Production Weighted Rainfall Index and Agriculture Production: Relationship Re-visited

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To assess the impact of Southwest monsoon (SWM) rainfall on agriculture activities, the Reserve Bank of India staff has been preparing Production Weighted Rainfall Index (PRN) which takes into account the state wise rainfall and their respective contributions in all-India foodgrain production. The PRN has proved to be a better rainfall indicator over IMD index for projecting kharif foodgrain production. This article attempts to modify the PRN (Modified PRN) for better monitoring of SWM rainfall as well as forecasting of kharif foodgrain production.

Introduction

Rainfall is a crucial aspect of agricultural production, especially in India, where nearly half of the net sown area is rain-fed. Other major drivers of production apart from rainfall include irrigation infrastructure, technological innovations, usage of high yield varieties of seeds, improved fertilisers, soil moisture level and temperature among others. Despite the rapid expansion in irrigation infrastructure in the recent years, the net irrigated area in India is only marginally higher than half of the total net sown area.[1] India Meteorological Department (IMD)[2] classifies the annual rainfall in India into four seasons: i) Winter (January to February), ii) Pre-Monsoon (March to May), iii) Southwest monsoon (SWM) (June to September), and iv) Post monsoon (October to December). Among these, SWM receives around 75 per cent of the annual rainfall and assumes great importance for the agricultural activities in the country. Along with being a major source for irrigation, SWM is also essential for maintaining the optimum level of storage in the reservoirs which facilitates irrigation during the entire year. A normal monsoon supports the crop production and boosts the rural consumption. Whereas, a deficit or an erratic monsoon can lower the productivity and affect the cropping pattern. Among the three seasons of agriculture in India, *kharif*, which accounts for around 50 per cent of the total foodgrain production of the country, has the highest dependency on SWM rainfall. Better SWM rainfall improves the prospects of *kharif* crops, however, excess rainfall during monsoon season may damage the crops and hence is detrimental to the *kharif* production. The excess rainfall during SWM, however, may lead to improved reservoir levels and might augur well for *rabi* production. Thus, analysing the impact of SWM rainfall - the quantum, spatial and temporal dynamics of it, on the *kharif* foodgrain production has always remained an area of concern.

Given the importance of rainfall in the Indian economy, the Reserve Bank monitors the progress of rainfall, particularly the SWM very closely. The IMD's rainfall index for the country is the weighted aggregation of sub-division wise rainfall wherein weights are based on geographical areas. To capture the impact of rainfall from the point of view of agricultural activities in a better way, the Reserve Bank has been compiling Production Weighted Rainfall Index (PRN), wherein state wise rainfall is aggregated based on the state wise share in total foodgrain production. RBI has been publishing PRN in the Monetary Policy Report and the State of the Economy article of the RBI Bulletin issues, released during and around the SWM season. The PRN addresses the concern that, despite IMD rainfall index falling in the normal range at the country level, the states with higher foodgrain

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1 Land Use Statistics, 2019-20.

2 https://internal.imd.gov.in/press_release/20220414_pr_1572.pdf

production capacity might receive lower rainfall as compared to the lower foodgrain producing states, leading to a lower foodgrain production than normal and *vice versa*. For example, in 2022, PRN stayed below the IMD index for the first three months of the SWM season,[3] reflecting the lower rainfall received by major foodgrain producing states in the northern and eastern parts of India. The methodology for construction of PRN which is explained in the subsequent section, broadly follows Cummings *et al.* (1969) and Arif (1988).

Though, a higher value of PRN indicates better rainfall which generally leads to better agriculture prospects, excess rainfall beyond a threshold might result in the incidence of crop damage, diminishing of nutrients and soil erosion, *etc.*, resulting in lower agriculture production (which is empirically proven in the subsequent section of this article) *i.e.,* if rainfall is below a threshold, the relationship between the foodgrain production and the rainfall index is positive, whereas if the rainfall is above the threshold, the relationship changes and becomes negative. While PRN is an improvement over IMD index, it is unable to differentiate the impact of excess rainfall on crop production with that of normal or below normal rainfall. Furthermore, there may be a case when PRN turns out to be normal despite deficit rainfall in some major foodgrain producing states and *vice versa*. This might arise due to the shortfall, in key foodgrain producing states, being offset by high rainfall in other major foodgrain producing states. Hence, to address the above mentioned shortcomings of PRN, this article attempts to modify the PRN [named as modified PRN (MPRN)] by using one-sided winsorisation at state-level, wherein, if a state receives rainfall more than a pre-decided threshold, the actual rainfall for the state is restricted to that threshold for the calculation of PRN. This article also empirically examines the usefulness of MPRN in the projection of *kharif* foodgrain production which is largely influenced by the SWM.

