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Recent Trends in Monsoon Rainfall and its Effect on yield of *Kharif* Rice in Five Subdivisions of North India

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Abstract—*Present study was attempted to explore the characteristics of monsoon rainfall in 55 districts spreading over five states in north Indian region for last 11-years. Three states belongs to the Western Himalayan region namely Uttarakhand, Himachal Pradesh and Jammu and Kashmir and the other two namely Punjab and Haryana falls under the fertile Indo-Gangetic plains. Mann-Kendall test was employed to find out monotonic trends in the rainfall pattern for all the districts in monthly and seasonal scale. Linear regression method of least square fit was used to find out any possible association between amount of rainfall and yield of Kharif rice. Results show that monsoon rainfall is scanty and not reliable for Haryana and Jammu and Kashmir while it's ample for Uttarakhand and can be dependable from an agricultural prospective. Rainfall has shown a non-significant increasing trend in the study domain for most of the states except Uttarakhand. Uttarakhand has shown a significant (95% level) increase of monsoon rainfall in the last decade. Yield of Kharif rice is found to be significantly influenced by rainfall climatology in August and September for all the states except Himachal Pradesh. Total monsoon rainfall is strongly related (R^2=0.67) to the yield of rice in Haryana as yield has shown a significant decrease for the monsoon rainfall of more than 550 mm.*

Keywords: *Kharif rice, Monsoon rain, North India, Trend.*

1. INTRODUCTION

Mother earth is beautiful and beautiful are its resources. Biodiversity and geodiversity are the integral part of natural resources which are frequently challenged by climate change. As an inevitable consequence of anthropogenic activity, climate change can be a threat to food and water security in many regions across the globe. According to report produced by intergovernmental panel on climate change (IPCC, 2014) food production and food security are most vulnerable to rising air temperature. There is a general consensus among the scientific community that global surface temperature is increasing at a rate of 0.74±0.18 ^{0}C over 1906-2005 (IPCC, 2007). Such an increase in air temperature is causing global warming and increase in the atmospheric moisture content. One of the most significant consequences of increasing temperature could be an uncertainty of the precipitation distribution both spatially and temporally.

The behaviour, distribution and characteristics of long term seasonal rainfall over the Indian subcontinent is well documented in several studies (Guhathakurta and Rajeevan, 2008; Kumar et al., 2010; Kumar and Jain, 2011; Krishnamurthy and Krishnamurthy, 2013). Starting from the erstwhile analysis of seasonal and annual rainfall (Parthasarathy and Dhar, 1978; Mooley and Parthsarathy, 1984) to contemporary years (Guhathakurta and Rajeevan, 2008; Krishnamurthy and Krishnamurthy, 2013) it is seen that annual and seasonal rainfall is free from any significant trend and typically random in nature. Monsoon season (Jun-September) which contribute 74.2% of the total annual rainfall in India (Guhathakurta and Rajeevan, 2008) has decreased non-significantly over the last century.

Northern region of India comprises of states Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab and Haryana. Major share of rice in these regions is cultivated during the monsoon season which is popularly known as *Kharif* rice. Agriculture in these regions is rain-fed as well as depends on irrigation. Rainfall during monsoon season plays a vital role for the yield of major crops like rice and wheat. Understanding rainfall distribution in the past and recent time will help the government for agricultural management as well as action plan for food and water security. Insight to rainfall trend in a regional scale sows that Punjab and Haryana has an non-significant increasing trend (i.e. 19.4 mm and 55.6 mm respectively) of monsoon rainfall from 1901-2003 as reported by Guhathakurta and Rajeevan (2008). Over the states of Uttarakhand and Himachal Pradesh same study has documented a non-significant decreasing trend of monsoon rainfall (i.e. -79.00 mm per year and -61.4 mm per 100 year respectively) while Jammu and Kashmir has a significant (90% level) increasing trend of 41.0 mm in 100 years. Interannual monsoon rainfall variability in India leads to large-scale droughts and floods, resulting in a major effect on Indian food grain production (Selvaraju, 2003; Kumar et al., 2004).

