	2.2	2.0	2.0	2.1	2.1	1.7	1.6	1.9	2.0	2.6	2.3	2.1
6	BIDAR	2.4	2.4	2.2	2.1	2.2	2.1	1.4	1.3	1.8	2.2	3.0	2.4	2.1
7	BIJAPUR	2.4	2.3	2.1	2.0	2.1	2.3	1.7	1.5	2.0	2.4	3.0	2.6	2.2
8	CHAMARAJA NAGAR	2.1	2.2	1.8	2.1	1.9	2.0	1.7	1.7	1.8	1.7	2.1	2.1	2.0
9	CHIKBALLAPUR	2.2	2.2	1.8	2.1	2.1	2.1	1.8	1.5	1.8	1.8	2.2	2.2	2.0
10	CHIKMAGALUR	2.0	1.9	1.9	1.7	1.9	1.8	1.5	1.6	1.6	1.8	2.3	2.2	1.9
11	CHITRADURGA	2.2	2.2	2.0	1.9	2.0	2.0	1.7	1.6	1.8	1.9	2.4	2.2	2.0
12	DAKSHINAKANNADA	1.9	1.7	1.8	1.5	1.7	1.6	1.4	1.5	1.5	1.7	2.2	2.1	1.7
13	DAVANGERE	2.2	2.2	2.0	1.8	2.0	2.0	1.6	1.6	1.7	2.0	2.5	2.2	2.0
14	DHARWAR	2.2	2.1	2.0	1.7	2.1	2.0	1.5	1.5	1.7	2.1	2.7	2.4	2.0
5	GADAG	2.3	2.2	2.0	1.9	2.1	2.1	1.6	1.5	1.9	2.2	2.8	2.4	2.1
6	GULBARGA	2.4	2.3	2.2	2.1	2.1	2.2	1.5	1.4	1.9	2.3	3.0	2.6	2.2
7	HASSAN	2.1	2.0	2.0	1.9	2.0	1.9	1.6	1.6	1.7	1.8	2.3	2.2	1.9
8	HAVERI	2.2	2.1	2.0	1.7	2.0	1.9	1.5	1.5	1.7	2.1	2.6	2.3	2.0

9	KODAGU	1.9	1.8	1.9	1.7	1.8	1.7	1.5	1.5	1.6	1.7	2.2	2.1	1.8
0	KOLAR	2.1	2.4	1.7	2.1	2.0	2.1	1.8	1.6	1.8	1.8	2.1	2.1	2.0
1	KOPPAL	2.4	2.3	2.1	2.0	2.1	2.2	1.7	1.6	2.0	2.2	2.7	2.4	2.1
2	MANDYA	2.1	2.2	1.9	2.1	2.0	2.1	1.7	1.7	1.8	1.8	2.3	2.1	2.0
3	MYSORE	2.1	2.0	2.0	2.0	2.0	2.0	1.6	1.7	1.7	1.8	2.3	2.2	1.9
4	RAICHUR	2.5	2.3	2.2	2.1	2.1	2.3	1.8	1.6	2.1	2.2	2.8	2.5	2.2
5	RAMANAGAR	2.0	2.3	1.8	2.1	2.0	2.1	1.8	1.7	1.8	1.7	2.1	2.1	2.0
6	SHIMOGA	2.1	1.9	1.9	1.6	1.9	1.8	1.5	1.5	1.6	1.9	2.4	2.3	1.9
7	TUMKUR	2.1	2.2	1.9	2.0	2.0	2.1	1.8	1.6	1.8	1.8	2.3	2.2	2.0
8	UDUPI	1.9	1.7	1.8	1.5	1.7	1.6	1.4	1.4	1.5	1.7	2.1	2.1	1.7
9	UTTARAKANNADA	2.1	1.8	1.9	1.6	1.9	1.8	1.5	1.5	1.6	1.9	2.5	2.3	1.9
0	YADGIR	2.5	2.3	2.2	2.1	2.1	2.3	1.7	1.5	2.1	2.3	2.9	2.6	2.2

Spatial and temporal variations exist for temperatures in coastal region. During Kharif season, the middle west coastal region has a temperature regime of 18/27 °C. In west coast, kharif rainfall ranged from 2000-4000mm The projected increase in seasonal mean minimum temperature during Kharif is about 1 °C in west coast.

Table 17. Deviation in monthly mean maximum Temperature in different districts.

NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annaul
BAGALKOTE	2.3	2.1	1.9	1.8	2.0	2.7	1.8	1.6	2.2	2.1	2.7	2.1	2.1
BANGALORE RURAL	2.0	1.9	1.7	1.9	1.9	2.5	2.0	1.6	1.8	1.8	2.2	1.9	1.9
BANGALORE URBAN	1.9	1.9	1.6	1.9	1.8	2.4	1.9	1.7	1.8	1.7	2.1	1.8	1.9
BELGAUM	2.2	2.0	1.8	1.6	2.0	2.4	1.6	1.6	1.9	2.1	2.6	1.9	2.0
BELLARY	2.3	2.0	1.9	1.9	1.9	2.4	1.9	1.6	1.9	2.0	2.5	1.9	2.0
BIDAR	2.4	2.0	2.0	1.7	1.9	2.3	1.1	1.0	1.7	2.3	2.7	1.9	1.9
BIJAPUR	2.4	2.1	1.9	1.8	2.0	2.7	1.7	1.4	2.2	2.2	2.7	2.1	2.1
CHAMARAJA NAGAR	2.0	1.9	1.7	2.0	1.7	2.4	1.9	2.0	1.9	1.7	2.2	1.8	1.9
CHIKBALLAPUR	2.2	1.9	1.7	1.8	1.9	2.3	2.0	1.4	1.7	1.8	2.2	2.0	1.9
CHIKMAGALUR	2.0	1.8	1.8	1.8	1.8	2.1	1.6	1.8	1.8	1.9	2.4	1.8	1.9
CHITRADURGA	2.1	2.0	1.9	1.9	1.9	2.5	1.9	1.7	1.9	1.8	2.3	1.8	2.0
DAKSHINAKANNADA	1.8	1.6	1.7	1.5	1.7	1.8	1.4	1.6	1.6	1.8	2.2	1.8	1.7
DAVANGERE	2.1	2.0	1.8	1.9	1.9	2.4	1.8	1.7	1.9	2.0	2.5	1.8	2.0
DHARWAR	2.1	2.0	1.8	1.7	1.9	2.4	1.6	1.6	1.8	2.1	2.6	1.9	2.0
GADAG	2.2	2.1	1.8	1.9	1.9	2.5	1.8	1.6	2.1	2.2	2.6	1.9	2.0
GULBARGA	2.4	2.0	2.0	1.8	1.9	2.5	1.4	1.2	2.0	2.3	2.7	2.1	2.0
HASSAN	2.0	1.9	1.9	1.9	1.9	2.3	1.8	1.8	1.9	1.8	2.4	1.8	2.0
HAVERI	2.1	2.0	1.8	1.8	1.9	2.4	1.6	1.7	1.8	2.1	2.6	1.9	2.0
KODAGU	1.9	1.6	1.8	1.7	1.8	1.9	1.5	1.7	1.7	1.8	2.4	1.8	1.8

KOLAR	2.1	2.0	1.6	1.8	1.9	2.2	1.8	1.5	1.7	1.8	2.1	2.0	1.9
KOPPAL	2.3	2.1	1.8	1.9	1.9	2.6	1.9	1.7	2.2	2.1	2.6	2.0	2.1
MANDYA	1.9	1.9	1.8	2.0	1.8	2.7	2.1	2.0	2.0	1.8	2.3	1.8	2.0
MYSORE	2.0	1.8	1.8	2.0	1.8	2.4	1.9	2.0	2.0	1.8	2.4	1.8	2.0
RAICHUR	2.5	2.0	1.9	1.9	1.8	2.6	2.0	1.6	2.2	2.1	2.6	2.2	2.1
RAMANAGAR	1.9	1.9	1.6	2.0	1.8	2.6	2.0	1.8	1.8	1.7	2.1	1.8	1.9
SHIMOGA	2.1	1.8	1.8	1.7	1.8	2.1	1.6	1.7	1.8	2.0	2.5	2.0	1.9
TUMKUR	2.0	1.9	1.8	2.0	1.9	2.5	2.0	1.7	1.9	1.8	2.3	1.8	2.0
UDUPI	1.9	1.6	1.7	1.5	1.7	1.7	1.4	1.5	1.6	1.8	2.2	2.0	1.7
UTTARAKANNADA	2.1	1.7	1.7	1.5	1.8	2.1	1.5	1.6	1.7	2.0	2.5	2.1	1.9
YADGIR	2.4	2.0	1.9	1.8	1.9	2.6	1.7	1.4	2.2	2.3	2.7	2.2	2.1
`State Mean	2.1	1.9	1.8	1.8	1.9	2.4	1.8	1.6	1.9	2.0	2.4	1.9	2.0

Table 18. Deviation in monthly mean minimum Temperature in different districts.

NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
BAGALKOTE	2.4	2.4	2.3	1.9	2.3	1.9	1.6	1.6	1.9	2.4	3.2	2.9	2.2
BANGALORE RURAL	2.1	2.6	2.0	2.2	2.3	1.9	1.6	1.5	1.6	1.9	2.2	2.6	2.1
BANGALORE URBAN	2.0	2.7	2.0	2.2	2.3	1.9	1.6	1.6	1.6	1.9	2.2	2.6	2.1
BELGAUM	2.4	2.2	2.3	1.8	2.2	1.7	1.5	1.4	1.7	2.3	3.0	2.8	2.1
BELLARY	2.4	2.5	2.3	2.0	2.3	1.9	1.6	1.5	1.8	2.2	2.8	2.8	2.2
BIDAR	2.4	2.7	2.5	2.3	2.4	1.9	1.5	1.5	1.8	2.2	3.3	3.0	2.3
BIJAPUR	2.4	2.5	2.4	2.1	2.3	2.0	1.7	1.6	1.9	2.5	3.3	3.0	2.3
CHAMARAJA NAGAR	2.1	2.7	2.1	2.1	2.2	1.8	1.6	1.5	1.6	1.9	2.2	2.6	2.0
CHIKBALLAPUR	2.1	2.6	1.9	2.2	2.3	1.9	1.7	1.6	1.7	1.9	2.3	2.7	2.1
CHIKMAGALUR	2.1	2.1	2.2	1.7	2.1	1.6	1.4	1.4	1.5	2.0	2.5	2.6	1.9
CHITRADURGA	2.3	2.4	2.2	1.9	2.2	1.8	1.5	1.5	1.7	2.1	2.6	2.7	2.1
DAKSHINAKANNADA	2.0	1.9	1.9	1.5	1.9	1.6	1.4	1.3	1.5	1.8	2.3	2.5	1.8
DAVANGERE	2.2	2.4	2.3	1.8	2.2	1.7	1.5	1.4	1.6	2.1	2.7	2.7	2.0
DHARWAR	2.3	2.3	2.3	1.8	2.3	1.7	1.5	1.4	1.6	2.2	2.8	2.8	2.1
GADAG	2.3	2.4	2.3	1.9	2.3	1.8	1.5	1.5	1.7	2.3	2.9	2.8	2.2
GULBARGA	2.4	2.6	2.5	2.3	2.4	2.0	1.6	1.6	1.9	2.4	3.3	3.0	2.3
HASSAN	2.1	2.3	2.2	1.8	2.1	1.7	1.5	1.4	1.5	2.0	2.4	2.6	2.0
HAVERI	2.2	2.3	2.3	1.7	2.2	1.6	1.5	1.4	1.6	2.2	2.7	2.7	2.0
KODAGU	2.0	2.1	2.0	1.6	2.0	1.6	1.4	1.4	1.5	1.8	2.3	2.5	1.9
KOLAR	2.0	2.7	1.9	2.3	2.3	1.9	1.7	1.6	1.7	1.8	2.1	2.6	2.1
KOPPAL	2.4	2.5	2.4	2.0	2.3	1.9	1.6	1.6	1.8	2.3	2.9	2.9	2.2
MANDYA	2.1	2.6	2.2	2.0	2.2	1.8	1.5	1.5	1.6	2.0	2.3	2.6	2.0
MYSORE	2.1	2.4	2.2	1.9	2.2	1.7	1.5	1.4	1.6	2.0	2.3	2.6	2.0
RAICHUR	2.4	2.5	2.4	2.2	2.3	2.0	1.7	1.7	2.1	2.3	3.0	2.9	2.3
RAMANAGAR	2.1	2.7	2.1	2.2	2.3	1.9	1.6	1.5	1.6	1.9	2.2	2.6	2.0
SHIMOGA	2.1	2.1	2.3	1.6	2.1	1.6	1.4	1.4	1.5	2.1	2.5	2.6	1.9
TUMKUR	2.2	2.5	2.1	2.0	2.3	1.8	1.6	1.5	1.6	2.0	2.4	2.7	2.1
UDUPI	2.0	1.9	1.9	1.5	1.9	1.5	1.4	1.3	1.5	1.8	2.3	2.4	1.8
UTTARAKANNADA	2.2	2.0	2.2	1.7	2.2	1.6	1.5	1.3	1.5	2.1	2.6	2.7	2.0
YADGIR	2.4	2.6	2.5	2.2	2.3	2.0	1.7	1.6	2.1	2.4	3.1	3.0	2.3
State Mean	2.2	2.4	2.2	1.9	2.2	1.8	1.6	1.5	1.7	2.1	2.6	2.7	2.1

The raise in mean annual temperature (Figure 6) indicated that all most all the districts have indicated the raise up to 2.2 Degree Celsius except DK, Udupi and Kodagu districts that have indicated up to 1.8. UK, Mysore, Shimoga, Hassan and Chikmagalure districts have indicated to be warmer up to 1.9 Degree Celsius. This overall increase in temperature leads to increase potential evapotranspiration. Higher increase in temperature in the decreased rainfall districts causes quick loss of soil moisture and reduces the growing period. This also increase the drought duration causing low productivity. Winter and pre-monsoon months are indicating higher raise in mean temperature than s-w monsoon months. This leads to increased local convectional rains and thunder storm causing natural disasters.

All most all the districts of the state barring Coastal, hilly and few eastern districts are likely to have increased wind speed. The increased wind speed may add to increase potential evapotranspiration causing further declining the growing duration.

District wise projected increase in precipitation in 2035 A1B scenario

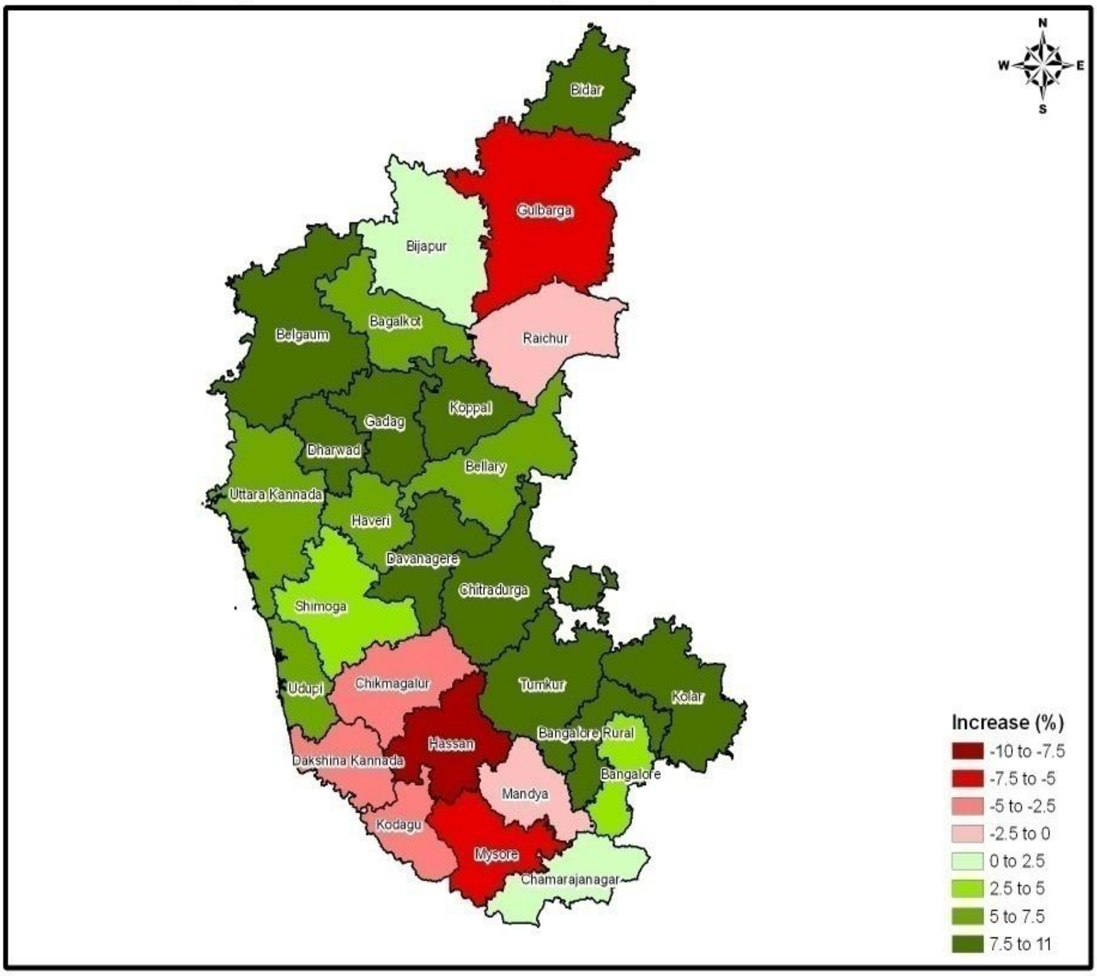


Figure 5. Rainfall percentages deviations projection for 2035

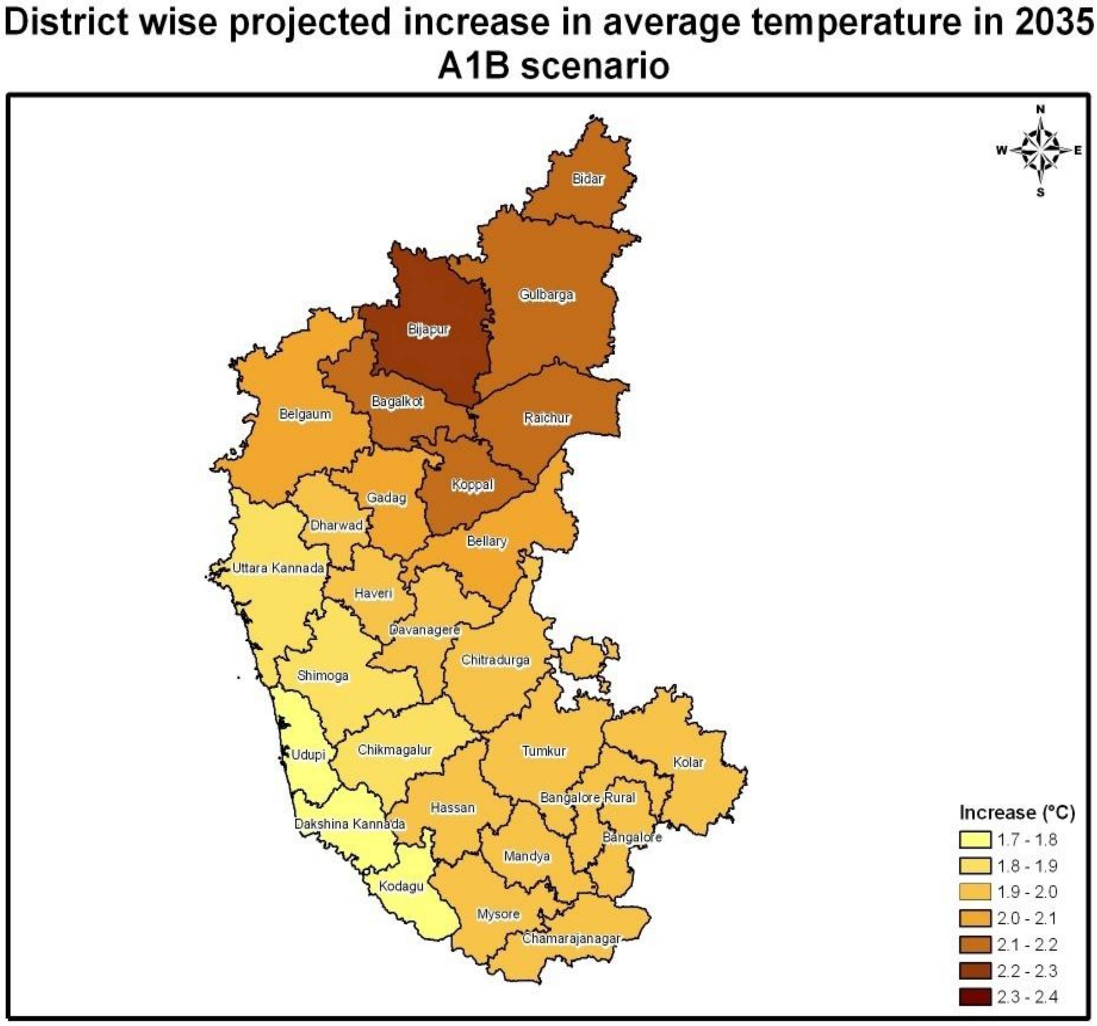


Figure 6. District wise rise in mean monthly Temperature

Table 19. Increase in the average monthly wind speed. Units is m/s. This are projections for increase in the period of 2021-2050 (A1B scenario), with respect to the base period of 1961-1990.