The remainder of the study proceeds as follows. Section II briefly presents the major literature explored for the study. The data being used for the study and methodology for calculation of PRN and MPRN is explained in Section III. The empirical results have been discussed in Section IV. Finally, Section V concludes by summarising inferences that emanated from the study.

II. Review of Major Literature

Various studies have been undertaken to examine the impact of several factors, such as, rainfall, weather, technological innovations, *etc.*, on the production of crops. Cummings *et al.* (1969) analysed the impact of New Agricultural strategy and provided an estimate of the foodgrain production for the year 1968-69, by taking into consideration the effects of rainfall and the role of technology. Similarly, the quantum of foodgrains produced in India was analysed by incorporating the spatial and temporal distribution of monsoon rainfall (Arif, 1988). Further, studies done on rainfall forecast and foodgrain production (Bhatia, 1997) emphasise on the importance of crop level production forecasting using crop-wise production weighted rainfall index. Another study finds the relationship of agricultural growth with deviation of rainfall from previous year and irrigation growth (Kumar *et al.*, 2019). The impact of climate change on major crops of Pakistan was assessed by analysing the factors, such as, maximum temperature, minimum temperature, relative humidity, sunshine and rainfall (Ali *et al.*, 2017). The potential impact of rising temperature on wheat yield is studied for the north Indian plains (Kuriachen *et al.*, 2022). Gupta *et al.* (2023) found statistically significant impact of SW rainfall on *kharif* production, though the impact has moderated over time. Singh *et al.* (2020) examined the impact of timing of arrival of monsoon on crop yields using district-level panel data. In India, technological innovations in crop forecasting have been a continuous

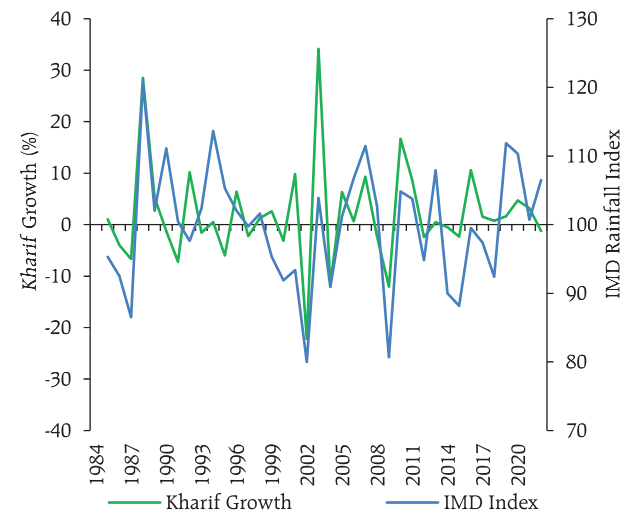
[3] State of the Economy article of the RBI Bulletin, October 2022.

phenomenon. Crop forecasting using remote sensing data, started in late 1980s, however, it became fully operational through a national level programme - FASAL (Forecasting Agriculture output using Space, Agro-meteorology and Land-based observations) since 2006 (Ray *et al.*, 2014). It involves econometric models to forecast area and production before crop sowing season. It aids in validating the estimates of the output along with the other sources. Due to this scientific advancement, the agriculture production estimates were believed to be more reliable since 2000s. This is also evident from the co-movement of *kharif* foodgrain production growth with the IMD rainfall index after 2002-03 (Chart 1).[4]

III. Data and Methodology

Given the better alignment of *kharif* foodgrain production estimates with rainfall since 2002-03, the timeframe to study the impact of SWM rainfall on *kharif* production was taken as 2002-03 to 2022-23 (Chart 1).

Chart 1: Growth of *Kharif* Foodgrain Production and IMD Index



Source: IMD, Ministry of Agriculture & Farmers Welfare and RBI Staff calculations.

[4] Directional concordance between *kharif* foodgrain production and IMD rainfall index improves by 28 per cent for the period 2002-2022 as compared to 1985-2001. Also, the correlation coefficient of foodgrain production's deviation from trend and IMD rainfall index increases from 0.5 to 0.7.

