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An Investigation into Growth, Instability and Role of Weather in Gujarat Agriculture: 1981-2011

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Abstract

The trend in instability in crop production in Gujarat has been analyzed for the 30-year period from 1980-81 to 2010-11 by following the method of 'first differences' or the moving period approach. The relation of instability with growth has also been examined. While investigating the growth performance at the district level, explicit account has been taken of the impact of rainfall on yield of crops/crop groups. The study has observed the decade of 2000s to be the period of high growth in the agricultural sector. But, despite accelerated agricultural growth in the 2000s' decade, the influence of climatic variables is rather strong on the productivity levels of major crops cultivated in Gujarat. This has been seen even for the districts. The crop sector is marked by volatility in its growth. Research and policy support is needed for raising productivity in the rain-fed areas and also for insulating the crop sector from year-to-year variations in rainfall. The study has suggested that development of assured irrigation measures, 'climate-smart' agricultural practices, farmer-friendly insurance schemes and better weather forecasting would provide a sound shield to crop production in Gujarat against the vagaries of weather and long-term changes in climate.

Key words: Growth, instability, climate change, crop production, Gujarat agriculture

JEL Classification: O12, O13, O47, Q 10, Q54.

Introduction

The changing rainfall patterns with more extreme droughts and floods along with increase in temperature can be attributed in part to the rise in emissions of green house gases, resulting from anthropogenic influences. The impact of changing climate on agriculture is envisaged to have repercussions on not only supply of food but also livelihoods of rural population. In the developing countries, agriculture accounts for 29 per cent of the gross domestic product and provides employment to 65 per cent of their populations. The economic health of these nations is thus undeniably tied to the status of the farming community. The effect of changing climate is likely to be very high in India because of its heavy dependence on agriculture and limits to the expansion of land for agriculture and other natural resource constraints coupled with fast changes in the social and economic structure. In 2007, the Inter-Governmental Panel on Climate Change (IPCC) had forecasted that the global average temperatures would rise by 1.1 ^{o}C to 6.4 ^{o}C by the end of the century, which would result in phenomenal changes in land-use patterns. Higher temperatures coupled with changes in rainfall are projected to cause significant declines in the yields of crops in the semi-aid, tropical and sub-tropical regions (CTA and CCAFS, 2011).

Weather parameters particularly the extent of rainfall plays an important role in Indian agriculture, as nearly 58 per cent of the cultivated area contributing to about 40 per cent of the country's food production is rain fed. Even after attaining full irrigation potential of the country, half of the cultivated area will continue

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to be under rain-fed farming (CRIDA, 2007). Substantial acreage under coarse cereals (88%), pulses (83%), oilseeds (70%), rice (42%) and cotton (65%) is rain-fed (Raju *et al.*, 2010). Dryland technologies developed in the research stations to a large extent are yet to reach the fields on a significant scale. However, rain-fed regions amount to nearly 40 per cent of the human and 60 per cent of the livestock population that make the performance and growth of rain-fed agriculture critical.

Data and Methodology

The paper has analyzed the trend in instability in crop production by following the method of 'first differences' or the moving period approach as elucidated by Ray (1983) and subsequently applied by Dev (1987); Rao *et al*. (1988) and Chand *et al*. (2011). Instability was computed by ascertaining the standard deviation in annual growth rates (of production, area or yield) over a specified period. This method does not suffer from properties such as arbitrary choice of an assumed trend line. The use of moving averages or first differences also minimizes the influence of slowly changing factors such as crop management (Lobell and Field, 2007). The method of de-trending the time series was evaluated which produced nearly similar results. The relation of instability with growth has also been examined.

Secondly, in examining the growth performance at the district level, explicit account was taken of the impact of rainfall on yield of crops/crop groups. Yield growth rates have been estimated by using the linear time trend analysis with and without the inclusion of the variable depicting rainfall index (Cummings and Ray, 1969). The study has covered 30-year period, from 1980-81 to 2010-11. For the analysis of growth and instability, the entire period was divided into three sub-periods, viz. 1980-81 to 1990-91, 1991-92 to1999-00 and 2000-01 to 2010-11. The data were sourced from the *Crop and Season Reports* published by the Directorate of Agriculture, Government of Gujarat. District-wise aggregate rainfall information was collected from the database of Indian Meteorological Department (IMD).

Instability in Gujarat's Crop Sector during High Growth Phase

Before we proceed with the analysis of crop sector growth and instability in Gujarat, let us have a look at some salient features of the state. Gujarat has been a frontline state since the accelerated reforms began in 1992-93. The state enjoys an entrepreneurial culture and people's participation in the development process. The state also enjoys several natural advantages such as a long coastline. By virtue of this and its location in the semi-arid region of the country, Gujarat is highly vulnerable to climatic variations. Agriculture is affected by erratic and uneven rainfall that often leads to scarcity conditions, especially in the Kutch and Saurashtra regions (Table 1). In the triennium ending (TE) 2010, the gross cropped area in the state was 115.6 M ha of which nearly 45.7 per cent was irrigated. The cropping intensity recorded an appreciable rise in the previous decade, increasing from 113 to 118 per cent, mainly on account of the improvement in water availability.

