Climate change, El-Nino, monsoon, climate variability over MP, impact on crops and role of GKMS

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- Aim of the study
- Extreme events
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- Impact of climate change on crops
- Quantified response of climate change on crops
- Adaptive measures and AAS towards sustainable solution
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CLIMATE CHANGE
The fact is Increase in atmospheric carbon dioxide (CO₂) and other green house gases *viz.* methane (CH₄), nitrous oxide (N₂O) and CFC:

- due to fossil fuel burning,
- rapid industrialization and
- deforestation,
- which reduce the amount of earth’s radiation, that escapes to space.
Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity.

**IPCC**

The UNEP and the WMO jointly established IPCC (Intergovernmental Panel on Climate Change) to assess available scientific information on climate change as well as to study its impact.
IT'S BECOMING WARMER AROUND HERE!

YES, IT'S HARD TO SURVIVE!!

SEE!!! THE CORALS ARE LOSING THEIR COLOURS!!!

YES—AND I'VE LOST WEIGHT!!!!

I'M SUFFOCATING! THERE'S LESS AND LESS OXYGEN!
AIMS OF THE STUDY

➢ To review and summarize key effects of climate change and climate variability in various parts of India with special reference to M.P.

➢ To study impact of climate change on Indian Summer monsoon.

➢ To summarize impact of climate variability on crops and to provide adaptive measures as sustainable solution under GKMS(Gramin Krishi Mausam Seva).
Increasing climate variability leads to floods, cyclones, tropical storms, heat and cold waves, droughts, frosts, dust / sand storms etc. (IPCC 2007)
Table 1. Summary of observed changes in extreme events and severe climate anomalies in India and adjacent countries

<table>
<thead>
<tr>
<th>Country/region</th>
<th>Key trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>A) Heatwaves</strong></td>
</tr>
<tr>
<td>India</td>
<td>Frequency of hot days and multiple-day heat waves have increased in past century</td>
</tr>
<tr>
<td></td>
<td><strong>B) Intense rains and floods</strong></td>
</tr>
<tr>
<td>South Asia</td>
<td>Serious and recurrent floods in Bangladesh, Nepal and N-E States of India during 2002 to 2004; a record 944 mm of r/f in Mumbai, India on 26 to 27 July 2005; floods in Surat, Barmer and in Srinagar during 2006</td>
</tr>
<tr>
<td></td>
<td><strong>C) Droughts</strong></td>
</tr>
<tr>
<td>South Asia</td>
<td>Consecutive droughts in 1999 and 2000 in Pakistan and N-W India lead to sharp decline in watertables; consecutive droughts between 2000 and 2002 caused crops failure in Orissa; droughts in N-E India during 2006</td>
</tr>
<tr>
<td></td>
<td><strong>D) Cyclones and typhoons</strong></td>
</tr>
<tr>
<td>South Asia</td>
<td>Frequency of monsoon depressions and cyclones formation in Bay of Bengal and Arabian sea on decline since 1970, but intensity increased causing severe floods</td>
</tr>
</tbody>
</table>
Extreme Weather Events in India

- Flood
- Storm
- Earthquake/tsunami, volcanic eruption
- Others (Heat wave, cold wave, forest fire)

Years: 1950 to 2005

Graph showing the frequency of extreme weather events over the years.
Heat Wave (2003) - Damage to Poultry

Andhra Pradesh

- 20 lakhs birds died in May & June 2003
- Highest in E. Godavari - 7 Lakhs; W. Godavari – 5 lakhs
- Egg production decreased in the state by 25%
- Total Loss by 27 Crores
Floods in Andhra Pradesh during the years 2005, 2006 & 2007
Cold Wave

Frost damage is the major weather hazard, on a planetary scale, as far as agricultural and forest economical losses are concerned.