District Name	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
BAGALKOTE	0.031	0.043	-0.030	0.053	0.063	0.228	0.179	0.024	0.125	0.079	0.036	0.065	0.075
BANGALORE RURAL	-0.015	-0.084	0.018	-0.082	0.059	0.104	0.025	-0.102	-0.012	-0.013	0.038	0.013	-0.004
BANGALORE URBAN	-0.015	-0.075	0.013	-0.085	0.053	0.090	-0.004	-0.113	-0.019	-0.014	0.047	0.008	-0.010
BELGAUM	0.026	0.031	-0.048	0.036	0.081	0.173	0.129	-0.002	0.071	0.042	-0.015	0.030	0.046
BELLARY	0.035	0.021	0.024	0.069	0.050	0.132	0.117	-0.032	0.056	0.037	0.042	0.074	0.052
BIDAR	0.019	0.096	-0.027	-0.053	0.010	0.129	0.160	0.018	0.051	0.064	0.000	0.047	0.043
BIJAPUR	0.028	0.070	-0.026	0.048	0.048	0.247	0.188	0.023	0.131	0.101	0.043	0.081	0.082
CHAMARAJA NAGAR	0.005	-0.065	0.028	-0.024	0.032	0.075	-0.042	-0.105	-0.016	-0.004	0.072	0.004	-0.003
CHIKBALLAPUR	0.003	-0.075	0.012	-0.091	0.054	0.090	0.045	-0.098	-0.012	-0.003	0.034	0.029	-0.001
CHIKMAGALUR	-0.001	-0.012	0.005	0.037	0.063	0.040	-0.047	-0.112	-0.019	0.005	-0.034	-0.012	-0.007
CHITRADURGA	0.011	-0.022	0.035	0.051	0.051	0.120	0.052	-0.074	0.035	-0.003	0.016	0.020	0.024
DAKSHINAKANNADA	-0.009	-0.011	-0.013	0.011	0.075	-0.003	-0.120	-0.174	-0.041	0.008	-0.060	-0.032	-0.031
DAVANGERE	-0.001	0.024	0.000	0.077	0.074	0.115	0.040	-0.070	0.028	0.023	-0.005	0.031	0.028
DHARWAR	0.013	0.030	-0.043	0.054	0.079	0.135	0.089	-0.026	0.036	0.030	-0.020	0.030	0.034
GADAG	0.009	0.034	-0.027	0.069	0.070	0.162	0.125	-0.018	0.066	0.055	0.018	0.053	0.051
GULBARGA	0.022	0.089	-0.016	-0.007	0.024	0.192	0.162	0.014	0.081	0.088	0.021	0.091	0.063
HASSAN	0.008	-0.024	0.025	0.036	0.051	0.071	-0.018	-0.098	-0.015	0.001	-0.003	-0.014	0.002
HAVERI	-0.004	0.037	-0.023	0.071	0.084	0.104	0.040	-0.063	0.014	0.030	-0.023	0.030	0.025
KODAGU	0.003	-0.026	0.002	0.036	0.071	0.001	-0.109	-0.157	-0.047	0.000	-0.033	-0.030	-0.024
KOLAR	0.004	-0.054	-0.001	-0.118	0.051	0.051	-0.005	-0.124	-0.019	0.001	0.037	0.021	-0.013
KOPPAL	0.028	0.030	0.003	0.078	0.047	0.164	0.148	-0.001	0.091	0.063	0.049	0.084	0.065
MANDYA	0.004	-0.062	0.041	0.007	0.050	0.126	0.017	-0.077	0.001	-0.007	0.053	0.000	0.013
MYSORE	0.014	-0.033	0.028	0.033	0.048	0.078	-0.018	-0.094	-0.022	0.011	0.031	-0.005	0.006
RAICHUR	0.049	0.055	0.032	0.041	0.030	0.188	0.168	0.021	0.097	0.070	0.070	0.138	0.080
RAMANAGAR	-0.011	-0.084	0.026	-0.052	0.049	0.108	-0.004	-0.101	-0.014	-0.021	0.062	0.002	-0.003
SHIMOGA	-0.005	0.005	-0.011	0.042	0.067	0.047	-0.021	-0.093	-0.008	0.016	-0.042	0.004	0.000
TUMKUR	0.001	-0.061	0.040	-0.005	0.052	0.131	0.049	-0.079	0.016	-0.017	0.035	0.006	0.014
UDUPI	-0.028	0.003	-0.035	0.006	0.070	0.008	-0.110	-0.184	-0.021	0.019	-0.071	-0.031	-0.031
UTTARAKANNADA	-0.012	-0.020	-0.028	0.025	0.078	0.066	0.000	-0.076	0.012	0.018	-0.057	0.009	0.001
YADGIR	0.037	0.074	0.015	0.014	0.024	0.193	0.155	0.018	0.095	0.080	0.053	0.137	0.075
State Mean	0.008	-0.002	0.001	0.013	0.055	0.112	0.046	-0.065	0.025	0.025	0.013	0.029	0.022

Table 20. Increase in the average monthly short-wave flux (Unit is Watts/m2).

NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
BAGALKOTE	0.207	-0.032	-0.264	-0.215	-0.433	1.074	-0.232	-0.057	0.466	0.047	0.091	-0.240	0.034
BANGALORE RURAL	0.148	-0.301	-0.089	0.179	-0.382	0.530	0.401	0.067	0.539	0.273	0.026	-0.634	0.063
BANGALORE URBAN	0.098	-0.286	-0.113	0.252	-0.338	0.548	0.290	0.057	0.453	0.289	-0.005	-0.606	0.053
BELGAUM	0.086	-0.022	-0.274	-0.225	-0.111	1.345	0.050	0.297	0.368	-0.012	0.027	-0.286	0.104
BELLARY	0.387	-0.128	-0.190	0.037	-0.376	0.621	0.156	0.222	0.472	0.101	0.133	-0.433	0.083
BIDAR	0.225	-0.248	-0.166	-0.256	-0.655	0.382	-1.241	-0.905	0.452	0.158	0.065	-0.455	-0.220
BIJAPUR	0.190	-0.057	-0.228	-0.248	-0.577	0.835	-0.670	-0.460	0.537	0.139	0.134	-0.246	-0.054
CHAMARAJA NAGAR	0.182	-0.359	-0.136	0.224	-0.494	0.904	0.358	0.435	0.460	0.222	0.270	-0.443	0.135
CHIKBALLAPUR	0.268	-0.307	-0.088	0.079	-0.449	0.374	0.369	-0.176	0.466	0.232	0.080	-0.649	0.017
CHIKMAGALUR	0.065	-0.208	-0.097	0.050	-0.343	1.082	0.543	1.051	0.639	-0.011	0.112	-0.386	0.208
CHITRADURGA	0.235	-0.156	-0.106	0.182	-0.294	0.803	0.744	0.605	0.611	0.132	0.156	-0.485	0.202
DAKSHINAKANNADA	-0.057	-0.287	-0.114	-0.529	-0.587	0.684	0.206	1.089	0.511	-0.075	-0.046	-0.421	0.031
DAVANGERE	0.151	-0.082	-0.144	0.144	-0.033	1.183	0.570	0.737	0.610	0.134	0.132	-0.332	0.256
DHARWAR	0.129	-0.017	-0.281	-0.131	-0.074	1.407	0.291	0.593	0.632	0.106	0.080	-0.292	0.204
GADAG	0.222	-0.031	-0.248	-0.066	-0.148	1.214	0.306	0.422	0.656	0.193	0.109	-0.314	0.193
GULBARGA	0.216	-0.174	-0.167	-0.240	-0.658	0.546	-1.050	-0.741	0.510	0.149	0.126	-0.346	-0.152
HASSAN	0.188	-0.242	0.022	0.188	-0.329	1.311	0.722	1.097	0.832	0.070	0.208	-0.466	0.300
HAVERI	0.095	-0.055	-0.214	0.056	0.047	1.380	0.375	0.765	0.627	0.117	0.082	-0.277	0.250
KODAGU	0.024	-0.336	-0.038	-0.054	-0.465	0.892	0.295	1.011	0.741	-0.004	0.129	-0.367	0.152
KOLAR	0.181	-0.204	-0.117	0.096	-0.391	0.083	-0.073	-0.663	0.283	0.260	-0.004	-0.583	-0.094
KOPPAL	0.367	-0.089	-0.250	-0.039	-0.428	0.765	0.043	0.168	0.576	0.150	0.152	-0.386	0.086
MANDYA	0.215	-0.324	-0.019	0.216	-0.355	1.414	0.803	1.024	0.684	0.226	0.187	-0.481	0.299
MYSORE	0.199	-0.338	-0.030	0.212	-0.480	1.439	0.760	1.217	0.799	0.140	0.302	-0.384	0.320
RAICHUR	0.497	-0.199	-0.243	-0.081	-0.726	0.530	-0.585	-0.246	0.319	0.050	0.194	-0.408	-0.075
RAMANAGAR	0.131	-0.317	-0.085	0.269	-0.348	0.817	0.417	0.349	0.480	0.265	0.052	-0.565	0.122
SHIMOGA	0.047	-0.114	-0.238	0.060	-0.181	1.170	0.448	0.984	0.574	0.010	0.043	-0.323	0.207
TUMKUR	0.218	-0.281	-0.033	0.158	-0.395	0.898	0.755	0.639	0.736	0.191	0.148	-0.574	0.205
UDUPI	-0.107	-0.159	-0.346	-0.610	-0.620	0.638	0.138	1.020	0.236	-0.217	-0.097	-0.419	-0.045
UTTARAKANNADA	-0.040	-0.173	-0.333	-0.131	-0.328	1.083	0.312	0.831	0.347	-0.120	-0.106	-0.365	0.081
YADGIR	0.368	-0.170	-0.200	-0.159	-0.740	0.574	-0.886	-0.526	0.417	0.104	0.194	-0.360	-0.115
State Mean	0.171	-0.190	-0.161	-0.019	-0.390	0.884	0.154	0.364	0.535	0.111	0.099	-0.418	0.095

Geographical regions (e.g. mountains / hills and plains, irrigated and rainfed, coastal and inland, north and south) and crops that are most vulnerable to climate change impacts. Based on the major crops raised in each of the districts and their current production and productivity and the anticipated deviation in the productivity with respect to the anticipated climate change, the vulnerable districts that are likely to be badly affected and thus the productivity of some crops is affected. The major crops are given in table 21.

Table 21. Vulnerable area falling different district for various crops.

Crops	Vulnerable districts with productivity loss from 5 % to 45 %
Rice (Rainfed)	DK, Hassan, Kodagu and majority of Northern districts
Rice (Irrigatde)	Belgaum, Bellary, Raichur, Kodagu, Dharwad, Chamarajanagar, DK & Hassan,
Maize	Bijapur, Chikmagalure, DK, SK, Udupi, Kodagu, Shimoga and partly Tumkur
Sorgam	Chikmagalure, DK, UK, Udupi, Davanagere, Hassan, Kolar, Shimoga, Tumkur,
Redgram	Bagalakote, Bellary, DK, Udupi, UK, Kodagu, Raichur,
Cotton	Bellary, Chikmagalure, Chitradurga, DK, UK, Shimoga, Kolar, Kodagu, Dharwad and Gadag.
Potato	Bangalore, Chikmagalure, Davanagere, Hassan,
Soybean	Bangalore, Tumkur and Chitradurga
Ragi	UK, DK, Udupi, Shimoga, Gulbarga and Bidar
Sugarcane	Hassan, Mandya, DK, UK and Udupi

The traditional sugarcane crop is likely to lose its productivity in majority of the irrigated area in Mandya and Hassan districts.

Assessment of impact of various climatic scenarios on agricultural productivity based on scaled-down IPCC GCM scenarios.

The potential effect of climate change on agriculture is the shifts in the sowing time and length of growing seasons geographically, which would alter planting and harvesting dates of crops and varieties currently used in a particular area. Seasonal precipitation distribution patterns and amounts could change due to climate change. With warmer temperatures, evapotranspiration rates would raise, which would call for much greater efficiency of water use. Also weed and insect pest ranges could shift. Perhaps most important of all, there is general agreement that in addition to changing climate, there would likely be increased variability in weather, which might mean more frequent extreme events such as heat waves, droughts, and floods.

Simulating production for 2035 scenario: Using InfoCrop models crop yield (Based on IPCC and national Climate Change Policies) was studied for major crops in the state. The climate models outputs on temperature (minimum and maximum) and rainfall for A1b-2035 scenario were used. Apart from this, frequency of occurrence of climatic extreme events such as higher/low rainfall events and high temperature events is inherently accounted for. The projected carbon dioxide levels as per Bern CC model for scenario was also included in the model for simulations. Based on the simulated yields in changed scenarios, productivity was estimated as in case of baseline production taking the changed climatic scenario and enhanced CO2. Then the simulation outputs are multiplied with the ratio constants (generated using the baseline yields) to get the estimated yields. To express the impacts on productivity, the net change in productivity in climate change scenario was calculated and expressed as the percentage change from baseline mean productivity. The infocrop model was used for Maize, Sorghum, Rice, Redgram, Cotton, Potato, Soyabean and Wheat crops. The Stocheometric crop weather model generated at UAS, Bangalore was used to estimate the productivity in the case of Ragi. Similar procedure was adopted to generate the baseline yields and also to estimate the yield for the changed scenario of 2035.

Limitations of the Models: Both the models have been statistically tested with the observed and predicted productivities. The model is able to predict the yield up to 89 % (R^2) accurately.

Projected impacts of climate change on crops in 2035 scenario: The simulation analysis indicates that the productivity of kharif crops such as irrigated rice in the State is likely to change by -14.4 to 9.5% from its base yield. Majority of the irrigated rice growing area is projected to lose the yields up to about 8.2% and smaller non-rice growing districts projected to gain up to 6.2% indicating the net decline in the irrigated rice. In case of rainfed rice, the projected change in yield is in the range of -13.8 to 7.2% with large portion of the region likely to lose the rice yields up to 9.6%. Since irrigated rice, in general, is supplied with better amount of fertilizers than the rainfed rice, it has better opportunity to benefit from CO_2 fertilization effects for production and accumulation of dry matter and hence grain yield. Both Irrigated and Aerobic rice in smaller area of south-western Karnataka is likely to gain. In these areas, current seasonal minimum and maximum temperatures are relatively lower (20-22^{o}C Tmin; 27-28^{o}C Tmax). The projected increase in maximum temperature is also relatively less in these areas (1-1.5^{o}C) as also increase in minimum temperature, which is projected to be about 1.3^{o}C. In most of the Western ghats region, the monsoon rainfall is likely to increase marginally. These changes in temperature and rainfall cause direct impacts on the production of kharif crops as indicated in the study (References 11 & 13) Variable response in both irrigated and rainfed rice can be attributed to the influence of major limiting factor at a given location, viz., rainfall, temperature and nutrient supply. Increased rainfall can be a surrogate for reduced Sunshine duration due to cloudiness, causing limitation to photosynthetic rates resulting in to reduced accumulation of dry matter, particularly in areas with high rainfall. Since Western ghat receive high rainfall, it can be inferred that heavy cloud cover causing low radiation as one of the limiting factors for lower productivity in this region, any further increase in rainfall (thus more cloudiness) will result in reduced yields in kharif season. Farmers in Western ghat regions can reduce the impacts of climate change and can reap higher harvests by adapting crop management strategies such as soil moisture conservation, provision for proper drainage, increased efficiency of water and nutrient supply and utilization and by growing cultivars tolerant to adverse climate.

Climate change is likely to change yields of maize from 27.6 % to -19.3 % and sorghum by 17.2 % to -18.4 in different districts with respect to baseline yield. These crops have C4 photosynthetic system and hence do not have relative advantage at higher CO_2 concentrations. Increase in rainfall in already high rainfall zones is detrimental to the crop production as mentioned earlier. Further, increased temperature causes reduction in the crop duration due to increased growth rates. Reduced crop duration means less opportunity for crop canopy to accumulate the photosynthates and thus dry matter. These conditions can cause the reduction in gain yield as indicated in this analysis. Further, any coincidence of high rainfall with pollination period will affect the production to spikelet sterility, especially in cross pollinated crops such as maize and sorghum.

Marginal increase in rainfall may not hamper the Sunshine period in interior districts providing ample scope for crops to carry the photosynthetic process benefitting the rice yields in elevated CO_2 conditions. Currently the productivity of irrigated maize yields higher than that of rainfed maize. Maize, being a C4 crop, is able to accumulate higher biomass even at current CO_2 levels due to higher photosynthetic efficiency and thus yields high when water and other nutrients are not limiting. On the other hand, growth and yield of rainfed crops are limited by water and nutrients. In 2035 scenario, higher temperatures and reduced Sunshine because of more rains may limit the biomass production and yield as compared to baseline conditions. Even though C4 crops do not get direct benefit of elevated CO_2 for higher photosynthetic rates, they may benefit through leaf water balance. The estimated 2.1 °C rise in mean temperature and a 4.5% increase in mean precipitation would reduce net agricultural productivity in the state by 1.2. Agriculture in the coastal and ghat regions is found to be the most negatively affected. Small losses are also indicated for the major food-grain producing regions of few districts. On the other hand, interior North and South Karnataka districts have shown benefit in rainfed crops to a small extent from warming. The net change in the productivity of few major crops from the baseline yields in the state is indicated in the table 22. The vulnerable districts for few crops are listed in table 2. Although total productivity is likely to be decreased by about 1.2% in the State, due to the benefit of the raise in temperature and CO2 level, few districts have indicated gain in productivity up to 35% (in some crops). By changing over to such crops in those vulnerable districts, the loss in the productivity can be compensated and the advantages of the climate change effects can be absorbed positively. The current and estimated productivity and per cent age of deviation from the baseline yield have been listed in the table 23.

Table 22. Changes in the net productivity (for the entire State) and expected increased yield levels (rainfed situation) in different crops in different districts to in the changed climate scenario.

Crops	Net Per centage Change in the Yield	Increase in Productivity up to 10 % and identified to increase the growing area	Increase in productivity from 10 % to 25 % and identified to increase the growing area for enhanced food production
Rice	-0.3 (Irri. Rice) -0.9 (rainfed)	Bagalakote,Bangalore, Chitradurga, Davanagere, Haveri, Kolar and Tumkur	Bangalore, DK, Udupi, UK , Raichur and Kodagu
Maize	1.2	Bidar, Chitradurga, Davanagere, Gadag, Gulbarga, Haveri, Kolar and Mandya,	Bangalore, Belgaum, Chamarajanagar, Mysore,
Sorgam	2.6	Bagalkote, Belgaum, Haveri, Raichur,	Bangalore, Bellary, Bidar, Chamarajanagar, Chitradurga, Gadag, Gulbarga, Kodagu, Mandya,
Redgram	1.3	Chamarajanagara and Hassan,	Bengalore, Chikmagalore, Chitradurga (upto 35%), Davanagere, Dharwad, Gadag, haveri, Kolar, Mandya, Mysore and Shimoga
Cotton	1.3	Bidar, Davanagere and Haveri,	Bangalore, Belgaum, Bijapur, Mandya, Raichur and Tumkur.
Potato	-14.0		
Soybean	-2.8		
Ragi	-5.8	Mysore, Hassan, Kolar, Chitradurga, Davanagere, Haveri and Gadag	Chikmagalore,
Sugarcane	2.6	Mandya, Shimoga and Belgaum	

District	Rice			Maize			Sorghum			Red gram			Cotton			Potato			Soybean		
	Current	Pred.	%	Current	Pred.	%	Current	Pred.	%	Current	Pred.	%	Current	Pred.		Current	Pred.	%	Current	Pred.	%
BAGALKOTE	36	39	8.3	28.9	29.3	1.4	19.5	20.6	5.4	6	5.5	-9	15	14.7	-2.3						
BANGALORE- U	35	35.6	1.7	28.1	35.8	27.6	19.3	21.3	10	17.6	20.1	14.1	13.5	16.6	22.6	**12.81**	**10.2**	-20.1	**13**	**12.55**	-0.8
BANGALORE- R	33	38	15.2	25.8	31.8	23.3	18	20	11	18	21.2	17.9	13.3	15.6	16.7				**13.55**	**12**	-11.4
BELGAUM	27	26	-3.7	30.6	34.6	13.2	17.7	18.5	4.9	10	9.8	-2	16.8	18.6	10.4						
BELLARY	28.7	27	-5.9	10	9.8	-2	13	15	15	6	5.5	-8.3	16.5	14.9	-10						
BIDAR	40.2	33.2	-17.5	12	13	8.3	14.8	17	15	10.2	10.4	1.5	11	12	9.1						
BIJAPUR	39.7	41.1	3.4	27.8	25.3	-9.1	25.3	26	2.9	10.2	9.8	-4.2	13	15	15.4						
CHAMARAJANAGAR	38	36	-5.3	25	28	12	20	22	10	5.5	6	9.1	10.9	11.2	2.9						
CHIKMAGALUR	38	35	-7.9	4.2	3.5	-17	15	14	-7	6.4	7.5	17.6	12	10.2	-14.8	**12.2**	**10.2**	-16.2			
CHITRADURGA	38	40	5.3	25	27	8	20	23	15	5	6.7	34	12.8	12	-6.3				**12.8**	**11.52**	-10.0
D.KANNADA	40.1	45.1	12.5	9.5	8	-16	10	9	-10	5	4	-20	9.5	8	-16						
DAVANAGERE	36	37	2.8	28	30	7.1	23	21	-9	8	9	12.5	14.2	15.3	7.7	**12.33**	**11.3**	-8.8			
DHARWAD	34.9	35.6	2	28.9	29.3	1.4	19.5	18.6	-5	7.5	8.3	11.1	15	13.3	-11.7				**16.0**	**17.03**	6.3
GADAG	35.9	37	3.1	27	29.6	9.6	18.9	21	11	6.5	8	23.1	15.5	14.5	-6.5				**15.3**	**15.55**	1.6
GULBARGA	28	24.6	-12.3	12.6	13.3	5.8	13	15.2	17	5.7	5.7	-0.5	16.6	17	2.4						
HASSAN	38.9	40	2.8	25	24	-4	18	16.5	-8	8.8	9.5	8	12	11.6	-3.7	**18.48**	**15.5**	-16.4			
HAVERI	36	38	5.6	28	30	7.1	23	24.3	5.7	8	9	12.5	15	16.2	8.2	**12.55**	**11.2**	-10.6			
KODAGU	38.1	44	15.5	6.5	5.5	-16	9.4	10.6	13	10.2	7	-31	9.3	8.5	-8.6						
KOLAR	34.3	36.6	7	18	19	5.6	17	15	-12	6.4	7.5	17.6	11.2	10.2	-8.9	**16**	**14.2**	-11.1			
MANDYA	41.7	40.9	-1.9	13	14	7.7	18	20	11	6	7	16.7	10	11	10						
MYSORE	40.6	42	3.6	15	16.5	10	20	22	10	8.5	9.5	11.8	10.6	10.9	3.3						
RAICHUR	36.6	40.9	11.8	35.9	36.4	1.4	21.3	23.4	9.9	5.5	4.7	-15	15.6	17.2	10.7				**11.98**	**13**	8.5
SHIMOGA	39.5	36	-9	15.1	13	-14	15	13	-13	8.5	10.2	20.7	11.4	10.2	-10.1						
TUMKUR	37.9	40	5.5	13.5	12.9	-4.4	16	13.1	-18	8.9	7	-21	10.6	13.6	28.4				**13**	**11.2**	-13.8
UDUPI	38	50.1	31.9	10.2	8.2	-19	15	14	-7	9.4	6	-36	10	9.8	-2						
UTTARA KANNADA	39	48	23.1	12	10	-17	14	12.3	-12	13.2	7	-47	9.6	8.2	-14.1						

Comprehensive list of adaptation strategies (technologies / options) that is required, to categorize them as short and long-term.