In the decade of 2000s, the agricultural growth rate in Gujarat accelerated at rates between 9 and 10 per cent (Gulati *et al*., 2009; Shah *et al*., 2009). Since 2008-09 was a drought year, the growth rate for agriculture up to 2007-08 was as high as 10.9 per cent. This was in sharp contrast to the growth of 2.9 per cent for agriculture and allied sector recorded at the national level. It was also in contrast to Gujarat's own highly volatile agricultural performance during the decades before 2000s. The primacy of agricultural sector in growth acceleration of Gujarat's domestic product during the previous decade has been established (Dholakia, 2010). The sources of stabilizing influence on Gujarat's agriculture after 2000-01 have been examined extensively (Gulati *et al*., 2009; Shah *et al*., 2009; Kumar *et al.*, 2010; Mehta, 2011; 2012). Several factors have been identified as the drivers of agrarian growth notably, an innovative agricultural development programme, liberalized markets, improvement in rural infrastructure, mass-based water harvesting and farm power reforms. Spread and wider adoption of bio-technology (for Bt. cotton), HYVS (for wheat and rice), and growth acceleration in the horticulture sector and dairying have also helped. It was aided by the increased water availability and increase in the gross area irrigated through the Narmada Canal System. Lastly, the climate-related variables also reiterated their primacy. It has been ascertained that the regional ecological conditions, dominantly rainfall explained 70 per cent of the variation in land productivity per hectare towards the end of the 2000s (Mehta, 2012).

Since the growth of agricultural production in Gujarat has undergone a sizeable increase over that

Table 1. Extent of rainfall and level of irrigation in districts of Gujarat

Agro-climatic region, Rainfall (mm)	Districts	Rainfall variability* (1980-81 to 2006-07)	Irrigation development (%) TE 2009
Southern hills (Humid,1793mm)	Dangs	23.2	2.50
	Valsad	25.3	60.2
Southern Gujarat (Semiarid, 974mm)	Surat	32.3	79.0
	Bharuch	25.8	37.9
Middle Gujarat (Semiarid, 904mm)	Vadodara	32.3	51.9
	Kheda	34.6	100.0
	Panchmahal	32.3	27.5
North Gujarat (Semiarid, 735mm)	Ahmedabad	29.4	52.1
	Mehsana	42.3	57.2
	Gandhinagar	40.9	84.0
	Sabarkantha	34.4	63.0
	Banaskantha	45.8	71.6
North-West Arid (Extremely arid, 340)	Kutch	60.3	36.5
North Saurashtra (Semiarid, 537mm)	Jamnagar	56.1	40.9
	Amreli	37.6	37.8
	Bhavnagar	27.7	53.5
	Rajkot	38.8	51.4
	Surendranagar	34.1	33.2
South Saurashtra (Dry Subhumid, 844)	Junagadh	34.1	63.6

Note: * Relative variability= y/x*100, where x= Σ (mean deviations); y= Σ (mean deviations)/ No. of years

experienced in the 1980s and 1990s, it would be pertinent to assess whether this growth has been accompanied by an increase or decline in the instability of agricultural output. This also raises the question whether there is a causal link between growth and variability of agricultural output. Sen (1967) had hypothesized that such a link existed when growth was based on area expansion in the post-independence period. Subsequently, Rao (1975) had also discussed the linkage between variability and growth based on productivity in the 1960s. Rao summarized that since variability in yields was higher than in area, productivity-based growth contributed to greater variability in output. The question becomes important in the case of Gujarat as a variety of crops are grown in the state under diverse agro-climatic conditions and technology adoption is uneven from one crop to the other. While spread of irrigation development is generally believed to promote input-use and hence output growth, it is also true that crop intensification and increased use of inputs can be associated with instability. In this paper, we have analyzed the instability in crop sector in Gujarat and its relationship with growth for the period 1980-81 up to 2010-11.

To assess whether growth in crop sector in Gujarat is associated with fluctuations in output and yields, we have analyzed the changes in the variability of output, area and yield of crops/crop aggregates over the period 1980-81 to 2010-11. The period was divided into three sub-periods, viz. the decade facing decline in agricultural output (1980s), decade of stagnancy (1990s) and the period of high growth (after 2000-01). The basic data comprise time-series information on annual production and area sown. Yield was calculated by dividing total production by the area under each crop.

The changes in crop production result from changes in area, yield and cropping pattern. The components may not trace a similar pattern over different periods due to varying emphasis in the production strategy. Further variability in the annual output growth rate is reinforced if year-to-year changes in the three components are positively correlated and

Table 2. Growth rates in crop area, production and yield in Gujarat: 1980-81 to 2010-11

(percentage)

