Department
for International
Development

July, 2017

Current Climate Variability Assessment, Climate Change Projections and Identification of "**Climate Hotspot Blocks**" for ICRG Blocks Under MGNREGA

Infrastructure for Climate Resilient Growth in India (ICRG) Programme

IPE GLOBAL
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Submitted By:

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1. INTRODUCTION

Climate change is one of the most important global environmental challenges facing humanity. Climate change, driven by the increasing concentration of greenhouse gases (GHG), is projected to impact natural ecosystems and socio-economic systems. According to IPCC (2014), climate change is already occurring and impacting natural ecosystems and socio-economic systems such as food production. India, is already experiencing a significant level of warming and changes in the rainfall pattern accompanied by increasing rainfall variability. The agriculture sector and farming communities are already experiencing higher levels of climate variability and extreme events (e.g., droughts and floods).

The Paris Agreement aims at "Enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change". Further, the Agreement highlights "The current need for adaptation is significant", and "the need for assessment of climate change impacts and vulnerability" and "Building resilience of socio-economic and ecological systems". India's INDC also aims "To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture and water resources and in regions such as the Himalayas and the coastal regions".

The vulnerability of developing countries to potential impacts of climate change and the need for adaptation is thus rapidly emerging as the central issue in the debate around policy responses to climate change. There is also a need for combining disaster reduction, natural resource management and climate change adaptation in a new approach to reduce vulnerability and enhance resilience to climate risks. Given the inherent costs involved, adaptation should be pursued not as an end but as a means to meet the development objectives of the countries. India has been implementing a large number of developmental programmes and projects as part of national economic development goals largely with domestic funding and limited bilateral and multilateral sources, which may have to be climate proofed. One such major developmental programme is the MGNREGA.

Climate change projections for India indicate that different parts of India will experience different levels of warming as well as changes in rainfall pattern. **A good understanding of the historical climate trends, current climate variability and climate change projections is very critical for identifying the most vulnerable regions, cropping systems, communities, etc., and to prioritize and implement adaptation / resilience measures.** This study aims at assessing the trends in observed climate, current climate variability and make climate change projections for the selected 100 blocks under the ICRG programme. The specific objectives as detailed in the proposal are:

1. Based on the IMD historical climate data, conduct climate trend analysis for monsoon seasonal rainfall, temperature changes and droughts at block level;
2. Conduct current climate variability analysis and a trend analysis of monsoon season rainfall at block level;
3. Make climate change projections at block level for 2030s and 2050s; maximum and minimum temperature, monsoon seasonal rainfall, monthly rainfall and droughts;

4. Rank and prioritize the 100 blocks to **identify the "Hotspots" of current climate variability and future climate change** according to:
    - Current monsoon season rainfall variability;
    - Projected monsoon season rainfall and its variability;
    - Occurrence of droughts.

2. METHODOLOGY

2.1. Study Area

The study is being conducted in the three states of Bihar, Chhattisgarh and Odisha, covering the 100+ blocks, identified under the DFID Infrastructure for Climate Resilient Growth in India (ICRG) Programme. The blocks selected under the ICRG program are presented in **Figure 2.1**.

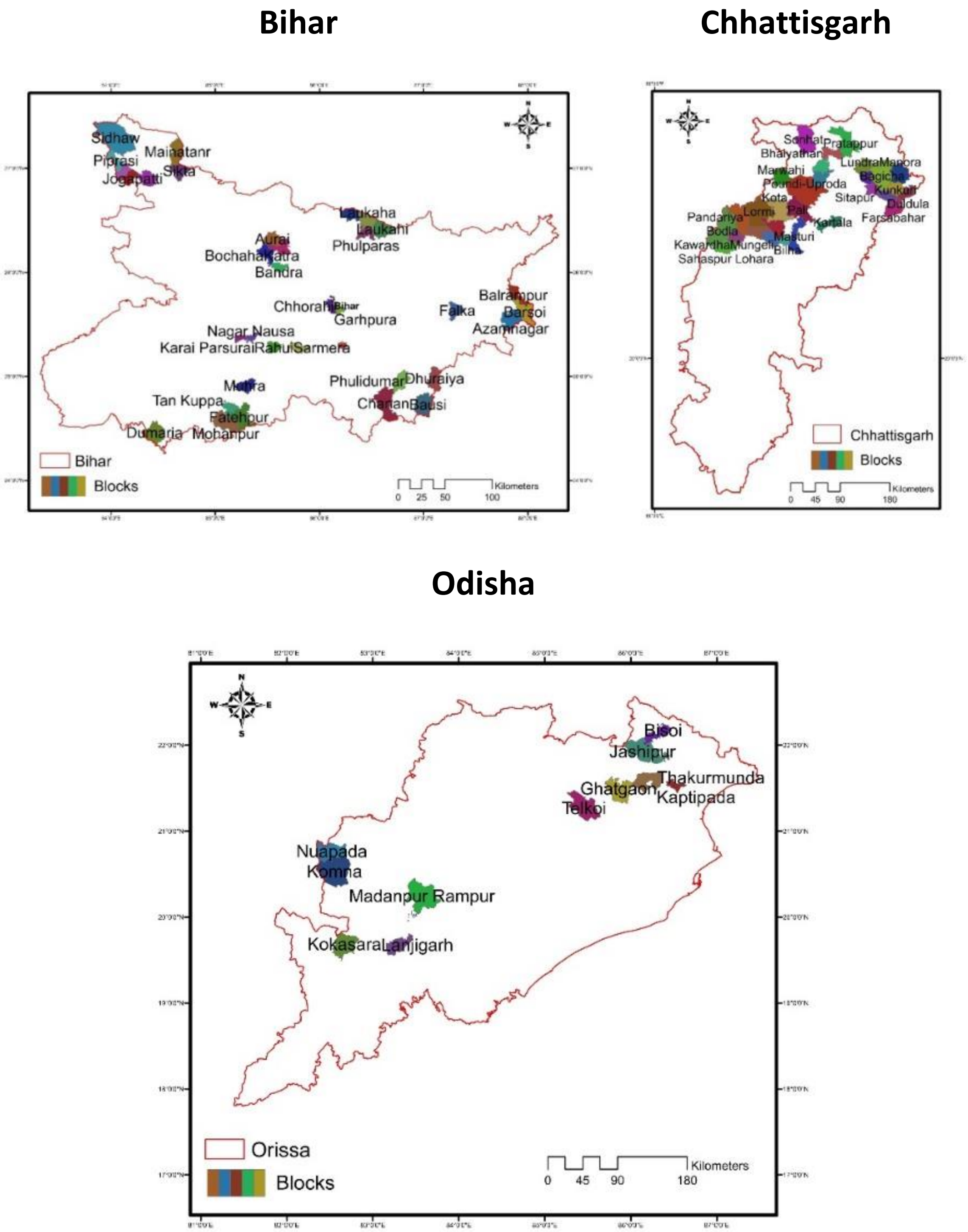

Figure 2.1: Study area; States and blocks included in the ICRG project

2.2. Approach and Steps Adopted for Rainfall and Temperature Trend Analysis for Past 30-Years (1984 to 2014)

The procedure adopted for historical climate analysis is presented in Table 2.1. Daily gridded rainfall dataset of 0.25° latitude x 0.25° longitude provided by Indian Meteorological Department (IMD) for the India region for the 30-year period of 1984– 2014, for precipitation (Pai et al. 2014), and 1.0°x1.0° latitude and longitude gridded daily temperature data, spanning over 30 years (1984-2014) for maximum and minimum temperature (Rajeevan et al. 2006), has been used to calculate the variability and trend in precipitation and temperature respectively. Rainfall variability is assessed only for the critical southwest monsoon (rainy) season and temperature is assessed only for the summer season for heat stress. For assessing the temperature variability block-wise data was obtained by re-gridding the temperature dataset to 0.2°x0.2°, and re-aggregating by the districts to study the maximum and minimum temperature variability at block level.

Table 2.1: Steps and approach to historical climate trend analysis

STEP 1	Selection of blocks	– Blocks identified under the DFID – ICRG programme
STEP 2	Access the IMD historical data for the past 30 years at block level	– Mean monthly temperature, max-min temperature, and daily rainfall
STEP 3	Conduct analysis of trends in climate parameters at block level	– Trends in Mean Monthly Max and Min temperature – Trends in Monsoon Season rainfall – Monsoon rainfall variability – Trends in occurrence of high intensity rainfall events – Trends in frequency of droughts

2.3. Approach and Steps for Climate Change Projections

The CORDEX South Asia modeled data on precipitation, maximum temperature and minimum temperature have been analyzed for 100 blocks. The details of data used for historical/observed and climate change analysis for 100 blocks is given in Table 2.2.

Table 2.2: Meta data of climate variability and climate change projection data used for 100 blocks

Variable	Data source	Period	Grid resolution (°)
Observed maximum temperature and precipitation	IMD, Pune (http://imd.gov.in/)	1984-2014	1° x 1°*(temp)* 0.25° x 0.25 *(rainfall)*
Projected maximum temperature and projected precipitation	CORDEX South Asia, IITM Pune (RCP 8.5) RCM - SMHI-RCA4 (Rossby Centre regional atmospheric model V.4, Swedish Meteorological and Hydrological Institute	2021-2050	0.5° x 0.5°

Daily data for the study blocks have been used for rainfall intensity analysis. Climate change projections on precipitation, maximum temperature and minimum temperature have been assessed. Grid-resolution for the climate projection is 0.5°x0.5°. The ensemble mean of 5 RCM models for precipitation, maximum temperature, and minimum temperature data has been analyzed for RCP 8.5 scenario, which is more likely.

PART - 1

Historical Climate Trends in the ICRG Blocks of Bihar, Chhattisgarh and Odisha

Climate in a narrow sense is defined as average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to hundreds of years. The relevant climate parameters include temperature, rainfall and wind. Climate variability refers to variations in the mean state of temperature, monthly or seasonal rainfall, etc. and other statistics such as standard deviations, statistics of extremes, etc. of the climate on a temporal and spatial scale, beyond that of individual weather events.

3. HISTORICAL CLIMATE: TRENDS AND EXTREMES

In this section, the historical trends in temperature and rainfall across the ICRG blocks in the three states of Bihar, Chhattisgarh and Odisha for the 30-year period of 1984-2014 is presented.

3.1. Temperature Trends during the Historical Period (1984-2014)

In this section, temperature analysis has been carried out for the March to May period (summer), since this is the period when heat stress events are likely to occur. Analysis of the IMD (Indian Meteorological Department) temperature data shows the following:

- In Bihar, mean summer maximum temperature for the selected ICRG blocks varied from 32.1 ^{O}C to 36.6 ^{O}C, whereas the mean summer minimum temperature varied from 14.9 ^{O}C to 18.2 ^{O}C.
- In Chhattisgarh, the mean summer maximum temperature in the ICRG blocks varied from 36.5 ^{O}C- 37.2 ^{O}C and mean summer minimum temperature varied from 17 ^{O}C - 19.8 ^{O}C.
- In Odisha, the mean summer maximum temperature for selected ICRG blocks varied from 35 ^{O}C to 37 ^{O}C and the mean summer minimum temperature varied from 20.12 ^{O}C - 23.13 ^{O}C.

3.1.1. Distribution of Blocks According to Mean Maximum and Minimum Temperature During Summer Months

In this section, the distribution of blocks according to maximum and minimum temperature during the summer months of March, April and May (MAM) is presented.

Bihar (Figure 3.1)

- Mean maximum summer temperature in the ICRG blocks of Bihar ranged from 32.1 ^{O}C to 36.6 ^{O}C during the historical period of 1984-2014.
- Sikta block recorded the highest mean maximum summer temperature (36.6 ^{O}C) during the historical period.
- In almost 50% (17 out of 35) of the ICRG blocks, mean maximum summer temperature recorded during the historical period was >35 ^{O}C.
- The mean minimum summer temperature in the ICRG blocks ranged from 14.9 ^{O}C to 18.2 ^{O}C during the historical period.
- Sikta and Laukha blocks recorded the least mean minimum summer temperature (14.9 ^{O}C) during the historical period.

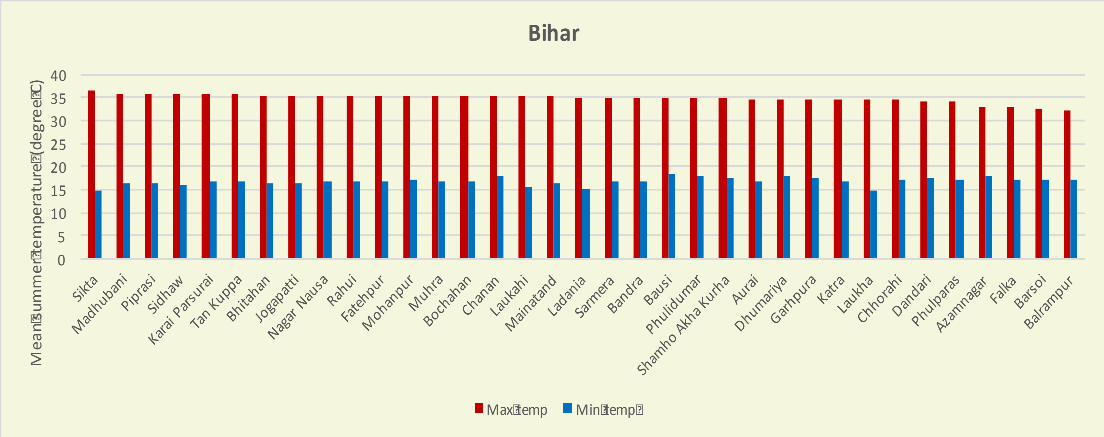

Figure 3.1: Observed mean maximum and minimum temperature (OC) in the ICRG blocks of Bihar during 1984-2014

Chhattisgarh (Figure 3.2)

Figure 3.2 illustrates the mean summer maximum and minimum temperature in the ICRG blocks.

- The mean maximum summer temperature ranged from 36.5 OC to 38 OC during the period 1984-2014 while the mean minimum summer temperature ranged from 17.1 OC to 19.8 OC during the same period, in the ICRG blocks of Chhattisgarh.
- In a majority of the ICRG blocks (20 out of 30 blocks), the summer mean maximum temperature was higher than 37 OC.
- Highest mean maximum summer temperature was recorded in Masturi block while the least minimum temperature during the summer months was recorded in Bharatpur block.
- Among the 30 ICRG blocks in Chhattisgarh, 18 blocks (60%) experienced mean maximum temperature of 19 OC or more.

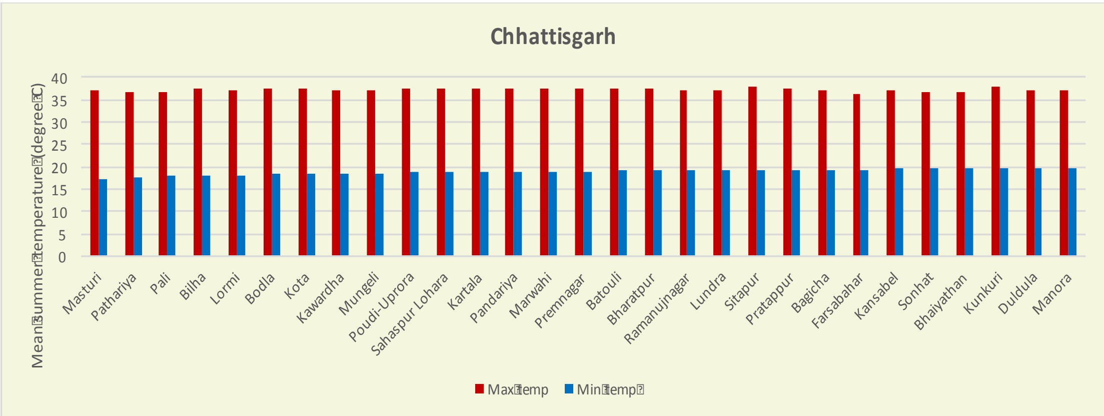

Figure 3.2: Observed mean maximum and minimum temperature (OC) in the ICRG blocks of Chhattisgarh during 1984-2014

Odisha (Figure 3.3)

- Mean maximum temperature during summer months ranged from 35.1 °C to 37.9 °C during the historical period.