The estimated 2.1 °C rise in mean temperature and a 4.5% increase in mean precipitation would reduce net agricultural production in the state by 2.5% for the State as a whole. Agriculture in the coastal regions Karnataka is found to be the most negatively affected. Small losses are also indicated for the major food-grain producing regions of few districts. On the other hand, interior North and South Karanataka districts have shown benefit to a small extent from warming. The net change in the productivity of few major crops in the state is indicated in the table below. Although total food production is likely to be decreased by about 12.3% in the State, due to the benefit of the raise in temperature and CO_2 level, few districts have indicated gain in productivity up to 35% (in some crops). Such of the districts have been identified and listed below. By changing over to such crops in those districts, the loss in the food production can be compensated and the advantages of the climate change effects can be absorbed positively. A Comprehensive list of adaptation strategies (technologies / options) that is required, to categorize them as short and long-term are given table 24.

Table 24. Mitigation and adaptation for increasing productivity in the vulnerable districts under changed climate scenario.

	Vulnerable districts with productivity loss from 5 % to 45 %	Action Plan	
		Short-term	Long-term
Rice (Rainfed)	Belgaum, Bellary, Chamarajanagara, Chikmagalure, Gulbarga, Shimoga,	- Selection and evaluation of existing lines for long duration and fine grain. -Popularization of high yielding variety/hybrids recommended for different ecosystems through large-scale FLDs whole package. - Demonstration of newly released varieties viz. KMP-150 and KMP-1 OS, BR-2655 on 1000 ha.	-Standardization of existing method of cult -Development and evaluation of varieties tolerant to abiotic stress. -Evaluation of water saving practices. -Development of high yielding varieties for fine grain, early medium and long duration varieties for the available length of growing season.
Maize	Bijapur, Chikmagalure, DK, SK, Udupi, Kodagu, Shimoga and partly Tumkur	-Adoption of crop rotation and in-situ incorporation of maize stalks. -Popularization and adequate supply of existing hybrid Nithyashreeseeds through large-scale demonstrations and farmers' participation. -Seed treatment for disease control before sowing.	-Evaluation of efficient short-duration legumes for in-situ mulching/ grain and green manures as intercrops. -Development and evaluation of hybrids for biotic stress.
Sorghum (Jowar)	Chikmagalure, DK, UK, Udupi, Davanagere, Hassan, Kolar, Shimoga, Tumkur,	-Organizing large scale demonstrations on integrated crop management practices involving moisture conservation, Integrated Nutrient Management (INM) and improved varieties in the cultivators' field. -Increased supply of quality seeds through seed corporations, private seed industries and also through farmers' participation.	-Development of early maturity seed varieties with Maldandi (M35-1) yielding ability for shallow soils.
Redgram (Pigeonpea)	Bagalakote, Bellary, DK, Udupi, UK, Kodagu, Raichur,	-Identifying Integrated crop production and management technologies -Identifying sustainable crop production agro ecosystem. -Contour broad beds and furrows or ridge and furrow system to prevent water logging. -Selection of varieties suitable to the location and having resistance to wilt and mosaic. -Seed treatment with rhizobium @ 2g/kg seed is essential.	
Cotton	Bellary, Chikmagalure, Chitradurga, DK, UK,	-Cotton farmers need to be educated about the	-Desi cottons are known to be very productive and

	Shimoga, Kolar, Kodagu, Dharwad and Gadag.	technologies available to mitigate the production constrains. -Identifying location specific Bt cotton hybrids. -Farmers awareness programme on Integrated Nutrient Management (INM) programmes (FYM 10t//ha + recommended dose of inorganic fertilizers). Leaf reddening management through foliar spray of 2% urea at 60 and 80 DAS and foliar application of 1% MgSo4 at 90DAS in all cotton zones.	hence need to enhance the productivity by incorporating traits like drought tolerance and fibre quality. -Development of genotypes with increased nutrient use efficiency and water use efficiency -Determination of organic nutrient management techniques to avoid the nutrient based disorders. . -Controlling the problem of sucking pests and mired bug.
Soybean	Bangalore, Tumkur and Chitradurga	-Demonstration of soyabean Integrated Crop management (ICM) module. -Development of Integrated Nutrient Management practice for sustained soyabean production.	
Ragi	UK, DK, Udupi, Shimoga, Gulbarga and Bidar	-Promotion of seed treatment with biofertilizers. -Promotion of organic manure promotion structures. -Popularization of existing varities through large scale demonstration. -Practicing of staggered nursery for timely transplanting.	-Selection and evaluation from existing genotypes on participatory approach.
Sugar-cane	Hassan, MandyaDK, UK and Udupi	-Evaluation of existing genotypes for all reason planting -Promotion of seed production technical know-how and supply of foundation seeds through sugar factories -Promotion of organic manure production structure, *in-situ* green manure growing. Trash recycling etc. -Encourage farmers to grow legumes as intercrop -Imparting training to extension personnel regarding balanced use of fertilizers -Demonstration on *in-situ* trash mulching and use of trash for vermin composting.	
Potato	Hassan, Bangalore, Kolar, Davanagere, Chikmagalure and Haveri	-Adoption of suitable varieties to withstand diseases and pests due to climate change. -Distribution of seed material of improved variities viz., Kufri Jyoti, Kufri Chandramukhi, Kufri pukharaj, Kufri Jawahar. -Crop rotation of 1-2 years to be followed and crops grown in rotation are Jowar, Maize, Horsegram, Chillies, Beans, Cabbage, sugar cane and paddy -Potato as intercrop with sugar cane and castor - Seed treatment with bio-fungicide trichoderma, line sowing/planting of potato tubers and better aftercare and	

		the post harvest practices will increase the productivity.	
Wheat	Raichur and Shimoga	-Use of recently released high yielding, disease resistant varieties like UAS-304, UAS-415, DWR-195, DWR-225, DDK-1025 and DDK-1029. -Use of organic manures (FYM/Compost @ 7.5/ha)/vermin compost @ 2t/ha/year) and use of Bio-fertilizers (Azospirillum @10g/kg of seed) and Phosphorous solubalizers @ 10g/kg of seed). -Identification of sources of early maturity for terminal heat stress. -Integrated disease management (IDM) using suitable seed dressing fungicides and bioagents to manage soil borne diseases. -Use of newly released resistant varieties like UAS-304, UAS-415, DDK-1025 and DDK-1029.	-Improvement of germplasms (bread wheat) for terminal heat stress (through trait like high 1000-grain weight. -Molecular characterization of terminal heat stress through elucidation of molecular and genetic basis of heat tolerance.

Strategies in terms of importance and immediacy on the basis of the identified criteria. To ensure that these priorities are consistent with the NAPCC National Mission on Sustainable Agriculture.

The estimated 2.1 °C rise in mean temperature and a 4.5% increase in mean precipitation would reduce net agricultural production in the state by 2.5**% for the State as a whole**. Agriculture in the coastal regions Karnataka is found to be the most negatively affected. Small losses are also indicated for the major food-grain producing regions of few districts. On the other hand, interior North and South Karanataka districts have shown benefit to a small extent from warming. The net change in the productivity of few major crops in the state is indicated in the table below. Although total food production is likely to be decreased by about 12.3% in the State, due to the benefit of the raise in temperature and CO_2 level, few districts have indicated gain in productivity up to 35% (in some crops). Such of the districts have been identified and listed below. By changing over to such crops in those districts, the loss in the food production can be compensated and the advantages of the climate change effects can be absorbed positively. Projected priorities for adaptation and mitigation strategies for combating the changes in the productivity of some crops are given table 25.

Table 25. Projected priorities of crops for adaptation and mitigation strategies.

Name of the Zone	Suggested Cropping Patterns for Different Agro climatic Zones
North–Eastern Transition zone	Area under rained Maize, Sorghum, Cotton and Wheat is proposed to be increased substituting the area under Redgram.
North-Eastern Dry zone	Area under rained Maize, Sorghum and Wheat is proposed to be increased substituting the area under Redgram and other crops.
Northern Dry Zone	The area under rainfed cotton, wheat and sorghum which have shoen higher productivity is proposed to be increased in Bijapur district. Maize, Sorghum and Redgram can be taken more in Gadag district reduce cotton area.
Central Dry zone	The area under Sorghum can be extended to entire Bellary district substituting the area under rice. Rice, Maize, Sorghum, Red gram and Ragi area is to be increased by intercropping sorghum and pearl millet. Cotton and Soya area area is proposed to be restricted to irrigated areas.
Eastern Dry zone	Maize, Sorghum, Redgram and Cotton area is proposed to be increased is substituting a part of rainfed finger millet in Bangalore district and in parts of Tumkur district. In Kolar district and Maize, Redgram and Ragi area can be increased in liew of Sorghum. With the increased rainfall, Mulbery and vegetable area can be enhanced during kharif.
Southern Dry zone	Rice area proposed to be reduced by Maize, Sorghum and Redgram crops in the zone. Rice can be increased in Mysore and Mandya district and parts of Hassan district in view of the high yield potential and water availability. Ragi can be continued in the same area.By increasing the cropping intensity under irrigation the area under rice and Sugarcane proposed to be increased.

Southern Transition zone	The area under kharif sorghum proposed to be increased in view of their high productivity. Summer rice area is proposed to be diverted to irrigated groundnut.
Northern transition zone	Because of the high yield potential, area under cotton, wheat, kharif sorghum and groundnut is to be increased. Green gram is to be introduced on large scale as a catch crop in kharif. A part of the area under rainfed rice is to be substituted by maize.
Hilly	Area under Redgram in Chikmagalur is to be increased. Rice area in Shimoga can be enhanced. Apart of the rice in the upland is to be substituted by finger millet. Green gram and black gram are to be introduced in rice fallows. Plantation crops is to be increased.
Coastal	The area under groundnut is to be increased in rice fallows on residual moisture/supplemental irrigation. Black gram is proposed as second crop after rice on residual moisture. In view of the sugar factories, area under sugarcane is to be increased to some extent.

Some of the recommended practices for different crops are as follows

Groundnut Crop:

Groundnut crop normally sown during June July in many districts of Karnataka. Under the normal rainfall situation July, August and Septembers months receive good amount of rainfall. In the recent years, July rains are decreasing and August rains are increasing and hence the sowings are extending up to mid August. Due to this delayed sowings, flowering occurs during mid September. Due to reduced rainfall during second fortnight of September, peg initiation percentage reduces and total yield reduces. The groundnut crop suffered substantial damage because of high as well as low rainfall at different stages of crop growth. While heavy rainfall early in the season adversely affected the development of pegs (which bear groundnut pods below the soil), the relative dry spell at the later stage hit the development of pods. In addition to this, high rainfall and cloudiness during October encourages the spread of (leaf spot) Tikka that reduces the Green Leaf Area which further reduces the pod weight. Late sown groundnut will be more affected by Tikka. Due to climate change mid season droughts are increasing due to dry weather, suffering of plants from lack of water, depletion of underground water supply.

Sunflower

Normal sowing period is from June to July for kharif and October to November for Rabi crops. During summer increased temperature causes low bee population which in turn leads to low pollination. In the event of normal sowings, normal yields are obtained. However, due to changed rainfall situation, the sowings are not completed before the end of July rather continued even after July. The crop sown beyond July may experience two situations. In the first situation, i.e. excess rainfall years, leaf spot, powdery mildew, bud necrosis and defoliation of leaves occurs. This causes 10-25 % yield losses. In addition to this the matured crop may be caught with prolonged rains causing huge loss. In the second situations, prolonged moisture stress (due to low rains) affects the seed setting that reducing the yield. By providing a protective irrigation during stress period, normal yield can be obtained. Rabi sowings are also being delayed due to late rains. Normal sowing is preferred.

Redgram

Redgram sown from last week of May to first week of July has performed well and recorded good grain yield even with 15 days dry spells during the crop growth period. However, in recent years, due to decreased rains during July, sowings are extended up to mid of August. The crop sown after mid July will have minimum number of rainy days due to change in number of rainy days, quantum of rainfall and hence potential growth cannot be attained. Under this situation only 50 to 60 per cent yield can be obtained. In the event of one or two dry spells of more than 15 days occurs during this season, 60 to 75 per cent the crop loss takes place. If any one or two protective irrigations available during late July for the crop sown during early June, very good redgram yield can be realized. If the redgram can not be sown up to the mid of July due to non-receipt of rains during June and July and if adequate rains are received during August, crops like Cowpea, Soybean, Black gram, Green gram, Horse gram can be sown.

Chickpea

Normally this is grown during rabi season. Normal sowing window is first week of October to November last week in the northern Karnataka and it is grown using residual moisture. During recent years, the cropped area is increasing, as the redgram and Jowar area could not be sown due to late rains. In northern Karnataka, since the harvest of the kharif crop is extended up to last week of November, the rabi Chickpea sowings are extended up to 2nd week of December. This crop is subjected to increased temperature during January and February leading to low flowering, low pollination and in-turn low grain yield. In the mean while, soil moisture stress also arises due to the non-receipt of rains far almost 90 days. Increased temperature and inadequate soil moisture causes declining in grain yield. Increased temperature and inadequate soil moisture could be minimized by providing a protective irrigation.

Ragi:

Optimum sowing period for ragi is from 2nd week of July to 1st week of August in many parts of Karnataka. In recent years, due to declining in July rains, ragi sowings are not completed and sowings of long duration varieties are continued even beyond 2nd week of August. The ragi sown after 2nd week of August will have only 70 days growing period and will suffer with moisture stress during maturity stage. This is causing heavy grain loss. In addition to this intermittent dry spells causing reduction in total biomass. Under such situations, it is recommended to go for short to medium duration varieties. Some times, late sown ragi will be affected by blast during flowering and filling stages with high humidity and cloudiness. Suitable plant protection measures have to be taken up. If the ragi sowings are not completed before 3rd week of August, it is better to go for small millets that grow even with reduced rainfall. Under normal date of sowing both long duration and medium duration varieties have performed well during this season as there was no moisture stress. However, it is better to go for long duration variety for early sowing rather than medium and short duration varieties. For delayed sowing medium duration variety (GPU-28) of ragi may be preferred over long duration variety

Paddy:

Delayed transplanted paddy used to be caught with cold spell during November – December. Due to cold, occurrence of blast increases and low thermal energy reduces the grain formation and panicle emergence. Paddy crops are affected due to flood mostly during harvesting stage. To minimize crop loss from floods and high winds, the following programs are suggested. Early sowings (using rain water) to avoid the coincidence of peak period of floods and stage of grain filling and maturity of paddy. Introduction of dwarf variety to minimize wind effect. Salt tolerant variety to withstand salinity to a considerable degree. Creation of windbreakers and shelterbelts. Creation and proper maintenance of embankments to protect the field from incursion of saline water. Creation of good drainage network to drain out excess water.

Actions / measures (both short and long term) needed to implement these strategies including natural, engineering and locally suitable solutions, including timeframe and sequence for implementation.

1. **Drought management strategies in Rainfed Agriculture**

In the absence of any assured irrigation facility and with ever growing changing patterns of temperature and precipitation, the rain water management technologies would play a greater role in rainfed areas. Renewed focus with incentive measures for in-situ especially in low to medium rainfall regions with farmers themselves taking the leadership in conservation should be the focal theme. The predominant interventions to overcome climate related impacts in rainfed areas include

- Soil and water conservation practices
- Agronomic interventions
- Nutrient management practices
- Livestock based interventions
- Development of alternate land use plans

These interventions have a role to play in all agro-eco systems except that their order of priority changes, which basically depends on rainfall, status of natural resources like soil, water etc. Crop based interventions need to be planned based on amount and distribution of rainfall, availability and further augmentation of water resources with watershed programme

2. **Rainwater management in rainfed areas**

Various soil and water conservation measures relevant for rainfed agriculture include

- *In-situ* measures for rainwater management in rainfall areas.
- Off season land treatment:
- *Conservation furrows*
- *Ridges and furrows system in cotton*
- *Cover cropping*
- *Micro catchments for tree systems*

Medium term measures rain water management in rainfed areas.

Stone and vegetative field bunds for soil and water conservation
Graded line bund helps in efficient drainage.
Trench cum bund for soil and water conservation

3. **Long term measures for rain water management in rainfed areas**

- Water harvesting
- Contour trenching for runoff collection
- On-farm reservoirs
- Ground water recharge structure (percolation tanks).
- Recharge through defunct wells.

These rainwater management strategies have good scope for adoption in regions receiving more than 700 mm rainfall.

4. Influence of Agromet advisory services on economic impact of crops.

Weather being an important influencing component in the field of agriculture, the crop growth and yield are regulated by its prevailing status in the region. The advance (3-5 days) information on likelihood of weather leads to the proper management of resources for agricultural operations to minimize the risk and facilitate the growth and realize the 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 indicated that the Agromet advisory can enhance the productivity of the crops. Hence this has to be expanded and adopted by the farming community to realize higher food production.

5. Entomology Aspects:

How rising CO_2 levels affect insects: Generally CO_2 impacts on insects are thought to be indirect - impact on insect damage results from changes in the host crop. Some researchers have found that rising CO_2 potentially have important effects on insect pests. Recently, free air gas concentration enrichment (FACE) technology was used to create an atmosphere with CO_2 and O_2 concentrations similar to what climate change models predict for the middle of the 21st century. FACE allows for field testing of crop situations with fewer limitations than those conducted in enclosed spaces. During the early season, soybeans grown in elevated CO_2 atmosphere had 57% more damage from insects (primarily Japanese beetle, potato leafhopper, western corn rootworm and Mexican bean beetle) than those grown in today's atmosphere, and required an insecticide treatment in order to continue the experiment. It is thought that measured increases in the levels of simple sugars in the soybean leaves may have stimulated the additional insect feeding (Hamilton et al 2005).

How this affect farmers: It is likely that farmers will experience extensive impacts on insect management strategies with changes in climate. Entomologists expect that insects will expand their geographic ranges, and increase reproduction rates and overwintering success. This means that it is likely that farmers will have more types and higher numbers of insects to manage. Based on current comparisons of insecticide usage between more southern states and more northern states, this is likely to mean more insecticide use and expense for northeastern farmers. Entomologists predict additional generations of important pest insects in India like Brown plant hopper, leaf hoppers, aphids, thrips etc. as a result of increased temperatures, probably necessitating more insecticide applications to maintain populations below economic damage thresholds. A basic rule of thumb for avoiding the development of insecticide resistance is to apply insecticides with a particular mode of action less frequently. With more insecticide applications required, the probability of applying a given mode of action insecticide more times in a season will increase, thus increasing the probability of insects developing resistance to insecticides. A number of cultural practices that can be used by farmers could be affected by changes in climate – although it is not clear whether these practices would be helped, hindered or not affected by the anticipated changes. Using crop rotation as an insect management strategy could be less effective with earlier insect arrival or increased overwintering of insects. However, this could be balanced by changes in the earliness of crop planting times, development, and harvest. Row covers used for insect exclusion might have to be removed earlier to prevent crop damage by excessive temperatures under the covers – would the targeted early insects also complete their damaging periods earlier or be ready to attack when the row covers were removed?

What farmers can do to adapt: Farmers should keep in mind that climate change is likely to be a gradual process that will give them some opportunity to adapt. It is not precisely understood how climate changes will affect crops, insects, diseases, and the relationships among them. If climate is warmer increases in yield offset losses to pests, or will losses to pests outweigh yield advantages from warmer temperatures? It is likely that new pests will become established in more areas and be able attack plants in new regions. It is likely that plants in some regions will be attacked more frequently by certain pests. A few pests may be less likely to attack crops as change occurs. It is likely that we will not know the actual impacts of climate change on pests until they occur. Clearly, it will be important for farmers to be aware of crop pest trends in their region and flexible in choosing both their management methods and in the crops they grow. Farmers who closely monitor the occurrence of pests in their fields and keep records of the severity, frequency, and cost of managing pests over time will be in a better position to make decisions about whether it remains economical to continue to grow a particular crop or use a certain pest management technique. If more insecticide applications are required to grow a particular crop, farmers will need to carefully evaluate whether growing that crop remains economical. Those farmers who make the best use of the basics of integrated pest management (IPM) such as field monitoring, pest forecasting, recordkeeping, and choosing economically and environmentally sound control measures will be most likely to be successful in dealing with the effects of climate change

6. Agronomic Practices:

Mitigation strategies for climate change:

- **Sequestration of Carbon (SOC)** in agriculture, forestry, and fisheries/aquaculture: The International Panel on Climate Change (IPCC) estimates that the global technical mitigation potential for agriculture will be between 5500 to 6000 mt CO_2 equivalents per year by 2030. Eighty nine per cent of which are assumed to be from carbon sequestration in soils.
- **Organic Farming (OF)** organic grain production requires an energy consumption of only 6% as compare to 46% for conventional production. The concept of organic agriculture globally is respecting natural capacity of plants to adapt to environmental condition and build their natural resistance. This reduces the need for external inputs such as chemical pesticides, herbicides and fertilizers. Organic agriculture principles including biodiversity, irrigation, plant nutrition and natural pest management

will conduct self regulation, sustainable agriculture and ecofriendly. Rice production is associated with the emission of green house gases (GHGs). Methane emission accounts for 20 per cent of the enhanced green house effect and 25 per cent more potent than CO_2.