Crop/Crop groups	Sub-period											
	1980-81 to 2010-11			1980-81 to 1990-91			1991-92 to 1999-00			2000-01 to 2010-11		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Rice	0.77	2.41	1.60	-0.05	0.69	0.71	1.18	4.47	3.23	2.01	8.00	5.91
Jowar	-7.60	-4.89	3.33	-4.42	-7.09	-2.95	-9.35	0.15	11.67	-1.75	2.25	3.77
Bajra	-2.51	-0.64	2.54	-0.64	-2.14	0.00	-2.56	1.89	4.70	-4.77	-2.33	2.69
Maize	1.55	2.10	2.35	2.15	0.07	1.21	2.21	8.08	5.60	0.14	-0.24	0.28
Wheat	1.89	2.98	1.04	-2.10	-3.22	-1.27	0.70	1.11	0.40	14.44	17.78	2.46
Cereals	-1.27	1.48	2.65	-2.00	-1.94	-0.41	-1.66	2.60	4.49	0.43	7.38	5.26
Gram	0.24	2.44	0.39	-0.95	-5.36	-4.40	1.34	2.81	1.41	15.16	34.73	3.84
Tur	-1.15	0.27	1.24	3.61	3.20	-1.93	-1.73	-0.87	2.54	-2.17	7.10	9.50
Pulses	-0.41	0.77	0.83	0.55	-1.38	-2.29	-1.07	-0.39	2.12	0.79	10.33	6.95
Foodgrains	-1.08	1.41	2.40	-1.55	-1.89	-0.79	-1.54	2.31	4.17	0.71	7.61	5.48
Groundnut	-0.25	3.23	3.39	-2.35	-5.23	-3.03	-0.87	5.92	6.91	-0.28	6.23	6.86
Castor	1.02	4.65	5.00	4.53	7.91	3.10	3.24	6.27	2.85	-4.06	6.80	19.79
Sesamum	4.86	5.72	2.24	3.82	0.08	-3.04	2.96	10.67	7.28	0.60	-5.92	-0.59
Rapeseed & mustard	0.69	1.26	0.60	6.62	4.23	-1.73	-2.73	-2.08	0.66	1.78	4.09	2.70
Oilseeds	0.41	3.05	2.54	-0.53	-1.14	-0.61	-0.22	4.77	5.00	-0.64	4.99	6.50
Cotton	2.36	5.45	3.72	-4.20	-0.33	0.57	5.25	8.48	4.81	5.60	24.90	17.30
Tobacco	-1.37	-3.14	0.15	1.30	0.42	0.70	0.03	1.01	0.41	1.17	-5.24	-0.96
Sugarcane	2.50	2.59	0.05	3.61	2.44	-0.44	4.80	4.16	-0.60	0.60	0.87	0.27

Note: A=Area, P=Production, Y=Yield
p values for all coefficients < 0.05.

is dampened if some or all components are negatively correlated. Thus, instability in production increases if there is synchronized movement in the components and it declines if the pattern in movement becomes dissimilar (Ray, 1983). Further, in dry or rainfed conditions cultivation may become more sensitive to weather changes and production increase may be accompanied by increasing amplitude of fluctuations. In addition to the nature of crop production technology and sensitivity to weather, the availability of material inputs may also affect the magnitude of fluctuations. High growth in production accompanied by low levels of instability is desired for the sustainable development of the agricultural sector.

The growth rates in area, production and yield for crop have been presented in Table 2. The exponential growth rates were derived by using the function $Y=Ae^{bx}$, where, Y is the area, production or yield, A is the initial value (or y-intercept) at b=0, and x is the number of time intervals. The exponential value of coefficient b minus one gives the growth rate. It can be seen that the 1980s decade witnessed a declining output for most of the crops. In the 1990s decade, most of the crops (with exception of pulses and some oilseeds) recorded a slow pace of growth. The output growth was largely the result of growth in the yields. In the third phase, i.e., after 2000-01 there was a significant acceleration in output. The area under bajra, maize, tur and castor recorded a decline. For all other crops, output growth was primarily on account of growth acceleration in yields that offset the deceleration in area growth. In Table 3, the estimates of instability in area, production and yield have been presented for major crops and crop groups. The indices were computed from index numbers with 1980-81 as the base year.

Foodgrains — Instability in area under foodgrains was quite high during the decade of 1980s as the growth rates showed standard deviation of 4.5 per cent. Area

Table 3. Instability in crop area, production and yield in Gujarat: 1980-81 to 2010-11

(percentage)