Frost damage to the different crops (Hisar, 2005-06)

- Papaya
- Mustard
- Ice
- Jatropha
Cyclone
HUDHUD ON 12/10/14
00 UTC of 11th OCTOBER 2014 IN ASSOCIATION WITH VERY EVERE CYCLONIC STORM HUDHUD OVER BAY OF BENGAL

IST = UTC + 0530 HRS
D: DEPRESSION
DD: DEEP DEPRESSION
CS: CYCLONIC STORM
SCS: SEVERE CYCLONIC STORM
VSCS: VERY SEVERE CYCLONIC STORM

MAX WIND: 95 KT
FCST WIND: 12/15000Z N1634 E0840
FCST WIND: 12/16000Z N1530 E0840
FCST WIND: 12/17000Z N1430 E0840
FCST WIND: 12/18000Z N1330 E0840
FCST WIND: 12/19000Z N1230 E0840
FCST WIND: 12/20000Z N1130 E0840
FCST WIND: 12/21000Z N1030 E0840
FCST WIND: 12/22000Z N0930 E0840
FCST WIND: 12/23000Z N0830 E0840
FCST WIND: 12/24000Z N0730 E0840

NEXT MSG: 201411210300Z

OBSERVED TRACK
FORECAST TRACK
CONES OF UNCERTAINTY
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<thead>
<tr>
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<th>30.vvp</th>
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</thead>
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<tr>
<td>Clutter Filter:</td>
<td>IIRDoppler 8</td>
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<tr>
<td>Time sampling:</td>
<td>50</td>
</tr>
<tr>
<td>PRF:</td>
<td>600 Hz / 450 Hz</td>
</tr>
<tr>
<td>Alg type:</td>
<td>Complete</td>
</tr>
<tr>
<td>Elevation:</td>
<td>0.2 deg to 21.0 deg</td>
</tr>
<tr>
<td>Second reg:</td>
<td>On</td>
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</tbody>
</table>

Rainbow® SELEX-SI
<table>
<thead>
<tr>
<th>DIVISION</th>
<th>CITY</th>
<th>RAINFALL (IN MM)</th>
<th>24 HRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>REWA</td>
<td>REWA</td>
<td>115.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SATNA</td>
<td>98.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SIDHI</td>
<td>191.2</td>
<td></td>
</tr>
<tr>
<td>SHAHDOLE</td>
<td>UMARIA</td>
<td>64.9</td>
<td></td>
</tr>
<tr>
<td>JABALPUR</td>
<td>JABALPUR</td>
<td>23.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MANDLA</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MALANKHAND</td>
<td>84.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NARSINGHPUR</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEONI</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KHAJURAHO</td>
<td>26.8</td>
<td></td>
</tr>
<tr>
<td>SAGAR</td>
<td>NOWGAON</td>
<td>5.0</td>
<td></td>
</tr>
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<td></td>
<td>SAGAR</td>
<td>0.8</td>
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<td>TIKAMGARH</td>
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<td>DAMOH</td>
<td>14.4</td>
<td></td>
</tr>
<tr>
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<td>BHOPAL</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAISEN</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAJGARH</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DHAR</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INDORE</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RATLAM</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHAJAPUR</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UJJAIN</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHAMBA</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHEOPURKALAN</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GWALIOR</td>
<td>DATIA</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GUNA</td>
<td>Tr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GWALIOR</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SHIVPURI</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HOSHANGABAD</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BETUL</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PACHMARHII</td>
<td>16.6</td>
</tr>
</tbody>
</table>

**CHIEF AMOUNT OF RAINFALL LAST 24 HOURS**

**RAINFALL DATA OF MP DATED 14-10-2014**
<table>
<thead>
<tr>
<th>DIVISION</th>
<th>FORECAST</th>
<th>WARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOSHANGABAD, JABALPUR, SHAHDOL</td>
<td>FAIRLY WIDESPREAD RAIN</td>
<td>HEAVY RAIN AT ISOLATED PLACES UPTO 14TH MORNING</td>
</tr>
<tr>
<td>SAGAR, SATNA</td>
<td>WIDESPREAD RAIN</td>
<td>HEAVY RAIN AT ISOLATED PLACES UPTO 15TH MORNING</td>
</tr>
<tr>
<td>BHOPAL, GWALIOR, CHAMBAL</td>
<td>SCATTERED</td>
<td>NIL</td>
</tr>
<tr>
<td>INDORE, UJJAIN</td>
<td>ISOLATED</td>
<td>NIL</td>
</tr>
<tr>
<td>CROP</td>
<td>ADVISORIES</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Matured and ready to harvest soybean crop</td>
<td>Harvest the crop before 13(^{th}) Oct</td>
<td></td>
</tr>
<tr>
<td>Matured Urd, Moong and Maize crops</td>
<td>Harvest the crop before 13(^{th}) Oct</td>
<td></td>
</tr>
<tr>
<td>Late sown leguminous crops</td>
<td>Harvest in due course of time as and when matured</td>
<td></td>
</tr>
<tr>
<td>Rice crop to be ready to harvest within 3-4 weeks</td>
<td>Rain due to HudHud will help in supplementing irrigation</td>
<td></td>
</tr>
<tr>
<td>Winter crops \textit{viz.} gram, wheat</td>
<td>Prepare land, conserve moisture/rainfall/water for \textit{rabi} crops</td>
<td></td>
</tr>
</tbody>
</table>

N.B. : As such impact of HudHud as depression/well marked low over the State will ultimately help in sowing and growth of winter crops.
ONE WINTER...

