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ANALYSIS OF EXTREME WEATHER EVENTS AT MALWA PLATEAU REGION OF MADHYA PRADESH, INDIA

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ABSTRACT

Climate change is likely to intensify the variability of weather patterns, leading to a rise in extreme seasonal aberrations. The temperature fluctuations as well as extreme weather events like heat waves and cold waves have great influence on agriculture productivity. These events have negatively impact on crop production and farmers' livelihood. The prediction of magnitude, timing and duration of extreme weather events in the changing scenario of climate can be supportive towards adaptation of suitable strategies to mitigate its adverse effects on agriculture and socio-economic aspects. The study of occurrence of significant climatic events were done by utilizing daily maximum temperature, minimum temperature for Mandsaur and Ujjain districts of Malwa Plateau region of Madhya Pradesh for the period of 38 years (1982-2019) with the IMD criteria. The study revealed that heat waves varied with annual time scale. The maximum number of heat waves was observed in the year 2010 in Mandsaur (32) and Ujjain (26). The average annual heat waves were observed 7.6 and 8.1 in Mandsaur and Ujjain districts, respectively during the period 1982-2019. About 2 heat waves could be expected in the month of June and July in Mandsaur. However, 3 heat waves could be expected in Ujjain during the month of June. An increasing trend of above normal Maximum temperature events was noticed in Mandsaur and Ujjain districts and pointed towards rising of maximum temperature over the Malwa plateau region. The cold waves were also exhibited variability. The maximum number of cold waves was observed in the year 2007-08 (14) in Mandsaur. Similarly, Ujjain districts also observed highest cold waves (16) in the year of 2007-08. On an average, about 3.8 and 3.9 cold waves were observed annually in Mandsaur and Ujjain districts during the period 1982- 83 to 2018-19. The trend analysis revealed that below normal minimum temperatures were becoming less frequent. There is a need for combining disaster reduction, natural resource management and climate change adaptation to reduce vulnerability and enhancement of resilience. Changes in technology and agricultural practices will help to create a society better able to survive the impacts of climatic extremes.

Key words : Agricultural planning, Cold wave, Heat wave, Risk.

Introduction

Indian agriculture is particularly vulnerable to climate change. The key characteristics of agriculture that could influence its vulnerability to climate change are the high level of subsistence agriculture with small land holdings, majority of rain-fed agriculture, frequent occurrence of extreme weather events and the wide variation in agricultural productivity across the country. Climate change will affect food security through its impacts on components of global, national and local food production systems, which is projected to affect food availability,

stability of food supplies, access to food and food utilization. India being mainly an agricultural country, the economy purely depends on the vagaries of the weather and in particular the extreme weather events. Extreme weather events such as heat and cold waves, frost, heavy rainfall and flood etc. are in fact hazardous weather. In past 50 years, India had lost assets of more than Rs 65000 crore and loss of more than 75000 human lives due to floods alone (Attri and Tyagi, 2010). The heat wave in 1995 and 1998 and cold wave in 2003 is matter of concern for scientists and planners resulted into partial loss in yield