Crop/Crop groups	Sub-period											
	1980-81 to 2010-11			1980-81 to 1990-91			1991-92 to 1999-00			2000-01 to 2010-11		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Rice	3.24	14.51	12.20	3.31	17.70	14.95	1.38	7.16	7.50	4.34	13.02	13.55
Jowar	14.63	16.13	18.61	21.48	15.57	28.62	2.09	15.73	15.25	14.13	14.47	8.87
Bajra	4.59	19.08	18.75	5.30	25.13	25.85	1.66	20.24	19.30	5.59	13.10	10.86
Maize	3.06	31.10	35.28	2.73	41.04	57.29	0.74	13.89	14.18	4.42	33.69	22.21
Wheat	12.28	16.84	7.12	12.85	18.45	8.36	9.86	15.42	6.18	14.17	15.80	7.16
Cereals	4.15	15.88	12.30	4.37	19.57	16.38	2.42	13.12	10.79	5.25	13.96	10.08
Gram	22.90	27.42	14.47	16.93	22.81	9.76	15.29	25.83	11.38	32.47	25.64	20.22
Tur	2.95	15.40	14.32	2.75	16.09	15.69	1.92	12.76	12.20	3.27	10.67	15.90
Pulses	4.77	17.17	12.89	5.42	19.65	15.25	3.01	13.07	9.58	5.56	15.07	14.01
Foodgrains	3.87	15.74	12.16	4.49	19.18	16.15	2.50	12.77	10.35	4.45	14.03	10.30
Groundnut	4.04	43.23	44.42	6.62	57.90	52.34	2.27	42.65	44.08	1.83	31.54	40.76
Castor	11.28	12.00	17.82	9.48	18.46	15.29	4.16	7.04	4.68	16.41	7.55	26.27
Sesamum	10.42	36.97	31.07	9.19	51.25	42.30	6.53	37.31	32.54	13.99	23.09	18.46
Rapeseed & mustard	6.50	12.54	10.79	4.70	14.40	12.32	2.30	13.38	12.08	9.33	11.49	9.03
Oilseeds	3.70	30.17	26.97	6.40	36.21	31.16	0.97	26.64	26.72	1.40	31.17	25.51
Cotton	6.52	19.17	15.61	10.45	25.99	18.05	2.82	15.16	14.38	2.98	11.99	15.35
Tobacco	9.92	13.03	4.70	3.68	10.64	6.17	1.29	7.30	3.90	16.36	17.92	4.10
Sugarcane	6.04	7.06	3.88	3.55	4.56	5.51	2.89	6.12	3.45	8.93	8.23	2.57

Note: A=Area, P=Production, Y=Yield.

instability during this period stemmed from the negative growth in area, and output of foodgrains. Area instability halved to 2.5 per cent in the 1990s, even though this period saw continued stagnation in the agricultural sector. It further rose to 4.5 per cent in the period of high agricultural growth (post-2000-01). Instability in the yield of foodgrains was more than three and a half times the instability in area in the 1980s decade. In the 1990s, there was a wider dissemination of technology and the period recorded a decline in foodgrain yield instability from 16.2 per cent to 10.4 per cent. This pattern continued in the period of high growth. Instability in foodgrain output showed a decline from 19.0 per cent to 12.8 per cent in the 1990s. However, the variability in foodgrain production after 2000-01 was still 10 per cent higher as compared to the 1990s, though considerably lower than that experienced in the decade of 1980s. In Gujarat, the period of agricultural resurgence recorded an acceleration in foodgrain output growth by more than 7.5 per cent per annum, but this pattern of growth was accompanied by high degree of area and output variations. The yields of foodgrains showed higher stability.

For cereals, the trend in area instability was similar to that of foodgrains; it halved in the 1990s to 2.4 per cent, but again increased to 5.3 per cent in the 2000s decade. The instability in cereal yields and hence output, declined by more than 30 per cent in the 1990s and this trend remained unchanged in the 2000s. During 2000s, the area instability for wheat was the highest ever recorded (14.2 %), but yield instability remained nearly half at 7 per cent with little change over the decades of 1980s and 1990s. During this period the production instability amongst cereals was the highest for maize (33.7%), followed by wheat (15.8%). It is evident that despite expansion in irrigation facilities, improvement in availability of inputs and a stable economic environment the production instability of most cereals did not show a significant improvement in the period of high growth in Gujarat.

The yield of pulses as a group was more volatile than cereals during the 2000s. Tur and gram are the important pulses cultivated in Gujarat. In the case of gram, the amplitude of area instability in 2000s was nearly double of that recorded in the 1980s. In the case of tur, area instability was less pronounced (remaining a uniform 3%). Yield instability was around 16 per cent in the 2000s — the same level as in 1980s. Overall, pulses yields are suffering from the lack of technological breakthroughs. Sharp rise in area and yield instability has led to increase in output volatility for pulses during the period of high growth.

Oilseeds — It is interesting to observe that trends in instability in area and production of oilseeds during the three sub-periods followed a pattern akin to foodgrains, but the amplitude of instability was much higher. While area instability for oilseeds declined significantly in the 1990s (6.4% to nearly 1.0%), it did not see major changes subsequently. The magnitude of production instability in oilseeds was nearly double that of foodgrains (36%), as oilseeds are predominantly cultivated under the rain-fed conditions in the state. The extent of instability in yields of oilseeds was 31 per cent in 1980s, but the amplitude reduced considerably after 1990-91.

The behaviour of groundnut, a major cash crop of the state, is noteworthy. Instability in the production of groundnut declined from 58 per cent in 1980s period to 43 per cent in 1990s and the decline continued in the high growth phase. However, production instability is still nearly double of that experienced by foodgrains. Area instability is quite insignificant at 1.8 per cent (having declined from 6.6% in 1980s); as traditionally groundnut is the most prominent non-food crop cultivated in the Saurashtra sub-region. It is the yield instability that largely contributes to variations in output of groundnut. It, however, needs to be appreciated that the yield instability in groundnut is reducing progressively and in 2000s it was 22 per cent lower than that recorded during the 1980s. However, despite decline in instability in groundnut yields, the overall production instability is still the highest amongst all the crops cultivated in the state. Thus, the growth acceleration of more than 6 per cent in output and yield of groundnut is accompanied by high levels of instability. Castor is the other important oilseed crop cultivated in Gujarat. It has witnessed technological breakthroughs that have led to acceleration in yield by 20 per cent per annum. The variations in area have not depicted major changes. The crop experienced unprecedented yield growth along with high degree of yield fluctuations — its amplitude increased by more than six-times in 2000s. In the case of sesame, output volatility is progressively reducing, largely as a result of the decline in yield instability.

