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Impact of rainfall variability on food production in India

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Abstract: The present study examines the trends and patterns in agricultural growth at the national level. Data on important variables like area, production, and value of output were compiled for the period 1967-68 to 2009-10 from various published sources. The analysis of data reveals that the cropping pattern in India has undergone significant changes over time. There is a marked shift from the cultivation of food grains to commercial crops. Among food grains, the area under coarse cereals has declined by 14.14 per cent between 1970-71 and 2009-10. Similarly, the performance of pulses in terms of area and output was not impressive during the study period. The most important feature controlling the Indian climate is that about 75 per cent of the annual rainfall is received during a short span of four months (June to September). India has witnessed 40 drought years since 1801, drought occurs at a recurrence interval of 5 years. Variability in the onset, withdrawal and quantum of rainfall during the monsoon season has profound impacts on water resources, agriculture, economics and ecosystems in the country.

Key Words: Cropping Pattern, Crop production, Drought, Rainfall variability

Introduction

The Indian economy has undergone structural changes over time with a desired decline in the share of agriculture in the GDP. Despite a fall in its share from 55.1 per cent in 1950-51 to 17.0 per cent in 2008-09, the importance of agriculture has not diminished for two major reasons. First, the country achieved self-sufficiency in food production at the macro level, but still is a food deficit country facing massive challenges of high prevalence of malnourished children and high incidence of rural poverty. The pressure on agriculture to produce more and raise farmers' income is high. Second, the dependence of the rural workforce on agriculture for employment has not declined in proportion to the sectoral contribution to GDP (Chand and Raju, 2009).

Indian agriculture is still heavily dependent on monsoons. Almost 53 per cent of its gross cropped area (GCA) is rainfed, and even the area that is irrigated through canals, tanks, watersheds, and groundwater is affected when rainfall is low, and reservoir levels and ground water levels dip. Broadly, only about 35-40 per cent of its area is under assured irrigation. There is no doubt that over the years irrigation cover has increased from 17 per cent in 1951 to 34 per cent in 1991 to 47 per cent in 2011 and the share of groundwater has surpassed the share of canal irrigation. With agriculture contributing to 14 per cent of India's GDP and providing employment to almost half of its work force, any variation in monsoons will influence the agricultural growth and intern influence prices, income and GDP growth. The present study was taken up with the objectives to study the changes in the cropping pattern and study the pattern of rain fall and its impact on crop production.

Material and methods

The study used secondary data compiled from various published sources. Data on area, production and yield and land use pattern were collected from the Directorate of Economics and Statistics (DES), Ministry of Agriculture. Data relating to rainfall distribution and occurrence of drought was collected from Indian metrological department. Data on value of crop output were compiled from the Central Statistical Organization, Government of India. Compound annual growth rates have been calculated by using the semi-log method.

The descriptive statistics like averages; percentages were used and tabulated. Regression analysis was carried out to know the relationship between rainfall pattern and production of food grains.

$$Y=a+b_1X_1+b_2X_2+b_3X_3+U$$

Y= Food production (Million tones)

a = Intercept

X_1= Area under food crops (Mha)

X_2= Average annual rainfall (mm)

X_3= Average annual temperature (^{0}C)

U= Random error

Results and discussion

Most of the increase in cropped area during the past decade was in wheat, maize, soybeans, pulses, and cotton with most of the decline coming from coarse grains (excluding maize), which has declined by 5 to 6 million hectares (Table 1). Area under rice and sugarcane has remained more or less unchanged, except for some year-to-year variations. The increase in cotton area in recent years coinciding with the introduction of Bt cotton. Area under pulses was stagnant between 2003–04 and 2009–10 and increased in the past two years with the rising prices inducing higher production and support from programs, such as, the National Food Security Mission. The emerging scenario points to the dominance of wheat, cotton, soybeans, and maize in India's overall cropping pattern and the declining importance of coarse grains (excluding maize). The share of rice in the total cropped area has also declined. In most of the states similar trends in area under different crops was noticed. For example study conducted by Acharya *et al.* (2012) reported that area

Table 1. Trends in crop area (million hectares)