- Blocks experiencing the highest mean maximum temperature in the summer months include Jharbandha and Nuapada with 37.9 °C, followed by Mathili and Paikamal blocks with 37.8 °C.
- The mean minimum summer temperature in the Odisha ICRG blocks ranged between 20.1 °C to 23.1 °C.
- Balisankar block experienced the least mean minimum temperature during the summer months (20.1 °C), followed by Jharbandha, Nuapada and Bisoi blocks

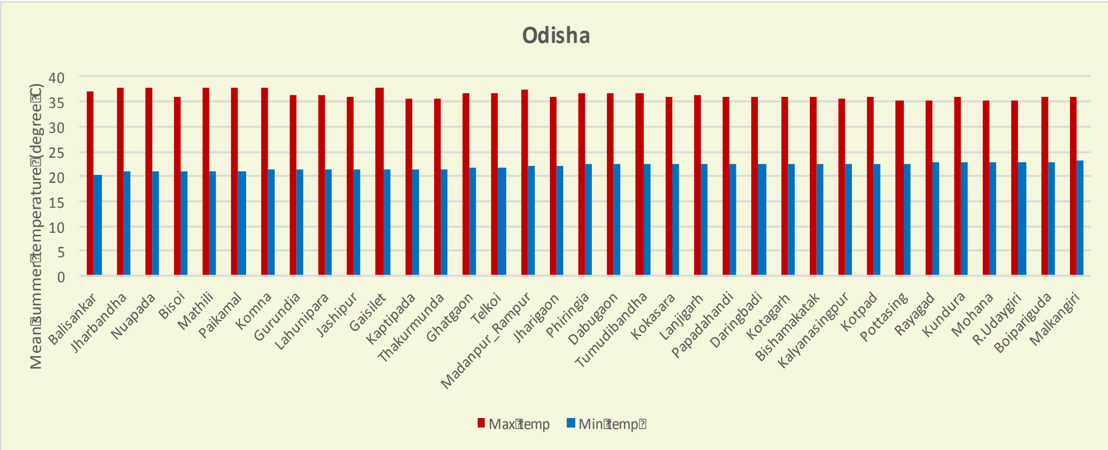

Figure 3.3: Observed mean maximum and minimum temperature (OC) in the ICRG blocks of Odisha during 1984-2014

3.1.2. Trends in Maximum Temperature during the Historical Period of 1984-2014

Trends in maximum temperature during the historical period was analysed and the results of this analysis is presented in this section. Average maximum temperature during the initial 10-year period of 1984-1994 and that during the recent 10-year period of 2004-2014 was compared to compute the change in temperature over the 30-year historical period.

Bihar (Figure 3.4)

- The identified ICRG blocks of Bihar experienced mostly warming but also a decrease in temperature in a few blocks during the historical period.
- The temperature increase was recorded in 77% of the blocks, in the range of 0.03 OC to 0.7 OC.
  - Highest increase in temperature of 0.7 ^{O}C was recorded in Laukha block, followed by Laukahi with 0.6 ^{O}C increase in temperature.
- A very slight decrease in temperature in the range of 0.01 OC to 0.1 OC was recorded in eight of the 35 blocks (about 23%) of Bihar.
  - Blocks with decrease in temperature included Sikta, Azamnagar and Barsoi with the maximum decrease, followed by Ladania, Balrampur, Bausi, Dhumariya and Falka blocks.

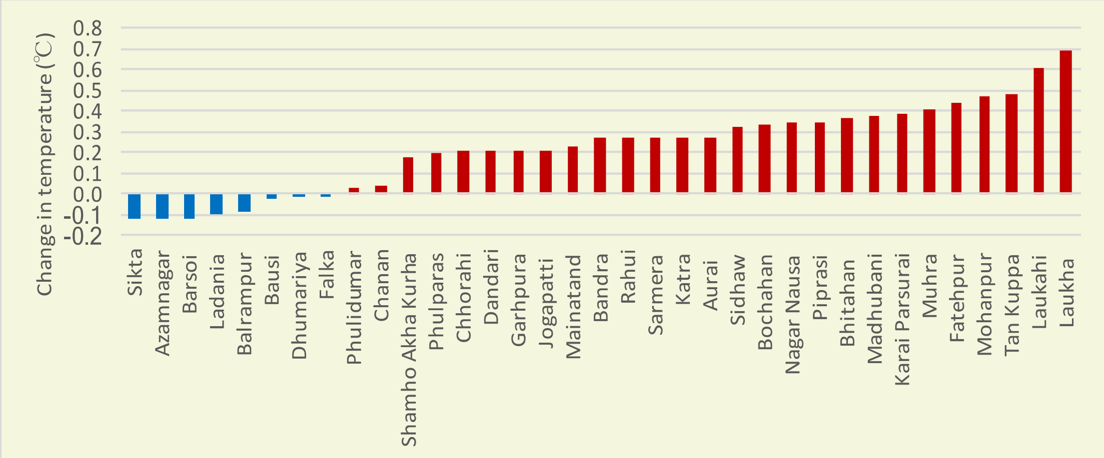

Figure 3.4: Change in mean maximum temperature (OC) during the 30-year period of 1984-2014 in the identified ICRG blocks of Bihar

Chhattisgarh (Figure 3.5)

- An increase in temperature in all the ICRG blocks of Chhattisgarh is recorded during the 30-year historical period.
- The increase ranged from 0.15 OC to 0.47 OC with the increase being:
  - 0.1 OC to 0.2 OC in five blocks, including Kawardha with the lowest, followed by Bodla, Lormi, Sahaspur-Lohra and Mungeli blocks
  - 0.2 OC to 0.3 OC in 13 blocks
  - 0.3 OC to o.47 OC in 12 blocks with the highest temperature increase recorded in Duldula, followed by Manora and Kunkuri blocks.

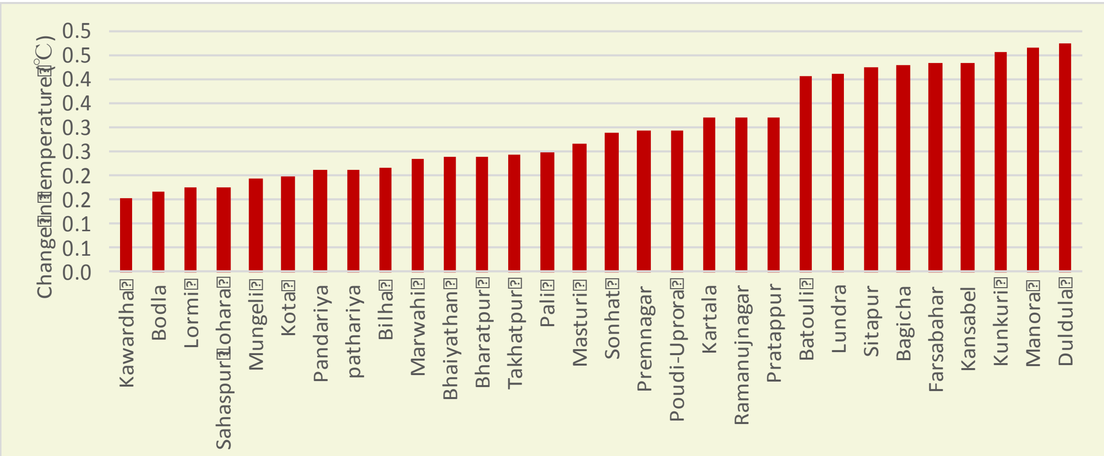

Figure 3.5: Change in mean maximum temperature (OC) during the 30-year period of 1984-2014 in the identified ICRG blocks of Chhattisgarh

Odisha (Figure 3.6)

- During the historical period of 1984-2014, all the identified ICRG blocks in Odisha recorded an increase in maximum temperature.
- The temperature increase was in the range of 0.18 OC in Malkangiri and Mathili blocks to 0.71 OC in Telkoi and Ghatgaon blocks.

- Majority of the blocks recorded a temperature increase of 0.2 OC to 0.5 OC.

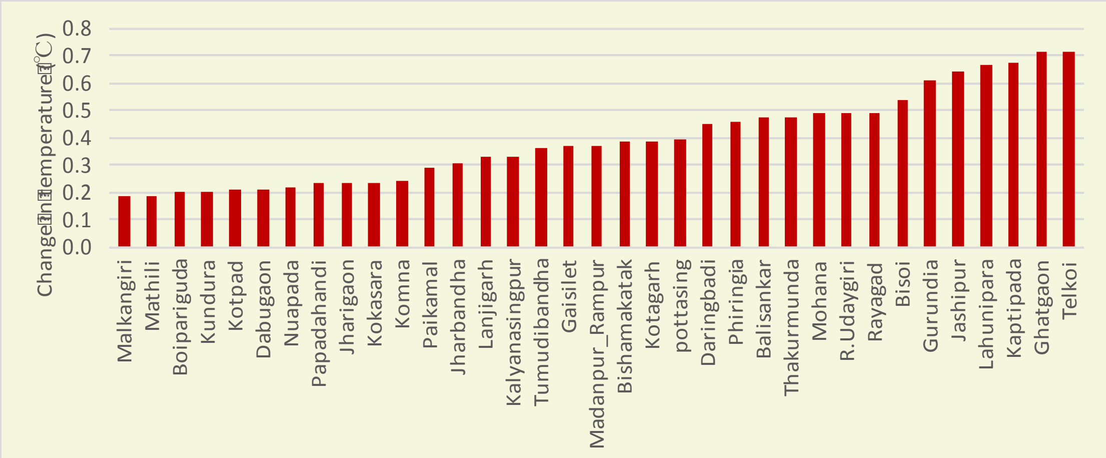

Figure 3.6: Change in mean maximum temperature (OC) during the 30-year period of 1984-2014 in the identified ICRG blocks of Odisha

Overall there was an increasing trend in warming as indicated by the increase in mean maximum temperature across all the identified ICRG blocks in Chhattisgarh and Odisha, and a majority of the blocks experienced warming, excluding eight blocks in Odisha, which recorded a marginal decrease in temperature.

- The increase in temperature in the range of 0.26 OC to 0.5 OC was recorded in the maximum number of blocks (**Figure 3.7**) across all the three states (>50% in Chhattisgarh, 49% in Odisha and 46% in Bihar).
- Across the states the increase in temperature in the range 0.26 to 0.5 OC was experienced in maximum number of blocks.
- An increase of > 0.5 OC up to 0.75 OC was recorded only in a few blocks of Bihar and Odisha.

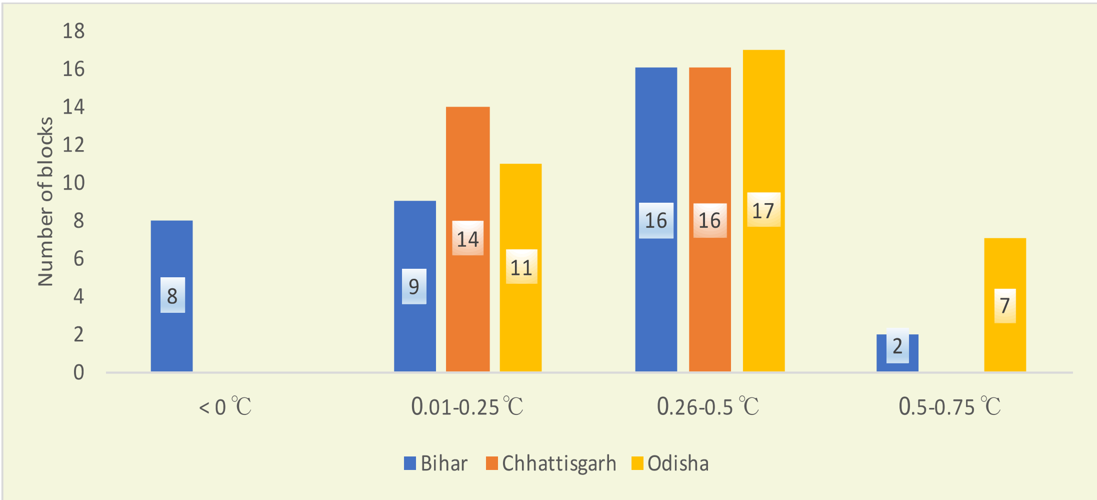

Figure 3.7: Number of blocks experiencing increase in temperature of varying degrees over the 30-year period of 1984-2014

3.2. Trends in Rainfall during the Historical Period (1984-2014)

Total rainfall and the distribution of monsoon rainfall is critical for agriculture and water supply in rural areas. The rainfall trend is analysed for the monsoon period – JJAS (June to August), which is the most important cropping season in the states. The mean seasonal rainfall trend and the seasonal rainfall variability is analysed and presented in this section for the three states for the period 1984 to 2014.

3.2.1. Mean Seasonal (JJAS) Rainfall during 1984-2014

Mean seasonal rainfall during June to September is analysed and presented in this section for the historical 30-year period of 1984-2014. **Table 3.1** presents the mean JJAS rainfall in the identified ICRG blocks of the three study states.

Bihar (Table 3.1)

- In Bihar, Balrampur block received the highest mean monsoon rainfall of 1274 mm, followed by Mainatand (1260 mm), Barsoi (1253 mm), Azamnagar (1253 mm) and Sikta (1217 mm) during the monsoon months.
- The lowest mean rainfall during JJAS was recorded in Sidhaw with 744 mm only, followed by five blocks receiving mean seasonal rainfall of 837 mm to 889 mm.

Chhattisgarh (Table 3.1)

- In Chhattisgarh, during the period 1984-2014, Kunkuri block received the highest mean monsoon rainfall of 1251 mm, followed by Poudi-Uprora, Duldula, Farsabahar, Kartala, Sitapur, Batouli and Pali blocks – all receiving more than 1200 mm of rainfall during the monsoon months.
- Lowest rainfall was recorded in Bodla block (927 mm) and four other blocks (Sahaspur-Lohara (929 mm), Kawardha (953 mm), Pathariya (979 mm) and Pandariya (992 mm)), all receiving less than 1000 mm of rainfall during the monsoon months.

Odisha (Table 3.1)

- In Odisha, Papadahandi block received the highest rainfall (1497 mm), followed by Kokasara block (1477 mm) during 1984-2014.
- Most of the blocks recorded a rainfall between 1100 mm to 1250 mm during the monsoon season.
- Rayagad block received the least monsoon rainfall of 761 mm, followed by R. Udaygiri (800 mm), Mohana (864 mm) and Pottasing (885 mm) blocks.

Table 3.1: Mean monsoon (JJAS) rainfall in the ICRG blocks of Bihar, Chhattisgarh and Odisha during 1984-2014

Bihar		Chhattisgarh		Odisha	
Blocks	Mean JJAS rainfall (mm)	Blocks	Mean JJAS rainfall (mm)	Blocks	Mean JJAS rainfall (mm)
Balrampur	1274	Kunkuri	1251	Papadahandi	1497
Mainatand	1260	Poudi-Uprora	1246	Kokasara	1477
Azamnagar	1253	Duldula	1241	Boipariguda	1366
Barsoi	1253	Farsabahar	1230	Kundura	1331
Sikta	1217	Kartala	1228	Gaisilet	1320
Jogapatti	1154	Sitapur	1223	Kotpad	1311

Bihar		Chhattisgarh		Odisha	
Blocks	Mean JJAS rainfall (mm)	Blocks	Mean JJAS rainfall (mm)	Blocks	Mean JJAS rainfall (mm)
Laukha	1136	Pali	1206	Gurundia	1304
Dhumariya	1119	Batouli	1206	Mathili	1303
Bausi	1110	Bagicha	1178	Thakurmunda	1246
Piprasi	1106	Takhatpur	1163	Dabugaon	1239
Dandari	1098	Lundra	1162	Madanpur-Rampur	1237
Ladania	1086	Premnagar	1147	Lahunipara	1234
Falka	1081	Manora	1147	Kaptipada	1227
Bhitahan	1076	Ramanujnagar	1136	Jashipur	1219
Madhubani	1068	Pratappur	1131	Jharigaon	1211
Laukahi	995	Masturi	1116	Balisankar	1195
Tan Kuppa	995	Marwahi	1116	Lanjigarh	1189
Garhpura	988	Bhaiyathan	1107	Ghatgaon	1183
Shamho Akha Kurha	968	Sonhat	1100	Telkoi	1162
Bochahan	957	Kota	1067	Phiringia	1159
Katra	946	Bilha	1064	Bisoi	1142
Bandra	943	Bharatpur	1052	Nuapada	1134
Chanan	934	Mungeli	1048	Tumudibandha	1103
Phulidumar	930	Lormi	1047	Paikamal	1093
Aurai	929	Kansabel	1019	Malkangiri	1082
Chhorahi	928	Pandariya	992	Komna	1076
Nagar Nausa	904	Pathariya	979	Jharbandha	1051
Karai Parsurai	901	Kawardha	953	Kalyanasingpur	1041
Fatehpur	889	Sahaspur-Lohara	929	Kotagarh	1038
Muhra	871	Bodla	927	Daringbadi	994
Phulparas	868			Bishamakatak	935
Mohanpur	866			Pottasing	885
Sarmera	843			Mohana	864
Rahui	837			R. Udaygiri	800
Sidhaw	744			Rayagad	761

3.2.2. Monsoon Rainfall Variability during 1984-2014

One of the major challenges faced by Indian agriculture is the monsoon rainfall variability. According to several studies, the monsoon rainfall variability has been increasing in the recent decades. Rainfall variability creates uncertainty and significantly impacts water availability and crop production. Rainfall variability is an important indicator which can be used to target resilience enhancement programmes.

