

Impact of climate change on Indian agriculture: a review

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TABLE I Selective reports on observed climate change during the twentieth century over India

Region	Temperature	Rainfall	Reference
All India	Increase in 0.4°C/100 years in the mean annual temperature.		Hingane et al. 1985
All India	Increase in max. Temp. (0.6°C/100 yrs) Min temp trend less. General increase in the diurnal range of temp		Rupa Kumar et al. 1994
Western Himalayas	Winter season, Srinagar, Mussoorie and Mukteswar shows increasing trend (0.5°C/100 year) Monsoon season, Srinagar, which is beyond the monsoon regime, shows significant increasing trend, whereas Mussoorie and Dehradun which are at the foothills of Himalaya show decreasing trend	No increasing or decreasing trend for last 100 years	Pant et al. 1999
Indo-Gangetic Plain Region (IGPR)	Annual surface air temperature of the IGPR showed rising trend (0.53°C/100-year, during 1875–1958 Decreasing trend (–0.93°C/100-year during 1958–1997	Summer monsoon rainfall over western IGPR shows increasing trend (170 mm/100 years) from 1900 while over central IGPR it shows decreasing trend (5 mm/100 years) from 1939 and over eastern IGPR decreasing trend (50 mm/100 years) during 1900–1984 and increasing trend (480 mm/100 years) during 1984–1999. Westward shift in rainfall activities over the IGPR.	Singh and Sontakke 2002
All-India		Monsoon rainfall is trend less and is mainly random in nature over a long period	Mooley and Parthasarathy 1984; Thapliyal and Kulshrestha 1991
NE Peninsula, NE India, NW Peninsula, West Coast and Central Peninsula		NE peninsula, NE India and NW peninsula show decreasing trend in the Indian summer monsoon rainfall (–6 to 8% of normal/100 years) while increasing trend was noticed along the west coast and over central peninsula	Rupa Kumar et al. 1992

TABLE I (continued)

Region	Temperature	Rainfall	Reference
Western and Eastern Himalayas		(+10 to 12 % of normal/ 100 years) Western Himalayas get more snowfall than the eastern Himalayas during winter. More rainfall in the eastern Himalayas than in the western Himalayas during the monsoon season	Kripalani et al. 1996
Rajasthan desert		Slight increase in monsoon rainfall; in spite of large inter annual variations	Pant and Hingne 1998
Luni River Basin (Arid west Rajasthan)	Rising trend at Barmer, Jodhpur, Ajmer and Pali Decreasing trend at Udaipur and jwaibandh	Annual rainfall indicating increasing tendency at 19 station (around Ajmer in upper part of the Luni basin) Decreasing trend at the remaining nine stations in lower Luni basin i.e. Barmer.	Singh et al. 2001

TABLE II Selective reports on projected climate change during next century over India

Region	Temperature	Rainfall	Reference
All India	Increase in winter or <i>rabi</i> crop growing season temperature by 1–4°C with increased CO ₂ concentration	Precipitation increase of approximately 20%. Increase in specific humidity by 19% Increase in heavy rainfall days during the summer monsoon period i.e. in <i>kharif</i> crop growing season, and an increased inter annual variability	Bhaskaran 1995
All India	Average temperature change is predicted to be in the range of 2.33–4.78°C with a doubling in CO ₂ concentration	Increase in the frequency of heavy rainfall events	Loneragan 1998
All India	Increase in annual mean day and night temperature of 0.7 and 1.0°C in 2040s with respect to 1980s.		Lal et al. 1995
All India	Increase in mean temp. (°C): Year 2020s <i>Kharif</i> season, 0.87 to 1.12 <i>Rabi</i> season, 1.08 to 1.54 Year 2050s <i>Kharif</i> season, 1.81 to 2.37 <i>Rabi</i> season, 2.54 to 3.18 Year 2080s <i>Kharif</i> season, 2.91 to 4.62 <i>Rabi</i> season, 4.14 to 6.31	Change in rainfall (%) Year 2020s <i>Kharif</i> season, 1.8 to 5.1 <i>Rabi</i> season, –2.0 to 4.7 Year 2050s <i>Kharif</i> season, 7.2 to 10.5 <i>Rabi</i> season, –9.2 to 3.8 Year 2080s <i>Kharif</i> season, 10.1 to 15.2 <i>Rabi</i> season, –24.8 to –4.5	Lal et al. 2001
All India	Increase in annual mean temperature by 1.3–1.7°C	6–13% increase in <i>kharif</i> season rainfall	Rupa Kumar & Ashrit 2001
All India	Year 2050s South of 25°N (south of cities such as Udaipur, Khajuraho and Varanasi) maximum temp. will increase by 2–4°C. In the northern region the increase in maximum temp. by more than 4°C. Increase in minimum temperature up to 4°C all over the country.	Year 2050s Decrease in number of rainy days over a major part of the country. This decrease is more in western and central part (by more than 15 days) While near the foothills of Himalayas (Uttaranchal state) and in northeast India the number of rainy days increase by 5–10 days. Overall increase in the rainy day intensity by 1–4 mm/day except for small areas in the northwest India where the rainfall intensities decrease by 1 mm/day.	Rupa Kumar et al. 2003