Hey, brother! What is the date?

Oh! I don't understand, it's still early in the season! But let's go—there's a meeting...

Dear fellow bears: I regret to inform you that, due to higher temperatures this year, our habitat is melting away!
MONSOON
The impact of climate change is intensifying day by day.

India has a unique climate system dominated by the monsoon.

Global warming is intensifying monsoon in central India, increasing risk from heavier rains during the season.

Heavy monsoon rains in central India were more intense between 1981 to 2000 than in 1950s, 1960s. Severe rains doubled over the same period. This was linked to rising global temperatures, as opined by IITM scientists.
Study shows that changing monsoon will have fewer rainy days.

More than half the world’s population depends on Asian monsoon to bring much needed water for agriculture.

The monsoon rainfall accounts for more than 80% of total rainfall in India, which accounts for 25% of GDP and 70% of the population.

Monsoon may be delayed by 5-15 days in next hundred years due to climate change, which can affect *kharif* agriculture in parts of India.
Rising temperatures may weaken the monsoon causing less or intense precipitation, longer breaks, floods, droughts, cyclones.

Future projections predicated that by end of 21st century, rainfall will increase by 15-31% and mean annual temperature by $30^\circ$C to $60^\circ$C.

The warming will be more pronounced over land areas, over northern India.

Climate change can bring, as opined by IPCC in 1994, changes in parts of Asia viz. increase in rainfall, strengthening monsoon and increase in monsoon variability.
Table 2. Summary of observed past and present changes in precipitation

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>Change in precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Asia</td>
<td>India</td>
<td>Increased rains in N-W during summer monsoon in recent decades; lower no. of rainy days along east coast</td>
</tr>
<tr>
<td></td>
<td>Pakistan</td>
<td>10 to 15% decrease in coastal belt increase in summer and winter precipitation over last 40 years in N-Pakistan</td>
</tr>
<tr>
<td></td>
<td>Bangladesh</td>
<td>Decadal rain anomalies above long term averages since 1960s</td>
</tr>
<tr>
<td>S-E Asia</td>
<td>Philippines</td>
<td>Increase in annual mean R/F since 1980s and number of rainy days since 1990s; increase in inter – annual variability of onset of R/F</td>
</tr>
</tbody>
</table>
IMD data in relation to climate change

IMD data revealed that annual mean temperature anomalies based on data set from 1901 to 2006 showed increasing trend especially from 1991 onwards.

Figure 1. Annual mean temperature anomalies (1901-2006)
The annual maximum and minimum temperature anomalies based on data set from 1901 to 2006 also showed increasing trend from 1991 onwards.

Figure 2. Annual maximum temperature anomalies (1901-2006)
Figure 3. Annual minimum temperature anomalies (1901 – 2006)
Coastal Andhra, West Bengal and Punjab showed significant increasing trends in the monsoonal rainfall.

Central India shows a decreasing monsoonal rainfall trend, which is significant over Chattisgarh and East Madhya Pradesh.

In the recent decades 16 meteorological sub-divisions showed decreasing and 20 sub-divisions showed increasing trends.
Figure 4. Increase/decrease in rainfall in mm in 100 year for each of 36 sub-divisions for the south-west monsoon season.
El Nino & La Nina
Increasing frequency and intensity of droughts in many parts of Asia is due to rise in temperature during summer ENSO events (Lal 2003).

El Nino causes above normal rains and droughts in many areas, while ENSO provides influences on weather and climate extremes.
The expected occurrence of an undesirable phenomenon- the El Nino over the Pacific Ocean, is considered to be a major factor in determining the fate of the monsoon.

El Nino years directly have impact on India’s agrarian economy as their effect tends to lower the production of summer crops such as rice, soybean, sugarcane and oilseeds.
El Nino (in Spanish) means “little boy” or “Child Jesus” in Spanish, is a weather system which re-emerges after a gap of about 3 to 5 years in the Pacific Ocean and lasts for about 12 months on an average. During this time the warming of sea surface temperature takes place, affecting wind pattern.