In this section, the rainfall variability is estimated at the block level for the three states – based on data for the 30-year historical period of 1984-2014. The coefficient of variation (CV) is taken as an indicator of the rainfall variability.

Bihar (Table 3.2)

- The CV of the monsoon rainfall varied from 23.90% to 38.8% in the ICRG blocks.
- Blocks with the highest rainfall variability are: Piprasi (39%), Sidhaw (36%), Aurai (34%), Katra (32%) and Nagar Nausa (32%).
- The blocks with low rainfall variability are: Rahui (25%), Phulidumar (24.6%), Fatehpur (24.5%), Shamho Akha Kurha (24%) and Mohanpur (23.9%).
- The standard deviation of the monsoon rainfall across the ICRG blocks varied from 207 (Mohanpur) to 430 (Piprasi).

Chhattisgarh (Table 3.3)

- In Chhattisgarh ICRG blocks, the CV of the monsoon rainfall varied from 19.9% to 35.3%.
- Districts with the highest rainfall variability with > 30% CV are Sahaspur Lohara and Pali blocks.
- Majority of the districts had a CV of 20% to 29%, indicating moderate rainfall variability.
- Marwahi block had the lowest CV (16.9%).
- Standard deviation of monsoon rainfall varied from 168 in Kawardha block to 371 in Pali block.

Odisha (Table 3.4)

- The CV of the monsoon rainfall varies from 18.6% to 37.1% in the ICRG blocks.
- Three of the 35 blocks had CV higher than 30%: Kokasara (37.1%); Papadahandi (36%) and Malkangiri (31.5%).
- Thakurmanda block showed the least CV with 18.6%, indicating low rainfall variability.
- Standard deviation of monsoon rainfall varied from 157 (R. Udaygiri) to 548 (Kokasara).
- The rainfall variability analysis of the ICRG blocks in the three states showed that 5 blocks in Bihar, 2 blocks in Chhattisgarh and 3 blocks in Odisha had a CV of over 30%. Further, the top five districts with respect to high CV in the three states are:
- Bihar: Piprasi, Sidhaw, Aurai, Katra and Nagar Nausa blocks
- Chhattisgarh: Sahaspur Lohara, Pali, Premnagar, Bodla and takhatpur blocks.
- Odisha: Kokasara; Papadahandi, Malkangiri, Lanjigarh and Gaisilet blocks.

Thus, these blocks could be considered as *hotspots* of current rainfall variability, requiring MGNREGA activities aimed at increasing irrigation water availability.

Table 3.2: June to September rainfall, standard deviation and Coefficient of Variation for the ICRG blocks in Bihar during 1984-2014

Blocks	Mean JJAS rainfall (mm)	Standard deviation (mm)	Coefficient of Variation (%)
Piprasi	1106	430	38.88
Sidhaw	744	266	35.75
Aurai	929	315	33.91

Blocks	Mean JJAS rainfall (mm)	Standard deviation (mm)	Coefficient of Variation (%)
Katra	946	305	32.24
Nagar Nausa	904	288	31.86
Phulparas	868	274	31.57
Madhubani	1068	327	30.62
Garhpura	988	302	30.57
Muhra	871	266	30.54
Tan Kuppa	995	297	29.85
Bandra	943	280	29.69
Ladania	1086	317	29.19
Bhitahan	1076	313	29.09
Laukha	1136	329	28.96
Falka	1081	312	28.86
Laukahi	995	287	28.84
Sarmera	843	242	28.71
Jogapatti	1154	327	28.34
Karai Parsurai	901	251	27.86
Chanan	934	259	27.73
Dandari	1098	300	27.32
Bochahan	957	259	27.06
Sikta	1217	329	27.03
Mainatand	1260	337	26.75
Chhorahi	928	247	26.62
Balrampur	1274	337	26.45
Dhumariya	1119	289	25.83
Barsoi	1253	321	25.62
Azamnagar	1253	321	25.62
Bausi	1110	283	25.50
Rahui	837	213	25.45
Phulidumar	930	229	24.62
Fatehpur	889	218	24.52
Shamho Akha Kurha	968	233	24.07
Mohanpur	866	207	23.90

Table 3.3: June to September rainfall, standard deviation and coefficient of variation for the ICRG blocks in Chhattisgarh during 1984-2014

Blocks	Mean JJAS rainfall (mm)	Standard deviation (mm)	Coefficient of Variation (%)
Sahaspur –Lohara	929	328	35.31
Pali	1206	371	30.76
Premnagar	1147	343	29.90
Bodla	927	277	29.88
Takhatpur	1163	317	27.26
Poudi-Uprora	1246	333	26.73
Bhaiyathan	1107	293	26.47
Farsabahar	1230	325	26.42

Blocks	Mean JJAS rainfall (mm)	Standard deviation (mm)	Coefficient of Variation (%)
Pratappur	1131	290	25.64
Ramanujnagar	1136	279	24.56
Kansabel	1019	248	24.34
Sonhat	1100	264	24
Bharatpur	1052	252	23.95
Duldula	1241	291	23.45
Masturi	1116	261	23.39
Manora	1147	266	23.19
Lundra	1162	254	21.86
Mungeli	1048	219	20.9
Kartala	1228	255	20.77
Kunkuri	1251	256	20.46
Batouli	1206	245	20.32
Kota	1067	213	19.96
Lormi	1047	201	19.2
Bagicha	1178	226	19.19
Bilha	1064	203	19.08
Sitapur	1223	218	17.83
Kawardha	953	168	17.63
Pathariya	979	171	17.47
Pandariya	992	173	17.44
Marwahi	1116	189	16.94

Table 3.4: June to September rainfall, standard deviation and coefficient of variation for the ICRG blocks in Odisha during 1984-2014

Blocks	Mean JJAS rainfall (mm)	Standard deviation (mm)	Coefficient of Variation (%)
Kokasara	1477	548	37.10
Papadahandi	1497	539	36.01
Malkangiri	1082	341	31.52
Lanjigarh	1189	338	28.43
Gaisilet	1320	366	27.73
Paikamal	1093	298	27.26
Nuapada	1134	306	26.98
Jharigaon	1211	325	26.84
Dabugaon	1239	330	26.63
Komna	1076	271	25.19
Madanpur_Rampur	1237	308	24.90
Boipariguda	1366	332	24.30
Kundura	1331	322	24.19
Kalyanasingpur	1041	250	24.02
Tumudibandha	1103	264	23.93

Blocks	Mean JJAS rainfall (mm)	Standard deviation (mm)	Coefficient of Variation (%)
Lahunipara	1234	280	22.69
Mathili	1303	290	22.26
Ghatgaon	1183	263	22.23
Phiringia	1159	257	22.17
Kotagarh	1038	228	21.97
Jashipur	1219	264	21.66
Rayagad	761	163	21.42
Bishamakatak	935	200	21.39
Pottasing	885	189	21.36
Jharbandha	1051	222	21.12
Kotpad	1311	276	21.05
Bisoi	1142	240	21.02
Balisankar	1195	250	20.92
Kaptipada	1227	256	20.86
Gurundia	1304	272	20.86
Daringbadi	994	202	20.32
Mohana	864	173	20.02
Telkoi	1162	232	19.97
R. Udaygiri	800	157	19.63
Thakurmunda	1246	232	18.62

3.2.3. Trends in Sowing Rains (June rainfall) during 1984-2014

June is the month of onset of monsoon in most parts of India. June rainfall is critical for crop production. The decision of farmers in deciding cropping pattern depends on the extent of rainfall received in June. Here we analyse the trends in rainfall during the month of June over the 30-year period. **Table 3.5** presents the number of years with onset of normal sowing rain across the ICRG blocks of the three states. **Figure 3.8** presents the number of blocks receiving normal sowing rain under three frequencies of 1-5 years, 6-10 years and >10 years during the 30-year period of 1984-2014.

Bihar (Table 3.5)

- In majority of the ICRG blocks, less than a–third of the years received normal sowing rains.
- In all the ICRG blocks, normal sowing rain has not been received in 50% of the 30-year period (1984-2014)
- In 10 blocks, it was 10-12 years out of 30 years, in 22 blocks-, it was 5-10 years and in the remaining three blocks it was less than 5 years
- Sidhaw, Karai Parsurai and Mohapur blocks have recorded less than 5 years with normal sowing rains out of 30 years.

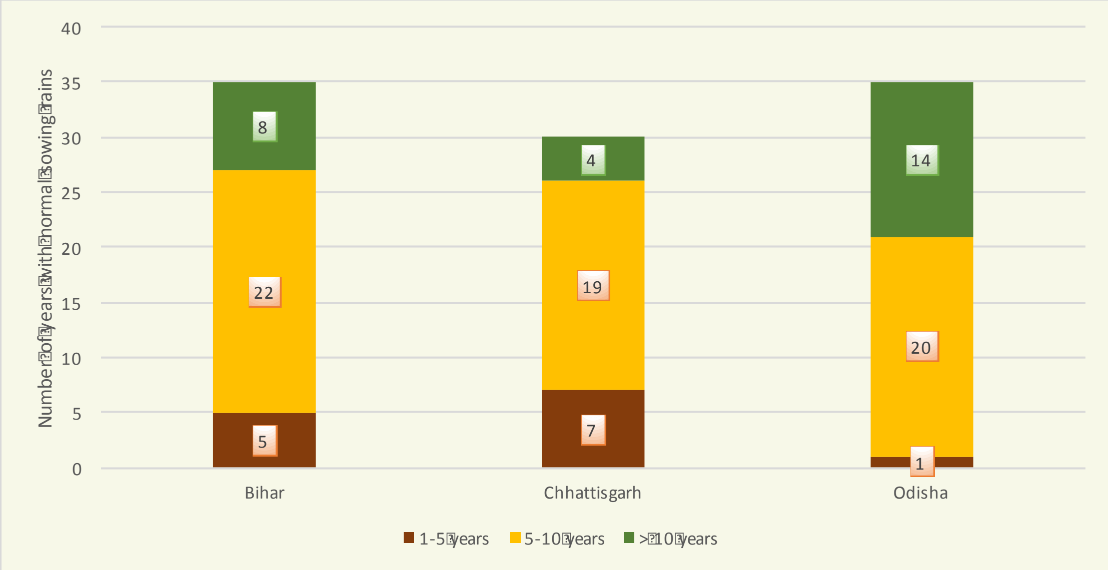

Figure 3.8: Number of blocks receiving normal sowing rains during June under three frequencies of 1-5 years, 5-10 years and >10 years during the 30-year period of 1984-2014

Chhattisgarh (Table 3.5)

- Among the 30 blocks of Chhattisgarh, only four blocks received more than 10 years of normal June rainfall during the historical 30-year period of 1984-2014.
- Farsabahar received only two years and Lormi received three years of normal sowing rain while Kawardha and Patahriya received only four years of normal sowing rains.
- Majority of the blocks (53%) received six to seven years of normal rainfall during 1984-2014.
- Highest number of years (12 out of 30) with normal sowing rain was recorded only in Poudi-Uprora block.

Odisha (Table 3.5)

- 15 ICRG blocks received normal sowing rains in the range of 10 to 14 years during the historical 30-year period of 1984-2014.
- In 19 of the 35 blocks, the normal sowing rain was received in 3 years to 9 years.
- Gurundia block received only 3 years of normal sowing rain while Nuapada received only 6 years of normal sowing rain.

Table 3.5: Number of years with normal sowing rains during the historical 30-year period (1985-2014)

Bihar		Chhattisgarh		Odisha	
Blocks	No. of years	Blocks	No. of years	Blocks	No. of years
Karai Parsurai	3	Farsabahar	2	Gurundia	3
Sidhaw	3	Lormi	3	Nuapada	6
Mohanpur	4	Kawardha	4	Lanjigarh	7
Fatehpur	5	Pathariya	4	Madanpur-Rampur	7
Muhra	5	Batouli	5	Balisankar	8

Bihar		Chhattisgarh		Odisha	
Blocks	No. of years	Blocks	No. of years	Blocks	No. of years
Aurai	6	Lundra	5	Komna	8
Chhorahi	6	Pandariya	5	Lahunipara	8
Katra	6	Bagicha	6	Mohana	8
Garhpura	7	Bodla	6	Paikamal	8
Jogapatti	7	Kunkuri	6	Phiringia	8
Madhubani	7	Manora	6	Bishamakatak	9
Tan Kuppa	7	Premnagar	6	Dabugaon	9
Balrampur	8	Sahaspur Lohara	6	Ghatgaon	9
Ladania	8	Bhaiyathan	7	Jharbandha	9
Bausi	9	Bharatpur	7	Jharigaon	9
Bhitahan	9	Duldula	7	Kokasara	9
Bochahan	9	Kansabel	7	Malkangiri	9
Chanan	9	Kota	7	Papadahandi	9
Dandari	9	Mungeli	7	Rayagad	9
Falka	9	Pali	7	Gaisilet	10
Laukahi	9	Pratappur	7	Thakurmunda	10
Phulparas	9	Sonhat	7	Boipariguda	11
Rahui	9	Takhatpur	7	Jashipur	11
Sarmera	9	Bilha	8	Kalyanasingpur	11
Shamho Akha Kurha	9	Marwahi	8	Kaptipada	11
Nagar Nausa	10	Masturi	9	Kotagarh	11
Phulidumar	10	Kartala	11	Mathili	11
Azamnagar	11	Ramanujnagar	11	R.Udaygiri	11
Bandra	11	Sitapur	11	Bisoi	12
Barsoi	11	Poudi-Uprora	12	Daringbadi	12
Piprasi	11			Kotpad	13
Dhumariya	12			Telkoi	13
Laukha	12			Tumudibandha	13
Mainatand	12			Kundura	14
Sikta	12			Pottasing	14

Analysis of occurrence of sowing rainfall events during June for the historical 30-year period showed that majority of the blocks did not receive June rainfall in most of the years. This mean only in few years the farmers received the normal sowing rain in June. This will have implications for designing MGNREGA works to assist farmers to cope with delayed sowing rains. The famers may require access to rainfall prediction in June and MGNREGA may have to have provision for contingency planning in case of delayed sowing rains.

3.2.4. Occurrence of Droughts: Frequency and Intensity during 1984-2014

Drought is the bane of Indian agriculture. Periodic occurrence of droughts adversely impacts food production, water availability, farmers' livelihoods and survival. India is likely to experience increased frequency and intensity in occurrence of droughts in the coming decades due to climate change. The historical climate data has been analysed for occurrence of droughts during the 30-year period of 1984 to 2014. The criteria for this analysis is presented in **Table 3.6**. **Figure 3.10**, **Figure 3.11** and **Figure 4.1** present the occurrence of mild, moderate and severe drought in the study blocks across the three states of Bihar, Chhattisgarh and Odisha.