- One of the emerging technologies to reduce GHGs emissions from rice fields is the use of zymogenic bacteria, acetic acid and hydrogen producers, methanogens, CH_4 oxidizers and, nitrifiers and denitrifiers in rice, which will help in maintaining the soil redox potential in a range where both N_2O and CH_4 emissions are low.
- Biochar or black carbon is a partly burnt rice residue. Instead of incorporating untreated rice residues use of biochar may reduce field emission of methane by as much as 80 per cent. The Biochar is inert and stable can be effectively stored in the ground for hundreds thousands of years. Biochar if byproduct of bioenergy production system can further useful as renewable energy resource. Technologies are now available for utilization of rice husk. In the similar lines feasible technologies for on farm utilization of bulky rice harvest residues may be generated.
- Water saving technologies such as alternate wetting and drying reduce the amount of time rice field flooded and can reduce the production of methane by 60-90 per cent (IRRI). Zero tillage in large rice-wheat system in India and aerobic cultivation of rice helps in mitigation of rice and favour diversity of microflora and fauna in the soil.
- Nitrous oxide (N_2O) emission will be will be enhanced under alternate wetting and drying or aerobic rice production system which is another potential GHG. It is 300 times more potential than CO_2. To mitigate N_2O emission apart from water saving technologies good nutrient management practices which reduce denitrification losses of N *viz.* optimum dose, proper time and method of nitrogen fertilizer and balanced use of nutrients, use of nitrification inhibitors, neem cake blended urea, use of organic nitrification inhibitors *viz.* pongamia, neem, castor seed cakes, coating the urea with nonedible oils may be followed.
- Half of the global population consumes cooked rice. Cooking time is positively correlated to energy consumption. The amount of GHGs emitted depends upon the type of energy used in cooking rice. During cooking the crystalline starch of rice melts known as gelatinization. The temperature of gelatinization varies with the rice cultivars. IRRI is exploring the ways of incorporating genes which affect the gelatinization temperature. A decrease of four minutes of cooking time can save 10,000 years of cooking time globally and massive energy required for cooking rice and emission of GHGs.
- Wheat production area may shift towards North as a result of increase in temperature. However wheat is grown in diverse condition. The consortia of wheat cultivars, species and germplasm enabled the wheat breeders to develop promising varieties tolerant to high temperature existing in central and southern India. Wheat cultivar DWR 162 known as Dewata found promising not only in southern India but also in Indonesia.

Best management practices in agriculture (BMPA) to reduce GHGs:

- Reducing the bare fallow
- Restoring the degraded soils
- Improving pasture and grazing lands
- Efficient irrigation water management practices
- Cropping systems: crop and forage rotation or ley farming, alley cropping, agro forestry, afforestation
- Emphasis on biofuel trees and crop production
- Tillage practices: zero tillage, minimum tillage conservation tillage
- Best livestock management practices: reduce food grains as feed to livestock, breeding heat tolerant breeds to reduce the energy required for moderating the temperature.

The technical potential of global crop lands to sequester carbon through a combination of these techniques has been estimated at 0.75 to 1.0 Gt per year. Estimates indicate that tillage reduction on global crop land could provide a full 'wedge' of GHG emission reduction upto 25 Gt over the next 50 years.

Adaptive measures for climate change

Good agronomic practices (GAPs): Tailor the agronomic practices to changing climatic scenario.

- Adjustment of planting dates to minimize the effect of temperature increase induced spikelet sterility.
- Changing the crop calendar to take advantage of the wet period and to avoid extreme weather events during the crop growing season
- Promotion of integrated farming system to minimize the risk
- Cropping systems *viz.* crop rotation, intercropping, multistory cropping, inclusion of perennial in dry lands.
- Integrated watershed management approach
- Bed planting of crops
- Conservation tillage
- Crop residue management – avoid burning of crop residues
- Integrated nutrient management (INM), integrated weed management (IWM), integrated pest management (IPM), integrated disease management (IDM) *etc.*
- Efficient use of water, conjunctive use of water, nutrients and other resources
- Reduction of post harvest crop losses
- Improve nutritional quality of crops
- Minimize environmental pollution
- Practices to adapt for biotic and abiotic stresses

7. **Pathology Aspects:**

Climate change effects on virulence, aggressiveness, or fecundity of pathogens: Pathogen evolution rates are determined by the number of generations of pathogen reproduction per time interval along with other characteristics such as heritability of traits related to fitness under the new climate scenario. Temperature governs the rate of reproduction for many pathogens, for example spore germination of the rust fungus *Puccinia substriata* increases with increasing temperature over a range of temperatures, and the root rot pathogen *Manosporascus cannonballus* reproduces more quickly at higher temperatures. Longer seasons that result from higher temperatures will allow more time for pathogen evolution. Pathogen evolution may also br more rapid when large pathogen populations are present, so increased overwintering and oversummering rates will also contribute. Climate change may also influence whether pathogen populations reproduce sexually or asexually in some cases, altered temperatures may favour overwintering of sexual propagules, thus increasing the evolutionary potential of a population. Under climate change, pathogens, like plants, may potentially be unable to migrate or adopt as rapidly as environmental condition change. But most pathogens will have the advantage over plants because of their shorter generation times and in many cases, the ability to move readily through wind dispersal. Climate variability itself may be an important form of selection.

Host pathogen interaction responses to climate change:

Biotrophic fungi, an increase in disease severity for six of ten biotrophic fungi studied, and a decreased for the other four. For fifteen necrotrophic fungi studied hey reported that, nine exhibited an increase in disease severity, four exhibited a decreased and two remain unchanged. This suggest that predicting effects for unstudied pathosystems will be quite challenging. Some mechanisms of effects of elevated CO_2 on plants are fairly well understood, such as reduced stomatal opening and changes in leaf chemistry, so that disease caused by pathogens that infect though stomata , such as *Phyllosticta minima* may be reduced. But combining the direct effects of elevated co2 on plants with the effects ion disease will make predictions of plant productivity even more challenging. For example, some scientists found that benefits from elevated co2 counter balanced negative effects from ozone but did not compensate for the effects of fungal infection. S in a study of plant disease in tall grass, found that elevated co2 increased the pathogen load of c3 grasses, perhaps due to increased leaf longevity and photosynthetic rate they suggested that one result of climate change for grassland ecosystem could thus be increased pathogen load.

The effects of elevated ozone on disease may not be straight forward to study and predict for rust fungi as examples, elevated ozone has been found to increase and decrease infection. The effects of ozone on leaf surface characteristics, including wettability, led to increased rust incidence. It was also observed that rust infected plants exhibited symptoms of ozone damage several weeks earlier and with higher severity than uninfected plants. Plant pathologists have studied the relationship between precipitation and disease for decades. Even without the added impetus of predicting climate change effects, this interaction is of primary importance for predicting disease severity. Decreases in precipitation or increased intervals between precipitation vents, have been predicted for a grater geographic area than are increases. Drought stress and disease stress may have additive effects on plants as observed for infection by *Xylella fastidiosa*, beet yellows virus and maize dwarf mosaic virus. Other pathogens such as *Macrophomina phaseolina* and *Septoria musiva* causing canker in popular may cause more deleterious effects on their hosts under drought conditions, though it is unclear whether this is because of increased infection rates under drought or because of increased impacts per infection event, suggest that the concentration of carbohydrates in host tissues as a result of drought stress might benefit pathogens such as *M. phaseolina* that could survive in extremely dry soils. While effects of temperature and disease epidemiology also have a long history of study in agricultural systems, newer work as also addressed temperature effects in a natural mo0untain meadow in rocky mountain biological station. In this study, many pathogens and herbivores were more abundant on plant populations with the longer growing season produced by artificial heating, but some were more abundant in the ambient cooler conditions. New approaches to the study of preserved specimen may reveal surprising correlation with environmental variables. The ratio of *Stagnospora* and *Septoria* species in historic British wheat samples was closely correlated with the levels environmental $S0_2$. This is also an illustration of how one pathogen might appear to emerge in recent decades when it is actually only regaining its historical advantage from the previous century.

Ecosystem Level effects:

The implications of plant disease at the ecosystem level have rarely been addressed. It was addressed incorporating insect and pathogens as biotic disturbance agents in models of vegetation change in response to climate. It was also developed a frame work for evaluating likely ecosystem effects for a pathogen and by extension, the potential ecosystem and metaecosystem impacts of a pathogen when its epidemiology shifts with a shifting climate of course, at this scale, the number of interactions and even types of interactions rapidly increases and changes in land use patterns will also be important factors but it is relevant to consider Eviner and Likens factors for predicting ecosystem effects and how pathogen characterization might shift with climate change. (a) pathogen effects on host survival, physiology, behaviour and or reproduction (b). life stages of a host vulnerable to a pathogen (c). proportion of individuals or biomass infected at a site. (d) spatial extent and distribution of infection (e)Rate of pathogen effects on hosts in relation to rate of response or recovery by hosts or individual replacing hosts; (f) functional similarity of infected individuals versus replacements (g) Frequency and duration of pathogen impact. Many of these factors have been addressed in other sections of this review, but the sixth is of particular interest for scaling up predictions to the ecosystem level. It is possible that, even in the extreme event that a plant species should go extinct due to greater pathogen effects resulting from climate change, plant species that replace it could maintain ecosystem function. On the other hand, if climate change produces major shifts in which agricultural species are present in a region, this may result in important changes in nutrient loss from agriculture to surrounding ecosystems. Ultimately, the study of such large scale processes will be facilitated by remote sensing of plant populations. Although remote sensing technologies have advanced rapidly, there are still challenges to identify particular plant species and to distinguishing between different types of plant stresses in the field. Global networking for impact assessment such as the global change and terrestrial ecosystems core project of the international geosphere- biosphere programme will provide context for evaluation.

8. **Bio-Technology aspects:**

Biotechnological approaches: Developing and introducing of later- maturing crop varieties or species,

Selective breeding of heat- and drought-resistant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions. Collections of genetic resources maintained in germ-plasm banks; these may be screened to find sources of resistance to changing diseases and insects, as well as tolerances to heat and water stress, drought ,salt and better compatibility to new agricultural technologies. Develop Crop varieties to help to exploit the beneficial effects of CO_2 enhancement on crop growth and water use. Select and develop crop(Agri+Horti) variety /animal/fish for yield and better nutritional quality and with a higher harvest index. Develop Animal(both for milk and meat), Pigs, poultry and fish verities for better feed conversion, disease resistant, tolerance to heat stress, for increased productivity. Develop fish varities suitable for Cage or pen farming and for salt resistant. Select ion and Promotion of seaweed farming in appropriate areas to reduce carbon dioxide concentration in seawater through photosynthesis. Abiotic and biotic stresses negatively influence survival, biomass production and crop yield ,being multigenic as well as a quantitative trait. Several biotechnological approaches have been made to understand the molecular basis of Abiotic stress and biotic stress factors and to overcome the negativity of these factors at molecular level. Abiotic stress factors (salinity, high light intensity, high temperature, and heavy metals) lead to oxidative stress with the formation of reactive oxygen species (ROS) causing extensive cellular damage and inhibition of photosynthesis.

9. **Extension Strategy:**

Extension has a major role to play in helping farmers adapt to and mitigate climate change. To capture this potential role, adaptation and mitigation funds could be used to support extension efforts that deliver new technologies, information, and education about increasing carbon sequestration and reducing GHG emissions. Traditionally extension has worked to promote new technologies and management techniques, educate farmers, and act as a facilitator or broker for rural communities. Now, too, extension can help link practice in the field to new policies regarding climate change. All of these roles can be exploited in a cost-effective way to help resource-poor smallholders deal with the issues of climate change that will so radically affect their livelihoods. Perhaps the most important purpose for extension today is to bring about the empowerment of farmers, so that their voices can be heard and they can play a major role in deciding how they will mitigate and adapt to climate change

10. Strategies to Protect Soil Health

Soils provide numerous ecosystem services essential to the well being of life on earth. Important among these are : producing biomass, cycling elements , denaturing of pollutants, purifying and filtering water, storing and creating habitat for a vast gene pool, providing foundations for civil structures , generating raw materials and serving as an archive of planetary and human history. Soil's capacity to provide these 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 SOC 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 SOC pools. The following points would help in augmenting soil health due to climate change: Carbon sequestration helps adaptation to climate disruption by buffering agricultural ecosystems against adverse changes in temperature, precipitation and other extreme events. Conversion to restorative land use and adoption of recommended management practices (**RMP's**), which create positive C and nutrient (N,P,K,S) budgets, can enhance SOC pool while restoring soil quality. The rate of SOC sequestration in soils of terrestrial ecosystem is 2-3 Pg C / yr. This helps in improving ecosystem services. Adoption of RMP's by the resource – poor farmers can be promoted by payment for soil C credits, green water credits and biodiversity credits. Low carbon farming (LCF) practices would help carbon emission. In conclusion it could be said that we (the humans) creators of climate change due to Global Warming need to sincerely and seriously address this issue and do whatever possible to protect our planet and ourselves. The simplest one can do is to grow a plant, such an effort world over would add upto to become a huge C sink this could change the world. Let us start today.

11. **Development of resource conserving technologies**:

Recent researches have shown that surface seeding or zero-tillage establishment of upland crops after rice gives similar yields to when planted under normal conventional tillage over a diverse set of soil conditions. This reduces costs of production, allows earlier planting and thus higher yields, results in less weed growth, reduces the use of natural resources such as fuel and steel for tractor parts, and shows improvements in efficiency of water and fertilizers. In addition, such resource conserving technologies restrict release of soil carbon thus mitigating increase of CO_2 in the atmosphere. Increasing income from agricultural enterprises: Rising unit cost of production and stagnation yield levels are adversely affecting the income of the farmers. Global environmental changes including climatic variability may further increase the costs of production of crops due to its associated increases in nutrient losses, evapotranspiration and crop-weed interactions. Suitable actions such as accelerated evolution of location-specific fertilizer practices, improvement in extension services, fertilizer supply and distribution, and development of physical and institutional infrastructure can improve efficiency of fertilizer use.

12. **Improved land use and natural resource management policies and institutions**:

Adaptation to environmental change could be in the form of social aspects such as crop insurance, subsidies, and pricing policies related to water and energy. Necessary provisions need to be included in the development plans to address these issues of attaining twin objectives of containing environmental changes and improving resource use productivity. Policies should to be evolved that would encourage farmers to enrich organic matter in the soil and thus improve soil health such as financial compensation/incentive for green manuring.

13. **Improved risk management though early warning system and crop insurance**:

The increasing probability of floods and droughts and other uncertainties in climate may seriously increase the vulnerability of eastern India and of resource-poor farmers to global climate change. Policies that encourage crop insurance can provide protection to the farmers in the event their farm production is reduced due to natural calamities. In view of these climatic changes and the uncertainties in future agricultural technologies and trade scenarios, it will be very useful to have an early warning system of environmental changes and their spatial and temporal magnitude. Such a system could help in determining the potential food insecure areas and communities given the type of risk. Modern tools of information technology could greatly facilitate this. Agriculture sector contributed 29% of the total GHG emissions from India in 1994. The emissions are primarily due to methane emission from rice paddies, enteric fermentation in ruminant animals, and nitrous oxides from application of manures and fertilizers to agricultural soils. These emissions can be minimized through knowledge transfer to the farming community through ICT on appropriate methodologies that can be adopted not only to reduce water use and increase WUE in rice cultivation but also decrease the methane emission significantly.

Climate change, it appears is now underway. Climate change is a global problem and India will also feel the heat. Nearly 700 million rural people in India directly depend on climate-sensitive sectors (agriculture, forests and fisheries) and natural resources (water, biodiversity, mangroves, coastal zones and grasslands) for their subsistence and livelihood. Under changing climate, food security of the country might come under threat. In addition, the adaptive capacity of dry-land farmers, forest and coastal communities is low. Climate change is likely to impact all the natural ecosystems as well as health. The increase in weather extremes like torrential rains, heat waves, cold waves and floods besides year-to-year variability in rainfall affects agricultural productivity significantly and leads to stagnation/decline in production across various agro-climatic zones.

To mitigate the climate change effects on agricultural production and productivity a range of adaptive strategies need to be considered. Changing cropping calendars and pattern will be the immediate best available option with available crop varieties to mitigate the climate change impact (Ref. 14). The options like introducing new cropping sequences, late or early maturing crop varieties depending on the available growing season, conserving soil moisture through appropriate tillage practices and efficient water harvesting techniques are also important. Developing heat and drought tolerant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions should be the long-term strategy. Genetic manipulation may also help to exploit the beneficial effects of increased CO_2 on crop growth and water use (Ref. 15). One of the promising approaches would be gene pyramiding to enhance the adaptation capacity of plants of plants to climatic change inputs (Ref. 16). There is thus an urgent need to address the climate change and variability issues holistically through improving the natural resource base, diversifying cropping systems, adapting farming systems approach, strengthening of extension system and institutional support. Latest improvements in biotechnology and information technologies need to be used for better agricultural planning and weather based management to enhance the agricultural productivity of the country and meet the future challenges of climate change in the dryland regions of the world.

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Chapter 5

IMPACT OF CLIMATE CHANGE ON WATER RESOURCES OF KARNATAKA

Indian Institute of Science

Bangalore

2011

Preliminary Report

Introduction

The impacts of climate change on water resources have been highlighted in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which predicts an intensification of the global hydrological cycle, affecting both the ground and surface water supply. The IPCC report also concluded that it is highly likely "**The negative impacts of climate change on freshwater systems outweigh its benefits",** with runoff declining in most streams and rivers. In addition, different catchments are likely to respond differently to the same change in climate drivers, depending largely on catchment physiogeographical and hydrogeological characteristics and the amount of lake or groundwater storage in the catchment. The IPCC has predicted with high confidence that the drought affected areas will show increase in frequency as well as the severity of drought. The IPCC also predicts with high confidence that the area affected by drought will increase in South Asia, including India (IPCC, 2007). The impacts of climate change are also dependent on the baseline condition of the water supply system and the ability of water resource managers, to respond to climate change in addition to pressures of increasing demand due to population growth, technology, and economic, social and legislative conditions (Gosain et al., 2006).

Surface water resources in Karnataka state

There are seven river systems in the state namely Krishna, Cauvery, Godavari, North Pennar, South Pennar and Palar as shown in Figure 5.1. The annual average yield in the seven river basins is estimated to be 98,406 Million Cubic Meters (MCM). However economically utilizable water for irrigation is estimated at 1,695 Thousand Million Cubic feet (TMC) (State of the Environment Report, 2003). According to the Karnataka State Environment Report (2003), there are 36,679 tanks in the state with an irrigation potential of 6,84,518 ha (0.6 Mha) and minor irrigation surface tanks with estimated irrigation potential at about 1.0 Mha.

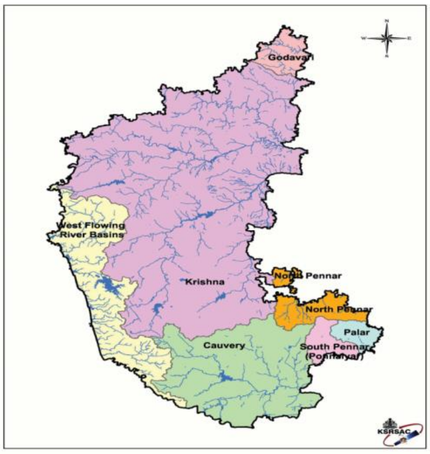


Figure 5.1: River systems of Karnataka (Source: State of Environment Report of Karnataka, 2003)

Objectives

Studies so far on the impacts of climate change on river basins are limited to national level assessments. In this report, we concentrate on the state-level (Karnataka) assessment: the two important river basins of the state, Krishna and Cauvery, were selected for the present study. This study aims to assess the impact of climate change on water resources on these two river basins using the HadCM3 Global Circulation Model (GCM). This study will address:

- Precipitation in the two river basins
- Runoff or water yield
- Evapotranspiration
- Drought

River Basins Selected

Krishna and Cauvery river basins have been selected for the study and in this report **we present a synthesis of available information on climate change impacts for the two river basins.** These two are the major basins in the state accounting for nearly 78% (Krishna- 59.60%, Cauvery- 18.34%) of the total basin area of Karnataka. It can be observed from Table 5.1 that Krishna and Cauvery river basins are the largest, in terms of the area drained in the state.