The warm sea-surface temperature (SST) anomaly is associated with reduced upwelling- reduced nutrients in the surface layer and hence the disappearance of fishes and birds on which the economy of Ecuador and Peru are dependent.
El Nino now refers to as a warm event, is a much larger scale phenomenon characterized by warm SST anomalies stretching from eastern to central equatorial Pacific. This phenomenon affects rainfall in India during Monsoon.
The cold events are known as La Nina or a girl.

During La Nina which is just the opposite of El Nino, less heating leads to colder sea water off western South America coast, thus making it a high pressure zone which pushes the moist sea winds towards the Indian Ocean.

This increases chances of normal or excessive rainfall in the Indian sub-continent.
El Nino Southern Oscillation (ENSO) events are irregular cycle of warming and cooling of the central and eastern equatorial Pacific.

The warming of the central Pacific, leads to organization of deep cumulonimbus convection and plentiful rainfall over the region, while cooling leads to a suppression of rainfall.
A warm phase of ENSO characterized by positive SST anomalies is called an El Nino, when the magnitude of the anomalies is large.

A cold phase of ENSO is called a La Nina when the magnitude of anomalies is large.
El Nino and the Indian summer Monsoon are inversely related.

The most prominent droughts in India--- six of them---since 1871 have been El Nino droughts, including the recent ones in 2002 and 2009 (Table 3).

Usually El Nino years affect the weather in India in terms of Monsoon rain. During this time, the rainfall is generally below normal, which has its bearing on crop production.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>OCCURRENCE</th>
<th>STATE</th>
<th>PRECIPITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>El Nino</td>
<td>Drought</td>
<td>-12%</td>
</tr>
<tr>
<td>2005</td>
<td>Neutral</td>
<td>Normal</td>
<td>+1%</td>
</tr>
<tr>
<td>2006</td>
<td>Neutral</td>
<td>Normal</td>
<td>+3%</td>
</tr>
<tr>
<td>2007</td>
<td>La Nina</td>
<td>Excess</td>
<td>+10%</td>
</tr>
<tr>
<td>2008</td>
<td>La Nina</td>
<td>Above Normal</td>
<td>+5%</td>
</tr>
<tr>
<td>2009</td>
<td>El Nino</td>
<td>Severe Drought</td>
<td>-21%</td>
</tr>
<tr>
<td>2010</td>
<td>La Nina</td>
<td>Normal</td>
<td>0%</td>
</tr>
<tr>
<td>2011</td>
<td>La Nina</td>
<td>Normal</td>
<td>+4%</td>
</tr>
<tr>
<td>2012</td>
<td>Mild El Nino</td>
<td>Below Normal</td>
<td>-8%</td>
</tr>
<tr>
<td>2013</td>
<td>Neutral</td>
<td>Above Normal</td>
<td>+6%</td>
</tr>
</tbody>
</table>
In one study, nine such El Nino events have occurred since 1958.

Of these, seven were associated with deficit rainfall, six of them being droughts. However, the monsoon rainfall was above average in 1963 as well as during the strongest El Nino event of 1997.

Here is a list of droughts in India in last two centuries have shown that some of them are an outcome of the El Nino phenomenon (Table 4).

During current year initially it was thought (not supported by IMD) that El Nino may create impact on Indian Summer Monsoon, resulting in drought like situation. However, impact of El Nino has now been reduced.
Table 4. Drought years in India

<table>
<thead>
<tr>
<th>Period</th>
<th>Drought Years</th>
<th>Number of Droughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1801-1830</td>
<td>1801, 1804, 1806, 1812, 1819, 1825</td>
<td>6</td>
</tr>
<tr>
<td>1831-1860</td>
<td>1832, 1833, 1837, 1853, 1860</td>
<td>5</td>
</tr>
<tr>
<td>1861-1890</td>
<td>1862, 1866, 1868, 1873, 1877, 1883</td>
<td>6</td>
</tr>
<tr>
<td>1891-1920</td>
<td>1891, 1897, 1899, 1901, 1904, 1905, 1907, 1911, 1918, 1920</td>
<td>10</td>
</tr>
<tr>
<td>1921-1950</td>
<td>1939, 1941</td>
<td>2</td>
</tr>
</tbody>
</table>
Climate Variability with respect to M.P.
In Madhya Pradesh, 72% of the cultivable area is under rainfed agriculture, which is subject to climate risk.