Table 3.6: Criteria for analysis of drought

Drought type	Rainfall deficit from normal
Mild Drought	0-25%
Moderate Drought	26-50%
Severe Drought	>50%

Source: Lala et al., 2013

Bihar (Figure 3.9)

- Most of the blocks experienced several years of mild to moderate drought. 24 of the 35 blocks experienced mild to moderate drought in over 50% of the years.
- 11 blocks out of 35 experienced moderate drought more than once in 5 years.
- Over the 30-year period, Piprasi block had two years of severe drought.
- In 34 out of 35 blocks, moderate drought is recorded ranging from two in Phulidumar block to 15 in Bhitahan block.
    - Pirasi and Aurai experienced moderate drought in a quarter of the 30 years
- Most of the blocks experienced moderate drought in 13% to 20% of the 30-year period.
- Barsoi block did not experience any moderate drought and Phulidumar experienced only two years of moderate drought.

Thus drought is a common occurrence in Bihar with 24 of the 35 blocks experiencing mild to moderate drought in over 50% of the years. Severe drought is not common in Bihar. Thus there is need for adaptation strategies to cope with mild to moderate drought in the identified ICRG blocks of Bihar.

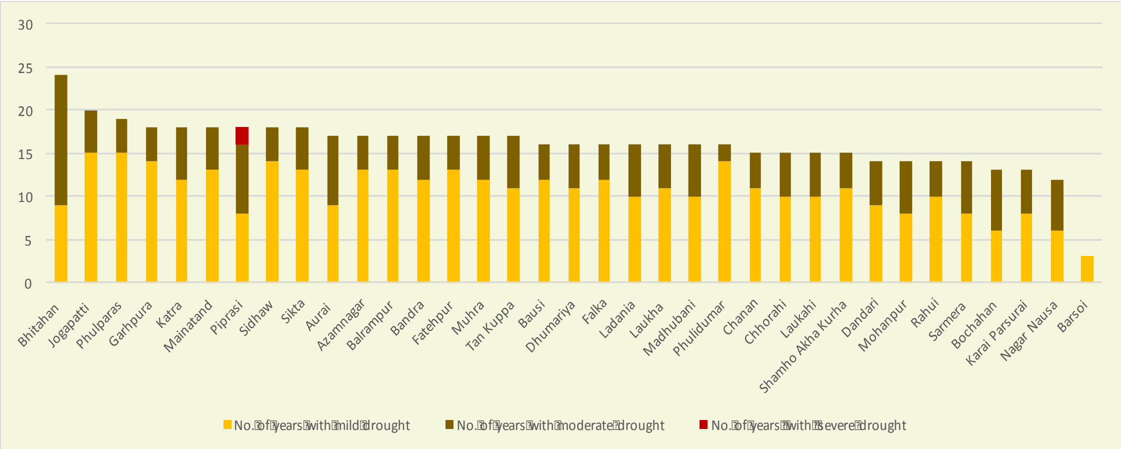

Figure 3.9: Drought occurrence frequency in study blocks of Bihar during 1984-2014

Chhattisgarh (Figure 3.10)

- Most blocks in Chhattisgarh have experienced mild drought during the historical 30-year period of 1984-2014.
- Severe drought is recorded in Bhaiyathan, Premnagar, Ramanujnagar and Pratappur blocks (one out of 30 years)
- Kansabel, Lundra and Manora blocks have recorded the highest number of years with moderate drought (5 out of 30 years).
- Of the 30 blocks in Chhattisgarh, Kartala, Poudi-Upora and Premnagar have recorded moderate drought in only one year over the 30-year period.

Thus, it can be concluded that severe and moderate droughts are not so prevalent in the identified ICRG blocks of Chhattisgarh.

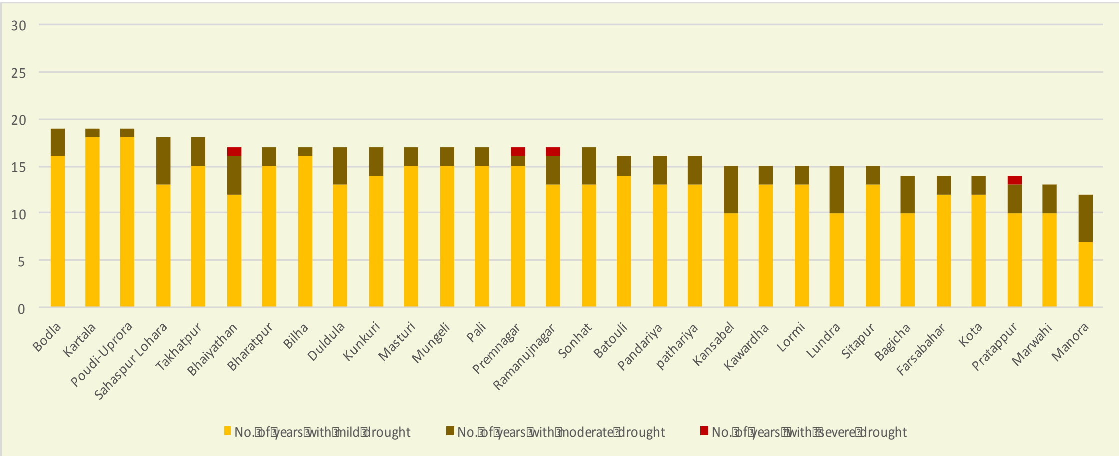

Figure 3.10: Drought occurrence frequency in study blocks of Chhattisgarh during 1984-2014

Odisha (Figure 3.11)

- Kokasara was the only block to experience severe drought over the 30-years (2 of 30 years).

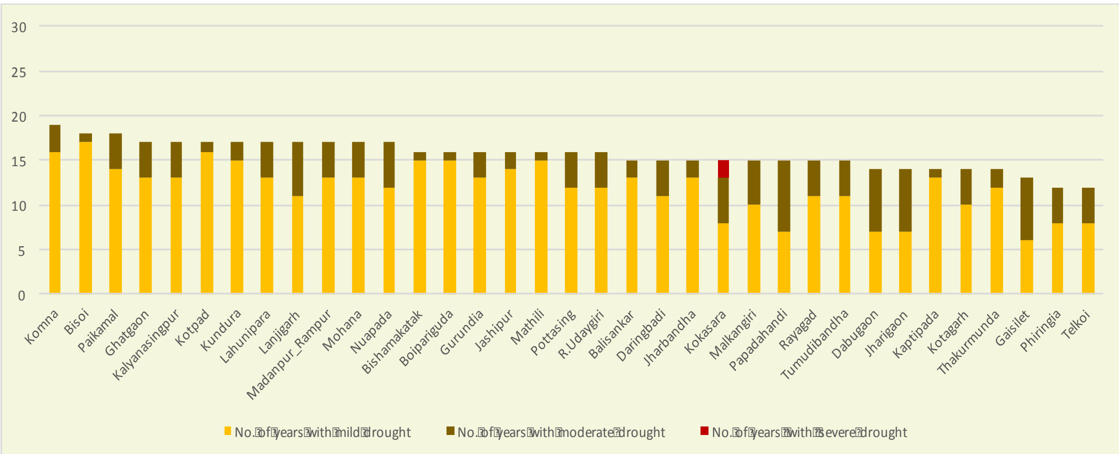

Figure 3.11: Drought occurrence frequency in study blocks of Odisha during 1984-2014

- All the blocks experienced a few moderate drought events over the 30-year period. Of these, Papadahandi had moderate drought in eight out of 30 years.

- Mathili, Kotpad, Kaptipadi, Bishamakatak, Bisoi and Boipariguada blocks recorded only one mild drought year during 1984-2014.
- Thus, in Odisha, occurrence of severe drought is a rare event. Majority of the blocks experienced only mild drought. The occurrence of moderate drought is also low for majority of the blocks.

3.2.5. Number of high intensity Rainy Days During the Historical Period (1984-2014)

In this section, an analysis of frequency of occurrence of high intensity rainfall events of intensity 51-100 mm and > 100 mm per day is presented for the historical period of 1984-2014 for the identified ICRG blocks of Bihar, Chhattisgarh and Odisha states. **Table 3.7** presents the frequency of occurrence of rainfall events with intensity of 51-100 mm to > 100 m per day.

Bihar

Number of rainy days – 51-100/day mm rainfall

- All the blocks received higher number of rainy days with 51-100 mm rainfall than > 100 mm rainfall.
- Among the 35 identified ICRG blocks in Bihar, the number of rainy days with this intensity rainfall varied from 13 days in Aurai block to 131 days in Mainatand.
- Number of rainy days - > 100 mm/day rainfall
- The number of rainy days with > 100 mm rainfall during the historical period varied from 6 to 42 days in the ICRG blocks.
- Mainatand, Sikta and Sidhaw blocks received 40-42 days of > 100 mm rainfall.
- 11 of the 35 blocks received 10-20 cm of > 100 mm rainfall.
- 13 out of the 35 blocks received less than 10 days of > 100 mm rainfall.

Table 3.7: Frequency of occurrence of rainfall events of 51-100 mm and > 100 mm (units are in days) in the ICRG blocks of Bihar, Chhattisgarh and Odisha

Bihar			Chhattisgarh			Odisha		
Blocks	Rainfall		Blocks	Rainfall		Blocks	Rainfall	
	51-100 mm	> 100 mm		51-100 mm	> 100 mm		50-100 mm	>100 mm
Mainatand	131	42	Bagicha	102	27	Balisankar	116	68
Sikta	122	41	Batouli	102	23	Bishamakatak	96	38
Sidhaw	116	40	Bhaiyathan	99	18	Bisoi	96	35
Piprasi	110	38	Bharatpur	102	16	Boipariguda	96	35
Bhitahan	116	36	Bilha	84	14	Dabugaon	102	35
Madhubani	116	35	Bodla	82	14	Daringbadi	89	34
Falka	113	29	Duldula	95	14	Gaisilet	123	30
Barsoi	125	22	Farsabahar	95	14	Ghatgaon	79	27
Azamnagar	121	21	Kansabel	75	13	Gurundia	78	25
Balrampur	125	20	Kartala	82	13	Jashipur	99	24
Ladania	94	20	Kawardha	103	13	Jharbandha	93	24

Bihar			Chhattisgarh			Odisha		
Blocks	Rainfall		Blocks	Rainfall		Blocks	Rainfall	
	51-100 mm	> 100 mm		51-100 mm	> 100 mm		50-100 mm	>100 mm
Phulidumar	63	19	Kota	103	12	Jharigaon	96	24
Dhumariya	79	17	Kunkuri	80	12	Kalyanasingpur	84	24
Bausi	79	16	Lormi	98	11	Kaptipada	75	23
Laukahi	105	15	Lundra	89	10	Kokasara	106	22
Chanan	61	12	Manora	83	10	Komna	56	22
Laukha	103	12	Marwahi	84	10	Kotagarh	66	21
Garhpura	25	11	Masturi	81	9	Kotpad	95	21
Jogapatti	25	11	Mungeli	91	9	Kundura	76	18
Fatehpur	47	10	Pali	85	8	Lahunipara	74	17
Katra	67	10	Pandariya	87	8	Lanjigarh	78	16
Phulparas	86	10	Pathariya	85	7	Madanpur-Rampur	71	13
Dandari	78	9	Poudi-Uprora	57	7	Malkangiri	58	12
Chhorahi	72	8	Pratappur	89	6	Mathili	62	12
Karai Parsurai	64	8	Premnagar	79	6	Mohana	58	12
Rahui	57	8	Ramanujnagar	84	6	Nuapada	84	11
Shamho Akha Kurha	96	8	Sahaspur Lohara	79	6	Paikamal	84	11
Aurai	13	7	Sitapur	84	5	Papadahandi	86	10
Bandra	81	7	Sonhat	61	4	Phiringia	58	9
Bochahan	81	7	Takhatpur	42	3	Pottasing	60	9
Muhra	55	7				R.Udaygiri	52	9
Mohanpur	46	6				Rayagad	48	7
Nagar Nausa	67	6				Telkoi	45	6
Sarmera	55	6				Thakurmunda	47	5
Tan Kuppa	62	6				Tumudibandha	51	4

Chhattisgarh

Number of rainy days - 51 – 100 mm/day rainfall

- The number of rainy days varied from 42 to 103 in the historical period.
- Maximum number of blocks – 21 of 30 (accounting for 70%) received rainfall for 75-100 days.
- About 17% (5 out of 30) blocks received rain for more than 100 days.
- Number of rainy days - > 100 mm/day rainfall
- The number of days receiving rainfall > 100 mm in the ICRG blocks of Chhattisgarh varied from as low as three in Takhatpur to 27 days in Bagicha block.
- 50% (15 of 30) of the blocks received 10-20 days of > 100 mm rainfall.
- 13 of the 30 blocks received less than 10 days of > 100 mm rainfall.
- Only 2 blocks received > 100 mm rainfall on > 20 days - Bagicha (27 days) and Botouli (23 days).

Odisha

Number of rainy days - 51 – 100 mm/day rainfall

- More than one-third (34%) of the blocks received 51-100 mm of rainfall for 50-75 days during 1984-2014
- Three blocks out of 35, namely Telkoi, Thakurmunda and Rayagad received 51-100 mm of rain in less than 50 days
- Four blocks – Dabugaon, Kokasara, Balisankar and Gaiselt blocks received > 100 mm of rainfall for more than 100 days during the historical period.
- Number of rainy days - > 100 mm/day rainfall
- > 100 mm rainfall was received by the ICRG blocks in Odisha for four (Tumudibandha block) to 68 (Balisankar block) days.
- Majority of the blocks received 51-100 mm of rainfall for 10-30 days.

Occurrence of high intensity rainfall is an indicator of flood causing rainfall events. More than 100 mm of rain/day could lead to damage to land, crops and may cause excessive runoff and even flood. These high intensity rainfall events could damage the soil and water conservation structures created under MGNREGA. It can be observed that the frequency of high intensity rainfall of > 100 mm is highest in the blocks of Odisha state and lowest in the blocks of Bihar. This information will have implications for designing soil and water conservation structures and flood control measures under MGNREGA.

4. HOTSPOTS OF CURRENT RAINFALL VARIABILITY

In this section hotspots blocks or blocks with high rainfall variability are identified among the ICRG blocks of Bihar, Chhattisgarh and Odisha. In this section, the top ten blocks in each of the three states is presented, to highlight the hotspots of current rainfall variability (**Figure 4.1**).

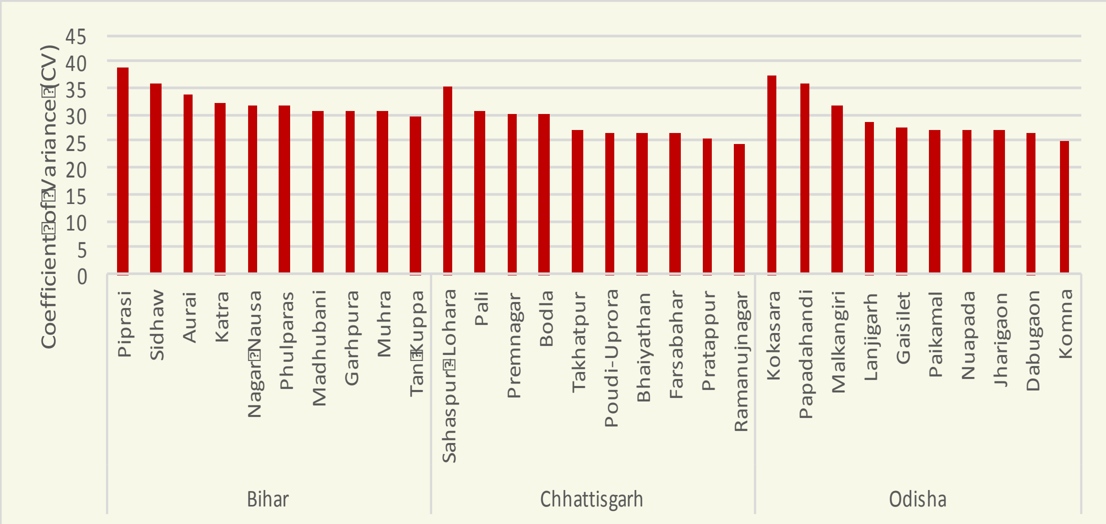

Figure 4.1: Blocks or hotspots of current rainfall variability as indicated by CV under historical 30-year period (1984-2014)

Among the 35 blocks in Bihar, ten blocks identified as hotspots of current rainfall variability have a CV ranging from 29.85 in Tan Kuppa block to 38.88 in Piprasi block. Similarly, in Chhattisgarh, the CV ranges from 24.56 to 35.31, and in Odisha the range is from 25.19 to 37.10 in the ten blocks with highest CV.

