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Rainfall diagnosis in context of cereal yields in Gujarat

DEEPA B. HIREMATH, R. L. SHIYANI* and K. K. DAKHORE**

College of Agriculture, Navsari Agricultural University, Bharuch – 392 012, India

**Jungadh Agricultural University, Junagadh – 362 001, India*

***AICRP on Agrometeorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani – 431401, India*

(*Received 25 February 2015, Accepted 2 November 2015*)

e mail : dakhorekk@yahoo.com

सार – इस अध्ययन में गुजरात राज्य में लक्ष्य क्षेत्रों का वर्गीकरण करने और परिभाषित करने के लिए तथा कृषि पर वर्षा की परिवर्तिता के प्रभाव को समझने के लिए वार्षिक औसत वर्षा का विश्लेषण किया गया। परिणामों से पता चलता है कि वर्षा पैटर्न में अत्यधिक प्रत्यंतरों के कारण सभी कृषि जलवायविक क्षेत्रों में से उत्तर-पश्चिमी कृषि जलवायविक क्षेत्र सबसे अधिक संवेदनशील था। उसके बाद उत्तरी सौराष्ट्र, दक्षिणी सौराष्ट्र और मध्य गुजरात क्षेत्र संवेदनशील रहा। दक्षिणी पर्वतीय क्षेत्र अत्यधिक प्रत्यंतरों सहित बहुत कम वर्षों के लिए संवेदनशील रहा। कृषि उत्पादन पर वर्षा की परिवर्तिता के प्रतिकूल प्रभाव से निपटने के लिए प्रशमन नीतियों के रूप में बीमा योजना और सूक्ष्म वित्तीय सुविधाओं के साथ-साथ ड्रिप सिंचाई, गहरे कुएँ खोदने, चेक-बांधों का निर्माण करने, समाकलित जलयुक्त प्रबंधन जैसी जल प्रबंधन पद्धतियों का सुझाव दिया गया है।

ABSTRACT. The present study was undertaken to analyze annual average rainfall in Gujarat in order to classify and define the targeted zones and to know the impact of rainfall variability on agriculture in the state. The results revealed that the Northwest Agro-climatic zone was the most vulnerable zone among all the agro-climatic zones due to extreme deviations in rainfall pattern. This was followed by north Saurashtra, South saurashtra and Middle Gujarat Zone. The southern hills zone had the least per cent of years with extreme deviations. Water management practices such as drip irrigation, deepening wells, constructing check-dams; integrated watershed management as well as insurance coverage and microfinancing facilities have been suggested as mitigation strategies to overcome the adverse impact of rainfall variability on agricultural production.

Key words – Rainfall variability, Vulnerability, Adaptation, Cereals.

1. Introduction

The year to year variability in monsoon rainfall in India leads to extreme hydrological events (large scale droughts and floods) resulting in serious reduction in agricultural output and affecting the vast population and national economy. The situation becomes more critical particularly in Gujarat as there have been frequent drought periods in many areas of the state. In Gujarat state, the monsoon normally sets in mid-June and withdraws by mid-September. The annual average rainfall of the state is 821 mm which is neither reliable nor representative. It ranges from as high as 1900 mm in the sub-humid southeast to as low as 320 mm in the arid north. The distributions of rainfall, particularly wet and dry characteristics, have largely determined the evolution of cropping patterns and agricultural practices. Much of the northern and northwestern portions of the state experience frequent failures of monsoon. Droughts, floods, cyclones etc, not only substantially affect human beings but also crops and animals as well. Of these, drought has special attention as drought prone areas are spread all over India in general and Gujarat in particular. Occurrence of drought is largely due to erratic and insufficient rainfall, particularly where irrigation facilities have not been well developed. Jani (1989) observed that "failure of monsoon" or flood in Gujarat may ultimately result in the failure of agriculture and create unemployment among small and marginal farmers and agricultural labourers.

