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Rainfall variability and yield gap analysis of rice (*Oryza sativa* L.) At western Uttar Pradesh in relation to crop planning and Management

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Abstract
The daily rainfall data for the period of 1992 to 2011 of Western U.P. was analyzed to variability of rainfall. Trends and variability for monsoon months show maximum, number of rainy days and length of monsoon season affected the productivity of rainfed rice. Analysis of monthly rainfall data suggests that when the quantum of rainfall during the monsoon months was close to its normal value the low production of rice can be attributed to the moisture stress during vegetative and reproductive stage of rice crop. This study provides help to former for enhancing the production and productivity of rice.

Keywords: Yield gap, Rainfed rice, rainfall variability, rainy days, rainy season

Introduction
Rice (*Oryza sativa* L.) is an important crop of Uttar Pradesh. In Uttar Pradesh rice is grown in almost all the district. The variability of rainfall and its effect on crop productivity, especially in context of rice production, has been an important subject of study particularly for rainfed area, (Rao and Vijayalakshmi 1993, Sastri and Patel, 1984) [4, 6]. The climatic factors that influence rice production are temperature, sun shine hours and humidity. Rainfall is very important for rice cultivation. The rainfall is main limiting factor affecting crop productivity. Therefore, its amount, time of occurrence and spatial variability controls the agriculture practices. Consequential to variability of rainfall during the monsoon period and events associated with it, even this low level of practices. Rainfall is a crucial agroclimatological factor in the seasonally arid parts of the world and its analysis is an important for agricultural planning. Therefore a case study has been conducted for this region to understand the exact effect of rainfall variability on rainfed rice production and suggest, if any remedial measure to stabilize rainfed rice production at satisfactorily high level. The average temperature required for kharif rice throughout the life period of crop ranges from 21 to 37^0 C in India. During tillering stage high temperature, at the time of blooming temperature range of 26.5 to 29.5^0C become congenial for optimum yield. Average temperature requirement during ripening for is in the range of 20-25^0C. (Singh *et al*. 2009) [8].

Material and Methods
The daily rainfall data for the period of 20 years (1992-2011) have been collected from State Agriculture department Lucknow. Data regarding productivity of rice for the period 1992-2011 has been taken from Agriculture Statistic of Uttar Pradesh.

General description
Uttar Pradesh is the most populous state in India with a population of over 199.5 million people, geographical area of 2,40,928 square km as of 1 March 2011. It is situated at 27°40'N Latitude & 80° 00' E Longitude.

Climatic profile of Uttar Pradesh
The climate of Uttar Pradesh is generally defined to be tropical monsoon type. It is primarily classified as *humid subtropical with dry winter* (CWa) type with parts of Eastern U.P. as *semi-arid* (BS) type. Variations do exist in different parts of the large state, however the uniformity of the vast Indo-Gangetic Plain forming bulk of the state gives a predominantly single climatic pattern to the state with minor regional variations. U.P. has a climate of extremes.

With temperatures fluctuating from 0 °C to 50 °C in several parts of the state and cyclical 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.

Season of Uttar Pradesh, India

Indian Meteorological Department (IMD) breakdowns the climate of India into the following seasons.

1. Winter Season/Cold Weather Season (December, January and February)
2. Summer season/Pre-monsoon season/ Hot weather season/ (March, April and May)
3. South-west Monsoon/Summer Monsoon (June, July, August and September)
4. Post-monsoon or Retreating SW Monsoon season (October and November).

Wind field

Depth of westerlies should be of magnitude maintained upto 600 hPa, in the box equator to lat. 10^{o}N and Long. 55^{o}E to 80^{o}E. The zonal wind speed over the area bounded by lat. 5-10^{o}N, Long. 70-80^{o}E should be of the order of 15-20 Kts. at 925 hPa. The source of data can be RSMC wind analysis/satellite derived winds.

Rainy day

A day is called as a rainy day when rainfall recorded is more than or equal to 2.5 mm on the day.

Yield gap

Yield gap of crop has been calculated at particular amount of rainfall over the year of data with difference of maximum yield and minimum yield at same amount of rainfall.