The top 5 or 10 blocks with highest rainfall variability could be selected for designing climate resilient infrastructure under the ICRG project. The water availability, crop yields and livelihoods are likely to be highly vulnerable to varying rainfall in these blocks.

PART - 2

Temperature and Rainfall (Climate Change) Projections

5. CLIMATE CHANGE PROJECTIONS FOR 2021-2050

All blocks and districts will be subjected to warming and climate change, in particular changes in total rainfall and rainfall variability to varying degrees. Climate change is also projected to impact the frequency and intensity of occurrence of droughts. Thus it is necessary to assess the projected impacts of climate change at block level, especially impact on rainfall variability. This would enable identification of *hotspot* blocks with respect to monsoon seasonal rainfall variability, so that adaptation or resilience programs can be targeted first.

The CORDEX South Asia model data on precipitation, maximum temperature and minimum temperature have been analysed for the 100 blocks for baseline (1984-2014) and mid-century (2021-2050). Climate change projections on precipitation, maximum temperature and minimum temperature have been assessed for the ICRG blocks. Projections have been made at a grid-spacing of 0.5°x0.5° resolution (50 km x 50 km) for the RCP 8.5 scenario (the most likely scenario).

IPCC has provided multiple pathways of future GHG emissions and irradiative forcings. The pathways are used for climate modeling and research. The recent IPCC Assessment Report (2014) used four possible climate futures. The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m^2, respectively) (Weyant et al., 2009).

CORDEX is a WCRP-sponsored program to organize an international coordinated framework to produce an improved generation of regional climate change projections world-wide for input into impact and adaptation studies within the AR5 timeline. CORDEX produced an ensemble of multiple dynamical and statistical downscaling models considering multiple forcing GCMs from the CMIP5 archive. Initially 50 km grid spacing has been selected. For the present study only the SMHI-RCA4 model data which was available is used.

5.1. CORDEX Models and RCP Scenario used for Projections

The CORDEX South Asia data on precipitation, maximum and minimum temperature have been analysed for 100 blocks for baseline (1984-2014) and mid-century (2021-2050) RCP 8.5 scenarios for RCM SMHI-RCA4 and the ensemble of the RCMs are taken for this study. List of CORDEX models used and their details are given **Table 5.1**.

Table 5.1: List of CORDEX models used in this study for climate change projections

Asia CORDEX RCM	RCM	GCM boundary condition	Institute	Scenario	Resolution (° lon x ° lat)	Daily time period
CNRM-CERFACS-CNRM-CM5_SMHI-RCA4	SMHI-RCA4	CNRM	SMHI	RCP8.5	0.5X0.5	1951-2100
NOAA-GFDL-GFDL-ESM2M_SMHI-RCA4	SMHI-RCA4	GFDL	SMHI	RCP8.5	0.5X0.5	1951-2100
IPSL-CM5A-MR_SMHI-RCA4	SMHI-RCA4	IPSL-CM5A	SMHI	RCP8.5	0.5X0.5	1951-2100
MIROC-MIROC5_SMHI-RCA4	SMHI-RCA4	MIRCO	SMHI	RCP8.5	0.5X0.5	1951-2100
MPI-M-MPI-ESM-LR_SMHI-RCA4	SMHI-RCA4	MPI-M	SMHI	RCP8.5	0.5X0.5	1951-2100

5.2. Temperature Projections for 2021-2050

Temperature projections have been estimated for the summer months of March to May for the 30-year period of 2021-2050. Mean maximum and mean minimum temperatures have been projected for this period.

5.2.1. Distribution of Blocks According to Mean Maximum and Minimum Temperature during Summer Months during 2021-2050

In this section, the mean maximum and minimum temperature projections for the different ICRG blocks of the three states of Bihar, Chhattisgarh and Odisha under the RCP 8.5 scenario for the period 2021-2050 is presented.

Bihar (Figure 5.1)

- Blocks Tan Kuppa, Muhra, Fatehpur, Mohanpur, Karai Parsurai and Nagar Nausa show the highest mean seasonal maximum temperature under projected (RCP 8.5) scenario, the temperature reaching 37 °C and above.
- Balrampur block recorded the least mean maximum seasonal temperature during 2021-2050.
- Bhitahan and Madhubani blocks are projected to have the least mean minimum seasonal temperature (17.5°C), followed by Jogapatti, Piprasi and other blocks with the maximum mean minimum seasonal temperature being 20.3 °C during 2021-2050.
- Chhattisgarh (**Figure 5.2**)
- Blocks Masturi, Pathariya, Takhatpur and Pali show the highest seasonal maximum temperature of 36 °C and above under RCP 8.5 scenario during 2021-2050.
- Blocks Sonhat, Bagicha, Bhaiyathan and Lundra blocks are projected to experience the lowest mean seasonal minimum temperature of 16.6 °C to 17.9 °C under RCP 8.5 scenario during the period – 2021-2050.

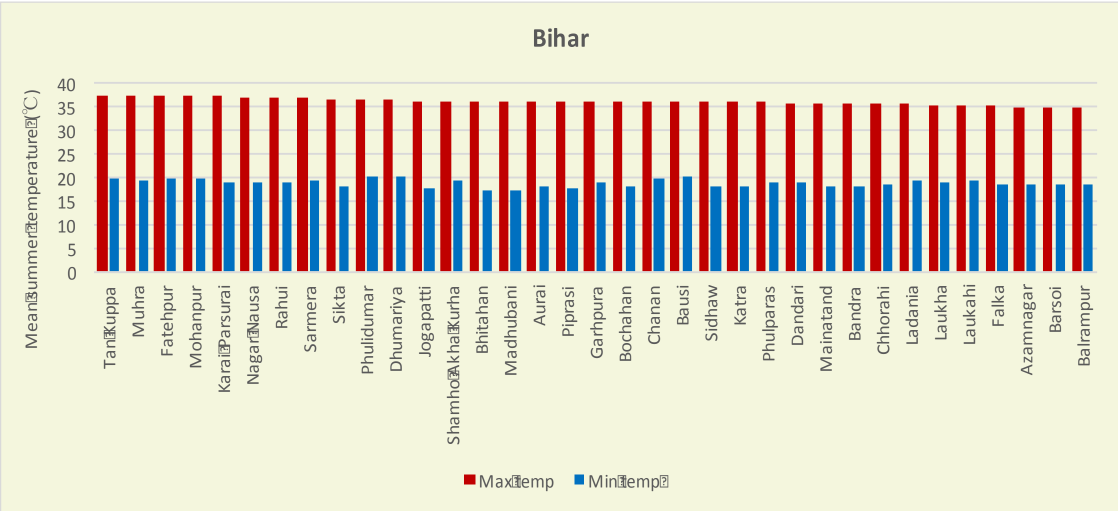

Figure 5.1: Projected mean seasonal temperature (°C) under RCP 8.5 scenario in the study blocks of Bihar for the period 2021-2050

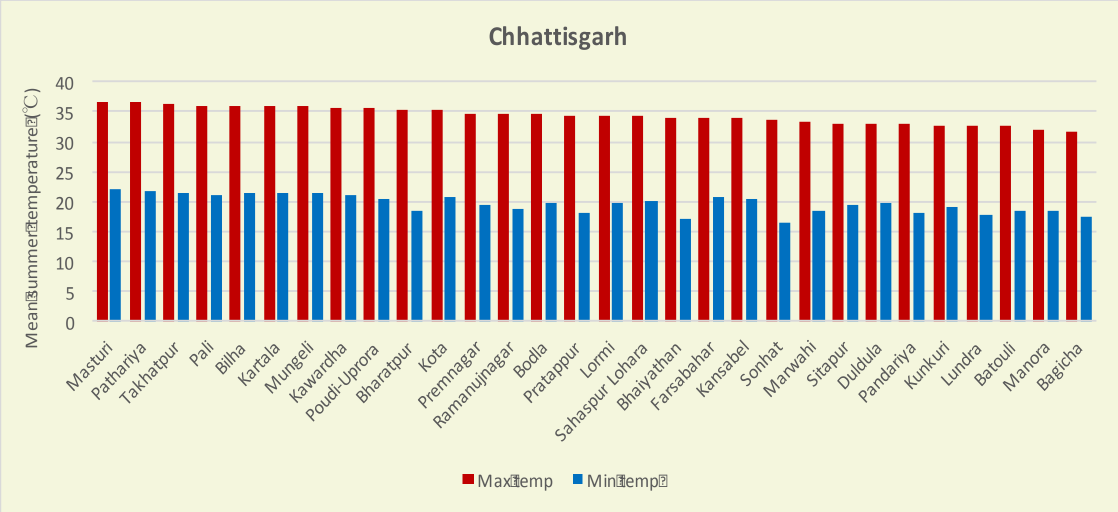

Figure 5.2: Projected mean seasonal temperature (°C) under RCP 8.5 scenario in the study blocks of Chhattisgarh for the period 2021-2050

Odisha (Figure 5.3)

- Blocks Nuapada, Paikamal and Jharbandha are projected to experience the highest seasonal mean maximum temperature of 35 °C and above under RCP 8.5 scenario.
- Blocks Jashipur, Kaptipada and Thakurmunda are projected to experience least mean minimum temperature of around 20 °C under RCP 8.5 scenario.

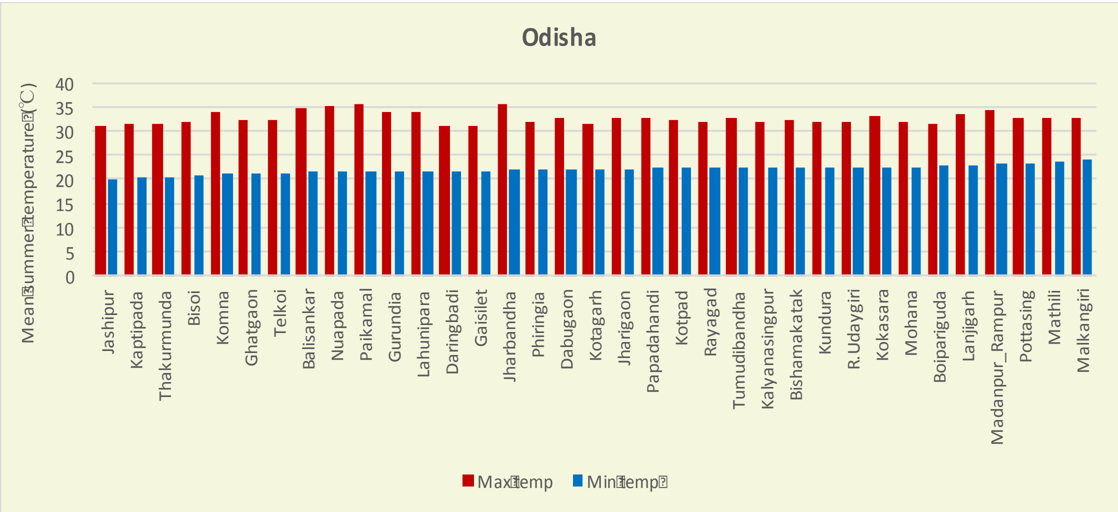

Figure 5.3: Projected mean seasonal temperature (°C) under RCP 8.5 scenario in the study blocks of Chhattisgarh for the period 2021-2050

5.2.2. *Trends in Maximum Temperature During 2021-2050 (by 2035) Compared to the Historical Period of 1984-2014*

Increase in temperature due to greenhouse warming can impact crop yields directly, increase evapo-transpiration demand and moisture stress, ultimately contributing to increased water demand and irrigation needs for agriculture. This will have implications for MGNREGA works related to water management. Further, under extreme cases high temperatures can lead to heat strokes, harming humans. In this section changes in maximum temperature during 2021-2050 over the historical period of 1984-2014 is analysed and presented for the identified ICRG blocks in the three states of Bihar, Chhattisgarh and Odisha.

Bihar (Figure 5.4)

- In the various ICRG blocks of Bihar an increase in maximum temperature during 2021-2050 over the historical period (1984-2004) is seen.
- The temperature increase is in the range of 1.2 °C to 5.1 °C.
    - Maximum increase of over 5 °C is seen in Ladania block, followed by Balrampur block.
    - Least increase of 1.2 °C is recorded in Laukha block.
- The temperature increase in the majority of the blocks over the historical period in Bihar is in the range of 3 °C to 4 °C (63% of the blocks).

Chhattisgarh (Figure 5.5)

The change in temperature in the ICRG blocks of Chhattisgarh is both positive and negative.

- The increase in temperature (during 2021-2050) compared to the historical period (1984-2014) is seen in 12 of the 30 blocks in Chhattisgarh – 0.09 °C to 2 °C
    - Highest increase is projected for Takhatpur block, followed by Masturi, Poudi-Uprora and Kartala blocks.
    - An increase of more than one degree C is projected in eight of thirty blocks.
- A decrease in temperature during the same period is projected in the remaining 18 blocks (60%).
    - The decrease in temperature ranges from -0.04 °C to -3.23 °C, with maximum decrease of more than 3 °C projected for three blocks namely, Lundra, Batouli and Bhagicha.
    - In a majority of the blocks projected to show a decrease in temperature as compared to the historical period, the decrease is less than one degree C.

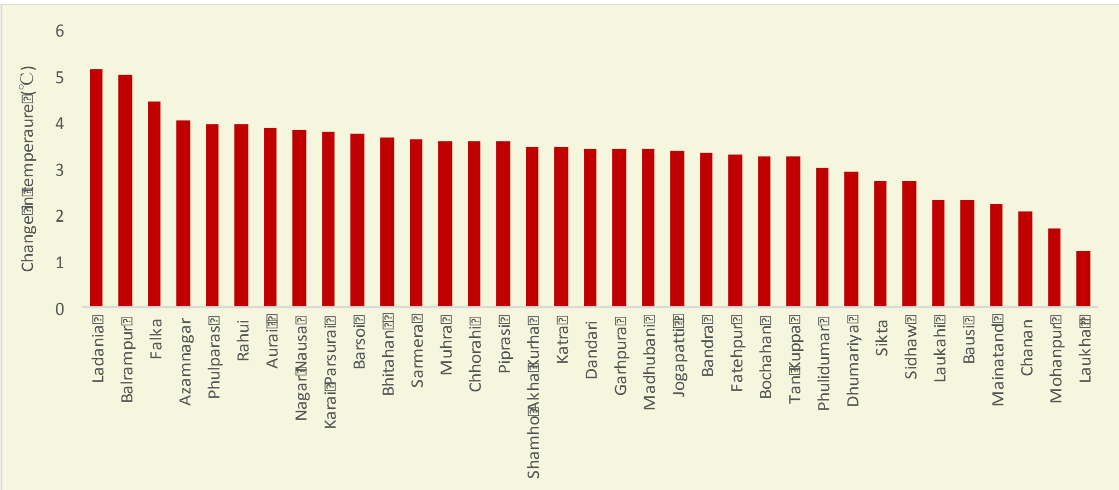

Figure 5.4: Change in temperature (°C) by 2035 (2021-2050) relative to the historical 1984-2014 period in the ICRG blocks of Bihar

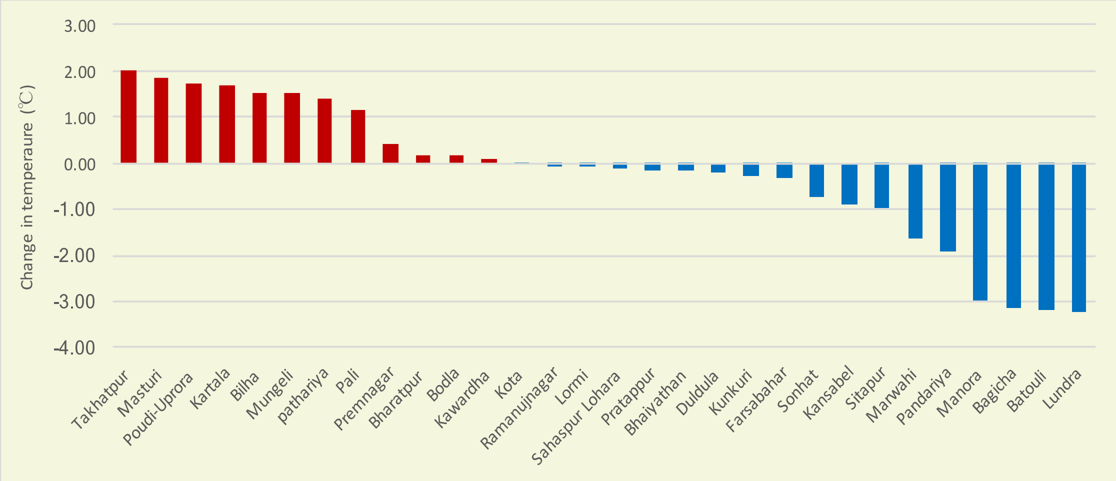

Figure 5.5: Change in temperature (°C) by 2035 (2021-2050) relative to the historical 1984-2014 period in the ICRG blocks of Chhattisgarh

Odisha (Figure 5.6)

The identified ICRG blocks in Odisha also show both increasing and decreasing trends in warming as compared to the historical period (1984-2014).