Cotton — Gujarat is the largest producer of cotton accounting for 35 per cent of the total production in the country. Cotton output accelerated to 25 per cent per annum in the 2000s decade due to both increase in yields and additions to area. In the 1980s, its production instability at 26 per cent was largely contributed by the fluctuating yields. In the recent period, the increased availability of water for irrigation and technological breakthroughs in cotton cultivation as a result of widespread adoption of Bt cotton, have led to expansion of area under cotton. Area instability has thus declined to nearly 3 per cent after the early 1990s. In the 2000s,despite acceleration in yield growth, instability in cotton yields recorded a marginal increase. Needless to add that with the rapid growth in output, fluctuations in production have declined considerably.

Other Non-food Crops — Volatility in output of tobacco and sugarcane has increased continuously; both are minor crops but of considerable regional importance in the middle and south Gujarat regions, respectively. In the recent decade, area instability for tobacco and sugarcane increased much more than the increase in yield instability. Price disincentives in the case of tobacco are leading to its replacement by other crops. Sugarcane being a water-intensive crop, is also facing unsustainable growing conditions with its yields getting adversely affected due to waterlogging and salinity as a result of over-irrigation.

The net impact of instability in area and yield on production clearly indicates that production of non-foodgrain crops is more unstable than that of foodgrains. Despite their dominance in the state's cropping pattern, the oilseeds group ranks highest in output instability, with groundnut being the most unstable crop. The declining trend in output instability for cotton over the three sub-periods is the result of larger spatial expansion under the crop and long-term decline in the magnitude of yield uncertainty due to advancements and wider adoption of technology.

Table 4. Ranking of crops in terms of output growth and instability in Gujarat

Crop	Ranks in terms of growth*			Ranks in terms of instability$		
	1980s	1990s	2000s	1980s	1990s	2000s
Rice	5	6	4	6	3	6
Jowar	14	12	9	4	10	8
Bajra	10	9	12	10	11	7
Maize	8	3	11	12	7	14
Wheat	11	10	3	7	9	9
Gram	13	8	1	9	12	12
Tur	3	13	5	5	5	3
Groundnut	12	5	7	14	14	13
Castor	1	4	6	8	2	1
Sesamum	7	1	14	13	13	11
Rapeseed & mustard	2	14	8	3	6	4
Cotton	9	2	2	11	8	5
Tobacco	6	11	13	2	4	10
Sugarcane	4	7	10	1	1	2

Note: * Crop with maximum growth is given 1st rank.
$ Crop with least fluctuations is given the 1st rank.

The analysis of growth and instability in the crop sector of Gujarat for the past 30 years brings out that amongst the important crops, castor, rice, wheat, tur, rape/mustard and sugarcane were less volatile (Table 4). Rice, wheat, tur and castor are also fast growing crops. Till the late 1990s, cotton was experiencing fast growth accompanied with high volatility due to weather and price adversities. The behaviour of cotton in the previous decade has shown a significant change; along with growth the crop is now more resilient in terms of output fluctuations. The growth record of groundnut, the most important oilseed in Gujarat is offset by the high degree of output volatility experienced by the crop. Wheat showed an improvement in growth performance, but with higher instability. The study reinforces the view that crops in Gujarat either do not show enough growth and /or are too volatile. On this count, the situation has not changed significantly over the decades of 1960s, 1970s and 1980s. Gujarat's agricultural economy is experiencing a growth pattern that is accompanied by high levels of instability which is showing a decline only in the case of non-food crops.

It is also evident that in the 2000s decade, the changes in instability in a large number of crops have shown a common pattern in production and yield. For most of the crops, yield rather than area instability moved with the output instability. This implies that even though expansion in production base for a crop ushers stability, technological advancement and irrigation development have a greater impact on the yields of crops. Gujarat's location in the semi-arid tract also pre-empts the fact that the behaviour of rainfall is an important determinant of total output. Instability in output across the crops has been found to depend significantly on the availability of water for cultivation. Crops like wheat, rice, sugarcane, castor, and cotton, are cultivated mostly under irrigated conditions that impart stability to their production. It may be noted that the crop area under irrigation (2009-11) was 63 per cent for rice, 95 per cent for wheat, nearly 70 per cent for cotton and castor and 100 per cent for sugarcane. In contrast, irrigation coverage was less than 10 per cent for bajra, maize, tur, 17 per cent for jowar, 29 per cent for gram and around 8 per cent for groundnut. Clearly, instability in these crops is associated with their dependence on rainfall.

Relationship between Growth and Instability

It is believed that instability is a consequence of growth and both are positively associated. This paper has studied the association of growth rates with instability across the major crops cultivated in Gujarat.

Table 5. Cross classification of crops in Gujarat: 1980-81 to 2010-11

Standard deviation in year-to-year changes	Growth rates of production		
	Low (< 2%)	Medium (2-3%)	High (>3%)
Low (<15%)	Rape & Mustard, Tobacco	Rice, Sugarcane	Castor
Medium (15-20%)	Jowar, Bajra, Tur, Cereals, Pulses, Foodgrains	Wheat	Cotton
High (>20%)		Maize, Gram	Groundnut, Sesamum, Oilseeds

To assess the performance of different crops/crop groups, the crops were cross classified in terms of growth in production and standard deviation of year-to-year changes in output, as given in Table 5.