More over studies related to precipitation in the Western Himalayan states, Punjab and Haryana are mostly limited to first decade of 21st century. Similarly studies related to productions of rice with monsoon rainfall variation are limited to last decade of 19th century only. Over the western Himalayan region scientific observations and its impacts on agriculture is poorly studied. A very recent study is missing in the literature which is necessary for short term agricultural and hydrological assessment. This study aimed at filling those gaps by analysing rainfall at district level for the regions mentioned above. This study also been attempted to find the association between the yields of *Kharif* rice with the monsoon rainfall in a state level.

2. MATERIALS AND METHODS

Present study was carried out in the north India region comprises of five meteorological subdivisions of India namely Uttarakhand, Haryana, Punjab, Himachal Pradesh and Jammu & Kashmir. Uttarakhand, Himachal Pradesh and Jammu & Kashmir falls under the western Himalayan region while Punjab and Haryana falls under the fertile Indo-Gangetic plain. Geographically the study region is located between 27.66 ^{0}N to 37.24 ^{0}N Latitude and 73.55 ^{0}E to 81.03 ^{0}E Longitude. District wise monthly rainfall data (June-September) for 55 districts (Table 1) over the states of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab and Haryana were taken from the Indian meteorological department (IMD) for last 11 years (2004-2014). As IMD have only rainfall records from 2009-2014 so the previous year's (2004-2010) data was collected from India Water Portal (http://www.indiawaterportal.org/). India Water portal and IMD made this data publicly available as an RTI filled by the South Asia Network on Dams, Rivers and People. Yield data of *Kharif* rice for the period of 2004-2012 were taken from the Directorate of Economics and Statstics (DES), Department of agriculture and cooperation, India. Advanced estimate of *Kharif* rice yield (State wise) for the year 2013-14 are not available in the DES archives so these years are excluded in the study. Only yield data of Haryana state for the year 2013 is taken from the Department of Agriculture, Haryana.

Table 1: Details of districts taken over the study domain with their Longitude and Latitude

Districts	Latitude (^{0}N)	Longitude (^{0}E)	District	Latitude (^{0}N)	Longitude (^{0}E)
Himachal Pradesh			**Haryana**		
Bilaspur	31.33	76.75	Ambala	30.5	76.71
Chamba	32.55	76.12	Bhiwani	28.78	76.13
Hamirpur	31.63	76.51	Faridabad	28.43	77.24
Kangra	32.21	76.31	Fatehabad	29.31	75.27
Kinnaur	31.58	78.41	Gurgaon	28.37	77.40
Mandi	31.70	76.93	Jhajjar	28.61	76.66
Solan	30.90	77.09	Jind	29.43	76.33
Una	31.47	76.27	Kaithal	29.8	76.39
Reg. avg#	32.40	76.89	Kurukshetra	29.97	76.85
Jammu and Kashmir			Mahendergarh	28.04	76.10
Anantnag	33.43	75.17	Panchkula	30.69	76.86
Doda	33.14	75.54	Panipat	29.43	76.93
Jammu	32.73	74.87	Rewari	27.95	76.28
Kathua	32.58	75.50	Rohtak	28.54	76.34
Kupwara	34.52	74.25	Sirsa	29.54	75.03
Leh	34.16	77.58	Sonepat	28.98	77.02
Baramulla	34.10	74.30	Yamuna Nagar	30.12	77.28
Pulwama	33.87	74.89	Reg. avg.#	29.33	76.23
Srinagar	34.08	74.83	Punjab		
Udhampur	33.00	75.16	Amritsar	31.64	74.86
Reg. avg#	34.33	76.40	Gurdaspur	31.96	75.25
Uttarakhand			Hoshiarpur	31.58	75.98
Almora	29.59	79.65	Jalandhar	31.33	75.57
Chamoli	30.42	79.33	Ludhiana	30.88	75.85
Champawat	29.33	80.10	Moga	30.82	75.17
Dehradun	30.19	78.40	Muktsar	30.47	74.51
Garhwal (Pauri)	30.15	79.30	Nawan shehar	31.12	76.11
Hardwar	29.96	78.16	Patiala	30.34	76.38
Nainital	29.38	79.45	Roop Nagar	30.97	76.51
Rudra Prayag	30.28	78.98	Sangru	30.23	75.83
Uttarkashi	30.73	78.45	Reg. avg.#	30.53	75.15
Reg. avg.#	30.33	79.15			

\# Here Reg. avg. is used for the whole state

Time series analysis is carried out for each district and their regional average under a particular state. Statistics namely long term mean and Coefficient of Variance (CV) are calculated along with Mann-Kendall trend test is employed to find out monotonic trend in the rainfall time series.