- The increase in temperature is in 13 of the 35 blocks while in the rest, a decrease in temperature is projected.
- The increase in temperature is in the range of 0.3 °C to 1.5 °C.
  - Highest increase in temperature of about 1.5 °C is projected in Telkoi, Balisankar and Gaisilet blocks.
  - Least increase in temperature is recorded in Kaptipada block.
- The decrease in temperature is highest in Tumudibandha block (-1.69 °C), followed by Madanpur_Rampur, Boipariguda, Thakurmunda, Daringbadi and Kundura blocks all showing an increase of more than one degree C under the projected 2021-2050 scenario.
- In nine blocks, the decrease in temperature is in the range of 0.5 °C to 1.0 °C.

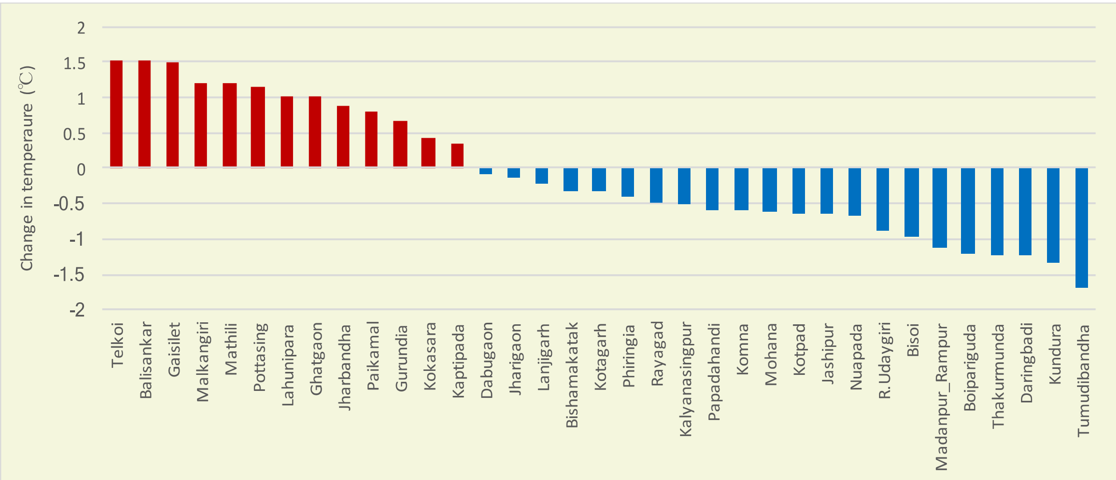

Figure 5.6: Change in temperature (°C) by 2035 (2021-2050) relative to the historical 1984-2014 period in the ICRG blocks of Odisha

5.3. Rainfall Projections for the Period 2021-2050 (2035)

In this section, assessment of rainfall projections for the period 2021-2050, with respect to number of rainy days and in comparison to the historical period (1984-2014) are presented. Any reduction in the number of rainy days, accompanied by either increase in total rainfall or no significant change in rainfall indicates the occurrence of flood events. Number of rainy days and rainfall intensity are also critical for designing water storage structures under MGNREGA.

5.3.1. Changes in Mean Monsoon (JJAS) Rainfall During 2021-2050 Compared to the Historical Period 1984-2014

The mean monsoon (June to September-JJAS) rainfall for the two periods – historical (1984-2014) and projected (2021-2050) is compared in this section to understand the changes in rainfall during the critical agricultural season. **Figure 5.7** presents the top five blocks among the identified ICRG blocks, showing increase or decrease in rainfall during JJAS in the three states of Bihar, Chhattisgarh and Odisha. Appendix gives the change in rainfall for all the identified ICRG blocks in the three states.

Bihar

- The top five blocks showing increase in rainfall during 2021-2050 over the historical period in Bihar are Azamnagar, Barsoi, Balrampur, Aurai and Karai Parsurai.
  - The positive change or increase in rainfall ranges from 31.4% in Karai Parsurai to about 40% in Azamnagar.
- However, in the blocks of Sidhaw, Nagar Nuasa, Phulidumar, Phulparas and Laukahi, a decrease in rainfall during the 2021-2050 compared to the historical period is projected.
  - In the other blocks, the decrease is in the range of -20.3% to -25.6%.

Chhattisgarh

- The increase in rainfall in the Chhattisgarh blocks (top five) ranges from 8% in Farsabahar to 16.8% in Kota block.
  - Other blocks showing an increase in rainfall include Bodla (15.7%), Sahasrapur-Lohara (10.1%) and Marwahi (9.7%).
- During the same period, a decrease in rainfall is projected in the blocks (top five) of Bhaiyathan, Pathariya, Pratappur, Kunkuri and Pali.
  - The decrease is greater than one-fourth in Bhaiyathan (-25.4%), it is -21.6% in Pratappur and -23% in Pathariya.
  - There is a 16% decrease in the other two blocks – Kunkuri and Pali.

Odisha

- Top five blocks with highest projected increase in monsoon rainfall in Odisha are Pottasingh, Daringbadi, Bisoi, Kaptipada and Jashipur.
  - The increase in rainfall is more than 20% in Pottasingh and Daringbadi and it is 13% and 14.6% in Kaptipada and Bisoi blocks, respectively.
  - The least increase of 8.9% is projected for Jashipur block.

- The decrease in rainfall in Odisha blocks is in the range of -11.2% to -28.9%.
  - The highest reduction in monsoon rainfall is projected for Bishamakatak, followed by Kundura and Papadahandi blocks.
  - In Gurundia block, it is -12.1% decrease and it is -11.2% in Jharigaon block.

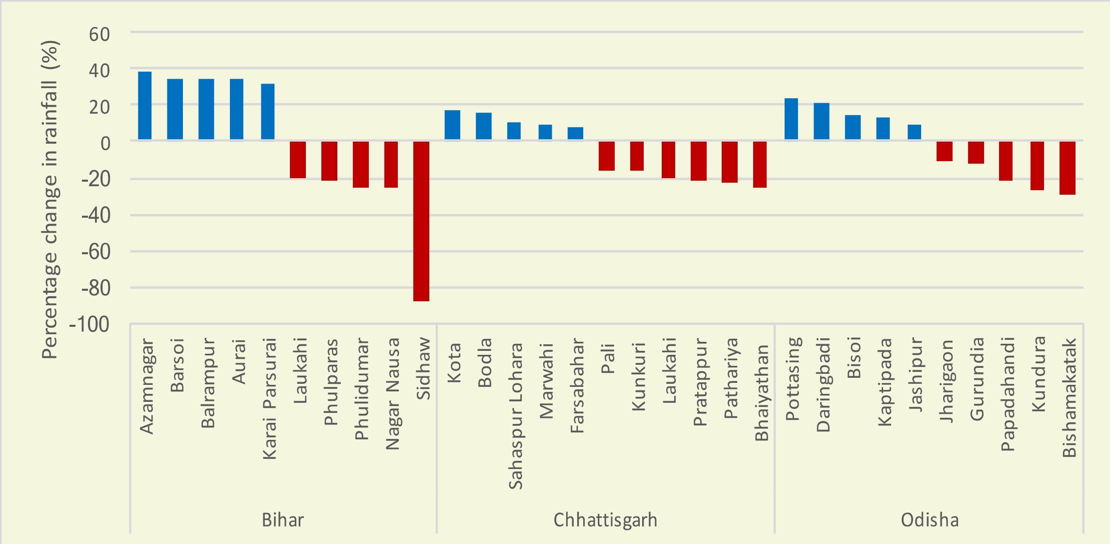

Figure 5.7: Top five blocks projected to increase or decrease in rainfall during 2021-2050 period compared to the historical period of 1984-2014

It is clear from this analysis that change in rainfall varied even within a state across the different blocks. This data will help in decisions on whether to plan for coping with decreased or increased rainfall in the blocks. Further, this information will help in designing land-water structures under MGNREGA according to changes in rainfall projected for the blocks.

5.3.2. Frequency and Intensity of Rainfall During the Projected Period (2021-2050)

Rainfall intensity data is very critical for designing water conservation and storage structures under MGNREGA. **Table 5.2** presents the number of days receiving rainfall of two intensity classes; 51-100 mm/day and > 100 mm/day in different ICRG blocks across the three study states.

Bihar (Table 5.2)

Number of rainy days – 51-100 mm/day

- All the blocks are projected to receive higher number of rainy days with 51-100 mm rainfall intensity than rainfall of > 100 mm during the projected period of 2021-2050.
- Blocks are projected to receive rainfall of this intensity for 71 to 218 days.
  - 18 blocks are projected to receive 71 to 150 days of rainfall of 51-100 mm intensity.

Number of rainy days - > 100 mm rainfall/day

- Number of days blocks receiving rainfall of > 100 mm intensity varied from 13 days in Sidhaw and Balrampur to 63 days in Piprasi.
- 21 blocks (60%) are projected to receive < 20 days of rainfall (least being 13 days) while the others are projected to receive > 20 days of rainfall of > 100 mm intensity.

Chhattisgarh (Table 5.2)

Number of rainy days - 51 – 100 mm rainfall/day

- The number of rainy days projected for the 2021-2050 period is 124 to 262 days.
  - Blocks projected to receive maximum number of days of rainfall with 51-100 mm intensity are Premnagar (262 days), Lundra (250 days) and Bagicha (250 days) blocks.
  - 19 blocks are projected to receive 100-200 days of rainfall of this intensity.

Number of rainy days - > 100 mm rainfall/day

- The number of days projected to receive rainfall > 100 mm in the ICRG blocks of Chhattisgarh is projected to be 14 days in Kartala block to 74 days in Kawardha and Sahasrapur-Lohara blocks.

Table 5.2: Distribution of rainfall across different ICRG blocks (units are days) across two rainfall intensity classes of 51-100 mm and >100 mm/day

Bihar			Chhattisgarh			Odisha		
Blocks	Rainfall (mm)		Blocks	Rainfall		Blocks	Rainfall (mm)	
	51-100	> 100		51-100	> 100		50-100	>100
Piprasi	198	63	Sahaspur Lohara	124	74	Nuapada	188	62
Rahui	146	49	Kawardha	141	74	Kokasara	168	58
Mainatand	176	49	Manora	151	63	Bishamakatak	294	54
Sikta	176	49	Ramanujnagar	159	63	Kotagarh	294	54
Shamho Akha Kurha	183	48	Kunkuri	149	44	Balisankar	384	51
Tan Kuppa	142	46	Duldula	154	43	Komna	131	48
Chanan	218	46	Kansabel	184	43	Thakurmunda	166	46
Bhitahan	119	37	Sitapur	184	43	Kaptipada	166	45
Madhubani	218	37	Bagicha	250	39	Kalyanasingpur	174	42
Barsoi	142	29	Lundra	250	39	R.Udaygiri	175	42
Sarmera	142	29	Bharatpur	128	37	Jharbandha	124	41
Phulidumar	150	28	Bodla	141	37	Paikamal	149	41
Laukha	176	27	Marwahi	178	37	Lanjigarh	173	40
Mohanpur	167	26	Farsabahar	194	34	Gaisilet	120	36
Bochahan	71	24	Batouli	147	33	Gurundia	127	35
Phulparas	117	24	Sonhat	173	32	Lahunipara	276	35
Laukahi	171	24	Premnagar	262	30	Rayagad	212	34
Ladania	163	23	Pathariya	167	28	Tumudibandha	235	34
Falka	198	22	Pali	133	24	Jharigaon	157	32
Azamnagar	76	19	Bhaiyathan	182	24	Dabugaon	172	32
Karai Parsurai	114	19	Pratappur	185	24	Papadahandi	175	27
Nagar Nausa	116	19	Bilha	192	23	Kotpad	177	27
Dandari	168	19	Mungeli	192	23	Mohana	204	26

Bihar			Chhattisgarh			Odisha		
Blocks	Rainfall (mm)		Blocks	Rainfall		Blocks	Rainfall (mm)	
	51-100	> 100		51-100	> 100		50-100	>100
Garhpura	174	19	Poudi-Uprora	192	23	Daringbadi	191	25
Chhorahi	188	19	Pandariya	175	22	Malkangiri	110	22
Bandra	138	18	Lormi	137	16	Mathili	110	22
Dhumariya	149	18	Masturi	158	16	Ghatgaon	268	22
Katra	106	17	Kota	173	16	Madanpur-Rampur	378	22
Bausi	114	14	Takhatpur	185	16	Pottasing	169	21
Muhra	114	14	Kartala	158	14	Phiringia	378	21
Aurai	142	14				Boipariguda	314	17
Fatehpur	142	14				Kundura	314	17
Jogapatti	176	14				Bisoi	131	15
Balrampur	174	13				Jashipur	131	15
Sidhaw	174	13				Telkoi	156	14

Odisha (Table 5.2)

Number of rainy days - 51 – 100 mm rainfall/day

- The number of rainy days projected for the 2021-2050 period in the ICRG blocks of Odisha are 110 days to 384 days.
  - Blocks projected to receive maximum number of days of rainfall (> 300 days) with 51-100 mm intensity are Boipariguda, Kundura, Madanpur-Rampur, Phiringia and Balisankar blocks.
  - Least number of rainy days (110-200 days) of this intensity is projected in 23 blocks.

Number of rainy days - > 100 mm rainfall/day

- Rainfall of intensity > 100 mm is projected to occur over 14 to 62 days in Odisha blocks.
- 12 blocks are projected to receive < 25 days of >100 mm rainfall; 18 blocks for 25-50 days and only 5 blocks for > 50 days.

5.3.3. *Change in Frequency and Intensity of high intensity Rainfall During the Projected Period (2021-2050) Over the Historical Period (1984-2014)*

A comparison of the frequency of occurrence (number of days) of rainfall of different intensities between the historical period (1984-2014) and the projected RCP 8.5 scenario for the period 2021-2050 indicates that the trends are varied across blocks and states.

Bihar (Figure 5.8)

Number of rainy days - 51 – 100 mm rainfall/day

- Among the identified ICRG blocks in Bihar, the frequency of occurrence of rainfall events of 51-100 mm intensity is projected to increase in all except two blocks – Azamnagar and Bausi.

- The increase in frequency projected for the blocks of Bihar ranges from ≤ 10 days in Phulparas (7 days) and Bochahan (10 days) blocks to 151 days in Falka block.
- About one-third of the blocks are projected to receive rainfall of 51-100 mm intensity for more than 100 days and 51-100 days, respectively.

Number of rainy days - > 100 mm rainfall/day

- The number of rainy days of > 100 mm intensity is projected to increase in 24 of 35 blocks while in ten blocks, a decrease is projected. In one block (Nagara Nausa), no change in frequency of occurrence of rainfall of this intensity is projected.
- The increase ranges from 2 days in Dandari to as high as 55 days in Piprasi block.

Chhattisgarh (Figure 5.9)

In all the blocks of Chhattisgarh the number of rainy days of both 51-100 mm and > 100 mm are projected to increase during 2021-2050 as compared to the historical 1984-2014 period.

Number of rainy days - 51 – 100 mm rainfall/day

- The increase is in the range of 26 days in Bharatpur to 183 days in Premnagar block.
- In one-third of the blocks, an increase of more than 100 days in occurrence of rainfall events of intensity 50-100 mm is projected.

Number of rainy days - > 100 mm rainfall/day

- Four blocks – Manora, Ramanujnagar, Kawardha and Sahasrapur-Lohara are projected to have an increase of 53 to 68 days in the frequency of occurrence of rainfall of this intensity, which is the highest.
- In seven blocks – Kartala, Kota, Lormi, Bhaiyathan, Masturi, Bilha and Batouli; the increase in number of rainy days is anywhere between one to ten days.