TABLE III Grain yield (t ha^{-1}) of wheat in current weather and percent change in response to climate change (425 pp CO_2 , 2°C increase in mean temperature) in different regions of India

Region	Potential yield		Irrigated yields		Rainfed yields	
	Current	Percent (%) change	Current	Percent (%) change	Current	Percent (%) change
>27°N	6.66	-3.9	4.89	3.7	2.95	28.6
25–27°N	5.84	-1.5	4.78	-4.4	3.34	-7.2
23–25°N	5.86	-5.6	4.18	-10.8	1.17	-19.6
20–23°N	4.18	-18.4	2.29	-18.3	0.51	-11.8
<20°N	3.69	-17.3	2.43	-21.4	0.97	-23.9

(Source: Aggarwal and Kalra 1994)

TABLE IV Increase in yield (%) of different cultivars under modified climate of northwest India

Cultivar (Station)	Rainfed		Irrigated	
	S-II	S-III	S-II	S-III
WH542 (Hisar)	37	30	27	23
HD2329 (Ludhiana)	31	22	16	12
HD2285 (Delhi)	29	24	22	19
Sonalika (Pantnagar)	34	27	22	18
Raj3765 (Jaipur)	36	29	28	22

S-I: current climate; S-II: $T_{\text{max}}+1.0^\circ\text{C}$, $T_{\text{min}}+1.5^\circ\text{C}$, $2\times\text{CO}_2$; S-III: $T_{\text{max}}+2.0^\circ\text{C}$, $T_{\text{min}}+2.5^\circ\text{C}$, $2\times\text{CO}_2$.

(Source: Attri and Rathore, 2003)

TABLE V Impact of uncertainties in climate change scenarios and crop models on rice yields at two contrasting level levels of management

Region	Percent (%) change in yield (range)									
	Improved level of management				Current level of management				Pooled	
	CERES-rice		ORYZAIN		CERES-rice		ORYZAIN		Pessimistic	Optimistic
	Pessimistic	Optimistic	Pessimistic	Optimistic	Pessimistic	Optimistic	Pessimistic	Optimistic	Pessimistic	Optimistic
2010 Scenarios										
North	2.5	6.8	3.7	6.6	1.3	3.5	3.7	6.9	1.3	6.9
East	2.3	5.4	3.5	5.1	1.9	4.3	4.1	7.4	1.9	7.4
West	1.0	4.5	2.5	4.8	1.5	3.8	3.4	5.8	1.0	5.8
South	1.4	3.9	3.3	7.2	1.9	3.6	4.0	5.2	1.4	7.2
2070 Scenarios										
North	12.0	30.0	15.9	25.7	9.0	22.3	15.5	24.2	9.0	30.0
East	9.5	31.1	13.9	23.8	6.0	13.8	6.1	16.6	6.1	16.6
West	6.5	31.5	16.8	25.1	3.6	15.2	11.3	17.2	8.9	31.5
South	7.5	33.8	15.7	24.9	4.0	19.9	10.8	20.2	10.8	33.8

TABLE VI Selective reports on impacts of projected climate change on yield of different crops in India

Crop	Region	Yield impact	Reference
Rice	All India	Increase (region wise and scenarios based)	Aggarwal and Mall 2002
	North–West, Central	Increase (decrease in North–West)	Rathore et al. 2001
	South	Decrease/increase (scenarios based)	Sasendran et al. 1999
	North–West	Decrease/increase (scenarios based)	Lal et al. 1998
	Punjab	Decrease/increase (scenarios based)	Hundal and Kaur 1996
	All India	Increase	Mohandass et al. 1995
	North	Increase	Achanta 1993
	All India	Decrease	Sinha and Swaminathan 1991
Wheat	Northern India	Decrease	Saini & Nanda 1986
	North	No impact/decrease (scenarios based)	Aggarwal 2003
	North–west	+16 to +37%	Attri and Rathore 2003
	North–West, Central	No effect in NW, 10–15% decrease in Central	Aggarwal 2000
	North–west	Decrease/increase (scenarios based)	Lal et al. 1998
	Punjab	Decrease/increase (scenarios based)	Hundal and Kaur 1996
	All India	Decrease	Gangadhar Rao and Sinha 1994
	All India	Decrease/increase (region wise and scenarios based)	Aggarwal and Kalra 1994
	All India	Decrease/increase (region wise and scenarios based)	Aggarwal and Sinha 1993
	All India	Decrease	Sinha and Swaminathan 1991
Soybean	All India	Decrease/increase (region wise and scenarios based)	Mall et al. 2004
Maize	Central	Decrease/increase (scenarios based)	Lal et al. 1999
	North	Decrease/increase (region wise and scenarios based)	Sahoo 1999
	Punjab	Decrease	Hundal and Kaur 1996
Chickpea	All India	Decrease	Mandal 1998
Pigeonpea	All India	Decrease	Mandal 1998
Groundnut	Punjab	Decrease	Hundal and Kaur 1996
Sorghum	All India	Decrease	Chatterjee 1998
	All India	Decrease/increase (region wise and scenarios based)	Gangadhar Rao et al. 1995
Brassica (Mustard)	North	Increase	Upreaty et al. 1996