and sometimes complete crop failure and hence reduced income to farmers (De *et al.*, 2005, Ochieng *et al.*, 2016; Howden *et al.*, 2007). The yield reduction in winter crops like wheat, mustard and vegetables due to abnormally high temperatures in the month of March 2004 has been reported by Samara and Singh (2004). Episodic heat waves can reduce yields, particularly when they occur during sensitive developing stages of the crops, such as the reproductive phase which increases sterility (Moriondo *et al.*, 2011). The higher temperature caused forced maturity which brought down seed productivity of broccoli, carrot, radish and turnip by 10–15% in Himachal Pradesh. Coconut, banana, cardamom, black pepper and cashew crops were affected due to heat wave-induced lower humidity and soil moisture in Kerala (Singh, 2016). During December 2002 to January, 2003 daily maximum and minimum temperatures at several places in north India remained unusually below the normal continuously for 3–4 weeks. As a consequence of such phenomena, about 600 ha of orchards of mango and litchi were severely damaged in the Shiwalik belt of Punjab. The extent of damage varied from 40–100 per cent in mango to 50–80 per cent in litchi with reduced fruit size and poor quality in guava, ber and kinnow (Samra *et al.*, 2003). Crop yields in the cold wave year of 2002–2003 were reported to be lowered by 10–42% in wheat, 25–30% in gram and 50–70% in mustard compared to the previous normal year of 2001–2002 at Agra. Similarly, tomato, potato, peas, papaya crops were severely damaged during 2005–2006 and 2007–2008 due to cold waves in the northern states of India (Singh, 2016). Increasing frequency of extreme weather events are expected to be the main reasons for reducing regional water availability and impacting hydrological cycles of evaporation and precipitation, water run-off and erosion. Adaptation strategies to climate change will have to be based on sustainable agriculture practices and coping with the impact of climate change on agriculture will require careful management of resources like soil, water and biodiversity. In the light of significance of extreme events in relation to agriculture, the study of extreme events has been carried out in Malwa Plateau region of Madhya Pradesh.

Materials and Methods

The $1^{\circ} \times 1^{\circ}$ gridded data on daily maximum temperature and minimum temperature were obtained from IMD, Pune for the period 1982–2019. The number of events with heat wave and cold wave conditions along with trend analysis of above normal maximum temperatures as well as below normal minimum temperatures were carried out by utilizing daily maximum

and minimum temperature with the IMD criteria. The IMD defines heat wave based on departure of maximum temperature from its normal. If the normal maximum temperature of plain area is $> 40^{\circ}\text{C}$ then departure of temperature 4 to 5°C above normal is called heat wave. If the normal maximum temperature of plain area is $\leq 40^{\circ}\text{C}$ then departure of temperature 5 to 6°C above normal is called heat wave. Similarly, if normal minimum temperature of an area is $< 10^{\circ}\text{C}$ then departure of temperature -4 to -5°C from its normal is called as cold wave. Similarly if normal minimum temperature of an area is $\geq 10^{\circ}\text{C}$ then departure of temperature -5 to -6°C from its normal is called as cold wave.

Results and Discussion

Above normal maximum temperatures

The data on occurrence of above normal maximum temperature conditions are presented in Tables 1 and 2. On an average about 29 above normal maximum temperatures were observed annually during the period 1982–2019 at Mandsaur and Ujjain districts. A considerable higher numbers of days with above normal maximum temperatures conditions were observed in the years 1996, 2002, 2004, 2005, 2010, 2018 and 2019 at Mandsaur. Similarly, higher numbers of above normal maximum temperature events were observed in the years of 1996, 2002, 2004, 2005, 2007, 2009, 2010 and 2019 at Ujjain. On an average, considerable higher above normal maximum temperature events were found in June–July than other months. On an average 6.6 above normal maximum temperature events were observed in the months of June and July at Mandsaur, Similarly, 7.4 and 6.7 above normal maximum temperature events were observed in the month of June and July at Ujjain. This is due to intense heating in the month of June which may continue to prevail in the month of July due to late onset of monsoon or sometimes monsoon failure conditions.

Heat waves

The data on heat wave events are presented in Tables 3 and 4 for Mandsaur and Ujjain districts. On an average 7.6 and 8.1 heat wave events were observed annually for Mandsaur and Ujjain district, respectively. The heat waves events were becoming more frequent in the month of June as compared to other months during 1982–2019. In the year 1987, 1992, 1995, 2004, 2010 and 2019 more frequent and higher occurrence of heat wave events was noticed at Mandsaur. However, the occurrence of heat wave events were higher in the year 1985, 1987, 1992, 1995, 2004, 2010, 2014 and 2019 at Ujjain. The heat waves were becoming more frequent due to rising of maximum temperature in the region (Hingane *et al.*, 1985;

Table 1 : Occurrence of above normal temperatures events at Mandsaur (1982-2019).