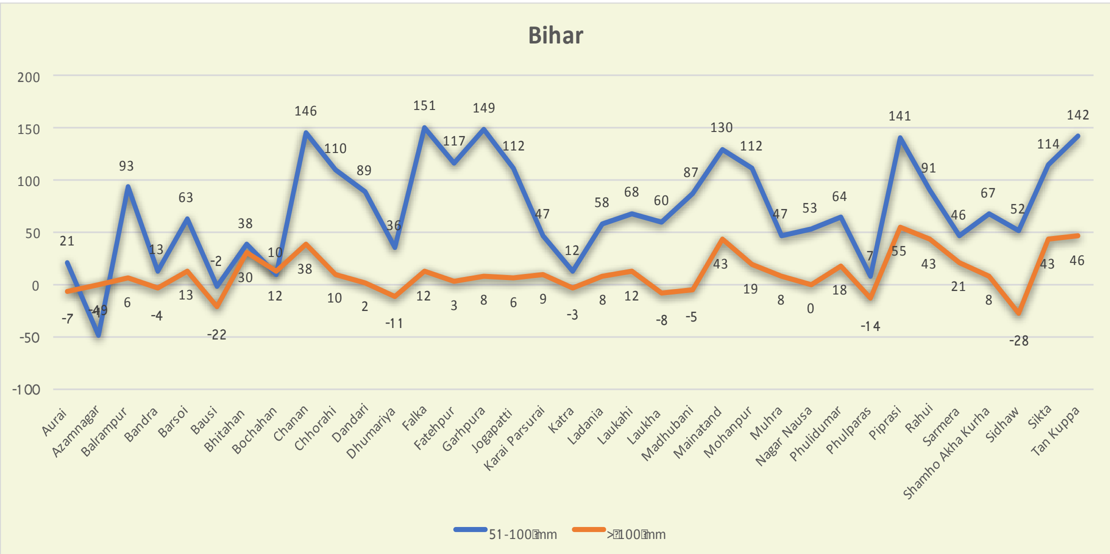

Figure 5.8: Change in frequency of occurrence (in days) of rainfall events of 51-100 mm and > 100 mm in the projected scenario (2021-2050) relative to the historical period (1984-2014) in the ICRG blocks of Bihar

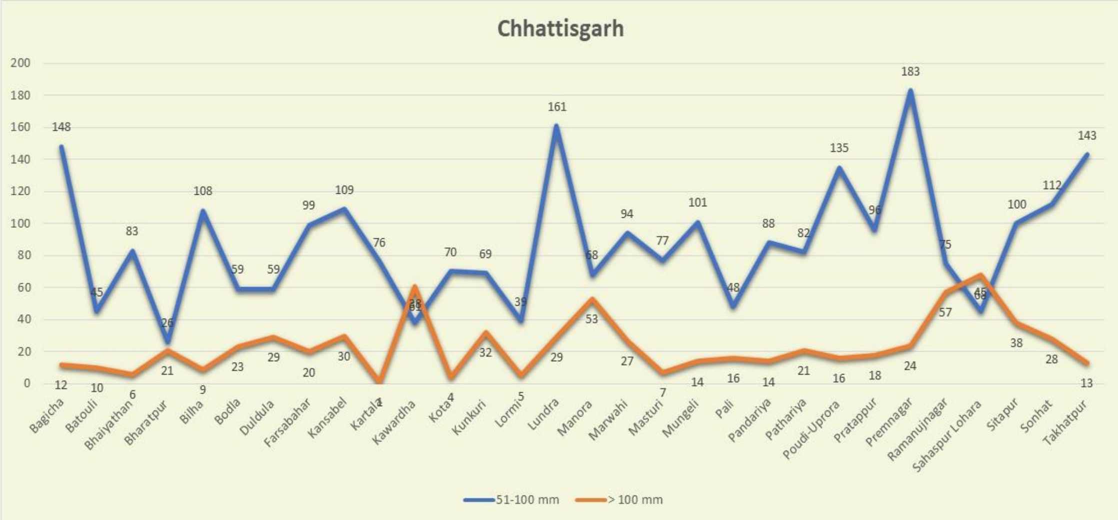

Figure 5.9: Change in frequency of occurrence of rainfall events of 51-100 mm and > 100 mm in the projected scenario (2021-2050) relative to the historical period (1984-2014) in the ICRG blocks of Chhattisgarh

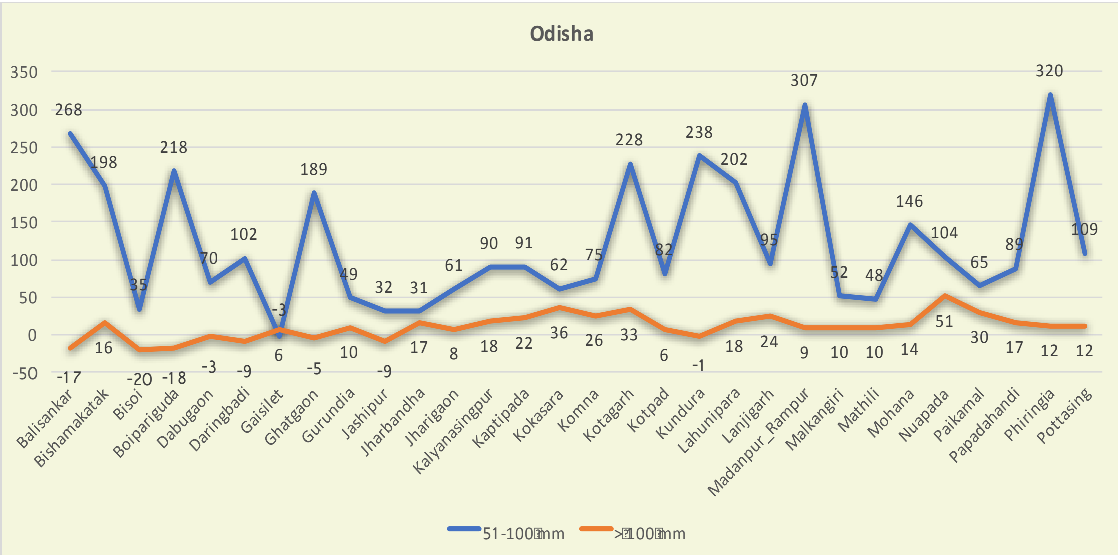

Figure 5.10: Change in frequency of occurrence of rainfall events of 51-100 mm and > 100 mm in the projected scenario (2021-2050) relative to the historical period (1984-2014) in the ICRG blocks of Odisha

Odisha (Figure 5.10)

Blocks of Odisha are projected to have an increase in the number of rainfall events of 50-100 mm and > 100 mm rainfall.

Number of rainy days - 51 – 100 mm rainfall/day

- In all but one block (Gaisilet), the frequency of occurrence of rainfall events of 51-100 mm is projected to increase in the range of 31 (Jharbandha) to 320 days (Phiringia).
- In 11 of the 35 blocks, the increase in frequency of occurrence of this event is in the range of 100-300 days.
- In a majority of the blocks (16 out of 35), the increase is anywhere between 30-95 days.

Number of rainy days - > 100 mm rainfall/day

- In 77% of the blocks in Odisha, an increase in > 100 mm rainfall is projected with the increase in number of rainy days being 6 to 51 days.
- Maximum decrease in the frequency of occurrence of > 100 mm rainfall is projected for Bisoi block, followed by Boipariguda and Balisankar blocks; 17 to 20 days.

6. CHANGES IN RAINFALL VARIABILITY DUE TO PROJECTED CLIMATE CHANGE

In this section, the changes in rainfall variability due to projected climate change is compared with the historical rainfall variability. The blocks in each of the states are ranked according to the current climate variability (Coefficient of Variation) and then the projected rainfall variability is compared. **Table 6.1** provides a comparison of changes in rainfall variability due to climate change compared to the historical rainfall variability.

Table 6.1: Hotspots of current and future climate variability based on Coefficient of Variation in rainfall

Bihar			Chhattisgarh			Odisha		
Blocks	CV (1984-2014)	CV (2021-2050)	Blocks	CV (1984-2014)	CV (2021-2050)	Blocks	CV (1984-2014)	CV (2021-2050)
Aurai	33.9	60.5	Bagicha	19.2	38.3	Balisankar	20.9	41.9
Azamnagar	25.6	44.6	Batouli	20.3	45.0	Bishamakatak	21.4	33.0
Balrampur	26.5	44.3	Bhaiyathan	26.5	31.4	Bisoi	21.0	54.8
Bandra	29.7	38.0	Bharatpur	24.0	20.9	Boipariguda	24.3	26.2
Barsoi	25.6	41.8	Bilha	19.1	39.3	Dabugaon	26.6	17.7
Bausi	25.5	51.6	Bodla	29.9	40.3	Daringbadi	20.3	33.8
Bhitahan	29.1	34.3	Duldula	23.5	14.9	Gaisilet	27.7	15.2
Bochahan	27.1	30.0	Farsabahar	26.4	12.8	Ghatgaon	22.2	48.0
Chanan	27.7	35.9	Kansabel	24.3	43.3	Gurundia	20.9	20.5
Chhorahi	26.6	38.9	Kartala	20.8	37.6	Jashipur	21.7	40.4
Dandari	27.3	40.3	Kawardha	17.6	41.6	Jharbandha	21.1	36.4
Dhumariya	25.8	53.8	Kota	20.0	16.7	Jharigaon	26.8	35.1
Falka	28.9	64.1	Kunkuri	20.5	39.5	Kalyanasingpur	24.0	29.1
Fatehpur	24.5	30.5	Lormi	19.2	40.3	Kaptipada	20.9	45.3
Garhpura	30.6	40.3	Lundra	21.9	45.0	Kokasara	37.1	16.2
Jogapatti	28.3	36.6	Manora	23.2	39.4	Komna	25.2	31.1
Karai Parsurai	27.9	29.9	Marwahi	16.9	19.3	Kotagarh	22.0	33.0
Katra	32.2	41.7	Masturi	23.4	40.3	Kotpad	21.1	29.7
Ladania	29.2	50.9	Mungeli	20.9	38.5	Kundura	24.2	41.3
Laukahi	28.8	58.9	Pali	30.8	42.2	Lahunipara	22.7	19.8
Laukha	29.0	65.9	Pandariya	17.4	42.1	Lanjigarh	28.4	25.3
Madhubani	30.6	30.6	Pathariya	17.5	44.7	Madanpur-Rampur	24.9	22.7
Mainatand	26.8	36.6	Poudi-Uprora	26.7	44.7	Malkangiri	31.5	37.3
Mohanpur	23.9	73.1	Pratappur	25.6	32.9	Mathili	22.3	29.6
Muhra	30.5	41.1	Premnagar	29.9	46.4	Mohana	20.0	42.6
Nagar Nausa	31.9	44.3	Ramanujnagar	24.6	46.4	Nuapada	27.0	32.8
Phulidumar	24.6	35.6	Sahaspur - Lohara	35.3	43.2	Paikamal	27.3	22.7
Phulparas	31.6	49.9	Sitapur	17.8	44.2	Papadahandi	36.0	24.8
Piprasi	38.9	30.6	Sonhat	24.0	18.3	Phiringia	22.2	25.4
Rahui	25.5	36.8	Takhatpur	27.3	39.3	Pottasing	21.4	36.7

Bihar			Chhattisgarh			Odisha		
Blocks	CV (1984-2014)	CV (2021-2050)	Blocks	CV (1984-2014)	CV (2021-2050)	Blocks	CV (1984-2014)	CV (2021-2050)
Sarmera	28.7	26.6				R.Udaygiri	19.6	47.7
Shamho Akha Kurha	24.1	33.3				Rayagad	21.4	40.7
Sidhaw	35.8	36.5				Telkoi	20.0	27.9
Sikta	27.0	38.9				Thakurmunda	18.6	47.2
Tan Kuppa	29.9	31.4				Tumudibandha	23.9	31.4

Bihar

- When CV of monsoon seasonal rainfall of all the blocks of Bihar is considered, 32 out of 35 blocks are projected to experience increased rainfall variability.
- Further, it is projected that six blocks may experience increase in rainfall variability by over 100% and 12 blocks out of 35 are projected to experience > 50%.

Chhattisgarh

- Out of the 30 blocks, 27 blocks are projected to experience increased rainfall variability.
- Among the 30 blocks, eight blocks are projected to experience > 100% increase in monsoon season rainfall variability and 18 blocks by over 50%.

Odisha

- In Orissa, out of the 35 blocks, 26 blocks are projected to experience increasing rainfall variability.
- Out of the 35 blocks, seven blocks are projected to experience over 100% increase in rainfall variability and 15 blocks are projected to experience by over 50%.

Comparison of projected rainfall variability (2021-2050) with the historical 30-year variability (1984-2014) shows an increase in rainfall variability under climate change for most of the blocks. Further, six blocks in Bihar, eight blocks in Chhattisgarh and seven blocks in Odisha are projected to experience more than doubling of the rainfall variability. Similarly, 34% of blocks in Bihar, 60% of the blocks in Chhattisgarh and 43% of the blocks in Odisha are projected to experience over 50% increase in rainfall variability. Thus, this is a significant impact of climate change on monsoon rainfall variability. This will have implications for agriculture, water availability and design of MGNREGA structures.

7. HOTSPOTS OF RAINFALL VARIABILITY

It is possible to rank the various identified ICRG blocks in the three states based on variability in monsoon rainfall, which is crucial for agriculture. The top ranked blocks with high rainfall variability (Coefficient of Variation) could be prioritized for designing climate resilient land and water related structures under MGNREGA. **Table 7.1** lists the top five blocks with highest CV under current climate (1984-2014) as well as under the projected RCP 8.5 scenario for the period – 2021-2050.

Bihar

CV under current climate

- It can be seen from **Table 7.1** that climate variability is greater than 30% in the top five blocks, showing highest CV.
- It is highest in Piprasi (38.8%) and lowest in Nagar Nuasa (31.8%)

CV under projected climate

- Climate variability under this scenario as indicated by the CV is very high and ranges from 58.9% in Laukahi block to as high as 73.1% in Mohanpur block.
- In the other three blocks, it is 60.5% to 65.8%.

Chhattisgarh

CV under current climate

- Among the top five blocks showing high climate variability, Takhatpur block has least CV (27.2%), followed by Bodla and Premnagar blocks.
- In Pali and Sahaspur-Lohara blocks, the CV is greater than 30%.

CV under projected climate

- Variability under the projected climate for the 5 blocks is within a small range of 44.7% to 46.3%.
- Highest variability is projected for Premnagar block (46.3%), which is the third most vulnerable block under the current climate.
- Least variability is projected for Pathariya block (44.7%).

Table 7.1: Hotspots of current and future climate variability based on CV in rainfall

State	Top 5 blocks with highest CV under current climate (1984-2014)		Top 5 blocks with highest CV under RCP 8.5 scenario (2021-2050)	
	Blocks	CV	Blocks	CV
Bihar	Piprasi	38.88	Mohanpur	73.14
	Sidhaw	35.75	Laukha	65.86
	Aurai	33.91	Falka	64.14
	Katra	32.24	Aurai	60.51
	Nagar Nausa	31.86	Laukahi	58.90
Chhattisgarh	Sahaspur-Lohara	35.31	Premnagar	46.36
	Pali	30.76	Ramanujnagar	46.36

State	Top 5 blocks with highest CV under current climate (1984-2014)		Top 5 blocks with highest CV under RCP 8.5 scenario (2021-2050)	
	Blocks	CV	Blocks	CV
	Premnagar	29.90	Batouli	45.04
	Bodla	29.88	Lundra	45.04
	Takhatpur	27.26	Pathariya	44.74
Odisha	Bisoi	54.83	Kokasara	37.10
	Ghatgaon	47.95	Papadahandi	36.01
	R. Udaygiri	47.68	Malkangiri	31.52
	Thakurmunda	47.17	Lanjigarh	28.43
	Kaptipada	45.29	Gaisilet	27.73

Odisha

CV under current climate

- CV ranges from 45.2% in Kaptipada to 54.8% in Bisoi under the current climate.
- Other three blocks have CV of 47% to 48%.