The present study was undertaken to analyze district wise rainfall data in order to classify and define the targeted agro-climatic zones, to understand what and how they varied and finally what is the impact of rainfall variability or change on major cereals, like, bajra, maize, jowar and paddy in Gujarat.

2. Agro-climatic description of the study area and rainfall variability in Gujarat

Gujarat (20° - 6′ to 24° - 42′ N and 68° - 10′ to 74° - 28′ E) has a long (1600 km) sea coast on the Arabian Sea which forms the western and southwestern

TABLE 1

Rainfall deviations in north west zone, Kutch district, 1978 - 2008

Wet/dry years	Rainfall deviation (%)	IMD Classification	Years
Wet Years	>50%	Very High	1979, 1988, 1994, 2003, 2007
	25-50%	High	1980, 1981, 1989, 1992, 2006
	0-25%	Moderately High	1998
Dry Years	0-25%	Moderately Low	1978, 1983, 1984, 1990, 1997, 1999, 2000, 2001, 2004, 2008
	25-50%	Severe	1982, 1985, 1986, 1991, 1993, 1995, 1996, 2002, 2005
	>50%	Disastrous	1987

boundaries. In the north, it forms the international boundary with Pakistan. The Gulf of Cambay separates the western Peninsula (from the arid) district of Kutch. The hill ranges of Aravalli in the northeast, Saputara in the east and Sahyadri in the southeast run along the eastern boundary of the state from the Northern district of Banaskantha to its southern end. Topographically, Gujarat state is characterized by large central alluvial plain and a peninsula, separated by the Gulf of Cambay. Kutch, the largest district of the state, lies north of the peninsula and on its northern border is the large Rann (desert) of Kutch. Among the rivers that flow westward across the plain, the most prominent, the Tapi, Narmada and Mahi, have perennial flow. The agriculture at the state level is predominantly occupied by oilseeds, cereals and cotton crops. The weather conditions over the state are mainly influenced by monsoon and subsequently by physiography, insularity and the Thar Desert. Gujarat is divided into eight agro-climatic zones based on rainfall, soils and cropping pattern. The distribution of cropping systems is determined largely by the climatic gradient and distribution of soils. Three types of tropical climate prevail across the state. An arid climate is seen in the extreme north and northwest, comprising Kutch and Western portions of Banaskantha, Patan and Jamnagar districts. The Surat, Narmada, Navsari, Valsad and Dangs districts in the extreme south have a sub-humid climate with good vegetative cover. The remaining parts of the state have a semi-arid climate, relatively sparse vegetative cover, frequent droughts and susceptibility to soil erosion. Gujarat state receives about 95 per cent of its annual rainfall through the influence of South West (SW) monsoon during June to September period. Saurashtra and Kutch region have mean annual rainfall of 428 mm with coefficient of variation of 44 per cent and decreasing trend of 5 per cent per 100 years while Gujarat region has mean annual rainfall of 863 mm with coefficient of variation of 32 per cent and decreasing trend of 5 per cent per 100 years. Temporal and spatial variability of rainfall analysis suggested occurrence of floods and droughts side by side (Pandey *et al*., 1999).

3. Materials and methods

Rainfall data were collected and compiled from the Departments of Agricultural Meteorology, Anand Agricultural University, Anand and Junagadh Agricultural University, Junagadh. Annual rainfall data for 31 years period (1978-2008) were utilized in assessing the magnitude and extent of rainfall variability for the 25 selected districts of Gujarat. Similarly, the data on cereal yield were collected from Department of Agricultural Economics, Junagadh Agricultural University, Junagadhand compiled for all these districts for the corresponding period. Moreover, based on the availability of data, districts were selected representative of eight agro-climatic zones of Gujarat. The mean annual rainfall (mm) and the rainfall deviations (per cent) from the mean (surplus/deficit) were computed for the selected districts falling under various agro-climatic zones of Gujarat. Based on the magnitude of these deviations, frequency distribution tables with classes corresponding to less than 10 per cent, 10 to 20 per cent, 20 to 30 per cent, 30 to 40 per cent, 40 to 50 per cent and finally, 50 per cent and above were constructed for both positive and negative rainfall deviations. The objective was to identify wet and dry years and the extent of surplus/deficit rainfall in percentage. The frequencies of wet and dry rainfall years during the period of study were also worked out for the selected districts. Furthermore, the year wise yields of major cereal crops like bajra in north west Arid zone , south Saurashtra, north Saurashtra and north Gujarat Agro-climatic zones, maize in middle Gujarat zones, jowar in South Gujarat and paddy in southern hills were selected and compared with the total rainfall of each year during the period 1988-2007.