The PRN and MPRN have been constructed by using the following formulas:

a. Production weighted Rainfall Index (PRN):

$$PRN_t = \frac{\sum_i P_{it} * A_{it}}{\sum_i P_{it} * L_{it}}$$

where, A_{it} Actual Rainfall of ith state during the year/month 't' and L_{it}: Long Period Average (LPA) Rainfall[5] of ith state for the year/month 't'. P_{it}: Foodgrain production share of ith state during the year/month[6] 't'. The state-wise foodgrain production share is derived based on the average share of latest five years. The state wise production share of foodgrains is given in the Annexure 1.

b. Modified Production weighted Rainfall Index (MPRN):

A one-sided winsorisation was applied on the actual state-wise rainfall to get MPRN. Accordingly, PRN is modified as follows to get MPRN:

$$MPRN_t = \frac{\sum_i P_{it} * A'_{it}}{\sum_i P_{it} * L_{it}}$$

where A'_{it}: Truncated actual rainfall of ith state during the year/month 't' which is derived as:

$$A'_{it} = \begin{cases} A_{it}, & A_{it} < (L_{it} * Threshold) \\ (L_{it} * Threshold), & A_{it} \geq (L_{it} * Threshold) \end{cases}$$

According to IMD, rainfall in the range of 96-104, above 104-110 and above 110 per cent of LPA rainfall is categorised as normal, above normal and excess rainfall, respectively, at all-India level. The above normal or excess rainfall may not be favourably impacting the agriculture activity and hence for this study various thresholds starting from 105 have been considered for constructing the MPRN. Results for the

[5] The latest LPA rainfall *i.e.* 50-year average rainfall for 1971-2020 is used for computing all three indices *viz.* IMD rainfall index, PRN and MPRN for the entire sample period considered.

[6] Since, state-wise foodgrain share is derived based on annual production, the state-wise foodgrain production share remains same across months of the year.

Table 1: Rainfall Indices during SW Monsoon - Descriptive Statistics

(Per cent)

	*Kharif**	IMD	PRN	MPRN 105	MPRN 110	MPRN 115
Mean	2.1	99.3	97.2	86.0	87.6	89.1
Median	0.7	101.2	100.2	88.1	89.6	90.8
Maximum	34.1	111.9	109.5	92.8	94.7	96.3
Minimum	-22.2	80.0	78.1	72.7	73.6	74.3
Std. Dev.	11.2	9.4	10.2	6.0	6.4	6.7
No. of Obs.	21	21	21	21	21	21

*foodgrain production growth.

Source: IMD, Ministry of Agriculture & Farmers Welfare and RBI Staff calculations.

alternative threshold settings in the range of 105 to 110 per cent and 115 per cent are presented in this article.

Descriptive statistics of IMD, PRN and MPRN show that due to one-sided truncation, the average value of MPRN is considerably lower than IMD and PRN, indicating that the definition of normal rainfall, which is based on IMD index, may not be applicable for MPRN (Table 1).

To examine the impact of SWM rainfall on *kharif* foodgrain production, the following regression model was used:

$$Production_t = \gamma_1 * Rainfall\ Index_t + \varepsilon_t \qquad ...(1)$$

where, $Production_t$ is the deviation of the actual *kharif* foodgrain production from its trend, and $Rainfall\ Index_t$ is the IMD/ PRN/ MPRN for the SWM season in the year 't'. The trend of *kharif* production was alternatively taken as time trend – deterministic trend and the Hodrick Prescott(HP) filter based trend – stochastic trend with a smoothing parameter λ=100. Deviation of foodgrain production from its trend eliminates the impact of gradual improvement in production on account of factors, such as, greater use of technology, high yielding variety of seeds, *etc.*, and hence is left with the short-run movement wherein rainfall could be a major driver.

Since rainfall in different months of the monsoon season may have differential impact on the agriculture activities, the temporal characteristic was factored-in by modifying the above model as:

$$Production_t = \sum_{j=1}^{4} \gamma_j * Rainfall\ Index_{j,t} + \varepsilon_t \qquad ...(2)$$

where, $Rainfall\ Index_{j,t}$ is the IMD/PRN/MPRN for the j^{th} month (j: June, July, August and September) of the 't^{th}' SWM year.