Years	March	April	May	June	July	Annual
1982	2	0	0	3	13	18
1983	1	0	0	9	7	17
1984	3	8	3	0	1	15
1985	18	0	4	4	8	34
1986	6	5	0	10	2	23
1987	2	5	0	8	21	36
1988	2	11	8	6	0	27
1989	1	3	13	0	4	21
1990	0	1	0	2	0	3
1991	5	0	4	14	15	38
1992	0	0	2	18	16	36
1993	0	3	7	6	8	24
1994	17	0	8	6	0	31
1995	1	0	8	17	11	37
1996	15	3	1	12	13	44
1997	4	0	0	1	1	6
1998	1	7	11	10	10	39
1999	3	12	3	0	3	21
2000	3	14	3	2	4	26
2001	1	4	5	0	0	10
2002	8	6	7	8	14	43
2003	10	5	7	7	1	30
2004	26	7	4	4	14	55
2005	12	5	3	13	8	41
2006	4	3	5	7	2	21
2007	6	13	5	4	9	37
2008	14	1	0	0	7	22
2009	10	8	2	8	6	34
2010	19	15	14	17	9	74
2011	6	0	0	3	3	12
2012	7	8	0	7	9	31
2013	10	0	3	0	0	13
2014	0	0	1	17	14	32
2015	5	4	7	1	6	23
2016	8	2	6	7	1	24
2017	11	12	5	1	0	29
2018	13	4	12	4	1	34
2019	4	18	4	14	11	51
Mean	6.8	4.9	4.3	6.6	6.6	29.3
CV	93.2	101.3	89.3	83.7	85.4	47.7

Table 2 : Occurrence of above normal temperatures events at Ujjain (1982-2019).

Years	March	April	May	June	July	Annual
1982	0	0	0	5	12	17
1983	2	0	0	11	8	21
1984	3	7	1	1	4	16
1985	17	0	5	9	8	39
1986	5	5	0	11	1	22
1987	1	4	0	13	19	37
1988	5	10	8	6	0	29
1989	2	2	13	0	5	22
1990	0	1	0	1	0	2
1991	4	0	7	15	13	39
1992	0	0	3	18	16	37
1993	0	3	9	7	9	28
1994	15	0	9	6	0	30
1995	1	0	3	21	10	35
1996	15	5	0	11	14	45
1997	4	0	0	1	0	5
1998	0	4	11	10	10	35
1999	5	14	3	0	3	25
2000	3	11	3	3	2	22
2001	1	2	5	0	0	8
2002	4	5	7	6	18	40
2003	9	6	6	7	1	29
2004	24	6	2	4	13	49
2005	12	4	2	16	7	41
2006	0	2	6	9	1	18
2007	7	11	5	4	12	39
2008	13	3	0	0	7	23
2009	9	8	2	13	5	37
2010	17	14	13	17	8	69
2011	8	0	0	1	4	13
2012	8	7	0	9	6	30
2013	6	0	3	0	0	9
2014	0	0	2	18	13	33
2015	2	2	7	0	8	19
2016	9	4	7	7	0	27
2017	10	12	5	1	2	30
2018	12	4	12	4	1	33
2019	3	19	4	18	13	57
Mean	6.2	4.6	4.3	7.4	6.7	29.2
CV	96.0	104.5	92.0	84.4	85.2	47.4

Srivastava *et al.*, 1992; Rupa Kumar *et al.*, 1994; Pant, 2003; Arora *et al.*, 2005; Dash *et al.*, 2007; Rohini *et al.*, 2016; Sharma and Majumder, 2017; Pal and Al-Tabbaa, 2010; IPCC, 2013). The abnormally higher temperature in reproductive stage of crop growth lead to forced

maturity in *rabi* season crops. The other consequences of abnormally higher temperature and heat wave conditions may be seen in the form of shortening of crop duration, increase in evapotranspiration and decrease in fertilizer use efficiency etc. The change in temperature

Table 3 : Occurrence of heat wave events at Mandsaur (1982-2019).

