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Rainfall variability analysis of onset of monsoon in different agro climatic regions of eastern Uttar Pradesh

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Abstract
It is quite evident from the data analyzed over last 30 years (1986-2015) that annual rainfall of Eastern U.P gradually declined over the normal 1000 mm. Seasonal rainfall variability (mm) of Eastern U.P have been presented and depicted S-W monsoon, Post monsoon, winter season per monsoon season. S-W monsoon and Post monsoon rainfall of Eastern U.P declined over the normal in recent years. Rainfall variability during different seasons of Eastern U.P has been presented. It is obvious from the data that rainfall occurred during winter season, summer season and SW monsoon periods were decreased while during post monsoon season rainfall was slightly increased by + 0.3% in the recent years to come. While trend of rainfall during winter and summer seasons found increased over the normal in recent years to come. The characteristics of rainfall of Eastern U.P. i.e. onset and withdrawal of monsoon from 1986 to 2015 revealed that shift of onset of monsoon in all the zones from 4 to 6 days toward rainy season consequently length of rainy season also shift on an average 5 to 6 days early. Withdrawal of SW monsoon in all the zones in recent years was found almost same i.e 24-26 September. Data analysis over past 30 years quite reveal that intensity of rainfall during monthly basis and whole S-W monsoon period were decreased in recent years.

Keywords: Rainfall, variability, onset of monsoon, agroclimatic regions and eastern Uttar Pradesh

Introduction
Agriculture sector alone represents 23 per cent of India's Gross National Product (GNP), plays a crucial role in the country's development and shall continue to occupy an important place in the national economy (Prema, 2015) [7]. It sustains the livelihood of nearly 70% of the population. The greatest risk to crop yields in Indian agriculture is attributed to the variability of seasonal rainfall and the uncertainty in the amount and its distribution in a given season. Hence, rainfall is one of the prime meteorological factors which controls the water balance of a particular area. Therefore, its amount, time of occurrence and spatial variability controls the agricultural practices adopted in the region (Baweja, 2011) [2].

The rainfall received in an area is an important factor in determining the amount of water available to meet various demands, such as agriculture, horticulture, livestock, industries and domestic water supply etc. Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the risk of increasing occurrences of droughts and floods. The southwest (SW) monsoon, which brings about 80% of the total precipitation over the country, is critical for the availability of freshwater for drinking and irrigation. Changes in climate over the Indian region, particularly the SW monsoon, would have a significant impact on agricultural production, water resources management and overall economy of the country. The heavy concentration of rainfall is observed in the monsoon Season (June– September) as compared to other seasons in a year.

Rainfall amount and its distribution is very important for rice cultivation. It is the highest in the North Eastern part of the country where annual precipitation of 508 cm is recorded. In eastern region, the annual or seasonal rainfall is about 125-150 cm. Rice is more suited to high rainfall regions because it requires abundant moisture either through rainfall or irrigation to keep the soil under saturation throughout its life period. Therefore, the practice of rice cultivation is mostly dependent on the rainfall conditions. It is the dominant crop in North Eastern part comprising Assam, West Bengal and South Bihar where precipitation is high. In the Peninsular India, it is concentrated in the east and west coastal areas of Tamil Nadu and Kerala. In the Northern and Central India, rice is grown where rainfall conditions are favourable.

Materials and Methods

Several climatic factors such as seasonal rainfall amount, intra-seasonal rainfall distribution and dates of onset/cessation of the rains influence crop yields and determine the agricultural calendar (Sivakumar, 1988; Kesava Rao *et al.*, 2013) [8, 5]. In particular, the onset of the rainy season appears to be the most crucial information (Ingram *et al.*, 2002; Barbier *et al.*, 2009) [2, 1] for agricultural management since it determines the planting period (Tiwari *et al.*, 1992; Sivakumar, 1992; Omotosho *et al.*, 2000) [10, 9, 6]. The historical data of soil, major crops and weather parameters especially rainfall and temperature of districts of Eastern region were collected for study depending upon the availability of the data from the period of 1986-2015. Climatic variability & weather trend analysis were made for past and future based on the historical data.