Study showed a decreasing monsoonal rainfall trend significant over East Madhya Pradesh and Chattisgarh, while West Madhya Pradesh showed increasing, insignificant trend.

Based on 60 years data, during winter, summer, monsoon and post-monsoon seasons, rainfall showed overall negative trend (-1.81 mm/year) with -1.74 mm/year during monsoon.
Figure: State level annual rainfall trends.
Figure: State level rainfall trends for monsoon season.
The mean maximum temperature showed positive trend during summer, monsoon and post-monsoon period.

The mean minimum temperature showed significant positive trend during post-monsoon season.

Among various months, mean monthly maximum temperature showed in August, September significant positive trend (0.02°C/year); November showed significant positive trend (0.04°C/year) for mean monthly minimum temperature.
August
Mean Max Temp Trends for 1951-2010
deg C/year

- Decreasing
- Decreasing significantly at 95%
- Increasing
- Increasing significantly at 95%
- No trend

Figure: State level mean maximum temperature trends for August.
Figure: State level mean maximum temperature trends for September.
Figure 1: State level mean minimum temperature trends for November.
Rainfall showed medium positive trend ($\geq 0.25$ mm/year) during June, July and high negative trend (-0.69 mm/year, -0.56 mm/year) during August and September, respectively.
Figure 1: State level rainfall trends for July.
August
R/P trends for 1951-2010
mm/year
- Decreasing
- Decreasing significantly at 95%
- Increasing
- Increasing significantly at 95%
- No trend

Figure: State level rainfall trends for August.
Study of cumulative rainfall during last 12 years (2002-2013) showed that more positive rainfall anomaly over Vindhyan, Gird and Tikamgarh zones (≥45%) during June (Fig.);

-over Satpura plateau, Malwa plateau and Nimar Valley zones (≥11%) during July (Fig.);

-over Jhabua Hills zone (33% and 16%, respectively) during August (Fig.) and September (Fig.).
Fig.: Rainfall trend in agroclimatic zones of M.P. in June for last 10 Years
Fig.: Rainfall trend in agroclimatic zones of M.P. in July for last 10 Years

Madhya Pradesh
Agroclimatic Zones
July
Fig. : Rainfall trend in agroclimatic zones of M.P. in August for last 10 Years
Fig. : Rainfall trend in agroclimatic zones of M.P. in September for last 10 Years
Study on 24 years of data (1991 to 2014) on cumulative rainfall,

The mean maximum temperature trend (°C/year) showed the highest trend during August and for Bhopal it was significant (0.055+) while for Jabalpur and Gwalior the values were high (0.058 and 0.064, respectively).

The mean minimum temperature trend (°C/year) showed very high significant trend over Bhopal during September (0.075***) and August (0.035**) followed by Jabalpur (0.033** during August and September).
The cumulative rainfall trend (mm/year) over Bhopal (4.893) and Jabalpur (6.817) were highly positive during July, while the same was highly negative (-6.596 and -5.971, respectively) during August.

The cumulative rainfall trend (mm/year) over Indore showed significant positive value during June.
Table 3: Station level trend in cumulative rainfall (mm/year) for 4 stations of M.P. during monsoon months for last 24 years (1991-2014)

<table>
<thead>
<tr>
<th>Month</th>
<th>Bhopal</th>
<th>Jabalpur</th>
<th>Gwalior</th>
<th>Indore</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>0.088</td>
<td>1.909</td>
<td>2.925</td>
<td>5.403+</td>
</tr>
<tr>
<td>July</td>
<td>4.893</td>
<td>6.817</td>
<td>-1.569</td>
<td>-0.489</td>
</tr>
<tr>
<td>August</td>
<td>-6.596</td>
<td>-5.971</td>
<td>-1.633</td>
<td>4.335</td>
</tr>
<tr>
<td>September</td>
<td>0.511</td>
<td>4.937</td>
<td>-0.661</td>
<td>1.996</td>
</tr>
</tbody>
</table>
SEPTEMBER CUMULATIVE RAINFALL

RAINFALL (IN MM)