Furthermore, the possible adverse impact of excess rainfall that is the rainfall being left out while computing the MPRN on crop production, was factored-in by taking the difference of MPRN from PRN as another explanatory variable in the Model (1). The modified regression equation transformed as:

$$Production_t = \gamma_1 * MPRN_t + \gamma_2 * DMPRN_t + \varepsilon_t \qquad ...(3)$$

where, $DMPRN_t$ is the difference of MPRN at a pre-decided threshold from PRN in the year 't' (*i.e.,* $DMPRN_t = PRN_t - MPRN_t$).

Given the differences in mean and variance of rainfall indices – the explanatory variables used in this study (Table 1), the associated coefficients of above regression models may not be directly comparable. Hence, to make them comparable, all the explanatory as well as dependent variables were standardised by using standard normal transformation. Therefore, all the above three models became regression through the origin (*i.e.* regression without intercept).

IV. Empirical Results

The correlation between SWM rainfall and the growth rate in *kharif* foodgrain production was found to be highly positive. Among the three indices, MPRN has slightly higher correlation. Though all the monsoon months have positive correlation with *kharif* foodgrain production, July has the highest, indicating that the July rainfall is crucial for the sowing activities and also for the early growing stage of the crops (Table 2).

Estimates of the regression model (1) using both the time trend and HP filter trend show that all the

Table 2: Correlation of Rainfall Indices with Growth Rate of *Kharif* Foodgrain Production

Month	IMD	PRN	MPRN 105	MPRN 106	MPRN 107	MPRN 108	MPRN 109	MPRN 110	MPRN 115
Jun	0.12	0.12	0.21	0.21	0.21	0.21	0.21	0.21	0.20
Jul	**0.59**	**0.66**	**0.67**	**0.67**	**0.66**	**0.66**	**0.66**	**0.66**	**0.65**
Aug	0.16	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.20
Sep	0.44	0.36	0.16	0.16	0.16	0.16	0.16	0.17	0.17
SWM	**0.60**	**0.60**	**0.67**	**0.67**	**0.67**	**0.67**	**0.67**	**0.66**	**0.65**

Source: RBI Staff calculations.

three rainfall Indices have positive and significant impact on the deviation of *kharif* foodgrain production from the trend. MPRN is found to have the highest impact on *kharif* production with significantly better in-sample fit (measured by Adj. R-square) followed by PRN and IMD. The MPRN at threshold value of 105 proves to be the best fit among all the threshold settings. Moreover, the Adj. R-square was observed to be declining sequentially when the threshold was increased beyond 105, indicating that rainfall above 105 per cent of LPA could start having adverse impact on *kharif* foodgrain production. Impact of temporal distribution of SWM rainfall on *kharif* production, which was captured in the model (2) with month-wise rainfall, reveals that the rainfall in the July month (the month accounting for around half of the *kharif* sowing) has the highest impact on output prospects followed by that in June, September and August, indicating that the adverse impact of delay in onset or subdued performance of monsoon in June on agriculture prospects may be somewhat mitigated if the monsoon picks-up in the subsequent month. Unlike IMD and PRN, MPRN shows that rainfall in all the four months of the monsoon season has significant implication for *kharif* foodgrains (Tables 3 and 4).