Annual rainfall, seasonal rainfall (SW) monsoon, post monsoon, winter season and summer season were analysed for rainfall variability of zone. Rainfall partitioning in different Agroclimatic zones were analysed. Onset & withdrawal dates and length of rainy season of SWM were analysed. Zone wise shift of onset and withdrawal of monsoon in different Agroclimatic zones were analysed. Zones with different categories of area, production and yield of wheat in eastern U.P.

Weather during summer

Summer season months March, April to May. It should also include rainfall events/wind conditions/extreme frequency events etc. The daytime temperature remains very high and usually touches above 45 °C in Eastern Uttar Pradesh. Night are relatively cooler. Typical of extreme climate and the temperature give some data of weather/extreme events/storms high winds etc. A heat waves/advection condition comes down to as low as 28 °C.

Weather during winter

Winter in Eastern Uttar Pradesh is a lot cooler with day temperature pleasant around 24°C. and nights are chilly with temperature getting as low as 2 to 4°C across the entire Eastern U.P. Earlier Eastern regions were comparatively warmer but due to change in the weather trends, even these areas fall under intense cold wave. Cities like Varanasi are continuously seeing mercury dipping to freezing point. The winter falls around Mid-November and continue till February end. Dew is very common in all the parts of Eastern Uttar Pradesh.

Weather during monsoon

As Eastern Uttar Pradesh stretches from North India towards Eastern, the rainfall of eastern U.P is about 900 mm. The climate of Eastern Uttar Pradesh is generally defined to be tropical monsoon type. It is primarily classified as *humid subtropical with dry winter* type with parts of Eastern U.P. as *semi-arid* type. Variations do exist in different parts of the large state, however the uniformity of the vast Indo-Gangetic Plain forming bulk this regions. State gives a predominantly single climatic pattern with minor regional variations. Eastern U.P. has a climate of extremes. With temperatures fluctuating from 0 °C to 47 °C in several parts of the Eastern Uttar Pradesh and cyclic droughts and floods due to unpredictable rains, the summers are extremely hot, winters cold and rainy season can be either very wet or very dry.

Seasons of Eastern Uttar Pradesh

1. Winter season / cold weather season (December, January and February)
2. Summer season/ Hot weather season/ (March, April and May)
3. South-West Monsoon/Monsoon season (June, July, August and September)
4. Post-monsoon season (October and November)

Analysis of Yield Series

District wise historical data of major crops such as rice (area, production and productivity) for period of 1986-2015 of Eastern U.P obtained from State Department of Agriculture of Lucknow, were analysed time series graphs were plotted for trend analysis of area, production and productivity of major crops.

Analysis of Rainfall

Districts wise historical data of rainfall on daily basis of districts of Eastern U.P. was obtained from State Agriculture Department or met centre of Lucknow. Rainfall variability, characteristics of rainfall, length of rainy season, onset/withdrawal of monsoon and time series analysis of rainfall and its relation with productivity was done.

Climate Trend

The year to year variability of climatic conditions may conceal gradual trends from one type of regime to another. Statistical methods such as moving average, frequency distribution and stepwise regressions were employed to study climatic trends.

Length of Rainy Season

Length of rainy season is defined as difference of date of withdrawal and onset dates of South-West monsoon. It differs from location to located on of Eastern U.P

Results and Discussion

Agro-climatic onset of cropping season acts as an alternative for making decisions on selecting proper sowing date since the methodology considers many parameters like rainfall threshold, dry day hreshold, dry spell threshold and dry spell search period along with the post-rainfall events (Huggi *et al.*, 2020) [3]. Data pertaining to Onset, withdrawal date and length of rainy season during SWM of Eastern U.P have been presented in Table-1. The analyzed data over last 30 years quite reveal that onset date of S-W monsoon in Eastern U.P have been found 20th June while the withdrawal date of monsoon have been found on 26th September. The length of rainy season have been found 98 days. Zone wise shift of onset and withdrawal of monsoon which describe the length of rainy season/ crop growing season of eastern U.P. has been presented in Table-2. The characteristics of rainfall of Eastern U.P. (i.e. onset and withdrawal of monsoon) from 1986 to 2015 reveals that shift of onset of monsoon in all the zones from 4 to 6 days toward rainy season consequently length of rainy season also shift on an average 5 to 6 days early. Withdrawal of SW monsoon in all the zones in recent years was found almost same i.e. 24-26 September.