Rainfall intensity

Intensity of rainfall is defined as amount of rainfall/duration. Intensity of rainfall during an individual storm or a still shorter period is of vital interest to hydrologist, agriculturist and water engineers concern with flood forecasting and prevention as well as to the conservationist dealing with soil erosion. High intensity rain is associated with increased drop size rather than an increase number of drops e.g. with precipitation intensities of 0.1, 1.3 and 10.2 cm/hour. The most frequent rain drop diameter of 0.1, 0.2 and 0.3 respectively.

Results and Discussion

Area, production and productivity of rice

Current time series (1992-2011) data of area, production and productivity of rice grown in western U.P. has been depicted in Table 1. and Fig. 1. From the table it has been observed that the average area of rice in western U.P was 65.00 thousand hectares. From the graph it is also obvious that the area of rice coverage in Wastern U.P. (0.80) was increasing trends may be because of low decreasing rate of South-West monsoon in Northern U.P. Time series (1992-2011) data analysis of average production of rice crop in Western U.P. 140.00 thousand mt has been shown in Table-2. The productivity of rainfed rice (q/ha) in Wastern U.P. has been depicted in Fig. 2. Time series variation from the graph it has been observed that productivity increased in recent year after 2000- 2001 in Wastern U.P. Higher productivity may be because more rainfall availability and better management of rainfall & water use efficiency during crop period.

Table 1: Area, production & productivity of rainfed rice in Western U.P. (1992-2011).

Year	Area (Thousand ha)	Production (Thousand mt)	Productivity (q/ha)
1992	55.53	117	21.1
1993	55.53	117	21.1
1994	60.54	127	20.9
1995	59.62	134	21.3
1996	59.06	141	21.1
1997	59.94	145	24.4
1998	59.94	145	24.4
1999	70.92	152	21.2
2000	72.24	150	20.5
2001	70.52	154	21.5
2002	55.65	147	20.6
2003	61.26	137	22.2
2004	70.83	155	24.0
2005	69.48	141	22.7
2006	65.09	132	22.7
2007	62.90	136	23.6
2008	71.59	148	23.0
2009	72.23	151	23.2
2010	72.17	135	21.0
2011	74.13	176	24.4
Total	1300.00	2838	444.9
Average	65.00	140	22.2

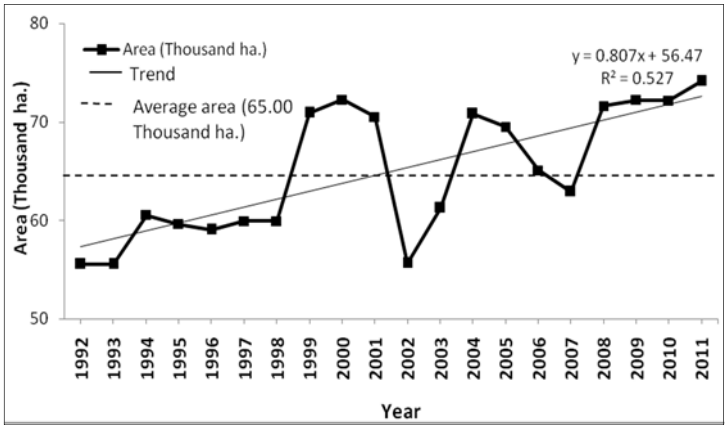

Fig 1: Area (Thousand ha.) of Rice in Western U.P

Variability of rainfall

Time series data of 1992-2011 has been sub divided in to two decades (i 1992-2001& ii 2002-2011). Decadal variation of rainfall during south west monsoon has been shown in fig. 3.to 4. From the figures, it has been observed that the average rainfall during 1992-2001, shows the decreasing trend in Western U.P. but in recent decade of 2002- 2011, the increasing trend was observed.