Year	Rice	Wheat	Maize	Other cereals	Pulses	Soybean	Oilseeds	Sugarcane	Cotton
2000-01	44.7	25.7	6.6	23.7	20.4	6.4	16.4	4.3	8.5
2001-02	44.9	26.3	6.6	22.9	22	6.3	16.3	4.4	9.1
2002-03	41.2	25.2	6.6	20.4	20.5	6.1	15.3	4.5	7.7
2003-04	42.6	26.6	7.3	23.5	23.5	6.6	17.1	3.9	7.6
2004-05	41.9	26.4	7.4	21.6	22.8	7.6	19.9	3.7	8.8
2005-06	43.7	26.5	7.6	21.5	22.4	7.7	20.2	4.2	8.7
2006-07	43.8	28.0	7.9	20.8	23.2	8.3	18.2	5.2	9.1
2007-08	43.9	28.0	8.1	20.4	23.6	8.9	17.8	5.1	9.4
2008-09	45.5	27.8	8.2	19.3	22.1	9.5	18.1	4.4	9.4
2009-10	41.9	28.5	8.3	19.4	23.3	9.7	16.2	4.2	10.1
2010-11	42.9	29.1	8.6	19.9	26.4	9.6	17.6	4.9	11.2
2011-12	44.4	28.9	8.7	18.1	25.4	10.2	17	5.1	12.2
CGR	0.04^{NS}	1.24^{**}	2.81^{**}	-2.01^{**}	1.69^{**}	5.21^{**}	0.47^{NS}	1.46^{*}	3.21^{**}

Note: ** Significant at 1%, * Significant at 10%, NS- Non significant

under Sorghum, Bajra, Ragi and other minor millets in state of Karnataka witness a substantial annual decrement, while the area under Rice is reported to experience a mild annual increment. The area under pulses, vegetables, spices and fruits and nuts was increasing year after year.

The cropping pattern in India has undergone significant changes over time (Table 2). As the cultivated area remains more or less constant, the increased demand for food because of increase in population and urbanisation puts agricultural land under stress resulting in crop intensification and substitution of food crops with commercial crops. In fact, it is observed that area under food grains in gross cropped area (GCA) has declined by 12.02 per cent mainly due to fall in area under coarse cereals by 14.14 per cent between triennium ending (TE) 1970-71 and TE 2009-10. Wheat has gained importance with area allocation of only 10.42 per cent in TE 1970-71, and it steadily increased to 15.08 per cent in TE 2009-10. Area under rice remained more or less constant during the period under study. Interestingly, area lost by food grains was used for the cultivation of oilseeds, fruits, vegetables and non-food crops to the extent of 4.0 per cent, 2.86 per cent and 7.02 per cent, respectively, between TE 1970-71 and TE 2009-10. Although the shift from coarse cereals to high value crops is likely to increase farm output and income to farmers, in dry land regions it will expose cultivators to serious weather-borne risks because high value crops have a high water requirement. The area under groundnut came down from 4.42 per cent in TE 1970-71 to 3.20 per cent in TE 2009-10. However, the area under commercial crop like cotton almost remained constant at 4.5 per cent and that of sugarcane registered marginal increase from 1.62 per cent in TE 1970-71 to 2.47 per cent in TE 2009-10. It is observed from the table that commercial crops are taking the lead in terms of area share.

As evident from Table 3, wheat production registered compound annual growth of 5.03 per cent during the early green revolution period (1967-68 to 1979-80). Both yield and area contributed to higher growth in production. In the case of rice, growth in yield contributed to production growth of

Table 2 Share of area under major crops in India (Percent of GCA)

Crops	TE 1970-71	TE 1980-81	TE 1990-91	TE 2000-01	TE 2009-10
Rice	23.02	23.18	23.00	23.82	23.05
Wheat	10.42	12.98	13.04	14.28	15.08
Coarse Cereals	28.48	24.25	20.48	16.17	14.14
Total Cereals	61.93	60.41	56.53	54.27	52.18
Total Pulses	13.50	13.23	12.94	11.49	10.89
Total Food grains	75.54	73.67	69.47	65.32	64.11
Total Oilseeds	9.85	10.11	12.51	12.96	12.04
Groundnut	4.42	4.14	4.64	3.68	3.22
Cotton	4.70	4.27	4.08	4.70	5.98
Jute	0.42	0.51	0.39	0.45	0.44
Total Fibres	5.41	5.08	4.64	5.27	5.22
Sugarcane	1.62	1.62	1.90	2.23	2.98
Tobacco	0.27	0.25	0.22	0.21	0.21
Condiments and Spices	1.04	1.23	1.32	1.52	1.58
Potatoes	0.31	0.43	0.51	0.69	0.88
Onions	-	0.14	0.17	0.24	0.45
Total Fruits & Vegetables	2.24	2.77	3.57	4.35	5.34
Fodder Crops	4.15	4.50	4.59	4.55	4.10
Total Non-Food grains	19.39	20.13	23.60	25.44	26.42
Gross Cropped Area (GCA)	100.00	100.00	100.00	100.00	100.00