TABLE 2

Rainfall deviations in the districts of south and north Saurashtra agro-climatic zone, 1978-2008

Wet/dry years	Rainfall deviation (%)	IMD Classification	Years						
			South Saurashtra		North Saurashtra				
			Porbandar	Junagadh	Amreli	Bhavnagar	Jamnagar	Rajkot	Surendranagar
Wet Years	>50%	Very High	1979, 1980, 1981, 1983, 1984, 1988, 1994, 2007	1979, 1980, 1981, 1983, 1988, 1994, 2007, 2008	1983, 1988, 2005, 2006, 2007	2005, 2006, 2007 ,2008	1979, 1980, 1981, 1994, 1997, 2003, 2005, 2007	1979, 1988, 1994, 2003, 2005, 2006, 2007	1979, 2005, 2007, 2008
	25-50%	High	1982, 1989, 1998	1984, 2003, 2005	1980, 1981, 1982, 1989	1979, 1981, 1994, 1998, 2002	1982, 1983, 2004, 2008	2008	1994, 1997, 2001, 2006
	0-25%	Moderately High	1995	1982, 1989, 2006	1979, 1994, 1998, 2003, 2008	1983, 1985, 1990, 1992, 1996, 2001	1984, 2006	1980, 1981, 1983, 1992, 1996, 1997, 2004	1981, 1982, 1990, 2002, 2003, 2004
Dry Years	0-25%	Moderately Low	1992, 1996, 2005, 2006	1995, 1998, 2001, 2004	1990, 1992, 1996, 2002	1978, 1980, 1989, 1995, 1997, 2003, 2004	1978, 2001	1978, 1984, 1998	1980, 1983, 1984, 1985, 1988, 1989, 1992, 1996, 1998
	25-50%	Severe	1978, 1986, 1990, 1997, 2003	1986, 1990, 1992, 1996, 1997	1978, 1986, 1993, 1995, 1997, 1999, 2001, 2004	1982, 1984, 1986, 1991, 1993, 1999	1988, 1992, 1996, 1998, 2002	1982, 1989, 1990, 2001, 2002	1978, 1993, 1995, 2000
	>50%	Disastrous	1985, 1987, 1991, 1993, 1999, 2000, 2001, 2002, 2004, 2008	1978, 1985, 1987, 1991, 1993, 1999, 2000, 2002	1984, 1985, 1987, 1991, 2000	1987, 1988, 2000	1985, 1986, 1987, 1989, 1990, 1991, 1993, 1995, 1999, 2000	1985, 1986, 1987, 1991, 1993, 1995, 1999, 2000	1986, 1987, 1991, 1999

4. Results and discussion

Comprehensive analysis of the district-wise results revealed certain major findings applicable to the agro-climatic zones as well as the state as a whole.

It can be seen from Table 1 that the year 1987 was identified to be the driest year and was falls in the category "Disastrous" as per IMD classification. On the other hand, the year 1979 received very high rainfall and was recognized as the wettest year in the northwest agro-climatic zone during the period 1978-2008. The severe dry years during this period were 1982, 1985, 1986, 1991, 1993, 1995, 1996, 2002 and 2005 where in the negative deviations from the mean ranged between 25-50 per cent accounting for 29.0 per cent of the total number of years. The driest year was 1987 with an average annual rainfall of only five mm resulting in a substantial negative deviation of 99 per cent, followed by the year 2002 with a negative deviation of 77 per cent.