YEAR

BHOPAL ACTUAL
BHOPAL NORMAL
JABALPUR ACTUAL
JABALPUR NORMAL

BHARAT MAUSAM VIJAYAN VIKASA
INDIA METEOROLOGICAL DEPARTMENT
AUGUST MAXIMUM - MINIMUM TEMPERATURE

YEAR


AVERAGE TEMPERATURE(°C)

Bhopal Maximum Temperature
Jabalpur Maximum Temperature
Bhopal Minimum Temperature
Jabalpur Minimum Temperature
Onset and withdrawal of Monsoon over M.P. – Is there any shift in dates?
Monsoon onset date
Monsoon withdrawal date
Withdrawal date of Monsoon (Bhopal)

Anomaly in Onset

Years


0.243
<table>
<thead>
<tr>
<th>Cities</th>
<th>Jabalpur</th>
<th>Bhopal</th>
<th>Indore</th>
<th>Gwalior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset date</td>
<td>12 June</td>
<td>13 June</td>
<td>13 June</td>
<td>18 June</td>
</tr>
<tr>
<td>(Normal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onset date</td>
<td>20 June</td>
<td>21 June</td>
<td>20 June</td>
<td>26 June</td>
</tr>
<tr>
<td>(Shifted to)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Withdrawal</td>
<td>02 October</td>
<td>28 September</td>
<td>27 September</td>
<td>22 September</td>
</tr>
<tr>
<td>date</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Normal )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Withdrawal</td>
<td>06 October</td>
<td>03 October</td>
<td>03 October</td>
<td>30 September</td>
</tr>
<tr>
<td>date</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Shifted to)</td>
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Impacts on crops
Agriculture is one of the most vulnerable sectors which is likely to be affected adversely by climate change.

Around 70% people in rural India are dependent on agriculture.

Agriculture and allied sectors (animal husbandry, poultry and fisheries) are inherently sensitive to climatic conditions and are vulnerable to weather and climate risks.

Although increase in carbon dioxide is likely to be beneficial to several crops, associated increase in temperatures and increased variability of rainfall would considerably impact food production.
Of the total annual crop losses in agriculture, a major share is directly due to weather and climate effects viz. floods, droughts, untimely rains, frosts, hails, heat, cold waves and severe storms (Hay 2007).

In India, 28% land is vulnerable to droughts, 12% to floods and 8% to cyclones.

*kharif* crops viz. rice, maize, cotton, oilseeds, soybean and coarse grains are heavily dependent on monsoon rains.

It will lead to a lower yield of *kharif* crops viz. rice, maize, cotton, oilseeds, soybean and coarse grains.

A high temperature during *rabi* season will affect yield of wheat, potato and vegetables.
Agriculture is inherently sensitive to climatic conditions. Most vulnerable to weather and climate risks, crop losses in agriculture, mainly due to direct weather and climate effects viz. floods, droughts, untimely rains, frosts, hails, heat/cold waves, severe storms (Hay, 2007). Risk factors in agriculture, relationship between weather, climate and production risk is well known (George et al., 2005).
Vulnerability of Agriculture to Climate Change

Climate Change

Direct effects on crop growth
- Physiology
- Phenology
- Morphology

Indirect effect
- Soil fertility
- Irrigation availability
- Pests
- Floods and Droughts
- Sea level rise

Socio-economic
- Food demand
- Costs and benefits
- Policy
- Trade
- Farmers response

Human intervention
Adaptation strategies
Mitigation strategies

Agricultural Production & vulnerability

Source: IARI Report
➢ Agriculture is likely to be worst affected in the coastal regions of Gujarat and Maharashtra, where agriculturally fertile areas are vulnerable to inundation and salinization.

➢ Agriculture will be adversely affected not only by an increase or decrease in the overall amounts of rainfall, but also by shifts in the timing of the rainfall.

➢ Chhattisgarh region has received less than its share of pre-monsoon showers in May and June which are important to ensure adequate moisture in fields being prepared for rice crops.

➢ In Rajasthan, a 2°C rise in temperature was estimated to reduce production of pearl millet by 10-15 per cent.
Impact Of Climate Change On Wheat Production

- Northern India
- Eastern India
- Rest of India
- India

Production, 000 tons

- 2000
- 2020
- 2050
- 2080

80000
60000
40000
20000
0
Impact Of Climate Change On Rice Production

![Graph showing the loss in rice production with and without adaptation from 2000 to 2080.](image)
The observed temperature rise in parts of Asia during recent decades ranged between less than 1°C to 3°C per century.