Table 1: Onset date/withdrawal date and length of rainy season of SWM

Year	Eastern U.P.		
	Onset date (June)	Withdrawal date (Sep.)	Length of rainy season (day)
1986	22	23	94
1987	28	13	78
1988	12	30	111
1989	9	28	112
1990	22	25	96
1991	20	22	95
1992	21	24	96
1993	23	27	97
1994	20	20	93
1995	20	24	97
1996	20	29	102
1997	20	25	98
1998	24	27	96
1999	21	27	99
2000	15	25	103
2001	18	19	94
2002	12	25	106
2003	22	28	99
2004	15	25	103
2005	23	25	95
2006	26	26	93
2007	17	29	109
2008	8	26	111
2009	24	16	95
2010	25	22	90
2011	18	25	100
2012	19	19	93
2013	17	30	107
2014	23	30	100
2015	25	17	85

Table 2: Zone wise shift of onset and withdrawal of monsoon in Eastern U.P

Zone	1986-2000		2000-2015	
	Onset of monsoon	With drawl of monsoon	Onset of monsoon	With drawl of monsoon
NEPZ	13-15 June	28-30 Sept.	17-19 June	24-26 Sept.
EPZ	17-19 June	19-21 Sept.	24-26 June	24-26 Sept.
VZ	21-23 June	25-27 Sept.	27-29 June	24-26 Sept.

Rainfall variability of Eastern U.P

Rainfall variability during different seasons of Eastern U.P have been presented in Table-3. It is obvious from the data that rainfall occurred during winter season, summer season and SW monsoon periods were decreased while during post monsoon season rainfall was slightly increased by + 0.3% in the recent years to come.

Table 3: Rainfall variability (mm) of Eastern U.P

Season	1986-2000	2000-2015	% increase or decrease
Winter	22.4	20.8	-7.4
Summer	37.1	35.2	-5.1
S-W monsoon	887.9	841.2	-5.2
Post monsoon	47.9	48.0	+0.3

Rainy days and rainfall intensity of SWM

Data pertaining to trend analysis of rainy days and rainfall intensity of SWM of Eastern U.P have been presented Table-4. It is quite evident from the data analyzed over last 30 years that rainy days and rainfall intensity of Eastern U.P declined over the normal in recent years to come.

Table 4: Rainy day and rainfall intensity of SWM of Eastern U.P. (1986-2015)

Year	Rainy day (days)	Rainfall intensity (mm/day)
1986	56	18.5
1987	61	16.4
1988	63.	19.1
1989	64	21.6
1990	51	19.6
1991	57	19.1

1992	51	15.3
1993	53	16.6
1994	49	19.9
1995	51	16.4
1996	50	14.6
1997	46	17.2
1998	42	18.2
1999	62	18.7
2000	53	20.0
2001	53	17.5
2002	43	15.8
2003	54	17.3
2004	43	16.9
2005	44	20.7
2006	33	17.6
2007	41	15.8
2008	63	15.4
2009	38	16.2
2010	44	16.9
2011	51	17.0
2012	48	18.2
2013	58	17.9
2014	43	16.5
2015	35	15.5

Annual variation of intensity of rainfall during S-W monsoon

Annual variation of intensity of rainfall (mm/day) on monthly basis (June, July, August & September) and during whole S-W monsoon period. Data analysis over past 30 years quite reveal that intensity of rainfall during monthly basis and whole S-W monsoon period were decreased in recent years.

Annual rainfall variability of Eastern UP

Data pertaining to annual rainfall variability of Eastern U.P have been presented in Table 5. It is quite evident from the data analysed over last 30 years (1986-2015) that annual rainfall of Eastern U.P gradually declined over the normal 1000 (mm) in recent years to come.

Table 5: Annual rainfall variability (mm) of Eastern U.P.