On the other hand, the very high rainfall years during the period were 1979, 1988, 1994, 2003 and 2007 in which the rainfall deviations from the mean were more than 50 per cent, *i.e.*, accounting for almost one-third (16.1%) of the total number of years. The wettest year was 1979 with an average annual rainfall of 840.1 mm resulting in the highest positive deviation of 144 per cent. It was followed by the year 1994 with a positive deviation of 132 per cent (mean annual rainfall 800.0 mm). The negative rainfall deviation from the mean was minimum during the years 1978 (-1%), followed by 1997 (-9%) and the minimum positive deviation year was 1998 (+21%). Interestingly, a cycle of 15 years was observed between the first two driest as well as wettest years. The northwest arid zone was found to be the most vulnerable zone among all the agro-climatic zones due to extreme deviations in rainfall pattern. Kutch having less rainfall (<350 mm) has the highest annual rainfall variability (57%). On monthly basis, the coefficient of variation is still higher, being > 100 per cent in Kutch even in

TABLE 3

Rainfall deviations in the districts of north Gujarat agro-climatic zone, 1978-2008

Wet/dry years	Rainfall deviation (%)	IMD Classification	Banaskantha	Gandhinagar	Mehsana	Patan	Sabarkantha
Wet years	> 50%	Very High	1994, 1997, 2005, 2006, 2007	1990, 1994, 1997, 2003, 2005, 2006, 2007	1994, 1997, 1998, 2005, 2006, 2007	1990, 1994, 1997, 2006, 2007	1994, 1998, 2005, 2006, 2007
	25-50%	High	1992, 2003	1984, 2004, 2008	1990, 2001	1978, 1983	1983, 1988, 1990, 1997, 2003
	0-25%	Moderately High	1978, 1984, 1988, 1989, 1990, 1993, 1998, 2001	-	1978, 1983, 2003	1979, 1981, 1984, 1988, 1998, 2003, 2005, 2008	1978, 1980, 1984, 1989, 1991
Dry years	0-25%	Moderately Low	1983, 1991, 1995, 2008	1981, 1985, 1986, 1988, 1989, 1991, 1993, 1998, 1999	1979, 1981, 1982, 1984, 1988, 1992, 1993, 1999, 2004, 2008	1982, 1992, 1993, 1995, 2001, 2004	1981, 1993, 1996
	25-50%	Severe	1979, 1980, 1981, 1996, 2004	1978, 1979, 1982, 1983, 1992, 1996, 2001	1980, 1991, 1995, 1996, 2000, 2002	1980, 1989, 1991, 1996	1979, 1982, 1985, 1992, 2001, 2004, 2008
	>50%	Disastrous	1982, 1985, 1986, 1987, 1999, 2000, 2002	1980, 1987, 1995, 2000, 2002	1985, 1986, 1987, 1989	1985, 1986, 1987, 1999, 2000, 2002	1986, 1987, 1995, 1999, 2000, 2002

monsoon months. Among the four months of the monsoon season, July contributes 35-45 per cent of annual rainfall. Kutch is having 80 per cent of chances of getting low rainfall (less than 500 mm). Kutch district and parts of Banaskantha, Patan, Surendranagar, Rajkot and Jamnagar districts were prone to experience severe drought in more than 30 per cent of the years (Pandey *et al*., 1999). State-sponsored interventions in Kutch have not only failed to mitigate water scarcity but have exacerbated problems in some areas. There is a need to further develop rainwater harvesting, livestock development and better techniques of dryland agriculture as uncertainty is a part and parcel of these drylands.