Onset date/withdrawal of monsoon and length of rainy season

Based on current time (1992-2011) series data analysis the average onset date of south-west monsoon has been shown in Table 3. From the table it has been observed that the average onset date of south-west monsoon in Western U.P was shifted to 21 June from normal onset date. Normal onset date in Western U.P. 17 June. Onset date delayed 4 days from the normal. The twenty years average (1992-2011) of withdrawal and length of rainy season has been depicted in Table 3. & yearly variation of these date in table 4. From the table it has been observed that in different years the range of onset date of south-west monsoon was in between 9th to 28 June. Average withdrawal date of south-west monsoon in Western U.P. (1992-2011) has been shown in Table 3. From the table it has been observed that the withdrawal date of south-west was 21 September where, average date of withdrawal was realized as 25th September against the normal date 30th September of withdrawal. Length of rainy season was therefore drastically reduced from normal 106 days to 93 days i.e. 13 days. This ultimately forced to reconsider the crop planning and selection of rice crop varieties of short duration as to minimize the risk losses.

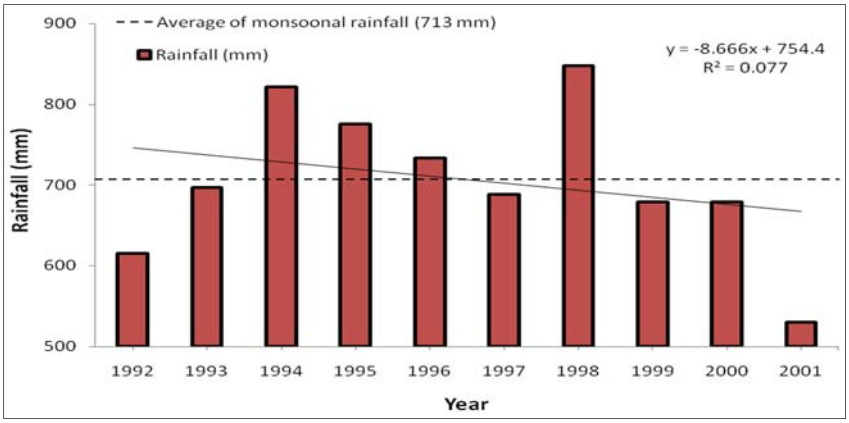

Fig 2: Decadal variation of SWM rainfall (mm) of Western U.P. (1992-2001)

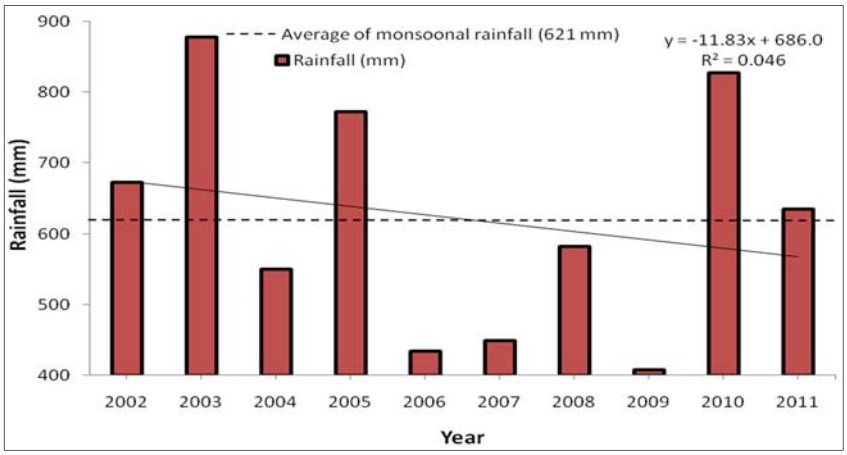

Fig 3: Decadal variation of SWM rainfall (mm) of Western U.P. (2002- 2011).

Table 2: Onset date/withdrawal date/length of rainy season of south-west monsoon of Western U.P.

Onset date of SWM (June)	Withdrawal date of SWM (Sep.)	Length of rainy season of SWM (days)	Deviation from normal
21 (17)	21 (30)	93 (106)	-13

Figure in parentheses shows the normal dates/days as per IMD, Govt. of India.

Table 3: Onset date and withdrawal date of south-west monsoon of Western U.P.