Source: Directorate of Economics and Statistics, Govt of India

1.84 per cent per annum. For food grains as a whole, the growth in area and yield were 1.75 per cent and 0.43 per cent, respectively and resulted in production growth of 2.19 per cent. However, it is interesting to observe a relatively higher growth in yield of all major crops during 1980-81 to 1989-90. It indicates that crops other than rice and wheat shared the technological benefits. With decline in area, impressive growth in production of most crops was mainly contributed by growth in yield. Rice registered production and yield growth rate of 3.62 per cent and 3.19 per cent, respectively. However, negative growth was reflected in the decline in area under food grains. Despite this, production of food grains was high at 2.73 per cent, which was contributed by yield growth of 2.97 per cent. Oilseeds recorded a growth rate of 5.46 per cent in production and 2.95 per cent in yield. This could be attributed to technology mission on oilseeds launched in mid-1980s, which laid emphasis on increasing productivity of oilseeds and bridging yield gaps between experimental stations and farmers' fields by adopting improved package of practices. Similarly, cotton showed high growth in area by 3.50 per cent, production by 5.19 per cent and yield by 6.01 per cent. Potato and coconut also recorded a high growth in production and yield.

However, the impressive growth in crop production observed during the 1980s was not sustained during the 1990s. Growth in the yield of almost all crops declined during 1990-91 to 1999-00. This was, in fact, a disturbing scenario, which resulted in low growth in crop output. However, there was increase in area for rice and wheat during this period. Growth in area under sugarcane and potato also increased during this period. Despite recording almost the same level of growth in yield, the negative growth in area resulted in a fall in production for coarse cereals. In the case of pulses, the decline in the growth of yield and negative growth in area led to fall in production. Consequently, growth in food grain production declined to 2.26 per cent during the economic reforms period when compared to 2.73 per cent in the mature green revolution period.

India has a tropical monsoon climate and rainfall is an important element for the economy. Although monsoons affect most parts of India, the amount of rainfall varies from heavy to scanty in different parts. Historically, it is known through official and unofficial records that practically every year, some part of the country experiences drought or flood, though there are certain areas more prone to such condition than others in the country. Traditionally Indian monsoon season is between June 1st to September 30th. The June-Sept rains (or South-West Monsoon Rains) account for nearly 76 percent of the annual precipitation and more than half of the total cultivated area is dependent on these rains (Krishna, 2009). The rainfall season between the months of October-December is known as the North-East monsoon season. The south Peninsular India consisting of five sub-divisions (Tamil Nadu, Coastal Andhra Pradesh, Kerala and south-interior Karnataka) receive about 30% of its annual rainfall during this season. The percentage change from actual to normal was more in winter season (-11.34) fallowed by pre-monsoon season (-7.07). The overall percentage change was -3.42 per cent. The average actual rainfall of a country is 1175.6 mm and normal rainfall is 1175.6 which was higher than the actual rainfall (Table 4).

The multiple regression function was estimated to analyse the relationship between food production and other parameters like temperature, rainfall and area under food production. The variables included in the model explained 57 per cent of variation in food production. The estimated parameter of area under food crops is 3.94 which is significant at one per cent and estimated parameter of rainfall and temperature is -0.38 and 2.83, respectively.

India has witnessed 40 drought years since 1801, drought occurs at a recurrence interval of 5 years. Frequent occurrence of drought is going to affect the area under various crop there by decreases the availability of food crops (Guhathakurta and Rajeevan, 2008). The drought of 1918 was a severe drought which affected 71 per cent of the area and percentage deviation of rainfall was -49 per cent (Table 6). In order to study the

Table 3. Compound annual growth rates of area, production and yield of major crops in India