Table 2 brings forth the rainfall deviations in the districts of south and north Saurashtra agro-climatic zones during the period 1978-2008. In south Saurashtra agro-climatic zone, the years 1979, 1980, 1981, 1983, 1988, 1994 and 2007 were found to be amongst the wettest years for all the districts in the zone with rainfall deviations greater than 50 per cent. Similarly, the years 1985, 1987, 1991, 1993, 1999, 2000 and 2002 were identified to be the driest years with more than 50% deviations for this zone. The year 1983 received the maximum rainfall of 2538 mm and proved to be the wettest year in South Saurashtra agro-climatic zone. The maximum deviation in the magnitude of average rainfall between the driest and wettest years was observed in Junagadh district, *i.e.*, 1794.18 mm. It reveals the possibility of greater vulnerability of the district to climate change so far as rainfall parameter is concerned. Junagadh district recorded 17 heavy rainfall years against 29 in the last 100 years in Saurashtra region. (Sahu *et al.*, 2010). Moreover, studies showed that as long as the rainfall variation in any year was within 10 per cent of the normal, the economy was not greatly affected. But when the variation was more than 10 per cent, the normal life of the people was severely affected (Sivasami, 2000). They were unable to cope with severe shortage in drinking water, loss of agricultural production, livestock and wage earnings. If such failure of monsoon occurred in consequent years, devastating famine occurred in such areas. Costly state intervention became a necessity in such situations (Sivasami, 2000). Trend analysis of 100 years of rainfall revealed that the annual and monsoon rainfall were increasing over Saurashtra region. The rainfall showed an increasing trend (0.4 mm) per year over Saurashtra region (Sahu *et al.*, 2010).

In case of North Saurashtra agro-climatic zone, the years 2005 and 2007 were observed to be the wettest years with very high rainfall while the years 1987, 1999 and 2000 were found to be the driest years in majority of the districts of the zone. Interestingly, the years 1987 and 2007 proved to be the driest and wettest years, respectively for all the districts in the zone with a difference of 20 years between the wettest and driest years. In the north Saurashtra agro-climatic zone,

TABLE 4

Rainfall deviations in the districts of southern hills agro-climatic zone, 1978- 2008

Wet/dry years	Rainfall deviation (%)	IMD Classification	The Dangs	Navsari	Valsad
Wet years	> 50%	Very High	1981, 1983, 1988, 1994, 1996, 1997, 1998, 1999, 2005	1979, 1983, 1988, 1994, 2003, 2004, 2005	1979, 1983, 1988, 1994, 2004, 2005
	25-50%	High	1980, 1984, 1993	1992, 2001	1992, 2001, 2003, 2007, 2008
	0-25%	Moderately High	1978, 1979, 2004, 2006, 2008	1980, 1981, 1989, 2006	1980, 1981, 2006
Dry years	0-25%	Moderately Low	1985, 2002	1978, 1984, 2008	1978, 1984, 1989
	25-50%	Severe	-	1991, 2007	1991, 1998, 2002
	>50%	Disastrous	1982, 1986, 1987, 1989, 1990, 1991, 1992, 1995, 2000, 2001, 2003, 2007	1982, 1985, 1986, 1987, 1990, 1993, 1995, 1996, 1997, 1998, 1999, 2000, 2002	1982, 1985, 1986, 1987, 1990, 1993, 1995, 1996, 1997, 1999, 2000

TABLE 5

Rainfall deviations in the districts of middle Gujarat agro-climatic zone, 1978-2008