Over the three decades, the crops that are important in the market economy of the state, notably oilseeds and cotton, are experiencing high growth. However, these crops are becoming more volatile, with the exception of castor. Wheat and rice that had recorded medium growth are also more stable in output. The crops can be classified on the basis of trend rates of growth and trends in instability for the period 1980-81 to 2010-11 as follows:

- High growth with declining instability: Castor, cotton, rice
- High growth with increasing instability: Wheat, maize, gram, groundnut, sesame
- Low growth with increasing instability: Tobacco, coarse cereals, tur, rapeseed and mustard.

It can be seen that category one, incorporating castor, rice and cotton, was in a favourable position. Category two crops, viz. wheat, maize, gram, groundnut, mustard, and sesame have recorded medium-to-high growth, but simultaneously have shown increasing instability. In the case of tobacco, tur and the coarse cereals (jowar, bajra) increasing instability is possibly due to the low growth in output. It may thus be surmised that high level of growth is desirable condition for any crop. But the desired and preferred outcome has to be grown with low or declining instability.

To ascertain the behavior of instability and output growth across the crop groups, we have also adopted a nine year moving period approach to ascertain trends in production instability. The nine year, instead of three or five year, moving period was used to provide more stable estimates (Dev, 1987). The trend in instability was derived by fitting the semi-log function to the nine year moving standard deviation (SD) and the results are given in Table 6.

Table 6. Trends in instability and growth rates for output of principal crops/crop groups in Gujarat: 1980-81 to 2010-11

Crop/ Crop group	Trends in instability	Compound growth rates
Rice	-0.47	2.41
Jowar	-0.81	-4.89
Bajra	-4.43	-0.64
Maize	-1.13	2.10
Wheat	-0.97	2.98
Cereals	-2.02	1.48
Gram	1.97	2.44
Tur	-1.17	0.27
Pulses	-1.04	0.77
Foodgrains	-1.84	1.41
Groundnut	-3.94	3.23
Castor	-5.61	4.65
Sesamum	-5.60	5.72
Rapeseed & mustard	-0.08	1.26
Oilseeds	-1.18	3.05
Cotton	-3.07	5.45
Tobacco	5.28	-3.14
Sugarcane	4.44	2.59

Note: All the figures have p values <0.05.

The trend rate in instability computed in this manner declined for all the crops in Gujarat. The instability increased significantly only for tobacco, sugarcane and gram. The decline in instability was the highest for oilseeds (castor, sesame, groundnut), followed by cotton. Amongst cereals, the instability recorded modest long-term decline for wheat, rice and jowar. On the other hand, trend in instability showed a sharp decline for bajra, followed by maize. Crops experiencing sharp fall in instability also recorded high output growth rates — with jowar, bajra and tobacco being the exceptions. The differences in estimation between the year-to-year changes in SD and trends in the nine-year moving SDs are quite noticeable. In the former approach, the levels of output instability showed varying trends from one sub-period to the other. In the latter approach, a more or less secular decline in output fluctuations was observed, though the pace of decline varied. The spread of irrigation, technological advancements and their wider diffusion is lending stability to the production of major crops in the state.

Crop-Weather Relations at District Level

The study of potential impacts of climate change on output variability and thus on food security is becoming an important area of enquiry. The results of such studies point to a possible reduction of yields and deteriorating food security as global warming occurs. According to the National Sample Survey Office (NSSO), in Gujarat during 2009-10 nearly 78 per cent of the rural workers derive their livelihood from agriculture. The largest proportion (63%) of total farmers is of small farmers (< 2 ha of land in 2005-06). Variations in rainfall, both in terms of total precipitation and its timing, affect the food security and output of non-food crops grown under rain-fed conditions in the state.

In this section we have tried to ascertain the relationship of crop output with rainfall for the period 1980-81 to 2010-11 for representative districts of Gujarat. This has been done by estimating apart from the usual unadjusted growth rates, the weather-adjusted trend growth rates of yields for crop groups that are traditionally dominant in the cropping pattern of representative districts in Gujarat. The impact of rainfall as a proxy for weather on the crop productivity has also been ascertained.

The rainfall index, a proxy for weather used in this paper calls for some description. Crop-wise rainfall indices have been used in literature for the major states (Ray, 1976; 1983; Cummings and Ray, 1969; Dev, 1987). Due to the difficulty in obtaining such indices at the sub-state levels, we have constructed a composite rainfall index for each district, which measured the departure of actual annual rainfall from its historically given normal level ($Rf_t - Rf_n / Rf_n$*100), where, Rf_t is the annual rainfall in a year in a district and Rf_n is the long-term normal rainfall in the district. Month-wise rainfall data for the districts was the basic source for constructing the rainfall indices. We have examined the net result of rainfall on yield of dominant crops grown in each district, viz. foodgrains (in Ahmedabad, Kheda, Surat and Kutch), oilseeds (in Junagadh, Amreli and Rajkot) and cotton (in Bharuch, Surendranagar and Bhavnagar). The districts selected fall in different rainfall regimes of the state (refer to Table 1).

