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Impact of Rainfall on Agricultural Production in Bihar : A Zone-Wise Analysis

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Abstract Agriculture in Bihar contributes about 19 percent to state Gross Domestic Product and provides employment to about 70% of working force in rural areas. Rainfall however is erratic to poor and unreliable. Though average rainfall in the State is adequate (1067 mm) but the variation is much higher. However, rainfall during June to September varied by 23 percent, adversely affecting rice production. Comparatively large decline in rainfall is observed in high rainfall area than low rainfall area. About 77 percent districts of Bihar experienced decline in rainfall by 5 to 25 percent and 8 percent of districts by more than 25 percent. The relationship between rainfall (SPI Index) and rice production has been positive in all the agro-climatic zones and highly significant in low rainfall area. It suggests creation of assured irrigation infrastructure in the State for sustainable agricultural production, in general and rice production, in particular. Besides, short duration and less water loving crops / varieties need to be developed on priority basis for sustainable livelihood of farming community in Bihar.

Keywords Agro-climatic zones, Rainfall pattern, Standardized Precipitation Index, Bihar.

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Introduction

With growing recognition of climate change and clear evidences of observed changes in climate during 20th cencury, an increasing emphasis on food security and its regional impacts has come to forefront of the scientific community. Most of the simulation studies have indicated that the direct impacts of climate changes would be small on *kharif* crops but *kharif* agriculture will become vulnerable due to increased incidence of weather extremes such as decline of rainy days and rainfall intensity, increase in duration and frequency of drought and floods, diurnal asymmetry of temperature, change in humidity, and increase in pest incidence and virulence. *Rabi* crop production may become comparatively more vulnerable due to increase in temperature, asymmetry of day and night

temperature and higher uncertainties in rainfall. The impacts of the climate change on Indian agriculture would be small in near future, but in long run the Indian agriculture may be seriously affected depending upon season, level of management, and mahnitude of climate change [1].

With the changing food habits and market conditions, farmers prefer wheat or rice in most parts of the country. The studies have already projected greater losses in *Rabi* season (e.g. in wheat yield) as compared to *Kharif* crops. Climate change will affect different parts of India in different ways. India may also be exposed to a greater number of floods due to the intensification of the Indian monsoon. The regional inequality in food production resulting from climatic change will thus cause great global implications [2].

Rainfall pattern is a very important limiting factor for rain-fed crop production. Higher variability in distribution and a likely decrease in precipitation adversely impacts rice production and complete crop failure is possible if severe drought takes place during the reproductive stages. Assessments predict a decrease in the rice production in tropical regions, but an increase of rice production outside tropical regions. This shift is of particular concern to India because lower rice production will immediately create a hunger situation on a large scale. There is a strong positive effect of rainfall on its yield and in states like MP, Odisha, West Bengal and Bihar, where declining rainfall may be a contributing factor towards declining yields of rice [3]. The effect of poor monsoon or monsoon failure is generally seen by looking at the changes in output between the years of monsoon failure and the previous years. This often conceals true effect of monsoon failure as the previous year may not be a normal year for agricultural production. Effect of monsoon rain on crop output is captured more accurately by the deviation in output from the underlying trend rather than change in output from the previous year [4]. Fertilizer use, irrigation and rainfall were found to cause significant variation in productivity across districts. The highest coefficient was that of rainfall, which shows that one percent increase in rainfall between districts results in 0.43 percent increase in agriculture productivity. This indicates the importance and need to manage rainfall water to raise productivity particularly in low productivity districts [5].

Bihar with a geographical area of 94.2 thousand square km is divided by river Ganges into two parts, the north Bihar with an area of 53.3 thousand square km, and the south Bihar having an area of 40.9 thousand square km. Agro-climatically the state falls under middle Gangetic plains region. The state lies 53 meters above the mean sea level. The climate of Bihar is favorable for the production of various crops. The average rainfall in the State is adequate but erratic and state witnessed two flood years and almost three drought years in the last decade.

Among major factors affecting overall production and productivity of rice in Bihar onset, distribution and intensity of rainfall. Onset of monsoon by the end of June or early July provides enough water for rice crop. Any aberration in rainfall during this period drastically affects the prostect of good yield due to delayed transplanting and its poor growth owing to water scarcity, heavy infestation by weeds and out- break of many diseases and insect-pests. An attempt has been made in this paper to study the variations in rainfall and its consequences on agricultural production.

Materials and Methods

The secondary data pertaining to 2001–10 were obtained from the Directorate of Economics & Statistics, Govt of Bihar [6]. Based on soil characterization, rainfall, temperature and terrain, four main agro-climatic zones (ACZ) in Bihar have been identified. These are: ACZ–I (North West Alluvial Plain), ACZ–II (North East Alluvial Plain), ACZ–IIIA (South West Alluvial Plain) and ACZ–IIIB, each with its own potential and prospects. Out of total 38 districts in Bihar, 13 districts belong to ACZ I, 8 Districts to ACZ II, ^ Districts to ACZ IIIA and 11 Districts to ACZ IIIB. These zones differ in cropping patterns, soil characteristics and availability of alternative sources of irrigation. The analysis aimed to examine the intra seasonal and inter seasonal variations in rainfall and their influence on crop production.