Wet/ dry years	Rainfall Deviation (%)	IMD Classification	Middle Gujarat					
			Ahmedabad	Anand	Dahod	Kheda	Panchmahal	Vadodara
Wet years	>50%	Very High	1981, 1983, 1994, 1997, 2005	1978, 1981, 1988, 1997, 2003, 2005, 2006, 2007	1989, 1990, 1994, 1996, 1997, 2004, 2006	1978, 1988, 1997, 2003, 2005, 2006, 2007	1989, 1990, 1994, 1996, 1997, 2003	1983, 1994, 2005, 2006, 2007
	25-50 %	High	1990, 1998, 2006, 2007	1980	1978, 1981, 1983, 2003	1980, 1981	1981, 1983, 1998, 2006	1978, 1988, 1996, 1997, 1998, 2004
	0-25 %	Moderately High	1985, 1996, 2003, 2004	1983, 1989, 1996, 2004	1980, 1988	1983, 1989, 1996, 1998, 2008	1978, 1980, 1988, 2004, 2005	1980, 2003, 2008
Dry years	0-25 %	Moderately Low	1978, 1980, 1982, 1984, 1988, 1989, 1993, 2001, 2008	1979, 1984, 1990, 1991, 1995, 1998, 2008	1979, 1984, 1992, 1993, 1995, 1998, 2002, 2007	1979, 1984, 1990, 1991, 1995, 1999, 2001, 2004	1979, 1984, 1992, 1993, 1995, 2007	1979, 1990, 1993, 2001, 2002
	25-50 %	Severe	1979, 1991, 1992, 1999, 2000	1982, 1987, 1992, 2001, 2002	1982, 1991, 2008	1982, 1992, 2000	1982, 1991, 2001, 2002	1981, 1982, 1984, 1991, 1992, 1995
	>50 %	Disastrous	1986, 1987, 1995, 2002	1985, 1986, 1993, 1994, 1999, 2000	1985, 1986, 1987, 1999, 2000, 2001, 2005	1985, 1986, 1987, 1993, 1994, 2002	1985, 1986, 1987, 1999, 2000, 2008	1985, 1986, 1987, 1989, 1999, 2000

Jamnagar district witnessed the maximum deviation in the quantum of average rainfall between the driest and wettest years, *i.e.*, 1114.40 mm. This suggests relatively greater vulnerability of Jamnagar district in comparison to other districts in this zone particularly with respect to rainfall parameter. Interestingly, four consecutive years 2005, 2006, 2007 and 2008 were found to be the wet years with positive rainfall deviations of more than 50 per cent in Bhavnagar district.

The positive and negative rainfall deviations in the districts of north Gujarat agro-climatic zone during 1978-2008 are presented in Table 3. In the north Gujarat agro-climatic zone, the common dry year (>50% deviation) identified among all the districts was 1987 and 1994, 2006 and 2007 were identified to be the common wet years (>50% deviation) respectively during the period. Again, the year 1987 was identified to be the driest year for all the districts in the zone. Similarly, the year 2006 was

TABLE 6

Rainfall deviations in the districts of south Gujarat agro-climatic zone, 1978 - 2008

Wet/dry years	Rainfall deviation (%)	IMD Classification	Bharuch	Narmada	Surat
Wet years	>50 %	Very High	1983, 1994, 2007	1983, 1994, 2003, 2004, 2005, 2006, 2007	1983, 1988, 1992, 1994, 2003, 2004, 2005, 2007
	25-50 %	High	1979, 1981, 1988, 1998, 2002, 2004	1979, 1981, 1988, 1998, 2008	1979, 2008
	0-25 %	Moderately High	1990, 1992, 1997, 2001, 2003, 2006, 2008	1992	1978, 1995, 1998, 2006
Dry years	0-25 %	Moderately Low	1978, 1984, 1989, 2005	1978, 1984, 1989, 1990, 1997, 2001, 2002	1981, 1982
	25-50 %	Severe	1980, 1985, 1993, 1995, 1996	1985, 1993, 1995, 1996	1980, 1984, 1990, 1996, 2001, 2002
	>50 %	Disastrous	1982, 1986, 1987, 1991, 1999, 2000	1980, 1982, 1986, 1987, 1991, 1999, 2000	1985, 1986, 1987, 1989, 1991, 1993, 1997, 1999, 2000

TABLE 7

Deviation in rainfall by agro-climatic zones (Percent of 31 Years)