Table 5.1: River systems of Karnataka, their average yield, area drained and percentage of water yield (Source: Department of Water Resources, Karnataka)

River system	Estimated average yield (Million cubic meters)	Drainage area (1000 km²)	Percentage of average yield
Krishna	27,451	113.29	27.90
Cauvery	12,304	34.27	12.33
Godavari	1415	4.1	1.44
West flowing rivers	56,600		57.51
North Pennar	906	6.94	0.92
South Pennar		4.37	
Palar		24.25	
Total	**98,406**	**190.50**	**100.00**

Krishna basin

Krishna river basin (Figure 5.2) is the fourth largest in India in terms of annual discharge and fifth largest in terms of surface area, covering parts of three states in South India. It covers approximately 59% of the geographic area of Karnataka (Table 5.2). The principal tributaries of Krishna in Karnataka are Ghataprabha, Malaprabha, Bhima and Tungabhadra. The main issue facing the river basin is that the construction of large dams on the river for generation of hydroelectricity has severely reduced the river discharge. In a study done by Bouwer et al. (2006) it was observed that climate variability varied the runoff by 6-15% while the construction of reservoir on the river decreased the runoff by 61%.

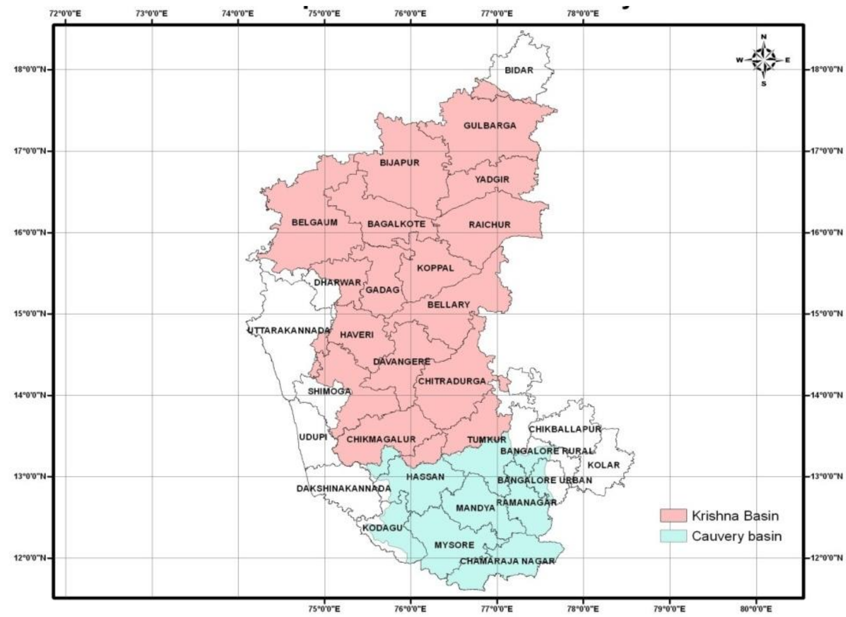


Figure 5.2: Location map of Krishna and Cauvery basin in Karnataka

Table 5.2: Area under the two river basins

	Area (sq km)	**% area of Karnataka under river basin**
Karnataka	1,91,791	100.00
Krishna basin	1,14,312	59.60
Cauvery basin	35,168	18.34

Cauvery basin

The Cauvery river basin (Figure 5.2) is the second major river system in Karnataka. It covers approximately 18% of the geographic area of Karnataka (Table 5.2). The principal tributaries of Cauvery in Karnataka are the Harangi, the Hemavathy, the Lakshmanathirtha, the Kabini, the Shimsha, the Arkavathi and the Suvarnavathy. All these rivers, except the Kabini, Arkavathy and Suvarnavathy rivers, rise and flow fully in Karnataka.

Methodology

An assessment of the impacts of climate change on water resources can be best handled through modeling of hydrological conditions in river basins under future predicted climate variables. The main components of the hydrological cycle are precipitation, evaporation and transpiration. Changes in climate parameters, solar radiation, wind, temperature, humidity and cloudiness affect evaporation and transpiration. The river basin is generally the most appropriate primary exposure unit for assessing impacts on hydrological resources. For the present study, three variables i.e. precipitation, evapotranspiration and surface runoff have been considered.

- **Precipitation** is any product of the condensation of atmospheric water vapor that falls under gravity. It manifests mostly as rainfall in a region.
- **Evapotranspiration** (ET) is a term used to describe the sum of evaporation and plant transpiration from the Earth's land surface to atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopies, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves.
- **Surface runoff** is the water flow that occurs when soil is infiltrated to full capacity and excess water from rain, melt water, or other sources flows over the land.

Global Climate Model (HADCM3): The process based, Global Climate Model, HadCM3, is used in this analysis for generating the A1B scenario for the three variables, precipitation, evapotranspiration and runoff. This model has been used recently for generating climate change projections for various parts of the Indian subcontinent (Rupa Kumar et al., 2006). According to this study, the Indian subcontinent could be subjected to an average of over 4 °C increase in temperature by 2085 under the SRES A2 scenario.

Data: Spatial data and the source of data used for the study include:

- *Current observed temperature and precipitation*: The 30-year climatological data from CRU (New et. al. 1999)

- *Climate change projections*: Regional Climate Model (RCM) outputs from Hadley centre model, the HadRM3 were used. These outputs are for the future term of 2021-2050, for the IPCC A1B scenario. This is also labeled as "2035", for brevity (which is the median of the period).
    - **IPCC A1B scenario.** The A1 storyline describes the future as a world of very rapid economic growth, a declining global population after it peaks in mid century and the rapid introduction of new and efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or ***a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies)*** (IPCC, TAR, WG-II, 2001).

Impact of Climate Change on the Water Sector

Precipitation

Krishna basin

Figures 5.3a and 5.3b show the percentage change in precipitation by 2021-2050, with respect to the baseline for the Kharif and Rabi seasons. For the Kharif months, it can be observed that for districts on the southern part of Krishna basin, the rainfall is projected to increase by as much as 10%. For districts like Shimoga, Chikmaglur, Haveri and Uttara Kannada and Dharwad, the rainfall is expected to increase between 20% and 10%. For Rabi season, a decline in rainfall is projected for most districts in the Krishna basin. The Yadgir district, in the North-Eastern part of Krishna basin is projected to show a decrease in rainfall by 20%, whereas in districts like Gulbarga, Bellary and Raichur, the percentage increase in rainfall ranges from 0 to 10%.

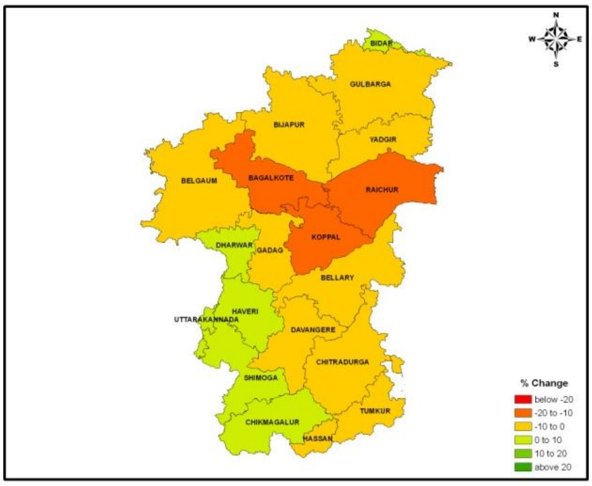


Figure 5.3a: Percent change in precipitation by 2021-2050 (A1B), with respect to the baseline for the monsoon or Kharif season in Krishna basin

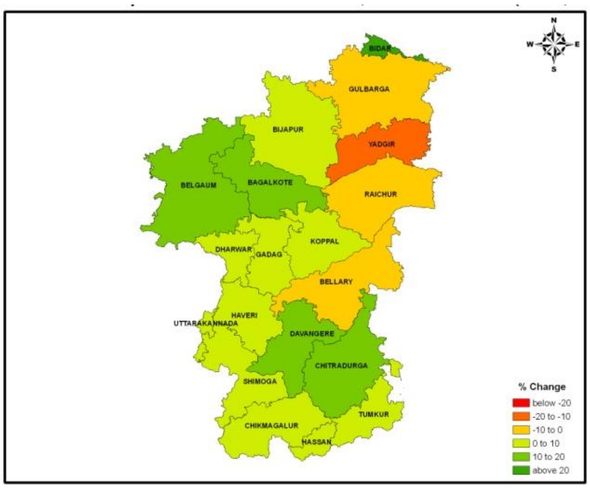
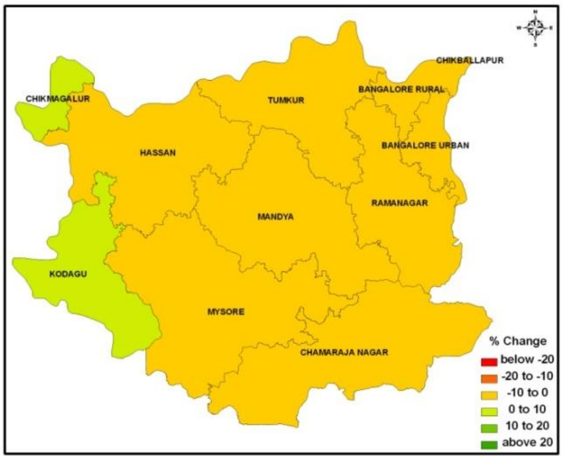


Figure 5.3b: Percent change in precipitation by 2021-2050 (A1B), with respect to the baseline for the post monsoon or Rabi season in Krishna basin

Cauvery basin

The Figures 5.3c and 5.3d show the percentage change in precipitation for the Kharif or monsoon and Rabi or post monsoon seasons, respectively for the Cauvery basin. During the Kharif season, percentage decline in rainfall is projected for all districts in the Cauvery basin with upto 20% decline projected for Kodagu and Chikmaglur districts. In the remaining districts of the Cauvery basin, the decline in rainfall ranges from no change to 10%. This is likely to have serious implications for Kharif crops.

For the Rabi or post monsoon season, a decline in rainfall by over 20% has been projected for Chamrajnagar. In the case of Ramnagar and Bangalore Urban districts, a rainfall decline of 20 to 10% has been projected. In Mandya and Mysore districts, no change in rainfall to 10% decrease has been projected. Rainfall in Hassan, Kodagu, Tumkur and Chikmaglur districts is projected to increase by 10% in the future.



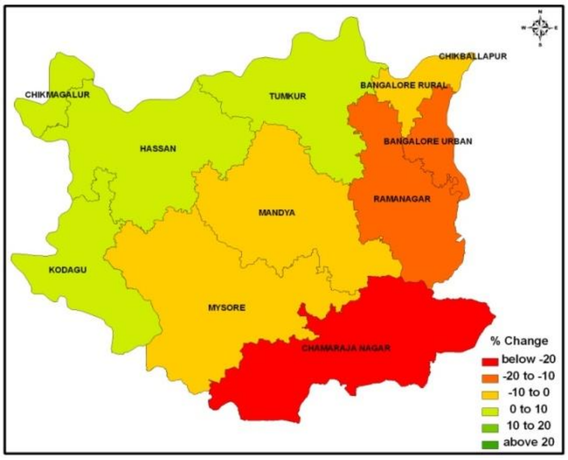


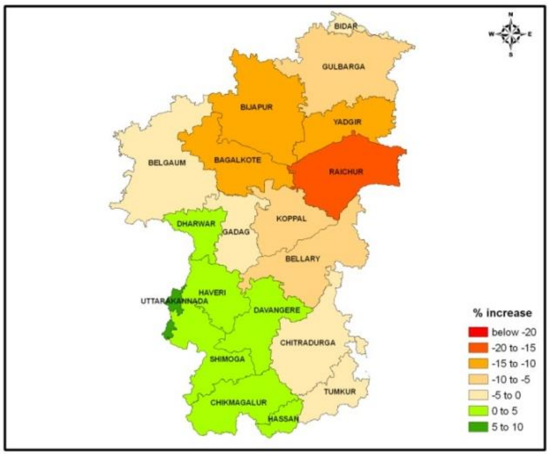
Figure 5.3c: Percentage change in precipitation for Kharif or monsoon season in Cauvery basin

Figure 5.3d: Percentage change in precipitation for Rabi or post monsoon season in Cauvery basin

Evapotranspiration

Krishna basin

Figures 5.4a and 5.4b represent the percentage increase in evapotranspiration for the Kharif and Rabi seasons. The color scale ranges from red (between 20 and 25% decrease in runoff) and orange (between 15% to10% decrease in runoff) to light brown (10 to 15% decrease in runoff), beige (upto 5% decrease in runoff) and light green (between 0% and 5% increase in runoff). It can be observed that in both seasons, in most of the districts, there is a decrease in evapotranspiration in the Krishna basin during Kharif as well as Rabi seasons.



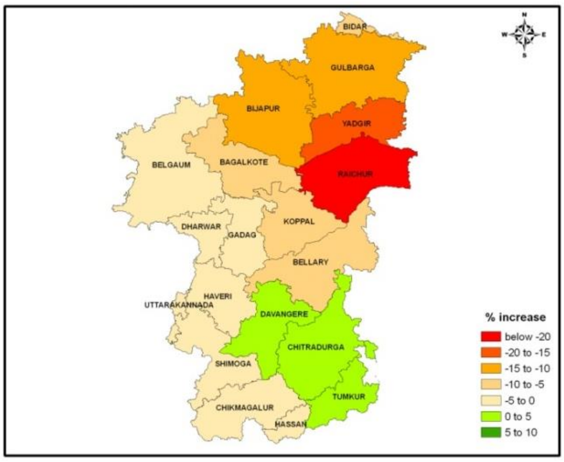


Figure 5.4a: Percent change in

Figure 5.4b: Percent change in

evapotranspiration by 2021-2050 (A1B), with respect to the baseline for the monsoon or Kharif season in Krishna basin

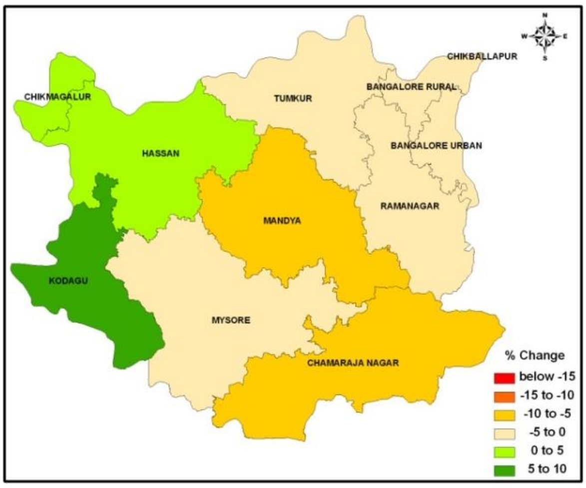
evapotranspiration by 2021-2050 (A1B), with respect to the baseline for the post monsoon or Rabi season in Krishna basin

In Kharif season, the South-Western districts are projected to show an increase in evapotranspiration. In the districts of Shimoga, Chikmaglur, Hassan and Haveri, ET is projected to increase in the range of 5-10% by 2021-2050 in the Kharif season. Conversely, for the same districts, the ET is projected to reduce in the Rabi season. The evapotranspiration of Raichur district on the east of Krishna basin is expected to decline by 20% in Kharif season and by more than 20% for Rabi season.

Cauvery basin

Figures 5.4c and 5.4d indicate the percentage change in evapotranspiration under the A1B scenario for Cauvery basin. Overall in the Kharif season, evapotranspiration is projected to decrease. Chamarajanagar and Mandya districts are projected to show a decline in ET, whereas Kodagu, Hassan and Chikmaglur are projected to show an increase in ET. The remaining districts are projected to show marginal decrease of 0-5%. The orange color indicates a significant decline in ET while the dark green color indicates an increase in ET.

For the Rabi season, only Mysore is projected to show a significant decline in evapotranspiration, and Ramanagar is projected to show maximum increase in ET. Mandya and Tumkur also are projected to show increase, while the remaining districts are projected to show marginal decrease in ET. The red color indicates a significant decline in ET while the light green color indicates an increase in ET.



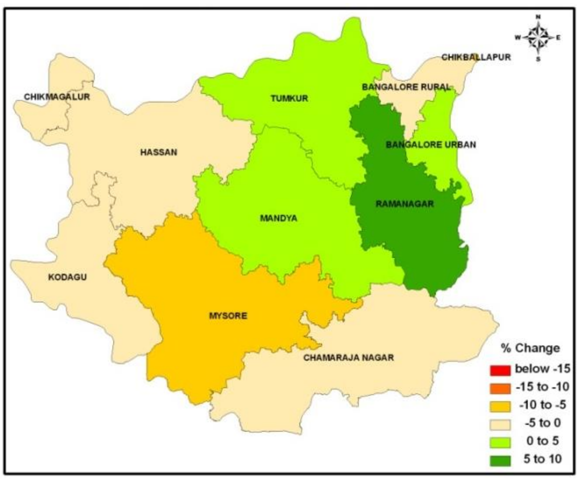


Figure 5.4c: Percent change in evapotranspiration by 2021-2050 (A1B), with respect to the baseline for the monsoon or Kharif season in Cauvery basin

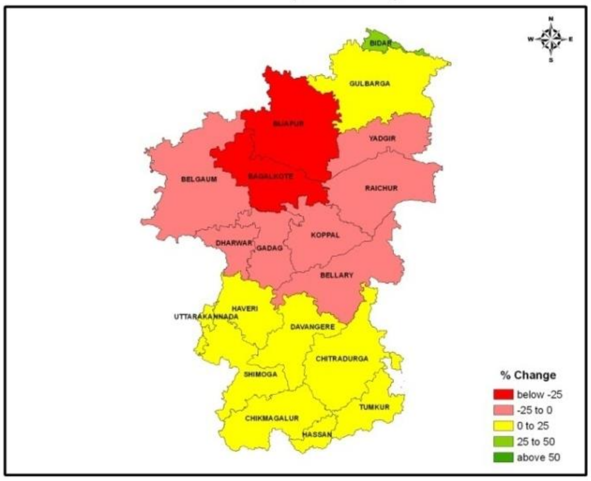
Figure 5.4d: Percent change in evapotranspiration by 2021-2050 (A1B), with respect to the baseline for the post monsoon or Rabi season in Cauvery basin

Runoff

Krishna basin

Figure 5.5a indicates the districts in the Krishna basin and the impact of climate change on total runoff during the monsoon/Kharif season. The color scale ranges from red (upto 25% decrease in runoff) and pink (between 25%-0% decrease in runoff) to light green (between 0% and 25% increase in runoff) and dark green (between 25% and 50% increase in runoff).

It can be observed that during Kharif season, an increase in runoff by more than 50% is projected for the northern most district of Bidar. For districts on the south of Krishna basin increase in runoff ranging between 0 and 25% is projected. It is observed that for the remaining districts in Krishna basin, runoff is not expected to increase significantly, especially for Bagalkote and Bijapur districts where a decline in runoff is predicted. The overall increase in runoff is likely to have serious implications for rainfed crops in these districts. Figure 5.5b shows the increase in total runoff for Krishna basin post monsoon/Rabi season. It can be observed that a decline in runoff is predicted for the northern and central districts with the exception of Bidar where, along with the districts on the south of the Krishna basin an increase in runoff is projected.



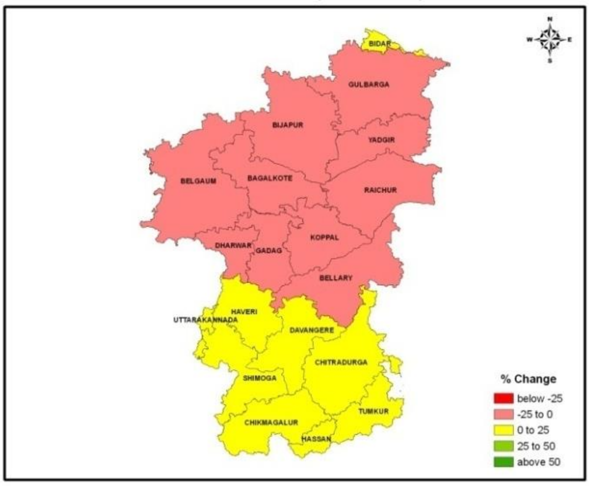


Figure 5.5**a**: Percent change in total runoff by

Figure 5.5**b**: Percent change in total runoff by

2021-2050 (A1B), with respect to the baseline for the Monsoon or Kharif season in Krishna basin

2021-2050 (A1B), with respect to the baseline for the post monsoon or Rabi season in Krishna basin

Cauvery basin

Figures 5.5c and 5.5d show the percentage change in total runoff for Cauvery basin. Red colour represents significant decrease and green colour represents increase. For both the Kharif and Rabi season, there is an increase in runoff in the Eastern districts of the basin. For Kharif season, districts like Mandya, Chamaraja Nagar and Ramanagar is projected to show increase in runoff by 50%, whereas districts like Hassan and Mysore represents a decline by 0-25% (figure 9a).

For the Rabi season, Chamaraja Nagar, Mandya, Ramanagar, Bangalore Urban and Bangalore Rural has been predicted to show an increase in total runoff in the A1B scenario. Tumkur and Chickmagalur have been predicted to show no change to an increase in 25% runoff. However Hassan, Mysore and Kodagu are projected to show a decrease in the runoff, upto 25%, when compared to baseline scenario. The increase in runoff in eastern districts in the Cauvery basin is a cause of concern.