CV under projected climate

- The CV under the projected climate ranges from 27.7% in Gaisilet block to 37.1% in Kokasara block.
- Lanjgarh, Malkangiri and Papdahandi are other blocks among the top five with CV of 28.4% to 36%.

It can be observed that the top five hotspot blocks for current monsoon season rainfall variability are different from the top five hotspot blocks under projected rainfall variability under climate change in all the three states. Only two blocks remained as hotspots under current rainfall variability as well as projected rainfall variability under climate change. Thus, it will be a challenge to decide whether to select the hotspot blocks of historical rainfall variability or hotspot blocks with high rainfall variability under climate change.

8. CONCLUSIONS OF THE STUDY AND IMPLICATIONS FOR CLIMATE RESILIENT INFRASTRUCTURE DEVELOPMENT UNDER MGNREGA

8.1. Main Conclusions

In this study, historical rainfall analysis was carried out for the identified ICRG blocks in the three states of Bihar, Chhattisgarh and Odisha for the period 1984-2014. Similarly, climate change projections were carried out using the latest climate models for the same blocks in the three states for the period 2021-2050. Some of the key highlights of this assessment are presented below:

i. Rainfall variability differs across states and across blocks within a state.

ii. Current rainfall variability is high for 88% of the blocks in Bihar to 30% of the blocks in Chhattisgarh. Number of blocks with > 25% Coefficient of Variation in the three states are:

- Bihar, 31 out of 35 blocks
- Chhattisgarh - 9 out of 30 blocks, and
- Odisha 10 blocks out of 35.

iii. Majority of the blocks across states experienced mild to moderate drought events

- In Bihar, 24 of the 35 blocks experienced mild to moderate drought in over 50% of the years.
- In Chhattisgarh, most blocks experienced mild drought only.
- In Odisha, majority of the blocks experienced only mild drought.

iv. The main implication of temperature and rainfall trend and variability shows that there is a large variation from block to block even within a state and definitely across states. Thus, block level detailed historical analysis of climate trends, especially rainfall trends is critical and necessary to:

- Inform block and district level engineers and staff involved in designing MGNREGA structures and assets, such as check dams, farm ponds, and minor irrigation works.
- Assist them in preparing coping strategies for mild and moderate droughts.
- Assist in contingency planning in the event of delay or failure of June or early sowing rains.
- Inform all the stakeholders about rainfall and temperature trends, frequency of potential extreme rainfall events or droughts.

v. Climate change projections show a large variation in projected temperature trends, with majority of the blocks projected to experience warming even by 2030s.

- Bihar is projected to experience very high levels of warming with majority of the blocks likely warm by 3 to 40C by 2030s. This will have significant implications for irrigation water requirement, soil water stress and heat stress for humans.
- The projected warming levels are moderate in Chhattisgarh and Odisha. Infact, some blocks may experience a marginal decline in temperature.

- Thus, temperature projections and high levels of warming and heat stress are critical for majority of the blocks in Bihar.

vi. Multiple CORDEX model ensemble projections of monsoon season rainfall showed the following:

- Climate change is projected to have significant impact on total monsoon rainfall with majority of the blocks projected to experience either increase or decline.
  - In Bihar, top five blocks are projected to experience 31 to 40% increase in rainfall. But, 5 other blocks are projected to experience decline in the range of 20 to 25%.
  - Chhattisgarh and Odisha are projected to experience moderate increase or decline in rainfall.
- Thus, it is necessary to use block level projections in designing MGNREGA structures, rather than the district or state level trends.
- High intensity rainfalls days (> 100mm/day) are projected to increase most in Odisha with some blocks likely to receive additional 2 days of high rainfall intensity per year.
- Rainfall variability has increased for most blocks and some blocks are projected to experience near doubling of the coefficient of variation of monsoon rainfall.

vii. Comparison of projected rainfall variability (2021-2050) with the historical 30-year variability (1984-2014) shows an increase in rainfall variability under climate change for most of the blocks.

- Six blocks in Bihar, eight blocks in Chhattisgarh and seven blocks in Odisha are projected to experience more than doubling of the rainfall variability.
- Similarly, 34% of blocks in Bihar, 60% of the blocks in Chhattisgarh and 43% of the blocks in Odisha are projected to experience over 50% increase in rainfall variability.
- Thus, climate change is projected to have significant adverse impact on monsoon rainfall variability in all the three states.

8.2. Implications for Developing Climate Resilient Infrastructure under MGNREGA

MGNREGA works are largely related to natural resources such as cropland, grazing land, forests and water resources. Majority of the MGNREGA works are related to land and water conservation and management. The new "Mission Water Conservation" guidelines focus on integrated natural resource management approach. The mission calls for a paradigm shift from promoting "relief measures" to integrated natural resource management approach in implementing MGNREGA. This calls for adoption of climate resilient infrastructure approach to natural resource management under MGNREGA. Under MGNREGA, 100 works out of 153 works relate to NRM, and further, 71 relate to water. Some of the NRM related activities which require climate resilience infrastructure are given below:

- *Check Dam, Earthern Dam, Farm Pond, Feeder Channel, Mini Percolation tank, Stop Dam, Sub Surface Dam, Sunken Pond, Underground Dyke, Boulder Check, Water absorption Trench, Box Trenches, Continuous Contour Trench, Contour Bunds, Earthen Bunding, Earthen Gully Plug, Staggered Trench, Dugwell, Farm Pond Construction of* *canal, Distributory and Minor, Lift Irrigation, Community Well for Irrigation, Desilting, Renovation, Strengthening of Embankment, Belt Vegetation, Afforestation, Eco Restoration of Forest, Forest Protection, Grass Land Development and Silvipasture, Nursery Raising, Plantation in Government Premises, Plantation, Earthen Bunding, Land Development, Development of waste land, Land Levelling, reclamation of Land, Recharge pits, etc.*

A study conducted by Indian Institute of Science in four states has shown that MGNREGA works related to water and land development have contributed to generation of environmental benefits and natural resource conservation - ground water recharge, increased water availability for irrigation, increased soil fertility, reduction in soil erosion, and improved tree cover. These environmental benefits derived from MGNREGA works have in turn contributed to reducing the agricultural and livelihood vulnerability, thus helping to cope with current climate risks and potentially build long-term resilience to projected climate change. Thus, a large poverty alleviation programme such as the MGNREGA is demonstrated to have the potential to deliver resilience or adaptation benefits to current vulnerability.

The MGNREGA is the largest rural development programme implemented in India with a large investment in works related to soil and water conservation, land development, and afforestation, all of which address the causes of degradation of natural resources. Such works lead to the creation of durable assets. MGNREGA works have led to enhanced productivity and regeneration of the natural resource base, further strengthening its potential for generating resilience benefits. In addition, soil conservation, fodder development, afforestation, and drought proofing works have sequestered carbon, thus mitigating climate change.

Potential could exist to further enhance resilience to long-term climate change, through packaging of MGNREGA as a programme to build long-term resilience to future climate change, in addition to reducing vulnerability to current climate risks. In this context, the "Infrastructure for Climate Resilient Growth (ICRG) – a technical assistance programme supported by Department for International Development (DFID) seeks to facilitate more effective investment in rural infrastructure under MGNREGA to support rural economic growth and improve the climate resilience of vulnerable communities. This is envisaged through improving the quality of the physical assets under MGNREGA in selected 103 blocks of three states namely, Bihar, Chhattisgarh and Odisha in India. These blocks are among the 2,500 blocks that the Government of India has chosen for focussed implementation of MGNREGA works.

The identified hotspots of rainfall variability could be the priority blocks wherein planning, designing and implementation of MGNREGA works take into consideration the current climate variability and long-term climate change risks.

8.2.1. Implications for ICRG

In India, programmes such as MGNREGA rarely use historical rainfall trends, flood or drought occurrence information and data in designing the water storage, transport, land management, etc., structures. Some of the potential reasons for not utilising the historical rainfall information are as follows:

i. Rainfall distribution or intensity data for a given village or even block may not be available to the staff of the Rural Development Department or the *Zilla Parishad,* to assist them in designing the MGNREGA structures.

ii. Infact, in states such as Bihar, with very few rain guage stations, rainfall data at the block level may not exist.

iii. In some cases, even if historical climate data are available at IMD or IITM at district or block level, the data may not be accessible to the staff of Rural Development Department or *Zilla Parishad*, who may have to design the structures under MGNREGA.

iv. Even if data is accessible - a rarity, the staff at the district or block level may not have computing facility or technical capacity to analyse large volumes of daily data for 20 or 30 years.

Thus, currently it is a challenge to design the land and water related structures based on historical climate variables at village or block level under the current climate scenario. However, under the ICRG project, historical climate data could be provided to the identified hotspot blocks, along with training of junior engineers and other staff.

8.2.2. Designing Climate Resilient MGNREGA Infrastructure

The challenges in using current and historical climate data in designing MGNREGA land-water structures were presented in previous section. In this section the challenges and options in utilising the climate change projections data are presented.

i. Climate change projections are at a scale of 50 km X 50 km, which is the finest scale available from CORDEX. This scale will limit the application of projected climate variables at village or *Panchayat* level for designing the MGNREGA structures.

ii. GCM and CORDEX projections are for a 30-year period of 2020-2050 and the projected changes occur on decadal scale, which is inadequate for planning the structures under MGNREGA for immediate implementation.

iii. Lack of simple manuals and toolkits for utilizing historical and climate change projections in designing land-water structures or assets at village, block or even district level under MGNREGA.

iv. Lack of technical capacity in utilizing the data on climate variables in designing the land-water structures.

v. Lack of computer skills and computing facilities at the *panchayat*, block and even at district level.

Suggested options for ICRG

i. Develop simple toolkits and manuals for utilizing historical and climate change projections in designing land-water structures at a decentralized scale under MGNREGA.

ii. Select pilot hotspot blocks based on rainfall variability (historical) and projected climate change rainfall variability.

iii. Prepare data packages of historical climate trends and climate change projections for the pilot hotspot blocks.

iv. Conduct training programmes to all technical staff at block and district level in utilising historical and climate change projections data in designing MGNREGA structures.

v. Organize and provide technical back up support to the technical staff of the pilot blocks under the MGNREGA programme.

vi. Monitor, evaluate and learn lessons for large-scale dissemination of climate resilient planning of MGNREGA works.

REFERENCES

1. Pai D.S., Latha Sridhar, Rajeevan M., Sreejith O.P., Satbhai N.S. and Mukhopadhyay B., 2014: Development of a new high spatial resolution (0.25° X 0.25°) Long period (1901-2010) daily gridded rainfall data set over India and its comparison with existing data sets over the region; MAUSAM, 65, 1 (January 2014), pp1-18.

2. A K Srivastava, M Rajeevan and S R Kshirsagar. Development of a High Resolution Daily Gridded Temperature Data Set (1969-2005) for the Indian Region

3. Lala I.P. Ray, P.K. Bora, A.K. Singh, Ram Singh, N.J. Singh and S.M. Feroze (2013). Meteorological drought occurrences at Shillong, Meghalaya, Keanean Journal of Science, Vol 2, 31-36.

4. John Weyant, Christian Azar, Mikiko Kainuma, Jiang Kejun, Nebojsa Nakicenovic, P.R. Shukla, Emilio La Rovere and Gary Yohe (2009). Report of 2.6 Versus 2.9 Watts/m2 RCPP Evaluation Panel (PDF). Geneva, Switzerland: IPCC Secretariat.

5. Collins, M., et al.: Section 12.3.1.3 The New Concentration Driven RCP Scenarios, and their Extensions, in: Chapter 12: Long-term Climate Change: Projections, Commitments and Irreversibility (archived 16 July 2014), in: IPCC AR5 WG1 2013, pp. 1045–1047.

APPENDIX 1: Percentage Change in JJAS Rainfall - Projected vs. Historical - Bihar

Blocks	Mean historical rainfall (mm)	Mean projected rainfall (mm)	% change in rainfall
Sidhaw	744	1391	-87.00
Nagar Nausa	904	1135	-25.60
Phulidumar	930	1164	-25.19
Phulparas	868	1058	-21.85
Laukahi	995	1197	-20.30
Falka	1081	1298	-20.10
Laukha	1136	1346	-18.52
Bhitahan	1076	1272	-18.18
Tan Kuppa	995	1130	-13.61
Jogapatti	1154	1304	-13.00
Madhubani	1068	1189	-11.33
Rahui	837	919	-9.83
Sikta	1217	1336	-9.81
Shamho Akha Kurha	968	1049	-8.38
Piprasi	1106	1189	-7.50
Mohanpur	866	930	-7.37
Ladania	1086	1133	-4.32
Mainatand	1260	1304	-3.49
Muhra	871	894	-2.59
Katra	946	960	-1.47
Bandra	943	872	7.58
Chhorahi	928	851	8.30
Dhumariya	1119	1020	8.83
Bausi	1110	1001	9.85
Chanan	934	841	9.99
Garhpura	988	859	13.06
Sarmera	843	703	16.60
Bochahan	957	780	18.45
Dandari	1098	859	21.77
Fatehpur	889	652	26.70
Karai Parsurai	901	617	31.47
Aurai	929	615	33.81
Balrampur	1274	830	34.83
Barsoi	1253	816	34.84
Azamnagar	1253	777	37.98

APPENDIX 2: Percentage Change in JJAS Rainfall - Projected vs. Historical - Chhattisgarh

Blocks	Mean historical rainfall (mm)	Mean projected rainfall (mm)	% change in rainfall
Bhaiyathan	1107	883	-25.42
Pathariya	979	796	-23.01
Pratappur	1131	930	-21.61
Kunkuri	1251	1076	-16.27
Pali	1206	1038	-16.16
Batouli	1206	1050	-14.87
Sitapur	1223	1075	-13.73
Bagicha	1178	1043	-12.97
Premnagar	1147	1031	-11.21
Takhatpur	1163	1046	-11.20
Kartala	1228	1105	-11.14
Lundra	1162	1050	-10.68
Ramanujnagar	1136	1031	-10.15
Manora	1147	1046	-9.65
Masturi	1116	1051	-6.16
Lormi	1047	1028	-1.86
Bilha	1064	1046	-1.73
Mungeli	1048	1041	-0.72
Pandariya	992	1017	2.50
poudi-Uprora	1246	1299	4.07
Duldula	1241	1326	6.41
Kawardha	953	1024	6.97
Kansabel	1019	1097	7.09
Bharatpur	1052	1134	7.22
Sonhat	1100	1195	7.94
Farsabahar	1230	1339	8.14
Marwahi	1116	1236	9.69
Sahaspur Lohara	929	1033	10.09
Bodla	927	1099	15.68
Kota	1067	1283	16.84

APPENDIX 3: Percentage Change in JJAS Rainfall - Projected vs. Historical - Odisha

Blocks	Mean historical rainfall (mm)	Mean projected rainfall (mm)	% change in rainfall
Bishamakatak	935	726	-28.86
Kundura	1331	1051	-26.61
Papadahandi	1497	1230	-21.72
Gurundia	1304	1163	-12.10
Jharigaon	1211	1089	-11.20
Lanjigarh	1189	1096	-8.51
Mathili	1303	1201	-8.50
Balisankar	1195	1102	-8.44
Nuapada	1134	1060	-6.99
Phiringia	1159	1089	-6.42
Kotpad	1311	1251	-4.77
Lahunipara	1234	1188	-3.85
Thakurmunda	1246	1213	-2.69
Komna	1076	1055	-1.96
Kokasara	1477	1461	-1.07
Kotagarh	1038	1029	-0.89
Ghatgaon	1183	1181	-0.19
Gaisilet	1320	1318	-0.17
Boipariguda	1366	1380	1.01
Malkangiri	1082	1095	1.20
Jharbandha	1051	1068	1.62
Kalyanasingpur	1041	1067	2.47
Tumudibandha	1103	1135	2.85
Dabugaon	1239	1277	2.95
Madanpur_Rampur	1237	1282	3.51
Mohana	864	897	3.72
Paikamal	1093	1143	4.40
Telkoi	1162	1222	4.94
Rayagad	761	819	7.03
R.Udaygiri	800	869	7.89
Jashipur	1219	1338	8.88
Kaptipada	1227	1411	13.02
Bisoi	1142	1338	14.63
Daringbadi	994	1259	21.04
Pottasing	885	1155	23.40