Rainfall deviations deficit/ excess (%)	North-west Arid	North Saurashtra	South Saurashtra	North Gujarat	Middle Gujarat	South Gujarat	Southern Hills
<10	6.45	16.77	11.29	16.31	19.35	21.51	27.96
10 – 20	9.68	14.19	24.19	18.24	21.51	15.05	31.18
20 – 30	12.90	12.26	11.29	14.42	14.52	20.43	20.43
30 – 40	6.45	17.42	11.29	13.04	12.37	11.83	6.45
40 – 50	3.23	5.81	11.29	9.86	9.14	13.98	6.45
50 and above	61.29	33.55	30.65	28.14	23.12	17.20	7.53

found to be the wettest year for majority of the districts in the zone. The deviation in the magnitude of average rainfall between the driest and wettest years was observed to be the highest in Banaskantha district, *i.e.*, 1124.82 mm thereby making it a relativelymore vulnerable district within the zone.

For the southern hills agro-climatic zone (Table 4), the years 1983, 1988, 1994 and 2005 were the common wet years (>50% deviation) for all the districts in the zone during the entire period of study. The years 1982, 1986, 1987, 1990, 1995 and 2000 were relatively dry years (>50% deviation) for the zone. According to Pandey *et al.* (1999) the Dang and Valsad have 70 per cent of chances of getting higher rainfall (>1500 mm).

In case of middle Gujarat agro-climatic zone, the years 1997 and 2005 were observed to be the wet years for majority of the districts (Table 5). Likewise, was the only common dry year (>50% deviation) for majority of the districts in the zone. The district of Vadodara witnessed the highest deviation in the magnitude of average rainfall between the driest and wettest years in this zone, *i.e.*; 1210.00 mm thereby indicative of a negative influence on its vulnerability to climate change.

Table 5 elicits that in middle Gujarat agro-climatic zone, the years 1997 and 2005 were observed to be the wet years for majority of the districts. Likewise, 1986 was the only common dry year (>50% deviation) for majority of the districts in the zone. The district of Vadodara witnessed the highest deviation in the magnitude of average rainfall between the driest and the wettest years in this zone, *i.e.*, 1210.00 mm thereby indicative of a negative influence on its vulnerability to climate change.

TABLE 8

Comparison of cereal yield during the wettest and driest years with average yield of 31 years in selected districts from 1978-2008 (kg/ha)

S. No.	District	Yield in driest year	Yield in wettest year	Average yield
1.	Kutch	1206	981	1234
2.	Junagadh	730	1549	1912
3.	Amreli	868	3280	1590
4.	Bhavnagar	670	2711	1440
5.	Jamnagar	1015	3168	1387
6.	Rajkot	735	3250	1592
7.	Surendranagar	837	2179	1186
8.	Ahmedabad	758	1198	1167
9.	Banaskantha	943	1119	1254
10.	Gandhinagar	1342	2614	1808
11.	Mehsana	1067	1778	1435
12.	Patan	-	-	-
13.	Sabarkantha	812	1529	1316
14.	The Dangs	1167	977	1199
15.	Navsari	-	-	-
16.	Valsad	1502	442	1588
17.	Anand	-	-	-
18.	Dahod	-	-	-
19.	Kheda	1419	1665	1472
20.	Panchmahal	932	1029	1038
21.	Vadodara	1273	1409	1302
22.	Bharuch	860	1374	991
23.	Surat	917	1382	1448

N.B. 31 years data on cereal yield were not available for Patan, Navsari, Anand and Dahod districts as they are newly formed districts of Gujarat

In the south Gujarat agro-climatic zone (Table 6), the years 1983, 1994 and 2007 were found to be the common years amongst the wet years (>50% deviation)for all the districts of the zone while 1986, 1987, 1991, 1999 and 2000 were found to be the drier years common to all the districts. Surat district witnessed the maximum deviation in the magnitude of average rainfall between the driest and wettest years, *i.e.*; 1464.53 mm. It implies relatively greater vulnerability of Surat district to climate change particularly with respect to rainfall parameter.