3. MANN-KENDALL TREND TEST

Mann-Kendall test (Here onwards MK test) is a nonparametric test for detection of monotonic trend in the time series of any frequency distribution. It is based on the test statistics S defined as (Yue et al., 2002a):

$$S=\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} sign(x_j - x_i)$$

Here, x_j are the sequential data values, N is the length of the data set (for our case N=11) and

$$sign(y) = \begin{cases} 1 if(y > 0) \\ 0 if(y = 0) \\ -1 if(y < 0) \end{cases}$$

For $N \geq 8$, the statistic S is approximately normally distributed with mean $\mu=0$ and variance is

$$V(S) = \frac{N(N-1)(2N-5)-\sum_{i=1}^{M} t_i(t_i-1)(2t_i+5)}{18}$$

Where M is the number of tied groups and t_i is the size of the ith tied group. The standardized test statistic Z is computed by

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{V(S)}} when S > 0 \\ 0 when S = 0 \\ \frac{S+1}{\sqrt{V(S)}} when S < 0 \end{cases}$$

4. SEN'S SLOPE ESTIMATOR TEST

The magnitude of trend is predicted by the Sen's estimator. Here, theslope (T_i) of all data pairs is computed as (Sen, 1968)

$$T_i = \frac{x_j - x_k}{j-k}, \text{ for } i = 1, 2 ..., N.$$

Here x_j and x_k are considered as data values at time j and k (j>k) correspondingly. The median of these N values of T_i is represented as Sen's estimator of slope which is given as

Sen's estimator is computed as $Q_{med}=T_{(N+1)/}2$ if N appears odd, and it is considered as

$Q_{me\ d}= [T_{N/2}+T_{(N+2)/2}]/2$ if N appears even. At the end, Q_{med} is computed by a two sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test.Positive value of Q_i indicates an upward or increasing trend and a negative value of Q_i gives a downwardor decreasing trend in the time series.

5. ANALYSIS OF RAINFALL AND YIELD

To find out whether there is any linear association between the yield of *Kharif* rice and the monthly and/or seasonal rainfall, yield data for each state were compared with the rainfall in each month as well as with their possible combination of months. As the yield data were taken state wise hence regionally averaged rainfall time series were tested for their correlation with the yield for the period 2004-2012. Linear regression line with 95% confidence level is fitted for each of the possible correlation pair or scatter plot between the rainfall and yield.

6. RESULTS AND DISCUSSION

Data pertaining to mean, coefficient of variance, MK trend results of rainfall in all 55 districts for the period 2004-2014 was calculated and results are presented as under:

Rainfall climatology in the whole monsoon season has a minimum of 57.8 mm in the Leh while the maximum of 1977.5 mm in Dehradun (Figure 1). Regional average rainfall in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Punjab and Haryana is observed as 454.1 mm, 883.4 mm, 1330.6 mm, 459.2 mm, and 444.8 mm respectively. Monsoon season have shown lower values of CV (0.25 to 0.40) in most of the districts over the study domain with some exception in Leh (2.46), Kinnaur, Moga, Kupwara (0.50 each), Muktsar (0.55), Hamirpur (0.10) and Ropar (0.16). CV value for entire of Himachal Pradesh (0.10) seems promising from an agricultural prospective.

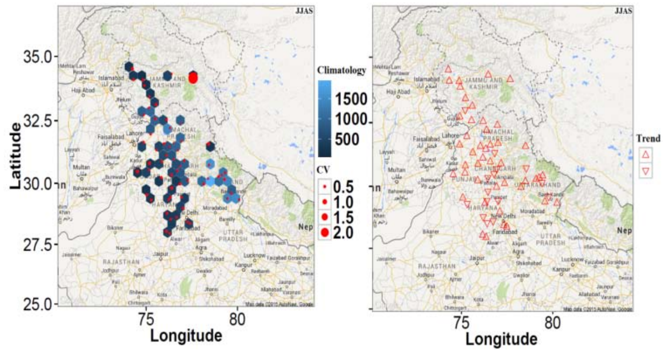

Fig. 1: Figure showing rainfall climatology at each districts and there corresponding coefficient of variation along with the Mann-Kendall trend. Where the symbol ∆ shows increasing trend and ∇ shows decreasing trend.