Years	March	April	May	June	July	Annual
1982	0	0	0	0	6	6
1983	0	0	0	2	1	3
1984	0	0	0	0	0	0
1985	11	0	0	2	0	13
1986	1	0	0	3	0	4
1987	0	0	0	3	12	15
1988	0	0	2	4	0	6
1989	0	0	2	0	1	3
1990	0	0	0	0	0	0
1991	1	0	0	7	6	14
1992	0	0	0	10	11	21
1993	0	0	0	5	1	6
1994	6	0	5	1	0	12
1995	0	0	0	11	8	19
1996	4	0	0	1	2	7
1997	2	0	0	0	0	2
1998	0	2	0	2	4	8
1999	1	7	0	0	0	8
2000	0	0	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	5	3	0	8
2003	1	0	0	0	0	1
2004	13	0	0	0	6	19
2005	2	0	0	3	2	7
2006	0	0	1	3	0	4
2007	2	1	0	0	1	4
2008	4	0	0	0	1	5
2009	5	1	0	0	3	9
2010	12	5	4	10	1	32
2011	1	0	0	0	1	2
2012	0	0	0	1	5	6
2013	0	0	0	0	0	0
2014	0	0	0	0	6	6
2015	0	0	0	0	0	0
2016	3	0	3	3	0	9
2017	4	5	0	0	0	9
2018	2	0	0	1	0	3
2019	0	2	0	8	7	17
Mean	2.0	0.6	0.6	2.2	2.2	7.6
CV	171.7	264.8	239.7	143.5	146.4	93.3

may adversely affect the growth of crops and hence agricultural products to a large extent (Attri and Rathore 2003; Parry *et al.*, 2004; IPCC, 2007).

Below normal minimum temperatures

The data on below normal minimum temperatures

Table 4 : Occurrence of heat wave events at Ujjain (1982-2019).

Years	March	April	May	June	July	Annual
1982	0	0	0	0	8	8
1983	0	0	0	2	2	4
1984	0	1	0	0	0	1
1985	12	0	0	2	2	16
1986	0	0	0	3	0	3
1987	0	0	0	4	11	15
1988	0	1	2	4	0	7
1989	0	0	2	0	2	4
1990	0	0	0	0	0	0
1991	0	0	0	8	6	14
1992	0	0	0	11	14	25
1993	0	0	0	6	0	6
1994	5	0	3	1	0	9
1995	0	0	2	14	9	25
1996	5	0	0	2	2	9
1997	1	0	0	0	0	1
1998	0	2	0	1	3	6
1999	1	4	0	0	1	6
2000	0	0	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	5	4	2	11
2003	2	0	0	0	0	2
2004	13	0	0	0	6	19
2005	0	0	0	7	4	11
2006	0	0	0	3	0	3
2007	1	1	0	0	2	4
2008	4	0	0	0	1	5
2009	6	1	0	5	2	14
2010	7	4	4	10	1	26
2011	0	0	0	0	1	1
2012	0	0	0	2	1	3
2013	0	0	0	0	0	0
2014	0	0	0	7	9	16
2015	0	0	0	0	1	1
2016	1	0	2	1	0	4
2017	3	4	0	0	0	7
2018	2	0	0	1	0	3
2019	0	1	1	10	8	20
Mean	1.7	0.5	0.6	2.8	2.6	8.1
CV	193.4	226.6	221.4	131.8	140.4	92.9

were presented in Tables 5 and 6. On an average 22.1 and 21.5 below normal minimum temperatures were observed at Mandsaur and Ujjain district, respectively during 1982-83 to 2018-19. A higher number of below normal minimum temperatures were observed during

Table 5 : Occurrence of below normal temperatures events at Mandsaur (1982-2019).