It is apparent from Table 7, that northwest arid zone was the most vulnerable due to extreme deviations in rainfall pattern. This zone observed 61.29 per cent deviation in rainfall over a period of 31 years. It was followed by north Saurashtra, south Saurashtra and middle Gujarat zones. The southern hills zone had the least per cent of years with extreme deviations.

It was noticed that during the entire period of study, during the dry years average cereal yield was low and it was high in the wet years as compared to the average yield of 31 years in almost all the districts except a few districts including Valsad and The Dangs (Table 8). Whether this impact was a result of climate change only could not be said with certainty due to the presence of several other non-climatic drivers. However, since rainfall is one of the most important components of climate change it has a

TABLE 9

Correlation between annual rainfall and cereal yields during the period 1988 to 2007

S. No.	Agro-climatic zone	District	Crop	Correlation Coefficient (*r*)
1.	Northwest Arid	Kutch	Bajra	0.696
2.	South Saurashtra	Junagadh	Bajra	0.062
3.	North Saurashtra	Amreli	Bajra	0.309
4.	Middle Gujarat	Panchmahal	Maize	0.056
5.	South Gujarat	Bharuch	Jowar	0.116
6.	North Gujarat	Banaskantha	Bajra	0.346
7.	Southern Hills	The Dangs	Paddy	0.022

direct bearing on cereal yields. In case of Valsad and Dangs district, heavy rainfall led to change in cropping pattern to commercial crops, thus less fertile areas remained for cereals. The northwest arid zone was found to be the most vulnerable zone among all the agro-climatic zones due to extreme deviations in rainfall pattern and the southern hills zone had the least per cent of years with extreme deviations. State-sponsored interventions in Kutch have not only failed to mitigate water scarcity but have aggravated problems in some areas. This has been largely due to the dryland blindness of planners who have applied solutions from the rest of Gujarat to Kutch where uncertainty seems to be a part and parcel of the life in the drylands, instead of designing strategies suited to the region. What Kutch needs is rainwater harvesting, livestock development and better techniques of dryland agriculture (Mehta, 2000).

A perusal of Table 9 indicates the correlation between annual rainfall and year wise cereal yields for selected crops during the period 1988 to 2007. It was found that the yields of all the selected cereal crops were positively correlated with the annual rainfall during the given period. The correlation coefficients are not significant in most of the cases except in the case of the yield of Bajra crop in Kutch district which shows a strong positive correlation (r = 0.69) with rainfall at 5 per cent level of significance.

5. Conclusion

Rainfall variability is one of the most important factors affecting agricultural production in any region. Hence, the proper understanding of rainfall pattern and its trends may help water resources development and to take decisions for the developmental activities of that place. In Gujarat state, the northwest arid zone was found to be most vulnerable to extreme climatesamong all the agro-climatic zones due to extreme deviations in rainfall pattern. This was followed by north Saurashtra, south Saurashtra and middle Gujarat zones. The southern hills zone had the least per cent of years with extreme deviations. The district of Kutch belonging to the northwest agro climatic zone, received the least annual rainfall of only 5.00 mm during 1987 which also happened to be the lowest magnitude of rainfall for the state as well during 1978-2008. The maximum quantum of annual rainfall among all the districts of Gujarat state being 4647.60 mm was received by the Dangs district of Southern Hills Agro-climatic Zone in 1994. Moreover, in Gujarat, the maximum deviation in the quantum of average rainfall between the driest and the wettest years was observed in Junagadh district, *i.e.*, 1794.18 mm. It revealed a possibility of greater vulnerability of this district to climate change so far as rainfall parameter is concerned. Accordingly, water management strategies like micro irrigation systems, deepening of wells, proper utilization of water supply system, construction of check-dams, integrated watershed management and rainwater harvesting are suitable mitigation options to overcome the adverse impact of rainfall variability on agricultural production. Insurance coverage (crop, livestock, etc.) and micro financing facilities must also be strengthened.

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