The physical factors appear as constraints on the production surface. Basic differences in physical conditions from region to region, lead to differences in land-use and cropping patterns. The biosphere over the soil also depends on the climate; hence soil quality is an expression of climate. Crop output fluctuates due to the relative magnitude and occurrence of various climatic factors from year to year (Ray, 1981). Unadjusted and weather adjusted growth rates in average crop yields were estimated by adopting the following linear functions respectively:

$$Y_t = b_0 + b_1 T \qquad \ldots(1)$$

$$Y_t = b_0 + b_1 T + b_2 W_t \qquad \ldots(2)$$

where, Y_t is the yield, T is time, and W_t is the rainfall index. The coefficient b_1 in both the equations is normalized by average of the yield and multiplied by 100 to get unadjusted and weather-adjusted trend in growth rates. The coefficient b_2 in Equation (1) provides the elasticity of yield with respect to rainfall fluctuations. Statistical significance of the impact of rainfall on overall yield growth is examined by testing the coefficient W_t in the Equation (2) for its t value. Statistical significance of the estimated growth rates for the entire period was examined by testing the coefficients b_1 in Equation (1) for its t value and in Equation (2) for its F value. The estimated results are given in Table 7.

Table 7. District-wise growth rates in crop groups in Gujarat: 1980-81 to 2010-11

District	R^2		Elasticity of yield with rainfall	Growth rates (%)	
	Unadjusted (without rainfall)	Weather adjusted (with rain)		Un-adjusted	Weather adjusted
Foodgrains					
Ahmedabad	0.66	0.69	0.32**	3.58*	3.59*
Kheda	0.63	0.69	0.17*	1.93*	1.95*
Surat	0.67	0.68	0.10	1.72*	1.57*
Kutch	0.33	0.47	0.25*	2.57*	2.11*
Oilseeds					
Junagadh	0.24	0.27	0.16	2.43*	2.33*
Amreli	0.03	0.13	0.51**	1.13	0.86
Rajkot	0.33	0.36	-1.42	5.76*	6.75*
Cotton					
Bharuch	0.54	0.66	0.83*	3.39*	3.16*
Surendrangr	0.53	0.75	1.34*	4.56*	3.52*
Bhavnagar	0.27	0.49	1.20*	2.90*	2.20*

Note: * Significant at 5 per cent; ** Significant at 10 per cent

It can be seen from the results that the inclusion of rainfall index improved the value of R^2, in all the districts. The improvement was more pronounced in Kutch and Kheda (for foodgrains), Amreli (for oilseeds) and for all the cotton-cultivating districts. This indicates that variations in rainfall help in explaining the variations in crop yields to a substantial extent across the state.

The estimated yield elasticity with respect to rainfall was statistically significant in seven out of the ten districts. The elasticity was largest in Bharuch, Surendranagar and Bhavnagar districts. Bharuch and Surendranagar are the low-irrigated districts, while Bhavnagar is a low-rainfall district with moderate irrigation development. Amreli is a low-rainfall and low-irrigation district and hence noted a larger coefficient. For Rajkot, the coefficient W^2 turned out to be negative for the yield, indicating an adverse effect of abnormal rainfall on yield of oilseeds (chiefly groundnut). However, the coefficient was statistically insignificant. It can also be noted that the effect of rainfall appeared to be more pronounced on the average yield of commercial crops. Foodgrains (mostly rice and wheat) are cultivated under the irrigated conditions. The exception is Junagadh district, where again irrigation is quite developed (64% of sown area was irrigated in TE 2009).

In all the studied districts, except Amreli, a statistically significant yield growth rate was obtained during the entire period under consideration. A comparison of the unadjusted with weather-adjusted growth rates reveal that the latter were higher in the districts of Ahmedabad, Kheda for foodgrains and Rajkot for oilseeds. In contrast, the weather-adjusted growth rates for the low-rainfall districts (Bharuch, Surendranagar, Bhavnagar, Junagadh and Amreli) were lower than the unadjusted growth rates. It is apparent that these regions are largely dependent on weather parameters notably rainfall, for output of the crops and the under-developed irrigation exacerbates the effect on yields for the main crops that are cultivated. Since agriculture is largely rainfed, climatic changes that alter temperature and/or precipitation patterns may pose serious threats to agricultural production. The obvious conclusion is that yields depend on the amount of rainfall. It is quite apparent that in the semi-arid regions yield is more strongly correlated with weather-induced fluctuations. The correlation is weaker in the regions with more developed irrigation facilities (Surat, Kheda, Junagadh) or have assured rainfall. It has been contended that to deal with water scarcity in the arid lands of Saurashtra region, there is a need to create micro-irrigation and recharge the structures with mass support, supplemented by financial and technical support of the government. Strategies such as rainwater harvesting, construction of check dams, efficient irrigation systems (e.g. drips), livestock development and techniques for dryland agriculture can help overcome the constraints in the dry regions (Hiremath and Shiyani, 2013). Further, development of climate-proof crops (drought-resistant and heat-tolerant varieties) can help agriculture to cope with the wide range of climatic conditions. An improvement in agronomic practices of different crops can help cope with variations in rainfall, dry spells and earlier plant maturity.