Years	November	December	January	February	Annual
1982-83	3	2	12	12	29
1983-84	29	16	5	17	67
1984-85	11	7	1	14	33
1985-86	4	2	6	3	15
1986-87	4	15	4	1	24
1987-88	1	1	0	0	2
1988-89	10	6	12	4	32
1989-90	2	5	1	7	15
1990-91	2	1	12	4	19
1991-92	5	7	10	14	36
1992-93	10	3	0	4	17
1993-94	4	4	2	11	21
1994-95	8	11	10	6	35
1995-96	11	3	7	3	24
1996-97	7	8	3	8	26
1997-98	0	2	9	6	17
1998-99	8	10	12	3	33
1999-00	4	18	6	17	45
2000-01	0	5	10	3	18
2001-02	6	4	5	6	21
2002-03	0	0	8	0	8
2003-04	0	1	1	7	9
2004-05	2	0	8	10	20
2005-06	6	17	6	0	29
2006-07	1	0	2	0	3
2007-08	4	4	9	18	35
2008-09	1	0	0	0	1
2009-10	4	0	4	1	9
2010-11	0	11	14	0	25
2011-12	0	2	11	6	19
2012-13	9	0	17	4	30
2013-14	5	0	2	5	12
2014-15	0	10	6	1	17
2015-16	0	12	5	2	19
2016-17	8	0	4	1	13
2017-18	2	0	5	0	7
2018-19	3	12	11	6	32
Mean	4.7	5.4	6.5	5.5	22.1
CV	114.4	102.2	68.0	96.0	58.9

1983-84, 1984-85, 1988-89, 1991-92, 1994-95, 1998-99, 1999-00, 2007-08 and 2018-19 at Mandsaur. However, higher number of below normal minimum temperatures were observed in the year 1983-84, 1984-85, 1991-92, 1999-00, 2005-06 and 2007-08 at Ujjain. On an average the higher number of below normal minimum temperatures

Table 6 : Occurrence of below normal temperatures events at Ujjain (1982-2019).

Years	November	December	January	February	Annual
1982-83	2	2	13	10	27
1983-84	27	14	3	13	57
1984-85	14	11	0	15	40
1985-86	10	3	8	1	22
1986-87	4	7	3	1	15
1987-88	1	2	0	0	3
1988-89	5	7	11	5	28
1989-90	1	4	1	4	10
1990-91	2	1	12	2	17
1991-92	5	5	10	13	33
1992-93	10	3	0	4	17
1993-94	7	4	3	12	26
1994-95	3	10	11	5	29
1995-96	12	3	5	3	23
1996-97	7	7	3	8	25
1997-98	0	0	6	4	10
1998-99	7	9	10	1	27
1999-00	7	19	6	15	47
2000-01	0	7	10	2	19
2001-02	10	5	7	5	27
2002-03	0	0	8	0	8
2003-04	1	2	4	8	15
2004-05	3	0	8	10	21
2005-06	11	18	8	0	37
2006-07	0	0	2	0	2
2007-08	8	3	9	17	37
2008-09	2	0	0	0	2
2009-10	4	0	5	0	9
2010-11	0	11	15	0	26
2011-12	0	1	10	4	15
2012-13	9	3	13	3	28
2013-14	6	0	1	4	11
2014-15	0	9	9	0	18
2015-16	0	7	6	2	15
2016-17	10	0	4	1	15
2017-18	1	0	5	0	6
2018-19	2	10	11	6	29
Mean	5.2	5.1	6.5	4.8	21.5
CV	107.1	100.3	64.9	104.9	57.6

were observed in the month of January as compared to other months during 1982-83 to 2018-19.

Cold waves

The data on number of days with cold wave condition are presented in Tables 7 and 8. Annually, 3.8 average cold wave events were observed at Mandsaur during

Table 7 : Occurrence of cold wave events at Mandsaur (1982-2019).