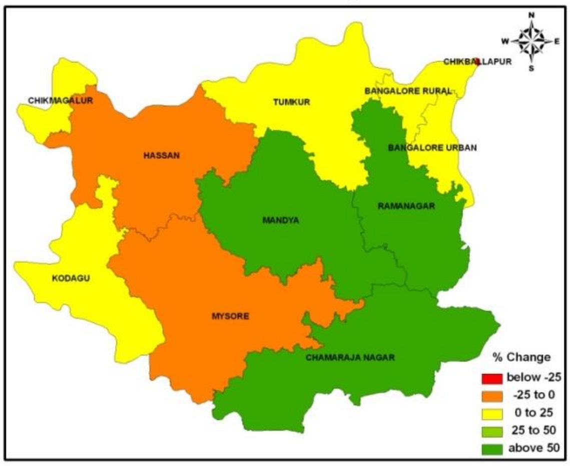


Figure 5.5c: Percent change in total runoff with respect to baseline for Kharif season in Cauvery basin (A1B)

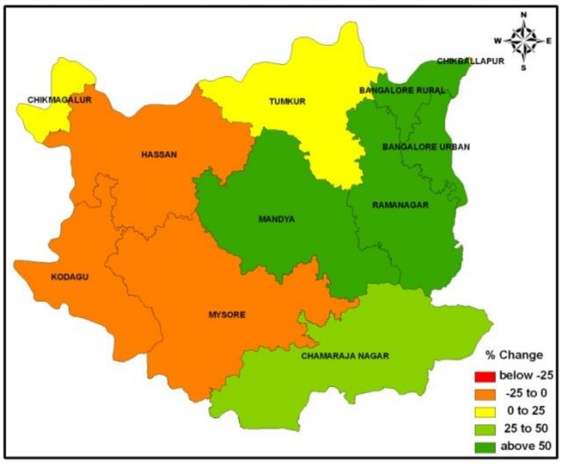


Figure 5.5d: Percent change in total runoff with respect to baseline for Rabi season in Cauvery basin (A1B)

Water yield

Krishna basin

Water yield is the amount of water leaving a watershed during a specified time period. It can be used as a proxy variable for measuring runoff. The data for water yield was obtained from IIT Delhi, and was prepared using SWAT model (http://gisserver.civil.iitd.ac.in/natcom/). For Krishna basin, a marginal increase in the average water yield (Figure 5.6a) has been projected in the mid-century scenario, when compared to the baseline scenario.

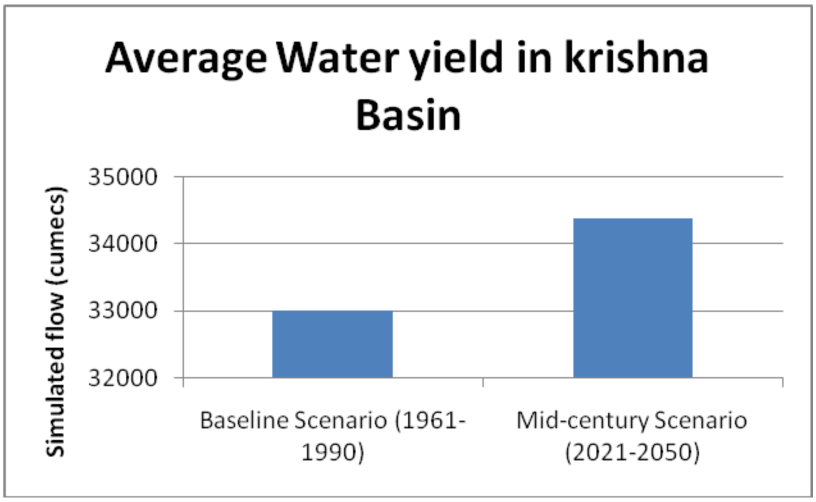


Figure 5.6a: Water yield in Krishna basin

Cauvery basin

For projections of the climate change scenario (2021-50's), the average water yield decreases in the Cauvery basin as compared to the baseline (Figure 5.6b). This indicates high amount of water not retained, in the basin. This is of immense concern to farmers, as this water scarcity will manifest itself as reduced yields in the Cauvery basin.

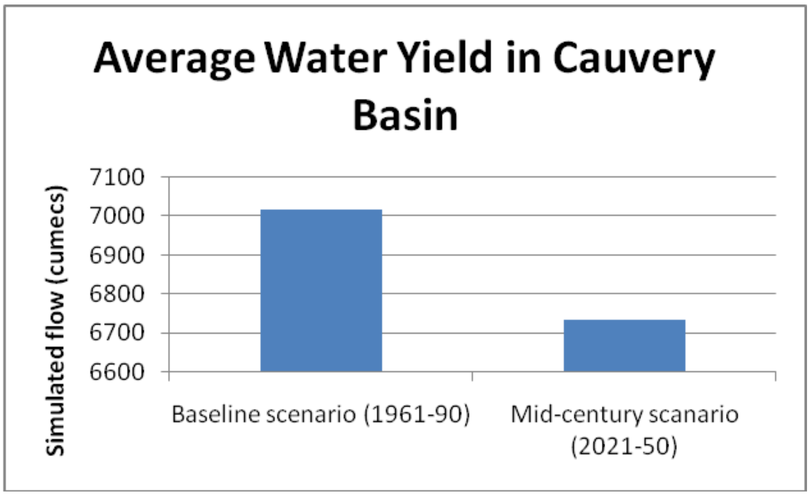


Figure 5.6**b**: Water yield in Cauvery basin

Drought

Drought is a normal, recurrent feature of climate and is observed in all the climatic zones. However, it has significantly different characteristics from one region to another. Drought over a geographic area is a temporary condition caused by significantly less (deficient) rainfall for an extended period of time, usually during a season when substantial rainfall is expected over the area. The severity of the drought can be aggravated by other climatic factors such as high temperature, high wind and low humidity.

Krishna basin

The drought prone districts in Krishna basin are Belgaum, Bellary, Bijapur, Chikmagalur, Chitradurga, Dharwar, Gulbarga, Hassan, Raichur and Tumkur (Compendium of Environment Statistics, 2002). It is projected that during the monsoon season, Raichur will be most affected with 10 to 20% decrease in rainfall projected for the future while the other drought prone districts show a marginal decrease in rainfall (0-10%). The Chikmagalur and Dharwar districts show an increase in rainfall during the same period. During the post-monsoon season, Raichur, Gulbarga and Bellary show a marginal decrease where as other drought prone areas show an increase in rainfall. The decrease in rainfall in these regions, especially in monsoon, will increase the water stress which may affect the crop yields negatively.

Cauvery basin

The drought prone districts in Cauvery basin are Bangalore, Chikmagalur, Hassan, Mandya, Mysore and Tumkur (Compendium of Environment Statistics, 2002). During the monsoon season (Kharif) all the districts excepting Chikmagalur show a marginal decrease (0-10%) in rainfall, only Chikmagalur shows a marginal increase in rainfall (0-10%). During the post-monsoon season Bangalore, Mandya and Mysore show a decrease in rainfall, where as Chikmagalur, Hassan and Tumkur show a marginal increase in rainfall during the same period. The decline in precipitation during monsoon can affect the crop growth due to increased water stress.

Summary Statistics on Precipitation, Evapotranspiration and Runoff (Climate Change (A1B) vs. Baseline)

An investigation of the percentage changes of the three variables - ET, Runoff, and Precipitation under the A1B climate change scenario, when compared to the baseline is conducted for both Krishna and Cauvery basins.

Krishna basin

Precipitation: Figure 5.7 indicates that on an average, annually, there would be a decrease in precipitation in the A1B scenario. Investigating further, there is a decrease in precipitation in the monsoon/Kharif season in the A1B scenario, whereas there is an increase in precipitation in the post monsoon/Rabi season, however, percentage-wise, the increase and decrease is very low.

Runoff

There is an increase in annual runoff in the Krishna basin, the percentage increase in runoff annually, is on an average 3%, in the A1B scenario. There is high increase in runoff in the monsoon/Kharif season (around 5%, average). However it can be observed that there is a decrease in runoff in the post-monsoon/Rabi season (around 2%, average).

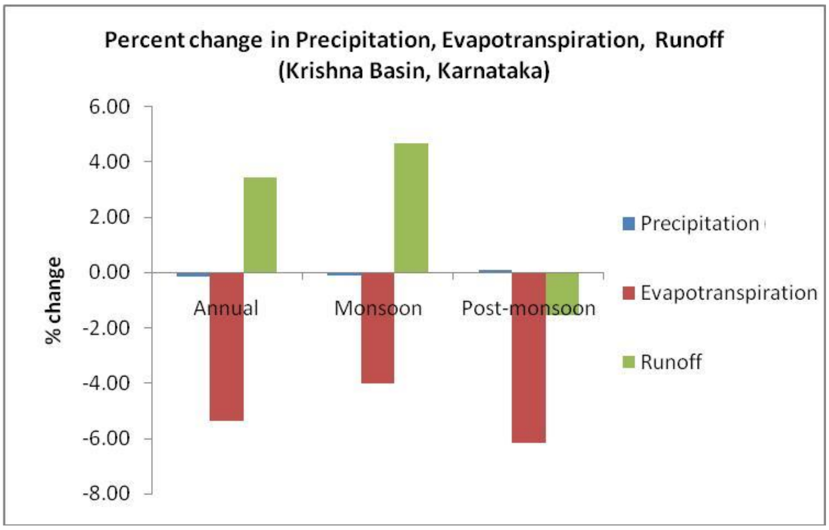


Figure 5.7: Percentage change in precipitation, evapotranspiration and runoff in Krishna Basin of Karnataka

Evapotranspiration

There is a decrease in the rate of evapotranspiration in the Krishna basin. Specifically an annual decrease of 6% is observed, the Kharif season decrease is on an average around 4%, while the Rabi season decrease is higher in absolute value, and around 6% on an average. This evapotranspiration decrease may be indicative of water stress in the climate change A1B scenario.

Cauvery basin

Precipitation: On an average, a slight decrease in precipitation annually in the Cauvery basin is projected under the A1B scenario (Figure 5.8). There is a decrease in precipitation in the monsoon season, an average of around 0.25% in the A1B scenario, when compared to the baseline scenario. However there is an increase in precipitation (around 1.75%) in the Rabi season in the A1B scenario. Even though the decrease in precipitation is slight, the decrease in evapotranspiration and the increase in runoff is a cause of concern, contributing to the uncertainty about the yields in the future in the Cauvery basin.

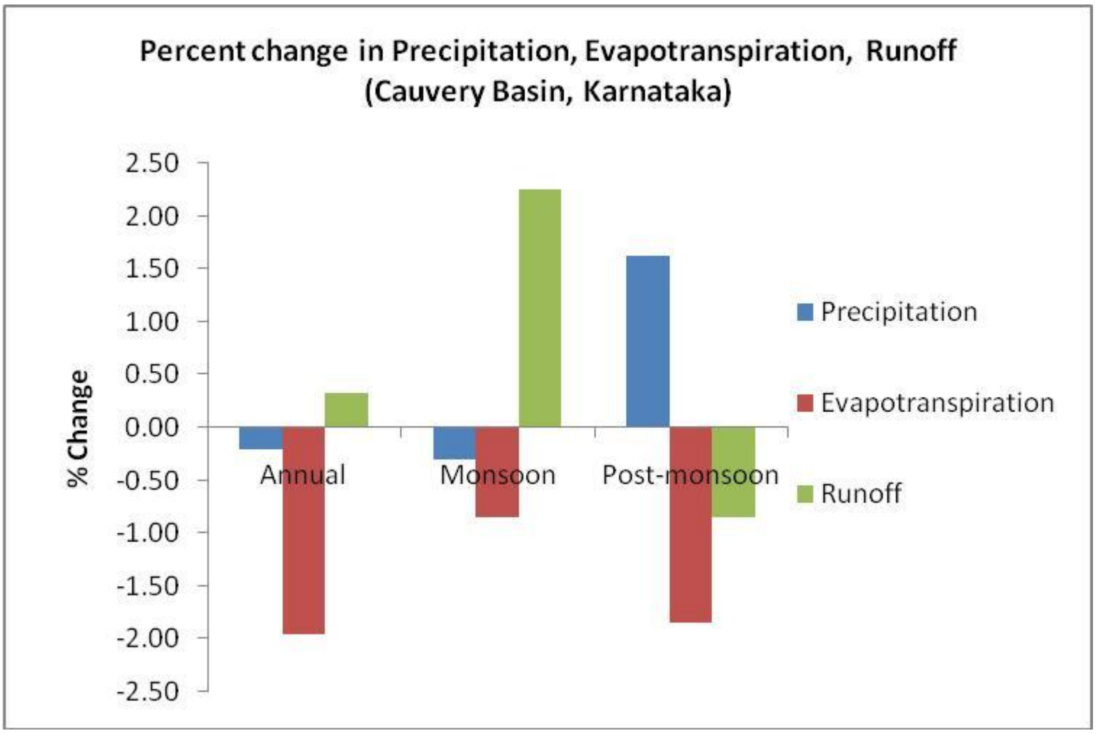


Figure 5.8: Percentage change in precipitation, evapotranspiration and runoff in Cauvery basin of Karnataka

Runoff: There is an increase in run off annually in the A1B scenario, when compared to the baseline scenario. The average annual increase in runoff is around 0.25%. The runoff increases during the monsoon season, an average of around 2.2.5% in the A1B scenario, when compared to the baseline scenario. The runoff decreases in the post-monsoon/Rabi season (0.75% in an average) when compared to the baseline scenario (Figure 5.8).

Evapotranspiration: From Figure 5.8, it can be observed that there is a decrease (2%) in evapotranspiration annually, in the A1B scenario, when compared to the baseline scenario. The decrease in evapotranspiration on an average is around 0.75% in the monsoon/ Kharif annually, when compared to the baseline scenario. The decrease in evapotranspiration was around 2% in the post-monsoon/Rabi season. This decrease in evapotranspiration in all the seasons is indicative of water stress and is a cause of concern in the Cauvery watershed.

Overall, among the two river basins, the increase in runoff and decrease in evapotranspiration in the Krishna basin in the A1B scenario is higher in absolute terms when compared to the Cauvery basin on an average, implying higher water stress and potential of droughts in the Krishna basin in the A1B scenario.

Effect of Climate Change on Water Resources of Karnataka and Impacts on Crop Yields

Krishna basin

Due to basin closure and high irrigation development in the Krishna basin, the streamflow to the oceans is only 20% of pre-irrigation discharge of the river. There are competing demands for irrigation from the tributaries, which is causing increasing basin closure in the tributaries as well (Biggs et. al., 2005). The increasing source of irrigation for crops in this location is groundwater. The major results of this study predict that there will be a decrease in precipitation, slight increase in runoff and water yield and decrease in evapotranspiration in the short–term (2020-2050). This is indicative of additional water stress in the future. The major crops cultivated in Krishna basin are rice and other grains, sugarcane, banana and other cash crops. These are all water-intensive in nature of cultivation, and therefore the increasing water stress is predicted to have negative effect on these crops, creating possible changes in cropping pattern and species cultivated.

Cauvery basin

The results of the assessment of the impact of climate change on the Cauvery basin indicates that decrease in precipitation in the basin, slight increase in runoff and water yield and a decrease in the evapotranspiration. This will affect the crops that are cultivated in the region. The major crops grown in the Cauvery region are rice, sugarcane, ragi, jowar and cash crops such as coffee, pepper and banana. The staple crops such as rice, and the other crops such as sugarcane and the cash crops are water-intensive in cultivation. Thus the increasing water stress in the region is predicted to affect the crops in the region negatively, leading to changes in the species cultivated.

Conclusions

- Climate change impact assessment indicates increased moisture stress in Krishna basin, especially in the north-eastern districts, and marginal impact on Cauvery basin for the A1B scenario.
- The water yield analysis indicates an increase in average water yield in the Krishna basin, while indicating a decrease in average water yield in the Cauvery basin.
- The precipitation analysis indicates:
    - Decrease in precipitation annually in the Krishna as well as Cauvery basins in the climate change scenario
        - Decrease in precipitation is similar, around 0.25% in the Krishna and Cauvery basins
- The runoff analysis indicates:
    - An increase in average annual runoff projected for both the river basins in the A1B scenario
    - The projected increase in average annual runoff is much higher for the Krishna basin in the A1B scenario, when compared to the Cauvery basin
    - This indicates that the water stress in Krishna basin would be much higher and farmers residing around the Krishna basin may suffer reduced crop yields.
- The evapotranspiration analysis indicates a decrease in evapotranspiration projected annually for both the river basins in the A1B scenario

The predominant crops such as rice, banana and sugarcane in both the Krishna and the Cauvery river basins being water-intensive crops will be affected negatively by the increased moisture stress in the short-term future, leading to reduced yields and change in cropping patterns.

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Chapter 6

Socio-economic Vulnerability and Adaptive Capacity Assessment

Institute for Social and Economic Change

Bangalore

2011

Introduction

Climate change will have a profound impact on human and eco-systems during the coming decades through variations in global average temperature and rainfall. A growing body of literature in the past two decades has identified climate change as the prime issue in global environment, and analyzed the associated vulnerability and biodiversity loss (Fourth Assessment Report of the Intergovernmental Panel on Climate Change).

Vulnerability is the degree to which a system is susceptible to or unable to cope with adverse effects of climate change including climate variability and extremes (IPCC, 2001a) and is the key concept of climate change. According to Fussel, climate related vulnerability assessments are based on the characteristics of the vulnerable system spanning over physical, economic and social factors (Fussel, 2007).

Box 1:

Vulnerability is the degree to which a system is susceptible to, or 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 to which a system is exposed, along with its sensitivity and adaptive capacity

Sensitivity is the degree to which a system can be affected, negatively or positively, by changes in climate. This includes change in mean climate and the frequency and magnitude of extremes. The effect may be direct (for example a change in crop yield due to a change in temperature) or indirect (such as damage caused by increased frequency of coastal flooding due to sea-level rise).

The Intergovernmental Panel on Climate Change (IPCC), in its Second Assessment Report, defines vulnerability as "the extent to which climate change may damage or harm a system." It adds that vulnerability "depends not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions".

Climate Change Implications for India and Karnataka

Climate forecasts indicate implications for India by altering the distribution and quality of India's natural resources ruthlessly affecting livelihoods, more so the vulnerable poor. India may encounter a major threat given its close linkages with its natural resource base economy and climate sensitive sectors like agriculture, water and forestry. Climate change is predicted to bring about diverse impacts with extreme weather conditions across regions like intense rainfall and flood risks while on the other side there would be extreme droughts besides higher tides, intense storms, warmer oceans and erosion along its coastline as an outcome of sea level rise. Climate change can affect lives, livelihoods and production systems posing high risk to people living in rural areas, particularly the poor. Climate change is seen as a challenge and threat specifically to India's growing economy. India's physical diversity makes it imperative to address the challenge besides developing adaptation strategies. Hence, an urgent need for action to avoid irreversible calamities with appropriate climate risk management. In this context, the consensus expert opinion during the National Consultation Workshop held on 19th August 2010 agreed upon developing 'State Level Climate Change and Action Plan' framework so that all States in India would prepare Action Plans suitable to their respective states with providing adequate scope for addressing state specific issues and context under the purview of National Action Plan on Climate change. This would help in promoting a common vision of the nature of climate change and its implications and policy commitments to be taken up in the coming future.

Karnataka is the second most vulnerable state in India to be impacted by Climate Change as the North Karnataka regions have the arid and driest regions (Ravindranath, 2011). Climate change will impact on natural resources to have social and economic consequences. While some of the impacts are presumed to be beneficial others could be disastrous. For instance, increased rainfall will increase water availability and in turn increase coconut production Simulation analysis depicting possible impacts of climate change on some of the prominent crops in coastal districts have specified that there will be a boost in coconut yields to the tune of 30 % caused mainly due to increase in projected rainfall and relatively less increase in temperatures. The social and economic implications of this would benefit farmers and the other sectors associated with its production. Similarly, floods could cause disruption and damage to crops and infrastructure. In brief, socio-economic consequences caused due to climate change are a resultant effect of the interactions between climate and society and their impact on natural and managed environments. Various factors could influence the climate change, viz. technological advancements, and economic development influencing social change in terms of livelihood changes. This in turn will cause considerable climate change variations. In this context, the implications for Karnataka in the long run will depend on the trends in climate change and its influence on its ability to cope besides making future plans towards developing coping mechanisms (INCAA, 2010).

Current Climate Variability in Karnataka

The annual rainfall in the State varies roughly from 50 to 350 cm. In the districts of Bijapur, Raichur, Bellary and southern half of Gulbarga, the rainfall is lowest varying from 50 to 60 cm. The rainfall increases significantly in the western part of the State and reaches its maximum over the coastal belt. The south-west monsoon is the principal rainy season during which the State receives 80% of its rainfall. Rainfall in the winter season (January to February) is less than one per cent of the annual total, in the hot pre-monsoon season (March to May) about 7% and in the post-monsoon season about 12% (Bala et.al, 2011).

Tropical monsoon climate covers the entire coastal belt and adjoining areas. The climate in this region is hot with excessive rainfall during the monsoon season i.e., June to September. The southern half of the State experiences hot and seasonally dry tropical savana climate while most of the northern half experiences hot, semi-arid and tropical steppe type of climate. The climate of the State varies with the seasons. The mild winter season from January to February is followed by relative warmer summer season from March to May. The period from October to December forms the post-monsoon or northeast monsoon season. The period from October to March, covering the post-monsoon and winter seasons, is generally pleasant over the entire State except during a few spells of rain associated with north-east monsoon which affects the south-eastern parts of the State during October to December. The months April and May are hot, very dry and generally uncomfortable. Weather tends to be oppressive during June due to high humidity and temperature. The next three months (July, August and September) are comfortable due to reduced day temperature although the humidity continues to be very high (Bala et.al, 2011).

Future climate projections for Karnataka

(As per Bala et.al study, 2011, IISc, Bangalore)

- The projected increase for annual average temperatures for the northern districts is higher than the southern districts. These regions are expected to experience a warming above 2^0 C by 2030s.
- Most of the state is projected to experience a warming of 1.8 to 2.2 ^{0}C.
- The northern part of the state is also projected to experience higher increases in minimum and maximum temperatures.
- The increase in the minimum temperature projected is slightly more than that of the average and the maximum temperatures.

Projected changes in rainfall

- The north-eastern and south-western parts of the state are projected to experience decrease in the quantum of rainfall, annually. This roughly correlates with observed trends over the last 30 years.
- Over the JJAS season too, north-eastern and south-western parts of the state are projected to experience reduced amounts of rainfall

Main observations:

- The minimum temperature goes up by as much as 2.4 to 3.3 ^{0}C in the winter months (November to February)
- The maximum temperature goes up by as much as 2.7 ^{0}C in June and November.
- The average daily maximum temperature is projected to go up to as much as 41.3 ^{0}C in the month of May. This may be detrimental to various crop systems and natural ecosystems.