Increase in surface temperature is more pronounced in North Asia.

Simulated climate change scenario indicated that a 0.5°C rise in temperature will reduce wheat yield by 0.45 tonnes per hectare in India (Kalra et al. 2003).
- 10 – 40% loss in crop production in India with increases in temperature by 2080 – 2100.

- IARI indicate the possibility of loss of 4 – 5 million tons in wheat production in future with every rise of 1°C temperature.

- Temperature increases of 2-4°C are predicted to reduce rice yields.

- Eastern regions are predicted to be most impacted by increased temperatures and decreased radiation, resulting in relatively fewer grains and shorter grain filling durations.
A temperature rise of 0.5 to 1.5°C in India will decrease yield of wheat and maize by 2 to 5 % (Aggarwal 2003).

A rise of 2°C temperature could decrease rice yield by 0.75 tonnes/hectare in India.

The net cereal production in South Asian countries is projected to decline at least by 4 to 10% by end of this century (Lal 2007).

At IRRI, rice yield is observed to decline by 10% for every 1°C rise in growing season minimum temperature.
Recent IPCC reports and other studies indicated 10-40% loss in crop production in India, will be due to temperature rise by 2080-2100.

FAO (2004) revealed that higher temperature and longer growing seasons can result in increased pest populations in temperate regions of Asia.

Production of rice, maize and wheat in past few decades have declined in many parts of Asia due to increasing water stress arising due to rise in temperature, increasing frequency of EL Nino and decline in number of rainy days (Tao et al., 2004).
More intense rain and frequent flash floods during monsoon results in run off and loss of *kharif* rice.

Projection says that in Indian agriculture, quantum rise in temperature will be higher during *rabi* season, while rise in rainfall will be higher during *kharif* season.

In India *kharif* rice yield is expected to be adversely affected by heat stress.

Rice diseases can become more widespread due to warmer and wetter Asian summer climate.

*kharif* agriculture is crucial in attaining food security under climate change regime.
Table 5. Climate change impact for India in different crop seasons

<table>
<thead>
<tr>
<th>Year</th>
<th>Season</th>
<th>Change in Rainfall %</th>
<th>Increase in temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lowest</td>
<td>Highest</td>
</tr>
<tr>
<td>2020s</td>
<td>Rabi</td>
<td>- 1.95</td>
<td>4.36</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>1.81</td>
<td>5.10</td>
</tr>
<tr>
<td>2050s</td>
<td>Rabi</td>
<td>- 9.22</td>
<td>3.82</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>7.18</td>
<td>10.52</td>
</tr>
<tr>
<td>2080s</td>
<td>Rabi</td>
<td>- 24.83</td>
<td>- 4.50</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>10.10</td>
<td>15.18</td>
</tr>
</tbody>
</table>
Semi-arid regions of western India are expected to receive higher rainfall, while central regions likely to experience 10-20% decrease in winter rainfall by 2050.

In semi–arid agroecological regions, water storages have already impact on agriculture.

In certain vulnerable arid and semi-arid regions, increased temperatures have already resulted in diminished precipitation.
Large areas in Rajasthan, Andhra Pradesh, Gujarat and Maharashtra and some areas of Karnataka, Orissa, Madhya Pradesh, Tamil Nadu, Bihar, West Bengal and Uttar Pradesh are already experiencing recurrent drought with several regions currently experiencing water deficits due to temperature increase.

The climate change is expected to reduce crop yield in tropical areas.

Increased temperatures have multiple impacts on crop productivity depending on the biological characteristics of the specific crop and the time of the heat stress in relation to its development.
Higher daytime temperature accelerates plant maturity and results in reduced grain filling, while higher night temperatures increase yield losses due to higher rate of respiration.

In dry farming regions even moderate warming of 1°C for wheat, maize and 2°C for rice will reduce yields significantly.

*kharif* rice is found to be more vulnerable to climate change.

High temperature around flowering reduces fertility of pollen grains as well as pollen germination on stigma in rice crop.
High temperatures reduced 1000-grain weight and amylose content and adversely affected important quality traits viz., grain elongation and aroma in rice cultivars.

A rise in temperature from 1 to 40°C reduces green gram and soybean yield.

Variation in rainfall, $T_{\text{max}}$, $T_{\text{min}}$ during monsoon will negatively impact maize crop.

Hence, a pattern of resource use to be thought, which aims at meeting current need with sustainable development.