Crops	1967-68 to 1979-80			1980-81 to 1989-90			1990-91 to 1999-00			2000-01 to 2007-08			1967-68 to 2007-08		
	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield
Rice	0.74	1.84	1.09	0.41	3.62	3.19	0.68	2.02	1.34	-0.11	1.9	2.01	0.45	2.47	2.01
Wheat	2.87	5.03	2.10	0.46	3.57	3.10	1.72	3.57	1.82	1.25	1.38	0.13	1.14	3.63	2.45
Coarse cereals	-0.98	1.11	2.11	-1.34	0.04	1.39	-1.83	-0.48	1.37	-0.47	3.52	4.01	-1.35	0.56	1.93
Pulses	0.71	-0.26	-0.97	-0.1	1.49	1.59	-0.6	0.67	1.28	1.93	3.31	1.35	-0.01	0.71	0.72
Total Cereals	0.39	2.16	1.77	-0.26	2.26	2.52	0.12	1.72	1.59	0.14	2.20	2.05	-0.06	2.06	2.12
Food grains	0.43	2.19	1.75	-0.23	2.73	2.97	-0.08	2.26	2.34	0.48	2.01	1.53	-0.07	2.27	2.33
Groundnut	0.00	1.64	1.64	1.65	3.76	2.08	-2.31	-1.25	1.08	-0.4	3.0	3.41	-0.26	0.86	1.12
Rapeseed and Mustard	1.05	0.64	-0.40	1.94	7.29	5.24	0.62	0.73	0.11	6.15	8.22	1.95	2.13	4.55	2.37
Oilseeds	0.76	1.88	1.11	2.44	5.46	2.95	0.15	2.27	2.12	3.43	7.44	3.88	1.53	3.51	1.95
Fibre crops	-0.34	3.44	3.79	-1.50	1.52	3.07	2.44	2.03	-0.40	1.08	9.68	8.51	0.35	2.45	2.09
Cotton	0.38	-0.41	-0.79	3.50	5.19	6.01	2.34	2.69	0.34	0.42	3.21	2.79	2.06	3.06	1.18
Sugarcane	1.41	1.99	0.57	1.26	2.71	1.43	1.67	3.05	1.36	1.91	2.39	0.47	1.63	2.68	1.03
Potatoes	4.08	8.07	3.83	2.93	5.17	2.18	3.84	5.44	1.54	3.46	1.65	-1.74	2.99	4.93	1.88
Coconuts	0.38	-0.41	-0.79	3.50	5.19	6.01	2.34	2.69	0.34	0.42	3.21	2.79	2.06	3.06	1.18

Table 4. Season wise rainfall distribution during 1992-93 to 2010-11 (in Mm)

Year	Monsoon season (June-Sept)			Post season (Oct-Dec)			Winter season (Jan-Feb)			Pre-Monsoon season (Mar-May)			Over all rainfall (June-May)		
	Actual	Normal	Change	Actual	Normal	Change	Actual	Normal	Change	Actual	Normal	Change	Actual	Normal	Change
1992-93	830.7	899.2	-7.6	106.5	114.1	-6.7	37.9	41	-7.6	116.5	121.3	-4	1091.6	1175.6	-7.1
1993-94	902.1	908.9	-0.7	131.6	119.6	10	44.5	40.8	9.1	106.1	123.3	-13.9	1184.3	1192.6	-0.7
1994-95	999.2	906.8	10.2	121.5	119.6	1.6	53.1	41.1	29.2	123.5	123.2	0.2	1297.3	1190.7	9
1995-96	904.5	904.7	0	117.8	119.9	-1.8	37.4	40.8	-8.3	94.9	123.9	-23.4	1154.6	1189.3	-2.9
1996-97	927.6	905.7	2.4	128	120.8	6	21	40.6	-48.3	118.9	123.2	-3.5	1195.5	1190.3	0.4
1997-98	927.4	908.6	2.1	187.7	119.5	57.1	44.1	41.9	5.3	132.3	128.3	3.1	1291.5	1198.3	7.8
1998-99	945.2	903.6	4.6	178.8	121.8	46.8	28.4	42.8	-33.6	123.1	130.6	-5.7	1275.5	1198.8	6.4
1999-00	866.9	903.2	-4	144.7	121.8	18.8	43.1	42.5	1.4	128.8	129.5	-0.5	1183.5	1197	-1.1
2000-01	833.7	902.3	-7.6	64.1	121.7	-47.3	16.2	42.2	-61.6	129.7	129.3	0.3	1043.7	1195.5	-12.7
2001-02	826	901.1	-8.3	137.7	121.7	13.1	35	41.2	-15	121.5	132	-8	1120.2	1196	-6.3
2002-03	737.1	911.7	-19.2	83.4	123.7	-32.6	53.2	38.3	38.9	107.7	131.7	-18.2	981.4	1205.4	-18.6
2003-04	947.3	902.7	4.9	134.6	125	7.7	34.5	39.2	-12	161.6	129.6	24.7	1278	1196.5	6.8
2004-05	779.6	893.3	-12.7	111.8	125.7	-11.1	69.8	43.8	59	124.7	134.5	-7	891.4	1019	-12.5
2005-06	879.3	892.5	-1	138.4	125.8	10	27.8	43.9	-37	139.9	134.6	4	1017.7	1018.3	-0.1
2006-07	886.6	892.2	-0.6	99.3	125.9	-21.1	34.3	43.8	-21.7	112.8	133.6	-15.6	1133	1195.5	-5.2
2007-08	936.9	892.2	5	85.4	125.9	-32.2	42.6	43.2	-1.4	115.3	133.5	-13.6	1180.2	1194.8	-1.2
2008-09	873.2	896.2	-2.1	87.2	125.9	-30.7	23.6	43.8	-46.1	91	134.5	-32.3	1075	1196.4	-10.1
2009-10	689.8	892.2	-22.7	135.5	125.9	7.6	24.6	43.8	-43.8	122.9	133.7	-8.1	972.8	1195.6	-18.6
2010-11	912.8	893.2	2.2	153.2	126.3	21.3	31.9	40.9	-22	114.4	131.3	-12.9	1212.3	1191.7	1.7
Average	873.99	900.54	-2.9	123.54	122.66	0.87	37	41.87	-11.34	120.29	129.56	-7.07	1135.8	1175.6	-3.42