Years	November	December	January	February	Annual
1982-83	0	0	2	5	7
1983-84	16	8	0	8	32
1984-85	0	0	0	5	5
1985-86	0	0	2	0	2
1986-87	0	1	0	0	1
1987-88	0	0	0	0	0
1988-89	0	0	3	2	5
1989-90	0	0	0	0	0
1990-91	0	1	4	0	5
1991-92	0	0	1	2	3
1992-93	0	0	0	3	3
1993-94	0	0	0	3	3
1994-95	0	2	0	2	4
1995-96	0	0	0	0	0
1996-97	3	4	1	0	8
1997-98	0	0	1	1	2
1998-99	0	0	1	0	1
1999-00	0	2	2	4	8
2000-01	0	3	1	0	4
2001-02	0	0	0	2	2
2002-03	0	0	0	0	0
2003-04	0	0	0	3	3
2004-05	0	0	0	5	5
2005-06	0	0	0	0	0
2006-07	0	0	0	0	0
2007-08	0	0	4	10	14
2008-09	0	0	0	0	0
2009-10	0	0	0	0	0
2010-11	0	0	5	0	5
2011-12	0	0	2	2	4
2012-13	0	0	2	0	2
2013-14	0	0	0	1	1
2014-15	0	0	0	0	0
2015-16	0	0	0	0	0
2016-17	0	0	3	0	3
2017-18	0	0	0	0	0
2018-19	0	1	3	4	8
Mean	0.5	0.6	1.0	1.7	3.8
CV	518.5	261.3	141.4	146.2	150.6

the period 1982-83 to 2018-19. The maximum events of cold waves *i.e.* 32 were observed during 1983-84. Considerable higher cold wave events were also observed in the years 2007-08. On an average 0.5 to 1.7 cold waves were analysed annually from November to February at Mandsaur. Similarly, the maximum number

Table 8 : Occurrence of cold wave events at Ujjain (1982-2019).

Years	November	December	January	February	Annual
1982-83	0	0	2	3	5
1983-84	13	4	0	9	26
1984-85	2	0	0	4	6
1985-86	0	0	2	0	2
1986-87	0	0	0	0	0
1987-88	0	0	0	0	0
1988-89	0	0	4	2	6
1989-90	0	0	0	0	0
1990-91	0	1	4	0	5
1991-92	0	0	1	2	3
1992-93	0	0	0	3	3
1993-94	0	0	0	2	2
1994-95	0	2	1	0	3
1995-96	0	0	0	0	0
1996-97	2	5	0	0	7
1997-98	0	0	1	2	3
1998-99	0	0	1	0	1
1999-00	0	2	2	3	7
2000-01	0	3	1	0	4
2001-02	0	0	4	0	4
2002-03	0	0	0	0	0
2003-04	0	0	0	5	5
2004-05	0	0	0	5	5
2005-06	0	0	0	0	0
2006-07	0	0	0	0	0
2007-08	0	0	5	11	16
2008-09	0	0	0	0	0
2009-10	0	0	0	0	0
2010-11	0	1	7	0	8
2011-12	0	0	3	3	6
2012-13	0	0	3	0	3
2013-14	0	0	0	1	1
2014-15	0	0	0	0	0
2015-16	0	0	1	0	1
2016-17	0	0	3	0	3
2017-18	0	0	0	0	0
2018-19	0	3	3	2	8
Mean	0.5	0.6	1.3	1.5	3.9
CV	471.8	221.9	137.0	166.6	130.1

of cold wave was observed in the year 1983-84 at Ujjain (26). Considerable higher number of cold wave was also observed in the year 2007-08. On an average 0.5 to 1.5 cold wave events were observed during 1982-83 to 2018-19. The data revealed that cold waves are becoming less frequent. This may be due to continuing rising of minimum