Adaptation strategies are better suited for local climatic variability due to climate change.
Adaptive Measures & Role of IAAS/GKMS
## Adaptive measures in agriculture

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Adaptation measures</th>
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</thead>
<tbody>
<tr>
<td>1°C temp. increase in June to August</td>
<td>A) Choice of crop and cultivar:</td>
</tr>
<tr>
<td></td>
<td>i) More heat/drought-tolerant crop varieties in areas under water stress</td>
</tr>
<tr>
<td></td>
<td>ii) More disease and pest tolerant crop varieties</td>
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<td>iii) Salt-tolerant crop varieties</td>
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<td></td>
<td>iv) Introduce high yielding, early maturing crop varieties in cold regions</td>
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<tr>
<td></td>
<td>B) Farm management:</td>
</tr>
<tr>
<td></td>
<td>i) Alter application of nutrients/fertilisers</td>
</tr>
<tr>
<td></td>
<td>ii) Alter application of insecticides/pesticides</td>
</tr>
<tr>
<td></td>
<td>iii) Change planting date to effectively use prolonged growing season and irrigation</td>
</tr>
<tr>
<td></td>
<td>iv) Develop adaptive management strategy at farm level</td>
</tr>
<tr>
<td>Improvement of agricultural infrastructure</td>
<td>i) Irrigation systems and their efficiency</td>
</tr>
<tr>
<td></td>
<td>ii) Use/store rain and snow water</td>
</tr>
<tr>
<td></td>
<td>iii) Information exchange system on new technologies at national, regional &amp; international levels</td>
</tr>
</tbody>
</table>
For coping up with impact of climate change on agriculture, modern era IAAS (Integrated Agromet Advisory Services) with district level forecast for generating location and crop specific agromet advisories on real time basis can serve as useful tool towards sustainable development and food security.

In the current five year plan IAAS is replaced by Gramin Krishi Mausam Seva(GKMS) in which block level forecast in pilot mode has already started for issuance of block level Agromet Advisories.
Different Tier in Integrated AAS in India

TIER 1
Apex Policy Planning Body

TIER 2
National Agro Met Service HQ (Execution)

TIER 3
State Agro Met Centres ~28 Coordination / monitoring

TIER 4
AMFUs
Agro Climatic Zone Level ~130

TIER 5
District Level Extension & Training
Input management as advisory
For this IAAS bulletins, extended range district level forecast with five days validity (useful for farming community) are issued from IMD HQ at New Delhi.

Value addition by respective MCs (for their States) based on their analysis, helps in further enrichment of the forecast, which serves the need for ideal MRF.

Now-a-days, Agromet Advisories are issued through a network 130 AMFUs (AgroMeteorological Field Units) located in 127 agroclimatic zones, in SAUs (State Agricultural Universities) throughout country, on every Tuesday and Friday.
The state of M.P. is divided into two meteorological subdivisions viz. East M.P. and West M.P.

During the current monsoon (2014) period rainfall received till date is 10% less than normal for West M.P. and 22% less than normal for East M.P.

The state is divided into 9 Agro-climatic zones covering all 51 districts.
Seasonal Rainfall
From 01.06.2014 to 06.08.2014

- Excess: 06
- Normal: 31
- Deficient: 13
- Scanty: 00
- No rain: 00

India Meteorological Department
Concluding remarks

- After IPCC documentation, scientific community is aware of impact of climate change on environment vis-à-vis on agriculture.
- In India IMD admits climate variability in various parts of the country. Impact of El-Nino on summer monsoon has not fully inverse relation.
- Study of climate variability over M.P. shows impact on monthly rainfall, Tmax and Tmin
- Under influence of climate change there is a shift in Onset and Withdrawal dates of monsoon over M.P.
- In order to coup up with negative effect of climate change on agriculture, block level Agromet Advisories can act as sustainable tool through which adaptive measures can be advocated.
Thanks to Mrs Deepa A. Kulkarni, Mrs Anita S. Bahot and Mrs Archana P. Hage of Agricultural Meteorology Division, IMD, Pune and to Mrs. Surabhi Purohit, Ms Apoorva Singhroul, Mr. Wahid Khan, Mr. V.S.Yadav of Meteorological Centre, Bhopal for their assistance in preparation of the Manuscript / Review materials.

- Work with reference to climate change issues of M.P. vis-a-vis India is in progress
THANK YOU