MK trend results (Table 2) show that four districts of the Himachal Pradesh and their regional average have an exceptionally significant (95% level) increasing trend which is not observed in any other regional averaged time series. The four districts are Chamba (slope 42.2), Kangra (slope 78.2), Mandi (slope 30.6) and Solan (23.7). In Uttarakhand there are also four such districts which are showing significant increasing and decreasing trend, the districts are Pauri Garhwal, Uttarkashi (slope -104.2 and -53.7 respectively, 90% level each), Nainital (slope 70.2, 90% level) and Rudra Prayag (slope 81.2, 95% level). In Jammu and Kashmir and Punjab nearly all the districts are showing non-significant increasing trend (slope between 1.4 and 42.1) with some exception to Udhampur (slope -1.24) and Patiala (slope -3.8). One district each in Jammu and Kahmir (Jammu, 90% level) and Punjab (Patiala, 95% level) has significant increasing trend of 37.0 mm $year^{-1}$ and 35.7 mm $year^{-1}$ respectively. In Haryana, both increasing and decreasing trends were found among the districts. In a regional context Haryana, Punjab, Jammu and Kahsmir, Uttarakhand has shown a non-significant increasing trend of 1.0 mm $year^{-1}$, 9.7 mm $year^{-1}$, 9.4 mm $year^{-1}$ and 0.3 mm $year^{-1}$ respectively.

Table 2: Mann-Kendall trend test results of monsoon (JJAS) rainfall.

District	Sen Slope	S	District	JJAS	S
Himachal Pradesh			Haryana		
BIL	-2.9	-1	AMB	-1.4	-3
CHA	42.2*	27	BHI	-4.1	-7
HAM	21.5	17	FAR	14.1	15
KAN	78.2*	35	FAT	-5.5	-5
KIN	14.6	11	GUR	9.5	9
MAN	30.6*	31	JHA	-7.8	-11
SOL	31.7*	29	JIN	-10.2	-7
UNA	6.3	5	KAI	-9.3	-9
REG	23.7*	29	KUR	0.4	1
Jammu and Kashmir			MAH	15.5	19

ANA	5.0	17	PAN	-3.4	-7
DOD	4.8	5	PAI	-11.3	-7
JAM	37.0^{+}	23	REW	3.5	3
KAT	42.1	13	ROH	-5.0	-7
KUP	12.3	19	SIR	4.1	5
LAD	1.7	19	SON	8.6	9
BAR	8.1	17	YAM	36.2	19
PUL	1.8	7	REG	1.0	3
SRI	4.7	21			
UDH	-1.24	-1	Punjab		
REG	9.4	7	AMR	10.9	5
Uttarakhand			GUD	24.2	11
ALM	-14.4	-11	HAS	32.0	17
CHM	17.5	7	JAL	1.4	3
CHP	8.3	3	LUD	15.5	11
DEH	12.8	3	MOG	35.7*	27
GAR	-104.2^{+}	-25	MUK	8.9	13
HAR	15.8	3	MAW	15.6	9
NAI	70.2^{+}	23	PAT	-3.8	-7
RUD	81.2*	27	ROP	0.8	3
UTT	-53.7^{+}	-23	SAN	23.3	21
REG	0.3	1	REG	9.7	11

Name of districts under each state is the abbreviated form of the actual names mentioned in table 1. Here numbers in bold show trends are either significant at 0.05 level (*) or 0.1 level (+)

7. STATE WISE ANALYSIS OF YIELD OF *KHARIF* RICE AND ITS ASSOCIATION WITH RAINFALL.

Scatter plots and the linear regressing model fit in between the rainfall time series (independent variable) and the yield data (dependent variable) shows (Figure 2) following results

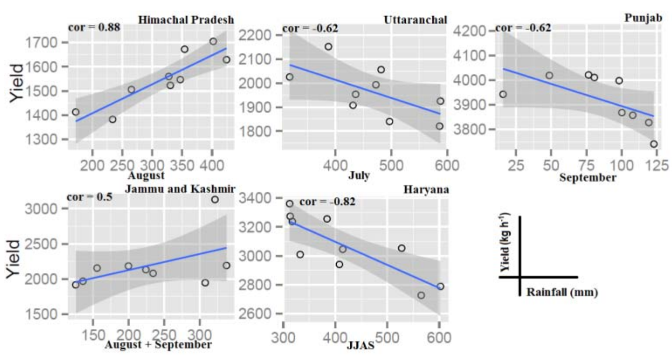

Fig. 2: Plots showing rainfall (mm) and Yield association at state level. The shaded region shows the 95% confidence level, Straight line shows the linear regression fit. cor is the Pearson product-moment correlation coefficient.