Year	Onset date of SWM (June)	Withdrawal date of SWM (Sept.)
1992	27	25
1993	21	24
1994	23	18
1995	20	16
1996	24	20
1997	18	27
1998	28	26
1999	24	25
2000	16	15
2001	17	19
2002	9	20
2003	20	20
2004	20	23
2005	25	26
2006	25	12
2007	18	27
2008	11	21
2009	25	12
2010	26	27
2011	19	22
Total	418	420
Average	21	21

Rainy day and rainfall intensity

Based on current time (1992-2011) series data of rainy season the rainy day & rainfall intensity received has been shown in Table 4. From the table, it has been found that the number of rainy days was 45 during south west monsoon where as rainfall intensity was almost same and ranged between 15.6 mm/day. In eastern U.P. rainfall intensity reduced from 25 mm/day (1971-1990) to 17.2 mm/day (1992-2011) i.e. 32% reduction. Similarly reduction in no. of rainy days was also noticed during recent years (1992-2011) but reduction in no. of rainy days from the normal for western U.P. was very small i.e. only 6% (Tripathi *et al*., 1998) [9].

Table 4: Rainy day and rainfall intensity during south west monsoon.

Rainy days of SWM (days)	Rainfall intensity of SWM (mm/day)
45	15.6

Yield gap analysis of rainfed rice

Based on current time (1992-2011) series data of yield gap of rainfed rice has been shown in Fig. 3. From the figure it has been observed that the lowest yield gap was found in western U.P. only 3.9 q/ha at 710 mm rainfall. Minimum yield gap in western U.P. even at low rainfall 710 mm shows the better management of rainfall i.e. low run off, better utilization of water use efficiency, better utilization of water during no rainfall situation and other water management & recommended package and practices caused lowest yield gap. In western U.P. at lower water availability 710 mm highest yield 25 q/ha was obtained as compared to other sectors of U.P. This showed that in western U.P. minimum water demand is required to harvest better yield of rice i.e. under mild drought condition, average rice yield can be obtained due to better management of water distribution.

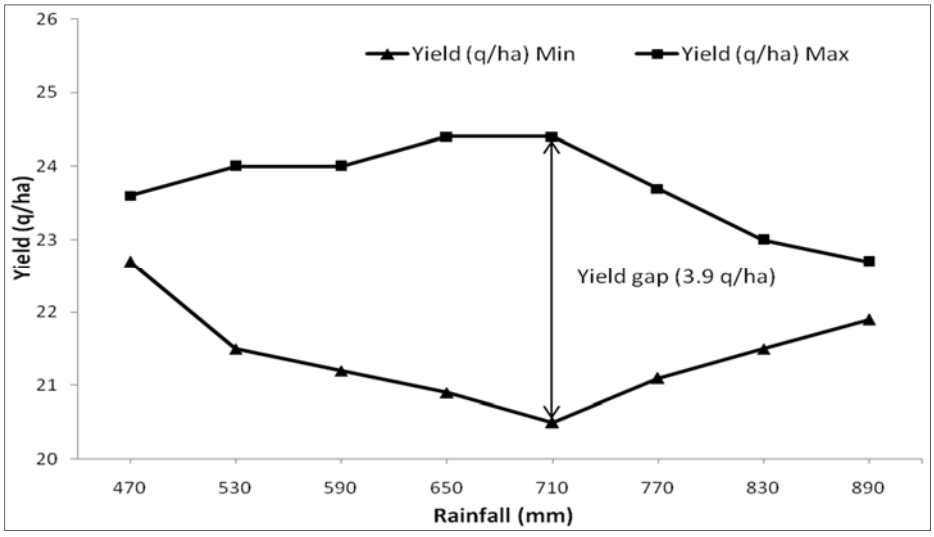

Fig 4: Yield gap analysis of rainfed rice in Western U.P. under variable rainfall condition

Conclusion

Overall from analysis of rainfall (1992-2011) it was concluded that the quantum of seasonal rainfall decreased in Western U.P. Length of rainy season was also reduced from normal 106 days to 93 days therefore crop planning to short duration and low water requiring variety of rice needs to be developed. The production/productivity constraints of rice through estimation of yield gap vis-à-vis climatic constraints for Western U.P. was identified & concluded accordingly. This study will provide render help not only to the farmers for selection of crop, cropping pattern and change required in ongoing farming operations but also help to open an option window to select the crop/variety to grow in Western U.P.

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