It was found by the study that:

- In the Kharif season, most northern districts are projected to have an increase in drought incidences by10-80%
- Districts of Koppal and Yadgir are projected to have almost a doubling of drought frequency in the Kharif season
- In the Rabi season, drought frequency is projected to increase in most of the eastern districts of the state.
- The western parts of the state are projected to have more rainfall and hence less number of droughts in the Rabi season.

The Study has Concluded that:

- The rainfall analysis IMD gridded data shows that there is a long-term negative trend of about 6% in precipitation over Karnataka for the period 1951-2004.
- The rainfall variability is very high in Chikballapur, Chitradurga, Gadag, Kolar, Mandya and Tumkur districts.
- There is considerable decrease in precipitation over the Coastal and North Interior Karnataka districts during the period 1951-2004.
- Annual mean minimum and maximum temperatures are highest in Raichur, Gulbarga and Yadgir districts of North Interior Karnataka.
- Bidar and Gulbarga districts indicate a larger inter-annual variability with respect to annual mean minimum and maximum temperature.
- A steady warming trend is observed in both the minimum and maximum temperature over Bijapur, Gulbarga and Raichur.
- Most of the areas in the state is projected to experience a warming of 1.8 to 2.2 ^{0}C
- The north-eastern and south-western parts of the state are projected to experience decrease in the quantum of rainfall, annually and during JJAS season.
- The OND rainfall is projected to decrease in the South-west part of the state (Bala et.al, 2011).

Possible Socio-Economic Impacts of Climate Change in Karnataka

Migration Problems

People from the high density rural areas will migrate to low density areas and to cities. The increasing concentration of people in urban areas may increase other risks of calamities like rare climate events causing pressures like heat stress, urban flooding, and urban drought causing immense pressures on infrastructure arrangements to be made. In brief, increase in population will increase vulnerability caused from climate change (Table 1).

Table 1: Population in different districts

Sl.No	Districts	1991 Census	2001 Census
1	Bangalore	4839162	6523110
2	Bangalore (R)	1673194	1877416
3	Chitradurga	1312717	1510227
4	Davanagere	1559222	1789693
5	Kolar	2216889	2523406
6	Shimoga	1452259	1639595
7	Tumkur	2305819	2579516
8	Belgaum	3583606	4207264
9	Bijapur	1533448	1808863
10	Bagalkot	1394542	1652232
11	Dharwad	1374895	1603794
12	Gadag	859042	971955
13	Haveri	1269213	1437860
14	Uttara Kannada	1220260	1353299
15	Bellary	1656000	2025242
16	Bidar	1255798	1501374
17	Gulbarga	2582169	3124858
18	Raichur	1351809	1648212
19	Koppal	958078	1193496
20	Chikmagalur	1017283	1139104
21	Dakshina Kannada	1633392	1896403

22	Udupi	1060872	1109494
23	Hassan	1569684	1721319
24	Kodagu	488455	545322
25	Mandya	1644374	1761718
26	Mysore	2281653	2624911
27	Chamarajanagar	883365	964275
STATE		**44977200**	**52733958**

Source: 1991, 2001 Census Data

Permanent migration is from densely settled areas to less denser areas. The major causes could be attributed to natural disasters which result in loss of land holdings, properties forcing them to relocate besides unfavorable social and economic conditions where livelihoods are insecure. Susceptibility to these implications is mostly due to lack of supportive infrastructure and employment to the poor. It is presumed that migration is likely to increase given the socio-economic impacts of climate change in the future. It is observed that the incidences of migration in northern Karnataka have increased. Coorg region in the South has encountered migration to a large extent because of coffee estates. Chamrajnagar and Kolar districts were also prone to large number of migrants traveling to Bangalore and Mysore. Similarly, farmers from Bijapur and Bagalkot traveled to Goa in search of livelihoods while farmers from Raichur travel to Bangalore as construction workers (Nagaraj, 2008). In families where the couple migrated, the children were left with the elderly to be taken care of making it difficult for them to cope with the physical and emotional pressures.

Implications for Agriculture and Food Security

Change in precipitation patterns will impact agricultural productivity and hence impact on food and livelihood security. A detailed study by O' Brien and others (2004), indicates the district level vulnerabilities where adaptive capacity was mapped as a component of biophysical, socioeconomic and technological factors and juxtaposed against a map of sensitivity to climate change indicating several districts with lower degrees of adaptive capacity in the interior regions of the country. Case studies at the community-level highlighted large discrepancies in adaptive capacity across villages, across communities in villages and specifically across individuals depending on land holding size, education etc. It was also observed that large farmers were able to benefit from government subsidies, formal bank credit, and crop insurance while smaller farmers were having less access to benefits caused due to lack of information and dependence on local merchants for credit.

Climate Change and Crop Productivity

Climate change is predicted to reduce yields of maize and sorghum by upto 50%. It is indicated that these crops being C4 photosynthetic systems, therefore do not have relative benefits at higher CO_2 concentrations. Similarly analysis of past weather conditions data across locations with respect to coconut growing regions in the Western Ghat areas and yield data have indicated warning trends in majority of the areas. The increase in maximum temperature varied from 0.01 to 0.04°C annually while the average minimum temperature showed a decreasing trend in many regions up to -0.03 to +0.03 annually. Dry spells showed an increasing trend in some regions in Karnataka. Change in dry spells varied from -1.98 to 0.27 days/year and change in coconut yields across the country ranged from -114 to 270 nuts/ha/year.

Livestock and Fodder Availability

Implications on livestock and fodder availability have been disastrous in many districts of Karnataka affecting the income of marginal communities and leading to distress sale of livestock. A study by Nagaratna (2009) on the consequences of the 2003 drought in Karnataka emphasizing on livestock and fodder have revealed interesting results. As 2003 drought was one of the severe droughts that occurred in Karnataka, the implications across the state indicated that the total coverage by all crops for the state as a whole was 56% of the normal and was not satisfactory for cereals, pulses and oilseeds. Similarly, the coverage was very less for cash crops, 34% of the normal. Chamarajnagar was a severely drought affected district while Gadag was moderately affected and Gulbarga less drought affected comparatively and the trends in their agricultural situation indicated it as well. All these three districts experienced meteorological, hydrological and agricultural droughts during all the seasons in 2003.

Identification of Livelihoods Support Base at the District Level:

For identifying proper interventions and the districts to be selected, livelihood support base was calculated on the basis of working population involved in various sectors. For this purpose, economic activities are divided into sectors of different orders depending on the extent of influence of climate change. For instance, rainfed agriculture is directly influenced by the amount and time of the rainfall, on the other hand, education sector influenced to lesser extent. Thus, it is possible to group various economic sectors on the basis of the extent of influence of climate has on the performance of these sectors. On such grouping is given below:

a) First Order

b) Second Order, and

c) Third Order sectors

First Order sectors are those whose performance is directly influenced by the climatic variations, such as Agriculture, Fisheries, Forestry, and Health. Second Order sectors are those susceptible to climatic conditions directly and indirectly as well, but certain measures could reduce the influence of climatic variations, for instance Mining, Construction, Household

Industries, Education, Transport, communication. Third Order sectors are represented by those sectors which are relatively independent to large extent of climatic variations such as Service Sector, industry and others. Further, it is possible to rank the districts of state on the basis of size of population dependent on that particular sector. This exercise would give us an idea about the percentage of district population vulnerable to climatic conditions. Census data of 1991 and 2001 was used to rank the vulnerability of districts.

1st Order Sectors

Primary economic activities such as agriculture, fishing activities, livestock rearing ect are directly influenced by the climatic factors and indirectly the size of population dependent on these sectors. Depending on the size of population engaged in 1st Order economic activities, districts were ranked and given in Table 2.

Table 2: Ranking of Districts According to Percentage of Dependent Population

	1991	2001	1991 Census		2001 Census	
District	Total Population	Total Population	1st Order (%)	Rank	1st Order (%)	Rank
Bagalkot	1,652,232	1651892	22.7	17	28.3	16
Bangalore	6,523,110	6537124	2.6	27	2.3	27
Bangalore(R)	1,877,416	1881514	23.5	15	29.3	13
Belgaum	4,207,264	4214505	22.4	19	30.7	11
Bellary	2,025,242	2027140	25.5	9	30.2	12
Bidar	1,501,374	1502373	23.3	16	23.2	20
Bijapur	1,808,86	1806918	25.1	11	27.9	17

	3					
Chamaraja Nagar	964,275	965462	28.1	3	32.9	7
Chikmagalur	1,139,104	1140905	22	20	22.5	22
Chitradurga	1,510,227	1517896	25.7	8	34.2	5
Dakshina Kannada	1,896,403	1897730	10	26	4.9	26
Davanagere	1,789,693	1790952	24.3	14	28.6	15
Dharwad	1,603,794	1604253	18	23	22.6	21
Gadag	971,955	971835	25.9	7	32.8	8
Gulbarga	3,124,858	3130922	24.9	12	28.9	14
Hassan	1,721,319	1721669	24.5	13	35	3
Haveri	1,437,860	1439116	27.2	4	34.4	4
Kodagu	545,322	548561	14.1	25	5.9	25
Kolar	2,523,406	2536069	25.4	10	31.2	10
Koppal	1,193,496	1196089	28.1	2	33.7	6
Mandya	1,761,718	1763705	28.2	1	35	2
Mysore	2,624,911	2641027	19.4	21	24.5	19
Raichur	1,648,212	1669762	26.7	6	32.1	9
Shimoga	1,639,595	1642545	22.6	18	26.9	18

Tumkur	2,579,516	2584711	26.9	5	35.4	1
Udupi	1,109,494	1112243	18.8	22	16.6	24
Uttara Kannada	1,353,299	1353644	16.5	24	16.8	23
State Average	52,733,958		20.7		24.8	

Details of ranks (given on the basis of percentage of population in select economic activities) show that the place of districts varied from 1991 to 2001. For instance, Tumkur which was having 5th position in terms of population in involved in 1st order activities has moved upwards to rank 1. In other words, size of population involved in first order activities has increased from 1991 to 2001. Similarly, Koppal district which was in second position as per 1991 Census has less population in 1st order sector in 2001 Census. To figure out probably reasons, in-depth studies are required to be undertaken.

2nd Order Sector

Economic activities such as construction, household activities are influenced by climate change, but impact are not severe as compared to the 1st Order activities. An effort was made to rank the districts on the basis of population involved in 2nd order activities. Details are given in Table 3.

Table 3: Ranking of Districts Dependent on the Population in 2nd Order Activities

	1991	2001	1991 Census		2001 Census	
District	Total Population	Total Population	2nd Order	Rank	2nd Order	Rank
Bagalkot	1,652,232	1651892	2.1	2	3.3	3
Bangalore	6,523,110	6537124	2.6	1	1.1	19
Bangalore(R)	1,877,416	1881514	1.6	14	2.3	5
Belgaum	4,207,264	4214505	1.7	7	1.6	12
Bellary	2,025,242	2027140	1.9	4	1.3	14

Bidar	1,501,374	1502373	1	25	0.9	23
Bijapur	1,808,863	1806918	1.2	23	1.2	16
Chamaraja Nagar	964,275	965462	1.6	11	2	6
Chikmagalur	1,139,104	1140905	1.3	20	1.1	20
Chitradurga	1,510,227	1517896	1.6	9	1.6	10
Dakshina Kannada	1,896,403	1897730	1.7	8	10.6	1
Davanagere	1,789,693	1790952	1.3	18	1.7	9
Dharwad	1,603,794	1604253	1.6	10	1.2	15
Gadag	971,955	971835	1.7	6	1.7	8
Gulbarga	3,124,858	3130922	1.6	13	1.1	18
Hassan	1,721,319	1721669	1	27	0.8	26
Haveri	1,437,860	1439116	1.2	22	1.9	7
Kodagu	545,322	548561	1.3	21	0.5	27
Kolar	2,523,406	2536069	1.5	16	1.6	11
Koppal	1,193,496	1196089	1.3	19	1.5	13
Mandya	1,761,718	1763705	1.2	24	1	21
Mysore	2,624,911	2641027	1.5	15	0.8	25
Raichur	1,648,212	1669762	1	26	0.9	24
Shimoga	1,639,595	1642545	1.4	17	1.1	17
Tumkur	2,579,516	2584711	1.6	12	2.4	4
Udupi	1,109,494	1112243	1.7	5	5.6	2
Uttara Kannada	1,353,299	1353644	2	3	1	22
State Average	52,733,958		1.6		1.8	

As in the case of 1st Order ranking, 2nd order ranks of districts are also varying over the time. Similarly, districts were ranked according to the 3rd Order activities and details are given in Table 4.

Table 4: Ranking of Districts Depending on Population in 3rd Order Sectors

	1991	2001	1991 Census		2001 Census	
District	Total Population	Total Population	3rd Order	Rank	3rd Order	Rank
Bagalkot	1,652,232	1651892	6.9	14	12	20
Bangalore	6,523,110	6537124	19.6	2	35.9	2
Bangalore(R)	1,877,416	1881514	7.1	13	15.9	10
Belgaum	4,207,264	4214505	7.3	11	12.3	19
Bellary	2,025,242	2027140	7.1	12	13.9	13
Bidar	1,501,374	1502373	6.4	17	13	17
Bijapur	1,808,863	1806918	5.1	26	10.7	26
Chamaraja Nagar	964,275	965462	6.1	21	11.5	23
Chikmagalur	1,139,104	1140905	6.6	16	21.7	5
Chitradurga	1,510,227	1517896	6	22	11.8	21
Dakshina Kannada	1,896,403	1897730	22.7	1	34.5	3
Davanagere	1,789,69	1790952	7.7	9	13.5	14

	3					
Dharwad	1,603,794	1604253	11.2	4	18.8	7
Gadag	971,955	971835	7.7	10	12.6	18
Gulbarga	3,124,858	3130922	6.1	20	13.1	16
Hassan	1,721,319	1721669	6.2	19	14.4	12
Haveri	1,437,860	1439116	5.9	23	10	27
Kodagu	545,322	548561	9.3	6	42.2	1
Kolar	2,523,406	2536069	6.8	15	15.9	9
Koppal	1,193,496	1196089	5	27	11.1	24
Mandya	1,761,718	1763705	5.7	24	11.7	22
Mysore	2,624,911	2641027	9.6	5	16.7	8
Raichur	1,648,212	1669762	5.6	25	11	25
Shimoga	1,639,595	1642545	8.3	8	15.5	11
Tumkur	2,579,516	2584711	6.2	18	13.1	15
Udupi	1,109,494	1112243	14.2	3	21.7	6
Uttara Kannada	1,353,299	1353644	8.9	7	25.1	4
State Average	52,733,958		9.3		17.9	

Observations

- Climate Change will have its negative impact primarily on the first order economic activities and Tumkur, Mandya, Hasan and Haveri with population percentages of 35.4, 35.2, 35, and 34.4 respectively would be negatively affected. On the other hand, Udupi, Kodagu, Dakishna Kanada and Bangalore districts are affected least as they have lowest percent of population dependent on the first order activities.

- With reference to Second Order Activities, it is again, Tumkur and Mandya districts are susceptible to climate change as they have 35.4% and 35% of working population is dependent on these sectors.

- Adaptation measures/ plans, thus, should focus on Tumkur, Mandya, Hasan, Haveri districts with focus on alternate/supplement activities in these districts.

Climate Change Vulnerability

At state level studies, High Power Committee (HPC) for Redressal of Regional Imbalances under the Chairmanship of Prof. D.M. Nanjundappa has considered 35 different indicators for classifying all the talukas and districts of Karnataka into backward, more backward and most backward. It can be seen from Table 5, that most of the backward talukas in the state are located in northern parts of the state. This indicates appropriate project interventions in the northern Karnataka regions on priority. Further it can be seen from Table-5 that a large proportion of talukas in Karnataka are most backward falling in Gulbarga division of the northern Karnataka.

Table 5: Regional Imbalances in Karnataka

Divisions	Most Backward	More Backward	Backward	Total
Gulbarga	21	5	2	28
Belgaum	5	12	14	31
Bangalore	11	13	9	33
Mysore	2	10	10	22
Total	39	40	35	114

However, HPC Report does consider indicators relevant to ‘development”, therefore, by considering climate change relevant parameters, vulnerability index at district levels was computed.

Measurement of Vulnerability based on Four Dimensions:

Vulnerability is often reflected in the state of the economic system as well as the socio-economic features of the population living in that system. By considering climate change relevant parameters, vulnerability index at district level was computed based on the following dimensions:

1. Demographic and Social
2. Occupational
3. Agricultural
4. Climatic

The index attempts to capture a comprehensive scale of vulnerability by including important indicators that serve as proxies.

Due to unavailability of data for all districts, the present report used data for 27 districts of Karnataka State. We have used data from Karnataka at a glace to calculate the composite vulnerability Index across the districts of Karnataka. Thus, computed Vulnerability Index of districts across the state is given in Table-6.

Table 6: District-wise Vulnerability Indices of Karnataka

District	Index of Demographic and Social Vulnerability	Rank	Index of Occupational Vulnerability	Rank	Index of Agricultural Vulnerability	Rank	Index of Climatic variability	Rank	Composite Index	Rank of Composite Index
Gulbarga	0.5780	2	0.5467	7	0.7169	1	0.7897	2	0.6578	1
Raichur	0.6616	1	0.5928	1	0.5698	7	0.6959	4	0.6300	2
Bijapur	0.4350	12	0.5472	6	0.5174	14	0.9294	1	0.6072	3
Chitradurga	0.4877	7	0.4938	14	0.5219	13	0.6908	5	0.5486	4
Tumkur	0.3580	18	0.4663	18	0.6143	3	0.7150	3	0.5384	5
Bellary	0.5483	4	0.4520	21	0.5122	17	0.6303	6	0.5357	6
Kolar	0.4404	10	0.4959	13	0.5713	6	0.5103	7	0.5045	7
Koppal	0.5567	3	0.5719	4	0.4160	23	0.3333	9	0.4695	8
Bidar	0.5255	5	0.5345	8	0.5164	15	0.2090	15	0.4463	9
Haveri	0.4434	9	0.5275	9	0.5238	12	0.1979	16	0.4232	10
Bagalkot	0.4523	8	0.5065	12	0.4033	24	0.3091	11	0.4178	11
Chikmagalur	0.3732	16	0.3820	23	0.5831	5	0.3284	10	0.4167	12

Mysore	0.4321	13	0.5072	11	0.4603	19	0.2382	14	0.4095	13
Chamaraja nagar	0.5089	6	0.5883	2	0.4293	22	0.1111	26	0.4094	14
Uttara kannada	0.2858	24	0.5563	5	0.6492	2	0.1199	25	0.4028	15
Mandya	0.2963	23	0.5849	3	0.4427	20	0.2777	13	0.4004	16
Hassan	0.3324	20	0.4748	17	0.5914	4	0.1751	19	0.3934	17
Davanagere	0.4390	11	0.4917	15	0.5008	18	0.1244	22	0.3890	18
Belgaum	0.4040	14	0.4650	19	0.5276	11	0.1206	24	0.3793	19
Shimoga	0.2993	22	0.4798	16	0.5439	9	0.1869	18	0.3775	20
Bangalore(r)	0.3345	19	0.4561	20	0.5597	8	0.1383	21	0.3722	21
Dharwad	0.3157	21	0.3774	24	0.3880	25	0.4067	8	0.3720	22
Gadag	0.3606	18	0.4374	22	0.3652	27	0.2789	12	0.3605	23
Udupi	0.2592	27	0.5103	10	0.5320	10	0.1207	23	0.3555	24
Bangalore	0.3861	15	0.1694	25	0.3723	26	0.1891	17	0.2793	25
Kodagu	0.2818	25	0.0799	27	0.5156	16	0.1207	23	0.2495	26
Dakshina kannada	0.2654	26	0.1250	26	0.4378	21	0.1553	21	0.2459	27

Table-6 shows the value of the vulnerability index across the districts of Karnataka. In the table rank 1 shows maximum vulnerable district and the vulnerability decreases as we go on increasing the rank. In Karnataka, Gulbarga district is the most vulnerable district when we calculate the composite index of a few important indicators such as demographic and social, occupational, agricultural and climatic indicators. According to the composite vulnerability index, Dakhina Kannada is the least vulnerable district of Karnataka.

After developing Composite District Level Vulnerability Index, for identification of suitable interventions at district level and sector wise, dependent population in various economic sectors was considered.

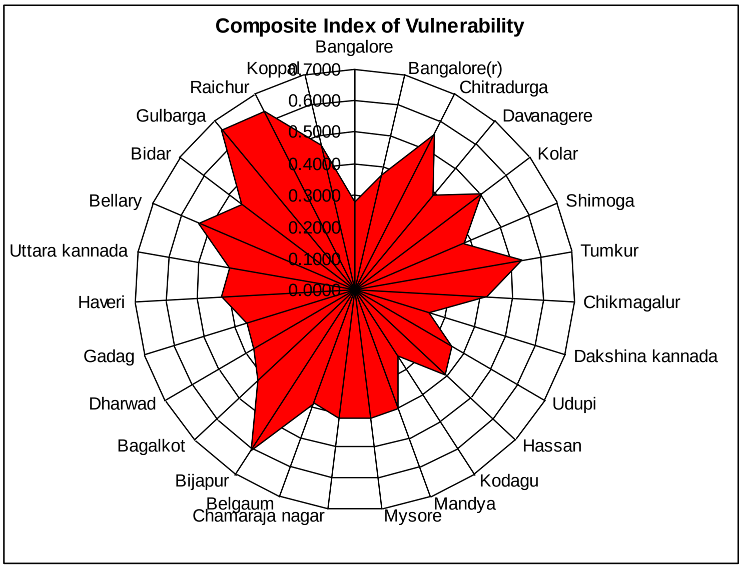

Fig 1: Composite index of Vulnerability across Districts of Karnataka

Adaptability/Coping Mechanisms to Vulnerability

Local communities at the Micro level/ecosystem level adopt/cope up with the changing climate conditions. This adaptability/coping mechanisms again are both external and internal. External in terms of government/NGO programmes/schemes, and internal in terms of their strategies, like change in cropping pattern, species composition of livestock, migration, wage labour, etc. In the process, some may be better off, some may remain same, and some may be worse off (detailed studies are required in these areas). The degree differs/varies depending upon the socio-economic background of the households in question.