Secondly, since adjustment for weather isolates the impact on the growth performance of rainfall conditions, the adjusted growth rates also reflect the intrinsic performance of the districts. In that context, in the entire period, the performance of Ahmedabad and Kutch districts in foodgrains output is noteworthy. Rajkot has taken tremendous strides in the cultivation and yield of oilseeds. Amreli, on the other hand, is agriculturally-underdeveloped and has recorded near stagnation in yield growth of the main crop cultivated in the district.

The fluctuations in rainfall are not the only explanation of changes in yields and in total output. The structure of agricultural economy has changed significantly in the state. Cash crops are expanding their share at the cost foodgrains in the total value of output. Commercialization is showing signs of deepening, as the crops having greater market-orientation are consolidating their share in the farm economy of the state. This has a bearing on the food-security concerns. This also has serious consequences for small-scale farmers whose total output is often barely sufficient to meet the household food needs and for whom access to groundwater is sometimes restricted in the drier regions.

Conclusions and Policy Implications

Despite dwindling share of agriculture in Gujarat's total output, it is still the largest employment generator. The sector is highly unstable but due to its reduced output share, the state's economy is insulated from fluctuations in its growth pattern. However, in the 2000s decade — a period of high growth in the agricultural sector — the primacy of agriculture in the overall growth acceleration cannot be denied. The analysis of crop sector has revealed that most of the important crops in the state have either not shown enough growth or have a volatile production record. In Gujarat, the level of instability for oilseeds is far more than for foodgrains, but the decline in it is sharper. In the final analysis, irrigated cereals (mainly rice), cotton, and castor amongst oilseeds have emerged the most stable crops, also having high growth. The fast growth in output for wheat, groundnut and maize is offset by high or increasing instability recorded by these crops.

In the period of growth acceleration, the crops that recorded high amplitude of output instability (maize, tur, groundnut, sesame) have also shown a higher degree of contribution to yield instability. Studies (Kumar *et al*., 2010) after examining historical data for 1949-2006 have also shown that production of wheat after the mid-1980s has become highly erratic with sharp declines in production during drought years. Cotton and groundnut have also reported fluctuations in output, a consequence of inter-annual yield fluctuations. Sharp decline in yield levels has been observed during drought years. After 1988, the yield fluctuations in groundnut too have become severe. Thus, yields of crops having a substantial rainfed component, are highly vulnerable to droughts.

Rainfall is the major source of moisture for crop cultivation in Gujarat. It explains to a large extent the fluctuations in production and yields of most of the crops that are cultivated in the rain-fed areas. Districts that receive low rainfall and/or have low levels of irrigation development experience high degree of fluctuations in the aggregate crop output. Unadjusted growth rates declined significantly once it was adjusted for rainfall changes in most districts, indicating thereby that high growth in yield is mainly an outcome of favourable weather conditions. Developments promoting assured irrigation can be a major force in conditioning the growth and variations in crop production across the crops and also across the regions.

The crop-wise yield elasticity with respect to rainfall is the largest for cotton, indicating that the adoption of new technology on a wider scale has made the crop yields more sensitive to variations in the natural phenomena. With the adoption of higher yielding varieties and now transgenic crop varieties, expansion of cultivation is happening even on marginal lands with degraded and fragile soils and with uncertain availability of irrigation facilities. It is possible that the adoption of new technologies in the case of cotton has rendered production far more sensitive than before even to small variations in weather-related phenomena.

Despite accelerated agricultural growth in the 2000s decade, the influence of climatic variables is rather strong on the productivity levels of the major crops cultivated in the state. This has been seen even for the districts. The crop sector is marked by volatility in its growth. Research and policy support is needed for raising productivity in the rain-fed areas and also for insulating the crop sector from year-to-year variations in rainfall. Environment and land-management related projects, including improved management of water resources, require policy focus. Farm systems approach to research and planning addressing the differential needs of agro-climatic regions is needed.

Adoption of 'climate-smart' agricultural practices would have to involve the use of varieties and species that have the ability to cope with drier conditions, higher temperatures and emerging pests and diseases. Adaptation to short-term climate variability and long-term climate change would involve risk management through insurance schemes as well as better methods of weather forecasting etc. This would enhance the capacity of the farmers to allocate their resources effectively and reduce risks. Increasing yields would involve, apart from upgradation of irrigation facilities, greater diffusion of technological innovations and large-scale investment in agricultural R&D. Government's role as a provider of agricultural extension services, would have to be complementary to the creation of efficient markets. Dissemination of appropriate crop technologies and farm management practices that result in efficient use of resources are bound to play a pivotal role in insulating crop production from the vagaries of weather and even the long-term changes in climate.

Lastly, resilience towards climate change can be built through greater diversification of production systems. The diversified crop rotations including crop varieties with different temperature and water-use requirements, water-use efficiency and lower yield variability would be an effective way to reduce/mitigate risks and to increase farming efficiency. The integrated crop and livestock system increases environmental sustainability and is crucial for adaptation responses to climate change. The diversification of food systems can also enhance the resilience of agriculture to climate change.

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