Source: IMD Annual Climate Summary, 2009

Table 5. Influence of area and climatic factors on food production

Particulars	Parameters	Coefficient
Intercept	a	-20.03
Area	b_1	3.94*
Rainfall	b_2	-0.38**
Temperature	b_3	2.83
R^2		57

Table 6. Severe drought years in India

Year	Percentage of area affected	% Deviation of rainfall in affected area	Decline in area under food grains
1918	71	-49	NA
1965	41	-36	3532 (3.00)
1972	47	-35	6040 (4.17)
1979	45	-38	3668 (2.88)
1987	50	-45	7116 (5.56)
2009	47	-41	5105 (4.03)

Figures in the parenthesis indicates decline in area over previous year

intensity and the volatility of the rainfall deviations, the decadal average deviation of the monsoon rains from LPA in the drought years and in the decade as a whole was considered (Table 7). So while there are not more than 3 years per decade categorized as drought, the average deviation (below LPA) of the decades is worsening. Even the intensity of the drought year is worsened; the average deviation of rainfall from LPA during drought years has increased from 13.9 percent fall in 1950s to close to 18.3 percent fall in the 2000s. Overall, in a decade there is a high probability that India face two drought years (when rainfall is less than LPA by a margin of more than 10 percent) with relatively increasing negative deviations.

Thus, the cropping pattern in India has undergone significant changes with a significant shift from the cultivation of food grains. The area under coarse cereals, which is generally cultivated in dry regions, has declined by

Table 7. Deviation of rainfall and frequency of drought

Decade	Frequency of drought (years)	Drought years (rainfall deviation from LPA>10%)	Average of deviation from LPA for drought years	Average of deviation from LPA(%) for decade
1950s	1	1951	-13.8	2.5
1960s	3	1965-66, 1966-67 and 1968-69	-13.9	-1.43
1970s	3	1972-73, 1974-75 and 1979-80	-18.3	-0.03
1980s	3	1982-83, 1986-87 and 1987-88	-15.53	-2.12
1990s	0	None	-	0.51
2000s	3	2002-03, 2004-05 and 2009-10	-18.27	-5.18

LPA-Long period average

13.3 per cent between TE 1970-71 and TE 2009-10. The performance of pulses in terms of area and output was not impressive during the study period. Nevertheless, increase in crop yield has been a major factor for accelerating crop production in the country since late 1960s. However, technological and institutional support for a few crops like rice and wheat have brought significant changes in crop area and output composition in some regions. Agriculture is one such sector which heavily depends on the monsoon. The deviation in the rainfall pattern led to changes in cropping pattern and also leads to food insecurity, poverty, unemployment and other socio-economic problems.

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