Table 1. Parameters of decadal variations in rainfall in Bihar.

Parameters	Agro climatic zones (ACZ) I	II	IIIA	HIB	Bihar
Mean (in mm)	1077.66	1334.54	919.27	899.83	1057.85
Maximum (in mm)	1767.21	1763.31	1309.03	1205.48	1477.7
Min (in mm)	832.05	1035.45	673.57	623.95	863.6
Range (in mm)	935.16	727.86	635.46	581.53	614.1
SD (in mm)	282.63	262.67	212.80	204.66	187.20
CV	26.23	19.68	23.15	22.74	17.70

A Standardized Precipitation Index (SPI) which may be taken as a drought index has been developed for classifying years, seasons, districts and zones in categories like, normal, drought and excessive rains. Based on this index the attribute of drought has been further classified as moderate & severe. The index can be based either on actual rainfall or the number of rainy days, but these two characteristics are highly correlated (+0.95), so would separately provide the same classification. In the study actual rainfall over the years is used to define the SPI index / drought index.

Drought index denoted by Z is defined for a year, season or district as:

Z = (Actual Rainfall– Average decadal rainfall) / Standard deviation

On the basis of computed Z values, the proposed annual classification is as follows:

Range of Z values	Classification
$Z < -1.5$	Severe drought
$-1.5 < Z < -0.75$	Moderate drought
$-0.75 < Z < 0.75$	Normal
$-0.75 < Z < 1.5$	High Rainfall
$Z > 1.5$	Excessive rainfall

Results and Discussion

Annual variation

Trans-Gangetic plain significantly gains rainfall during the month of June [7]. However, 85% rainfall is received during the months of June to September. The average decadal rainfall of 1058 mm is adequate, but the temporal variations adversely affect crop production. The highest rainfall of 1478 mm was observed in 2007 whereas the lowest rainfall was only 864 mm in 2009, giving the range of variations of 614 mm. Only 864 mm annual rain has caused drought in 2009 whereas 1478 mm annual rain has caused floods in certain areas in 2007. The standard deviation of rainfall was found to be 187 mm giving 18% variation in average rainfall during the decade (Table 1).

Zone-wise analysis of rainfall data reveals that highest rainfall was received in ACZ II and lowest in ACZ III B. However, higher variations in rainfall (26.2%) were observed in ACZ I and lower in ACZ II (19.7%, but no association could be observed between intensity and variations of rainfall. When the average rainfall of the previous decade was compared with normal rainfall, a decrease of nearly 8 to 10% rainfall was observed in all the zones. Further analysis shows that out of 38 districts, 4 still received the usual rainfall whereas, 2 (Vaishali and East

Table 2. Change in rainfall intensity in Bihar (2001—2010).

Particulars	No. of districts
Districts showing no change in rainfall	04
Districts showing Positive change in rainfall	02
Districts showing Negative change in rainfall	
<5%	01
5—10%	08
10—15%	12
15—20%	01
20—25%	07

Table 3. Seasonal variations in rainfall in Bihar.

Season	Month	Mean	SD	CV
Kharif	Jun	163.51	74.56	45.60
	Jul	325.52	108.36	33.29
	Aug	241.11	60.31	25.01
	Sep	181.11	81.81	45.17
	Total	**911.25**	**209.06**	**22.94**
Rabi	Oct	61.89	55.72	90.02
	Nov	1.39	1.80	129.95
	Dec	2.23	5.65	253.52
	Jan	7.72	8.99	116.51
	Feb	9.72	13.15	130.34
	Total	**82.95**	**56.52**	**68.13**
Summer	Mar	4.99	5.83	116.77
	Apr	12.80	7.90	61.74
	May	59.39	22.12	37.25
	Total	**77.18**	**20.67**	**26.78**

Champaran) received higher than normal rainfall (based on 30 years average). The largest decline in rainfall was observed in Saharsa, Madhubani and Darbhanga of ACZ I. Also, a a significant decrease in rainfall were observed in Aurangabad (24%), Rohtas (24%) and Buxar (22%) of ACZ IIIB (Table 2).

Seasonal variations in rainfall have also been attempted as *kharif* (monsoon) rainfall is the life line for agriculture in Bihar and it receives rainfall mainly due to south west monsoon (June to September) which contributes more than 85% of the total rainfall. Study reveals that variation in the rainfall during *kharif* (22.94%) is very high, causing uncertainty in rainfall dependent *kharif* production (Table 3), thus, a need to create assured irrigation facilities for sustainable crop production.