Chapter 7

Mitigation options in energy sector

Centre for Study of Science, Technology and Policy (CSTEP)

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Mitigation Options in Energy Sector

Introduction

Today the total annual emissions from Karnataka are around 80 million tons of CO2 eq[1]. Emissions from LULUCF constitute a negligible amount of net emissions[2] and hence are ignored. In order to project future emissions, one needs to project energy required, future technology developments and the fuel mix. An estimate of elasticity of GDP of that sector is needed to project production or growth of any sector. However, estimating the elasticity to use in such a projection is difficult, as future elasticity trends would depend on several macro-economic factors such as relative fuel prices, technology advancement, development priorities of the state, structural shift in the state's economy, etc. In this section all projections have been undertaken limited up to the year 2020-21 as it is difficult to project technology developments further into the future.

Projecting forward to 2020-21, assuming the gross state domestic product (GSDP) was to grow at 8% annually in line with the country; the total emissions could reach to over 244 million tons of CO_2 eq. in the business-as-usual case. However, this can be reduced by adopting GHG mitigation strategies. By increased use of energy efficient appliances, adopting energy efficient measures in manufacturing, and by introducing greater percentage of energy generated from renewable energy, the GHG emissions level can come down in the future.

India currently has policy, regulatory and legislative structure towards GHG mitigation in place. The integrated energy policy was adopted in 2006, followed by the National Action Plan for Climate Change (NAPCC), announced in 2008. Two of the core missions announced as part of the NAPCC, are the National Mission for Enhanced Energy Efficiency (NMEEE) and the National Solar Mission (NSM). These plans can help direct Karnataka to reduce the future energy demand and to improve the fuel mix. These policies in turn can help to reduce the GHG emissions substantially. Some of the key technology options that will help mitigate GHG emissions along with the current plans of the government of Karnataka are discussed below.

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[1] Section on GHG Inventory of Karnataka

[2] Per 2004 NATCOM report this is true for India, and we assume the same for Karnataka

Power Sector

Hydro electricity in 2010 constituted about 27% of the total energy mix in the state, while coal accounted for 58%[3]. For comparison, hydro makes up 15% and coal accounts for 72% of the national generation. However, in determining the future energy mix for the state of Karnataka, one needs to consider resource limitations, cost of generation, and other social and political constraints. Going forward, the percentage of these renewable sources in the total energy mix is unlikely to increase given the severity of the constraints.

As of January 2010, the total installed capacity of utilities, including allocated shares in joint and central sectors, and captive generation was around 11,459 Mega Watts (MW)[4] . In the period 2009-10, the net generation after considering auxiliary consumption was around 47 billion kWh and the associated CO_2 emissions were 28.7 million tons. As of January 2010, the peak power deficit was 22.8% and the energy deficit was 13%[5]. If the generation for this period were 50 billion kWh the state would have been able to meet its electricity demand. If this were projected using an elasticity of 0.95[6] (assuming a GSDP growth rate of 8% for Karnataka), the electricity demand required in 2020-21 would be 112 billion kWh in the business as usual case. However, by adhering to strict energy efficient programmes and adopting DSM options, the demand could be reduced by 10-15% or to 95 to 100 billion kWh by 2020-21.

Energy Efficiency and Demand Side Management

Promoting energy efficiency (EE) and demand side management (DSM) can help rain in the growth of demand of electricity. This would imply a reduced demand in the future and thus a reduced carbon footprint for the state. Several EE measures are cheaper to implement on a life cycle basis and should be considered as means of reducing the demand. The Bureau of Energy Efficiency (BEE) under the NMEEE has several programmes to encourage reduced consumption of energy in buildings, industry and irrigation.

Transmission loss in Karnataka is 4.2% in 2009-10 which is on par with international standards. In 2008-09, the average distribution losses, including both technical and commercial losses, were 20%[7].The technical losses are marginal in cities, while being very high in the rural areas with 11 KV feeder lines running long distances. Re-engineering of these feeder lines and

[3] Ministry of Power, Annual Report 2010
[4] Ministry of Power, Annual Report 2010
[5] Government of Karnataka, Department of Energy
[6] Integrated Energy Policy, 2006
[7] KPTCL

LT lines in the state would help reduce technical losses. The first step to achieve this would be to carry out the energy audit of the distribution system to segregate and pinpoint the commercial and technical losses. Having identified these causes, the DISCOM must analyze the same and further develop them in the form of several DPRs (detailed project reports). Finally, a list of projects showing gestation period, investment, and benefits must be listed so that the projects can be prioritized[8].

The increased use of energy efficient lighting such as compact fluorescent lamps (CFL) and Light Emitting Diodes (LED) has large potential in bringing down the total consumption of electricity due to lighting in buildings – residential and commercial. Under the 'Belaku scheme' in Karnataka (the national 'Bachat Lamp Yojana'), the power utility in exchange for incandescent bulbs will provide 4 CFLs at a subsidized rate of Rs 15 each to every household. Similarly, the use of energy efficient five star labeled appliances such as air-conditioners and refrigerators have enormous potential to reduce energy consumption. Bangalore Electricity Supply Company's (BESCOM) success of shaving off morning peak load by incentivizing the use of solar water heaters should be replicated in other parts of the state. Public and commercial buildings should be mandated to install solar water heaters.

In the agricultural sector, most irrigation pumps in Karnataka are grid connected and hence diesel based pumps are rare. As grid power is heavily subsidized, the farmers do not have any incentive to switch to efficient pump sets (The majority of the pump sets in operation operate at an average efficiency of around 30%). Hence, most of the irrigation pumps are highly inefficient and are massive consumers of power. Better load management, and reducing water consumption along with replacement of the existing pumps with efficient pumps can result in very large savings in this sector. However, due to political repercussions this is difficult and requires strong political will.

Clean Coal Technologies

Coal will remain the mainstay for electricity generation for the immediate future. Moreover, at present coal is one of the lowest cost options and will continue to be so for a large percentage of total generation by 2020 as well. To meet the projected demand of the state the coal based generation might have to increase considerably in capacity by 2020. Today all the coal based plants in the state of Karnataka as well as in the country are based on sub-critical technology

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[8] Change Management in Power Distribution, Distribution Reform, Upgrades and Management (DRUM) Training Program, Report prepared by USAID for Ministry of Power

with an average specific CO_2 emission of about 1.1 kg per net kWh. However, the new 500 MW sub-critical plants will have a lower specific emission of 0.93 kg per net kWh[9,10].

To reduce the specific emissions from coal based generation, the combustion efficiency can be improved by the use of super-critical technology. The plants based on this technology operate at higher temperature and pressure than the sub-critical ones leading to lower specific emission of 0.83 kg per net kWh. This technology is available and costs almost the same as sub-critical technology. NTPC has plans to set up five 800 MW of supercritical plants in Bijapur district[11]. However, it is not clear how much of this plan will be realized.

Natural Gas generation

Gas based power plants have low capital cost (around Rs 2.7 crores/ MW), even lower than coal based generation, and have a much lower specific emission of 0.42 kg per net kWh and hence an attractive option. However, the availability of gas is a concern. Gas Authority of India Limited (GAIL) is planning a 746 km of gas pipeline from Dabul in Maharashtra to Bangalore via Belgaum, Gadag, Davanagere and Tumkur in Karnataka. This will help setting up gas based power plants along route of the pipeline. There are two combined cycle power plants planned in Bidadi and Tadadi of 1400 MW and 2100 MW[11] respectively.

Hydro Power

Karnataka is endowed with a large hydro potential of about 7,750 MW[11]. However, the installed capacity of large and small hydro together is only around 3,763 MW today. Full exploitation of hydel potential is difficult due to environmental concerns, people displacement problems and inter-state water disputes. At present, a 400 MW hydel scheme in Hassan district and a 345 MW seasonable scheme at Shivasamudram are awaiting environmental clearance from the Ministry of Environment and Forestry (MoEF). Hence, going forward, mini and pico hydel projects are more likely to come up than large projects. Though generation of hydro power is carbon free, the environmental impact of large hydro plants also has to be taken into consideration.

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[9] Discussion with NTPC
[10] *Future of Coal*, Massachusetts Institute of Technology, 2007.
[11] Government of Karnataka, Planning Programme Monitoring and Statistics Department. http://www.planning.kar.nic.in/sites/planning.kar.nic.in/files/AnnualPlan2011-12/vol-I/10%20-%20Chapter10-F_199-218_.pdf

Biomass

Biomass cogeneration in sugar mills is a promising option in Karnataka, as about 165,000 tons of sugar cane is crushed daily in the state[12]. At present, 623 MW of biomass based power plants are in operation. A large percentage of this is perhaps based on sugar cane bagasse. In addition, the state has accorded permission to 54 new and old sugar factories to establish co-generation and up to 600 MW is expected to be exported to the grid from these after captive usage[34]. Biomass based power is considered carbon neutral and hence no CO_2 emissions is attributed due to this.

Solar and Wind

Karnataka Power Corporation Limited (KPCL) has set up three 3 MW solar photovoltaic plants. Plans are underway for more, making Karnataka an early mover into the utility scale solar PV based power generation. Most parts of Karnataka are reasonably endowed with global radiation suitable for large scale adoption of solar PV. The northern part is said to have sufficient direct normal irradiance (DNI) that is necessary for concentrated solar thermal power (CSP) generation. Given this and the impetus provided by the National Solar Mission, solar energy can play a large role in the power generation of the state. However, the current impediment of solar technology is its high cost Again, careful planning, implementation and continuous servicing and maintenance of these plants will lead to successful generation of electricity from these technologies. The state could also consider incentivizing roof top PV systems to abate the usage of diesel in urban buildings.

About 15% of the total capacity and 6% of the total electricity generation in the state is from wind power. With an installed capacity of 1448 MW of wind, Karnataka has the fourth largest installed capacity in the country after Tamil Nadu, Maharashtra and Gujarat. The theoretical installable potential for Karnataka is very high around 8,600 MW[13], however it is unclear how much of this will be realizable.

Nuclear Power

The Nuclear power plant at Kaiga has 4 units of 220 MWs each (Pressurized Heavy Water Reactors technology). Three of these were recently commissioned. There is a proposal to

[12] Government of Karnataka, Planning Programme Monitoring and Statistics Department. http://www.planning.kar.nic.in/sites/planning.kar.nic.in/files/AnnualPlan2011-12/vol-I/10%20-%20Chapter10-F_199-218_.pdf

[13] Centre for Wind Energy Technologies; http://www.cwet.tn.nic.in/html/departments_wra.html

expand the generating capacity by adding one more unit of 500 MW in the near future. Overall, nuclear power can contribute up to 1380 MW by 2020 if pursued diligently. Generation of electricity from nuclear power plants is almost carbon free and hence the emission from this is considered to be zero.

Conclusion

The table below gives the current and possible energy mix in 2020-21, in the business as usual case. It has been assumed that almost all of the planned coal based power plants will be commissioned while some may not be fully realized. As per discussions above, Karnataka has been a forerunner in exploiting several of the low carbon renewable resources and it has a high percentage of renewable energy in its total mix. However, going forward, it is unlikely for the energy mix to have such a high percentage from carbon-free sources due to the constraints discussed above. Perhaps if prices were to come close to grid parity, solar energy may play a bigger role. However, it is doubtful if it can contribute to more than 2-3% of the generation by 2020. Beyond 2020 one can perhaps believe that solar might be able to scale up and efficient coal technologies might be the order of the day. However, coal is likely to dominate the energy mix for the foreseeable future. The CO_2 emissions in 2020-21 would be around 84 million tons in the business as usual case, extrapolating from the current level of 29 million tons. The adoption of DSM measures can reduce this by 15% to 71 million tons. There is scope for further reduction by shifting to more carbon friendly sources.

Table 2.1 / Karnataka: Power Sector – Current and Projected				
	2010		2020 Business as usual scenario	
	Total installed Capacity (MW)	Net Generation (Billion kWh)	Total installed Capacity (MW)	Net Generation (Billion kWh)
Coal Sub-critical	3,903	23.59	12,600	81.24
Coal-supercritical	-	-	400	2.58
Gas	220	0.84	440	1.87
Diesel	333	1.28	460	1.96
Nuclear (PHWR)	195	0.62	880	5.55
Hydro + Small hydro	3,763	11.44	4,200	12.77
Wind	1,448	2.49	2,000	3.43
Biomass + Cogeneration	623	2.03	800	2.61
Solar	10	0.02	100	0.16
Captive Generation	1,000	2.01	-	-
Total (Utility + Non Utility)	11,495	44	21,880	112
CO2 emission (million tons)		29		84

Transportation

The transportation sector is a large emitter of CO2 and its share of GHG emissions have been consistently increasing. India imports 80% of its petroleum requirements, and a significant percentage of this is used for transportation. In Karnataka, the emissions due to transportation were 8.35 million tons in the year 2007-08. At a state GDP growth rate of 8%, assuming an elasticity of 1, the emissions due to this sector is likely to be 23 million tons.

To lower emissions in this sector, efficient modes and technologies must be used, while inefficient ones should be discouraged through policy or fiscal instruments. Some of the following measures will help the state reduce emissions along with improving the overall infrastructure of the state as well.

- Rail freight is considerably more energy and carbon efficient than road freight. The falling trend in the rail freight and the gain in share of the road freight should be reversed.
- Increase the share of public transportation in the cities – increased buses, metro.
- Bicycle lanes should be made available where possible in all the cities.

- Minimum efficiency standard for the country's vehicle fleet should be defined. Fuel efficiency should be improved by imposing periodically tightening fleet efficiency, with mechanisms to penalize non-conformance. The state government should work with the BEE to establish these standards.
- The hybrid electric vehicle combines the internal combustion engine (ICE) with anelectric propulsion system. The electric vehicle's 'tank to wheel' efficiency is higher by a factor of three as compared to a conventional IC engine vehicle.
- The state government has set up a task force with the objective to prepare a road map for the GoK to make transition towards Electric/Hybrid public transportation. It is intended to develop a few prototypes to run within Bangalore and in a few select inter-city corridors in the state in the upcoming year. If the state were to transition into low-carbon public transportation system, it will be a great achievement and should be pursued.
- Use of bio-fuels could potentially lead to net zero carbon emissions on a life cycle basis. Recent reports suggest that the state government is considering this as an option. However, we caution large scale thrust to bio-fuels because of the concerns of food security and inflation.

Industries

In the industrial sector, cement, iron & steel, aluminium, textile and paper are some of the most energy intensive manufacturing industries. While the large plants are generally very efficient, efficiency often reaching the global best standards, the small and medium scale plants are often not so. The government of India's Perform Achieve and Trade (PAT) scheme is a market based mechanism to optimize energy efficiency in industries. This mechanism allows plants to trade energy efficiency certificates in the market.

Karnataka ranks seventh in the production of cement in the country with an annual production of 12.1 million tons[14] of cement which emits 7.6 million tons[15] of CO_2. The state is also the third largest steel producer in India with an annual production of 10.7 million tons[16]. In Karnataka these two industries account for over 20% of the overall emissions of the state and over 40% of the emissions from the industrial sector. Future consumption, of cement and iron & steel needed, to sustain economic growth of the economy can be projected using elasticity of these

[14] Directorate of Economics and Statistics, Government of Karnataka
[15] Cement Manufacturers Association and MoEF – Assumptions -0.537 t CO2/t Clinker produced and production of clinker uses 85% of total energy used in cement manufacturer.
[16] Karnataka advantage, steel sector ; http://www.advantageKarnataka.com/pdf/steel.pdf

resources in GDP growth. These elasticities have been assumed to be a little over 1. The emissions in 2020-21 are likely to increase to 47 million tons from 16 million tons for the year 2008-09.

- Most industries consume thermal and electrical energy. It is the requirement of thermal energy that can be reduced by adopting energy efficient practices.
- In the case of cement sector, adding fly ash and slag to clinker would reduce the carbon footprint considerably.
- Use of natural gas based DRI steel making process where possible as this has approximately 40% less CO2 emissions compared to a basic oxide (BOF) process[17].
- The use of solar thermal technologies for process heat applications can reduce the fossil fuel usage in industrial applications.

Residential

Currently biomass is the mainstay as a cooking fuel in a large percentage of rural households. This results in deforestation and GHG emissions. Over 75% of the households in India use biomass. While biomass is considered carbon neutral, its CH_4 and N_2O emissions are taken into account. Extending the supply of LPG to all households can have positive environmental impact and will help alleviate indoor air pollution related health problems.

[17] *Options for the Swedish steel industry – Energy efficiency measures and fuel conversation*, Linkoping University Post press

TABLE 2.2 / EAST OF IMPLEMENTATION*

		MODERATELY CHALLENGING	CHALLENGING	VERY CHALLENGING
COST	**NEGATIVE**	• Energy efficient appliances • Energy efficiency equipment • Solar water heaters in residential, public and private buildings • Mileage standard in automobiles	• Energy efficiency in iron & steel industry.	• Clinker substitute by fly-ash and slag in cement • LED lighting • Efficient cook stoves • Efficient irrigation pumps in agriculture
	MODEST	• Small hydro • Wind • Solar thermal applications for industrial heat, agricultural drying, water heating. • Supercritical technology • Nuclear	• Reduction in T&D losses • Building efficiency	• Efficiency from other sectors
	HIGH	• Solar photovoltaic for electricity generation • Public bus-based transportation systems • Shift to freight by rail	• CSP • Shift to gas based (direct reduced iron) DRI in steel manufacturing	• Large hydro • Large scale deployment of CSP • Ultra supercritical coal technology

* Ease of Implementation based on financing issues, regulating support, agency issues, entrenched behaviour, supply constraints & technological readiness.
Sources: McKinsey Report on Environment and Energy Sustainability and CSTEP's analysis.

Cost of Mitigation

The investments required for abatement and cost per ton of saved CO2 should be ideally obtained by undertaking a life cycle analysis of each option. However, due to lack of data this has not been done here. The economics of abatement option has been done to a reasonable accuracy. However, in this phase of the report we have not been able to look at the economics of mitigation of other sectors and options, in particular transportation and industry. It is because these entail more complex analysis and data availability curtailed from this analysis.

For some of the abatement options such as in the power sector, the approximate capital investment was known and this was used (cost of operations and maintenance was ignored) to compute the cost of abatement. This analysis is given in table 2.3. The abatement choices are compared with subcritical coal technology. The changeover to natural gas for generation of electricity has a negative cost for abatement since the capital cost here is lower than that of sub-critical technology. Here for the sake of analysis, it is assumed that all the planned supercritical and gas based plants are built.

In the case of compact fluorescent light (CFL) life cycle analysis, the switch to CFL from the incandescent lamp would result in the savings of Rs 4,400 per ton of CO_2 avoided. In the state of Karnataka, assuming that on average each urban household is given 2 CFLs, the total investments today would be Rs 176 crores[18]. However, the total amount saved due to reduced electricity cost would be Rs 949 crores. However, a note of caution here is that the CFL lamps contain mercury and hence proper disposal should be designed for the same. Light Emitting Diodes (LED) have a negative abatement cost as well. However, this is not yet commercially viable.

Table 2.3 / Karnataka: Mitigation Options for Power Section

Option	Total New Capacity between 2010-2020 (MW)	Net Generation (Billion kWh)	Cost Rs(crores)/ MW	Total Investments (crores)	CO_2 savings vs. sub-critical (kg/kWh)	CO_2 Annual Savings (Million Tons)
Sub critical	-	-	4.5	-	-	-
Super critical*	4,000	25.79	4.7	18,800	0.10	2.58
Gas*	3,500	14.90	2.7	9,450	0.48	7.15
Nuclear	685	4.32	7.0	4,792	0.93	4.02
Wind	552	0.95	9.0	4,968	0.93	0.88
Solar	177	0.30	14	2,478	0.93	0.28

* Under the assumption that all the super-critical and gas based plants under plans are built by 2020.

Assumptions in computing net generation

1. Plant load factors (PLF) for 2020: Coal 80%, gas and diesel 55%. Nuclear 80%, hydro 35 %, wind 17%, solar 20%, biomass and others 40%, Non utility (40%)
2. Auxiliary power consumption: coal 8%, nuclear 10.5%, gas and diesel 3.1%, hydro 0.5%, wind 2%, solar photovoltaic 1 %, concentrated solar thermal power 7%, biomass and others 7%, non utility (3%)
3. Specific emission of the total current fleet of coal and lignite power plants is 1.1 kg of CO2 per net kWh. Based on CEA data (Central Electricity Authority, Co2 baseline database, version 5 and November 2009).

[18] Other assumptions: 15 W CFL to replace 75 W incandescent lamp. Emission factor of 0.8 kg/kWh is employed for CO_2. Unit cost of electricity assumed is Rs 3.5/kWh.

4. For the new 500 MW sub critical power plants , net heat rate is 2450 Kcal/Kwh leading to a specific emission of 0.93 kg of CO_2 per net kWh (Discussion with NTPC and Future of Coal MIT report).For the super critical plants we have assumed a net heat rate of 2235 kCal per kWh leading to a specific emission of 0.83 kg of CO_2 per net kWh (Discussions with NTPC and Future of Coal, MIT report)
5. Non Utility CO_2 emissions are mainly based on diesel. Specific CO_2 emissions of 0.67 kg/kWh Net.