8. HIMACHAL PRADESH

August month rainfall in Himachal Pradesh is found out to be best correlated with the yield data of *Kharif* rice with a correlation of 0.88 (99% level). The linear regression line fit show that for the regional rainfall received during August month lies between 340 mm to 450 mm there is a significant (95%) rice yield of 1550 kg ha^{-1} to 1700 kg ha^{-1}. For a scanty august rainfall year of 150 mm to 275 mm the yield has reduced which varies between 1380-1500 kg ha^{-1}.

9. JAMMU AND KASHMIR

Total aggregate rainfall of August and September is found out to be correlated with the yield having a non-significant correlation of 0.5. The liner regression fit show that, for the regional total rainfall received during August and September lies between 150 mm to nearly 230 mm there have been a significant rice yield of 2000 to 2250 kg ha^{-1}. Above 300 mm rainfall the yield results are insignificant.

10. UTTARAKHAND

July month rainfall in Himachal Pradesh is found out to be best correlated with the yield having a correlation of -0.62 (90% level). The linear regression line fit show that, for the regional rainfall received during July month lies between 440 mm to 470 mm there is a significant (95%) rice yield of 1950 kg ha^{-1} to 2000 kg ha^{-1}. In a year with high august rainfall of 590 mm to 600 mm yield have shown a reduction which is below 1925 kg ha^{-1}.

11. HARYANA

Total monsoon rainfall in Haryana is found out to be highly correlated with the yield data of the state having a high correlation of -0.82 (99% level). The linear regression line fit show that, for regional rainfall received during monsoon season lies between 300 mm to 320 mm there is a high yield of 3200 kg ha^{-1} to 3400 kg ha^{-1}. For a high monsoon rainfall year of more than 400 mm the yield decreased significantly below 3100 kg ha^{-1} to even 2700 kg ha^{-1}.

12. PUNJAB

September month rainfall in Punjab is found out to be correlated with the yield data of the state with a correlation of -0.62 (90% level). The linear regression line fit shows that, for regional rainfall received during September month lies between 100 to 125 mm the yield has decreased significantly below 3900 kg ha^{-1}.

13. CONCLUSION

Following important conclusions can be made from the results discussed above,

- Out of all the districts taken for study Leh has experienced very less amount of rainfall during the monsoon season with high value of CV while Dehradun has experienced highest amount of rainfall. High value of CV in some stations denotes that rainfall is not dependable for agricultural prospective over those stations as the farmer can't reliably use the average rainfall as an estimate of what might occur in the forthcoming years. In a state wise context rainfall climatology in the Jammu and

Kashmir and Punjab is not reliable for agriculture while in Uttarakhand and Himachal Pradesh the monsoon rainfall can be dependable followed by Haryana. Overall monsoon rainfall is found out to be scanty for Haryana while it's very high for Uttarakhand.

- Monsoon rainfall is found out to be significantly increasing for Himachal Pradesh. Non-significant and nominal increasing trends in the monsoon rainfall is observed in Uttarakhand and Haryana but for Jammu and Kashmir and Punjab the rate of this increment is found out to be nearly equal.
- Productivity of *Kharif* rice in most of the states (except Uttarakhand) is found out to be highly influenced by the rainfall in August and September. For more than climatological rainfall in August and September, the yield is found out to be significantly reduced over all the states except Himachal Pradesh. In Himachal Pradesh higher value of August rainfall than the long term average has a positive impact on the yield of *Kharif* rice. Total monsoon rainfall is found out to be strongly related (R^2=0.67) to the yield of *Kharif* rice in Haryana. Yield has shown a significant decreasing trend for the monsoon rainfall of more than 550 mm.

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