It was also observed that the within month, variations in rainfall during June and September was very high (> 45 %), whereas these are crucial months for rice production. June is the sowing month of rice nursery and September is the flowering month for rice, which is crucial for production. During *rabi* the variations in rainfall was observed to be very high in spite of low rainfall during the season, causing low productivity of *rabi* crops, in general and pulses, in particular.

Standardized Precipitation Index

Standardized Precipitation Index (SPI) for Bihar was calculated to know the extent of rainfall during various years of the decade (2001—10), which had six normal years (including the 2 years of high rainfall). Others have also observed significant trends in monthly SPI in middle gangetic plains of India [8]. Bihar received excessive rainfall in 2007 followed by severe drought in 2010, whereas 2005 and 2009 were moderate drought years. The extent of rainfall was not uniform across different ACZs of Bihar because in drought years some ACZs received normal rainfall whereas in normal years, some ACZs faced drought situation (Table 4). The same proposition holds true in district wise analysis also. Despite higher rainfall in ACZ I and II, there were four drought years in Zone I and three in Zone II during the decade. It is mainly due to year to year variation in rainfall particularly in *Kharif* season. ACZ IIIA is drought prone area and faced five years drought but received excess rainfall in four years during the decade. The situation is almost similar in ACZ IIIB. All the zones do not face drought year or excessive rainfall situation in a particular year. ACZ IIIA faced drought in 2001 but the other three zones received high rainfall. Similarly, 2009 was drought year but ACZ II received normal rainfall. With so much variation in rainfall, Bihar often faces drought in one part and flood in other part of the state.

Table 4. SPI Index of all zones of Bihar (2001—2010).

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
AC Zone I	1.42	– 0.48	0.47	0.25	**– 1.45**	**–1.04**	4.72	0.66	**– 1.88**	**– 2.75**
AC Zone II	0.69	0.44	1.24	1.33	**– 0.90**	**–0.79**	0.85	0.19	– 0.44	**– 1.49**
AC Zone III A	**– 2.17**	1.54	1.74	**– 1.54**	**– 1.28**	3.17	5.51	0.03	**– 2.15**	**– 4.23**
AC Zone III B	1.06	1.04	2.68	**– 5.24**	**– 3.62**	2.34	6.14	6.10	**– 3.94**	**– 6.56**
Bihar	0.49	– 0.08	0.60	– 0.04	– 0.87	–0.12	1.94	0.60	– 0.85	– 1.67

Table 5. Total production of rice (in lakh MT) in different zones of Bihar (2001—2010).

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
AC Zone I	16.65	15.87	16.03	7.55	10.53	12.47	6.97	19.88	11.56	8.61
AC Zone II	8.50	9.03	10.70	6.23	8.1-0	9.46	9.56	9.59	10.67	9.32
AC Zone IIIA	3.26	4.01	3.87	1.96	2.85	3.29	3.67	3.37	1.74	0.75
AC Zone IIIB	23.63	21.94	23.88	8.97	15.61	25.99	24.53	22.96	12.28	12.44
Bihar	52.03	50.86	54.48	24.72	37.09	51.21	44.73	55.79	36.25	31.12

Since rice is the most important crop in Bihar, an attempt has been also made to find out relationship between SPI and rice production during 2001—10. It has been observed that rice production varies with the level of rainfall. The higher variations in rainfall observed in ACZ III A (22.93) and ACZ IIIB (25.87) where variation in rice production was also higher (>32). On the other hand, average rainfall was higher and variation in rainfall was lower in ACZ II (22.82), where least variation in rice production (14.28) during the decade was reported. It was further observed that, higher the average decadal rainfall, the lower the association between SPI and rice production, indicating that higher rainfall holds the key of rice production and minor variation in rainfall may not adversely affect the production.

Conclusion

Bihar agriculture is still a gample of monsoon due to poor and unreliable rainfall. Some part of the State experienced five droughts during last decade. Average rainfall in the State thought adequate (1067 mm) but the variation is much higher and range of rainfall is 808 mm. Average rainfall in the State showed declining trend from 8 to 10 percent. Variation in rainfall during June to September adversely affects the rice production in the State. The comparatively large decline in rainfall is observed in high rainfall area than low rainfall area. About 77 percent districts of Bihar experienced decline in rainfall by 5 to 25 percent and 8 percent by more than 25 percent. It is not possible to avoid droughts, but drought preparedness can be developed and drought impacts can be minimized. The success of both depends, amongst the others, on how well the droughts are defined and drought characteristics quantified [9]. A drought event occurs if SPI value is less than-1 and the event ends when it becomes positive [10]. The relationship between rainfall (SPI Index) and rice production has been positive in all the agro-climatic zones in bihar and highly significant in low rainfall area. It suggests creation of assured irrigation infrastructure in the State for sustainable agricultural production, in general and rice production in particular. Besides, short duration and less water loving crops / varieties need to be developed on priority basis for sustainable livelihood of farming community in Bihar.

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