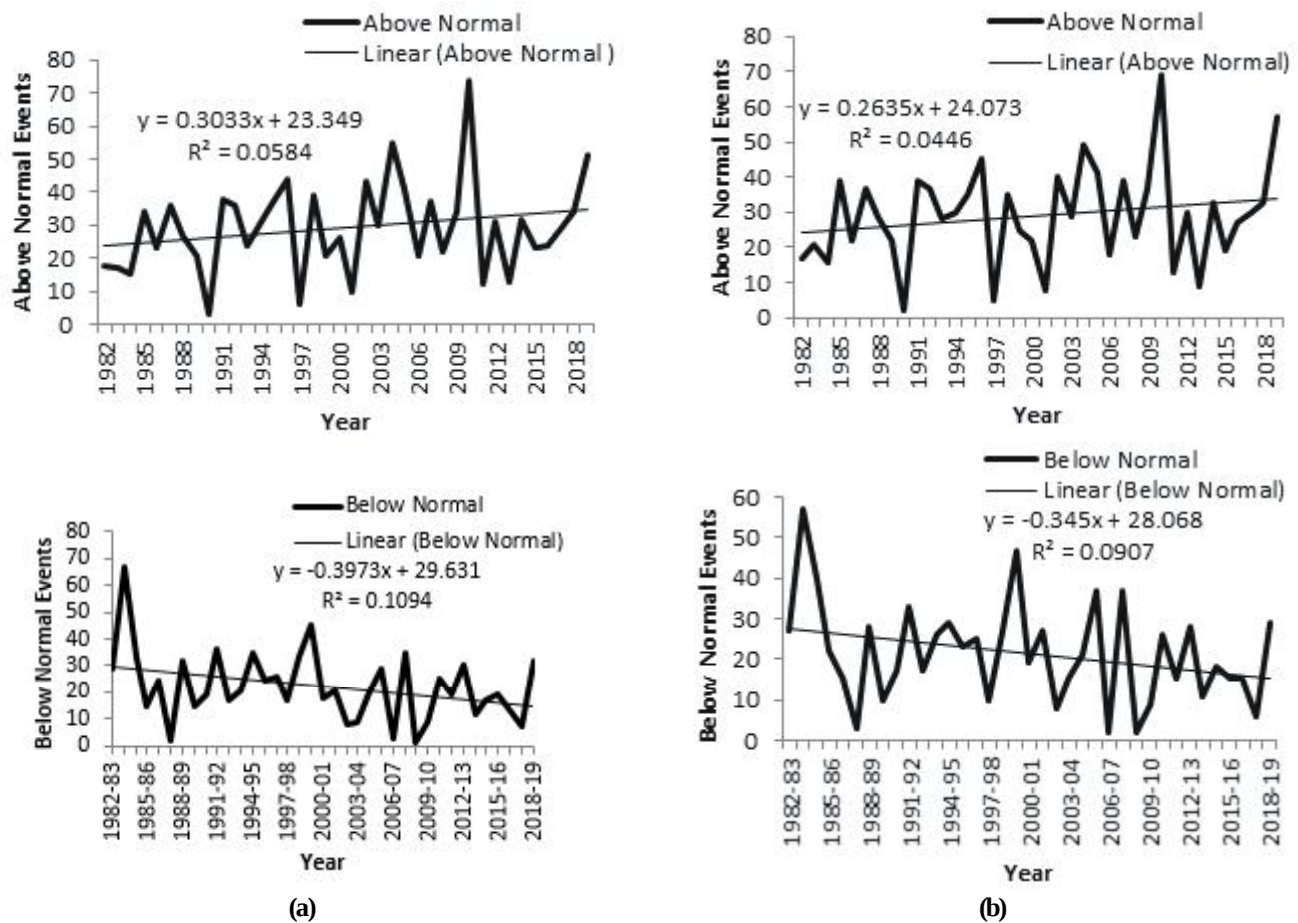


Fig. 1 : Trends of above and below normal temperatures at (a) Mandsaur and (b) Ujjain (1982-2019).

temperature over the region resulting and reduced frequency of colder nights and cold temperature extremes (Rupa Kumar *et al.*, 2002; IPCC, 2012; Kumar *et al.*, 2013; Dash and Mamgain, 2011).

Conclusion

The impact of climatic risk on agriculture can be reduced by altering sowing period, switching to crops which are less sensitive to extreme temperatures, switching to new heat resistant varieties, dissemination of agro-advisories based on local weather forecast through mobile, encouraging adoption of weather index based crop insurance might reduce loss in the case of unfavorable weather or crop failure.

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