Year	Rainfall (mm)
1986	1041.4
1987	1002.2
1988	1206.8
1989	1387
1990	1002.7
1991	1092.8
1992	786.3
1993	797.3
1994	1028.5
1995	911.1
1996	1055.6
1997	1285.7
1998	989.8
1999	1237.5
2000	855.4
2001	1015.7
2002	833.8
2003	1148.6
2004	844.2
2005	872.7
2006	864.3
2007	654.6
2008	1207.6
2009	1042.6
2010	786
2011	1239.9
2012	878.4
2013	1148
2014	687.3
2015	542.3

Seasonal rainfall variability (mm) of Eastern UP

Data pertaining to seasonal rainfall variability (mm) of Eastern U.P have been presented in Table-6. It is quite evident from the data analysed over last 30 years (1986-2015) that S-W monsoon and Post monsoon rainfall of Eastern U.P declined over the normal in recent years. While trend of rainfall during winter and summer seasons found increased over the normal in recent years to come.

Table 6: Seasonal rainfall of Eastern U. P.

Year	Seasonal rainfall (mm)			
	SW monsoon	Post monsoon	Winter season	Summer season
1986	904.4	37	92	8
1987	834.4	105.2	41.4	21.2
1988	1102.3	56.2	19.6	28.7
1989	1335.6	9.2	36.2	6
1990	937.3	7.4	37.6	20.4
1991	1041.6	4	32.8	14.4
1992	551.5	198.8	13.4	22.6
1993	737	0	7.4	52.9
1994	962.8	2	45.1	18.6
1995	833.8	24.5	40.8	12
1996	834.6	139.6	78.8	2.6
1997	1138.9	52	61.4	33.4
1998	866.2	47.4	26.4	49.8
1999	1084.7	105.4	25.6	21.8
2000	790.8	8.4	10.6	45.6
2001	915.4	45.1	7.6	47.6
2002	764.1	4.2	34.9	30.6
2003	1059.1	0	77.1	12.4
2004	735.5	40.4	34.7	35.6
2005	781.7	29.8	31.6	29.6
2006	715.3	13.6	0	135.4
2007	504.6	41	36.2	72.8
2008	1129.5	42.8	0	35.3
2009	846.6	136.4	18.6	41
2010	636.1	32.9	30.9	68.1
2011	1193.2	0	10.2	36.5
2012	792.4	0	81.8	4.2
2013	1055.1	6.7	86.2	0
2014	435.1	98.2	108.5	45.5
2015	390.7	0	39.7	111.9

Rainfall partitioning in Agro-climatic Zones of Eastern UP

Rainfall partitioning (%) in Agro-climatic Zones of Eastern U.P. are presented in Table-7, S-W monsoon partitioned about 80% of total rainfall in the region. Highest partitioning of normal during S-W monsoon was experienced in Northern Eastern Plain Zone (NEPZ) (82.7%) followed by VZ (80.8%). While only 74.7% in Eastern plain zone. It is also evident that summer and winter rainfall in EPZ is higher as compared to other zones which facilitate to grow efficiently winter and summer crops with little irrigation.

Table 7: Rainfall partitioning (%) in Agro-climatic Zones of Eastern U.P.

Zones	SWM	Summer	Winter	Post monsoon
NEPZ	82.7	6.6	7.3	6.7
EPZ	74.7	10.5	11.6	4.4
VZ	80.8	6.6	8.2	5.2

Where
NEPZ- Northern Eastern Plain Zone
EPZ- Eastern Plain Zone
VZ- Vindhyan Zone

Conclusion

The South-West Monsoon which brings most of the rain, although rain due to the western disturbances, also contribute small quantities towards the overall precipitation of the Eastern they received during June-September. Most of the rainfall (about 85%) of Monsoon period, excess rain can lead to floods and shortage lead to droughts. As such these two phenomenons of floods and droughts are a common recurrence in the Eastern region. Though there are many districts in each zone of Eastern U.P. *viz*. 26 districts in Eastern U.P., But only representative districts has been selected due to unavailability of data on daily basis of all the districts.

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