Table 3: Regression Estimates of Total SWM and Month-Wise Rainfall - Time Trend

	IMD	PRN	MPRN 105	MPRN 106	MPRN 107	MPRN 108	MPRN 109	MPRN 110	MPRN 115
	Total SW Rainfall (Model 1)								
Rainfall Index	0.720 (0.002)	0.742 (0.002)	0.851 (0.00)	0.849 (0.00)	0.847 (0.00)	0.844 (0.00)	0.842 (0.00)	0.839 (0.00)	0.824 (0.00)
Adj-R-Square	*0.519*	*0.550*	***0.725***	*0.722*	*0.717*	*0.713*	*0.708*	*0.703*	*0.679*
LM Test (P-value)	*0.577*	*0.802*	*0.895*	*0.898*	*0.900*	*0.899*	*0.898*	*0.895*	*0.884*
DW Statistic	*2.148*	*2.075*	*2.100*	*2.096*	*2.094*	*2.094*	*2.095*	*2.097*	*2.101*
No. of Obs.	*21*	*21*	*21*	*21*	*21*	*21*	*21*	*21*	*21*
	Monthly Rainfall (Model 2)								
Rainfall(June)	0.423 (0.043)	0.360 (0.089)	0.422 (0.008)	0.418 (0.009)	0.415 (0.01)	0.413 (0.011)	0.410 (0.012)	0.406 (0.013)	0.392 (0.02)
Rainfall(July)	**0.427** (0.108)	**0.523** (0.014)	**0.620** (0.001)	**0.618** (0.002)	**0.616** (0.002)	**0.613** (0.002)	**0.611** (0.002)	**0.609** (0.002)	**0.597** (0.003)
Rainfall(August)	0.154 (0.175)	0.181 (0.23)	0.267 (0.049)	0.268 (0.051)	0.269 (0.054)	0.270 (0.055)	0.270 (0.057)	0.272 (0.058)	0.272 (0.071)
Rainfall (September)	0.337 (0.087)	0.241 (0.081)	0.304 (0.014)	0.299 (0.016)	0.295 (0.019)	0.291 (0.021)	0.287 (0.023)	0.283 (0.026)	0.268 (0.04)
Adj-R-Square	*0.475*	*0.511*	***0.688***	*0.684*	*0.679*	*0.674*	*0.669*	*0.663*	*0.635*
LM Test (P-value)	*0.658*	*0.680*	*0.989*	*0.991*	*0.994*	*0.996*	*0.998*	*0.998*	*0.994*
DW Statistic	*2.110*	*1.992*	*1.881*	*1.887*	*1.896*	*1.907*	*1.917*	*1.928*	*1.968*
No. of Obs.	*21*	*21*	*21*	*21*	*21*	*21*	*21*	*21*	*21*

Note: 1. Figure in parenthesis is the associated p-value.
2. Standard errors are heteroscedasticity and autocorrelation consistent (HAC).
Source: RBI Staff calculations.

Table 4: Regression Estimates of Total SWM and Month-Wise Rainfall - HP Filter Trend

	IMD	PRN	MPRN 105	MPRN 106	MPRN 107	MPRN 108	MPRN 109	MPRN 110	MPRN 115
	Total SW Rainfall (Model 1)								
Rainfall Index	0.702 (0.002)	0.730 (0.002)	0.845 (0.00)	0.843 (0.00)	0.840 (0.00)	0.838 (0.00)	0.835 (0.00)	0.832 (0.00)	0.817 (0.00)
Adj-R-Square	*0.493*	*0.533*	***0.713***	*0.710*	*0.706*	*0.702*	*0.698*	*0.692*	*0.667*
LM Test (P-value)	*0.637*	*0.855*	*0.951*	*0.951*	*0.951*	*0.949*	*0.946*	*0.943*	*0.933*
DW Statistic	*2.126*	*2.064*	*2.091*	*2.090*	*2.089*	*2.090*	*2.092*	*2.095*	*2.097*
No. of Obs.	*21*	*21*	*21*	*21*	*21*	*21*	*21*	*21*	*21*
	Monthly Rainfall (Model 2)								
Rainfall(June)	0.432 (0.043)	0.371 (0.08)	0.446 (0.006)	0.443 (0.007)	0.440 (0.007)	0.437 (0.008)	0.434 (0.009)	0.430 (0.01)	0.414 (0.016)
Rainfall(July)	**0.398** (0.116)	**0.496** (0.011)	**0.595** (0.001)	**0.594** (0.001)	**0.592** (0.001)	**0.589** (0.001)	**0.587** (0.001)	**0.585** (0.001)	**0.573** (0.002)
Rainfall(August)	0.148 (0.181)	0.172 (0.223)	0.265 (0.043)	0.266 (0.045)	0.266 (0.047)	0.267 (0.048)	0.268 (0.049)	0.269 (0.051)	0.270 (0.062)
Rainfall (September)	0.337 (0.085)	0.252 (0.066)	0.300 (0.012)	0.296 (0.014)	0.292 (0.016)	0.288 (0.018)	0.284 (0.02)	0.280 (0.023)	0.265 (0.036)
Adj-R-Square	*0.444*	*0.483*	***0.671***	*0.668*	*0.663*	*0.658*	*0.653*	*0.647*	*0.617*
LM Test (P-value)	*0.733*	*0.700*	*1.000*	*1.000*	*1.000*	*0.999*	*0.997*	*0.995*	*0.982*
DW Statistic	*2.099*	*1.969*	*1.957*	*1.963*	*1.972*	*1.982*	*1.992*	*2.001*	*2.032*
No. of Obs.	*21*	*21*	*21*	*21*	*21*	*21*	*21*	*21*	*21*

Note: 1. Figure in parenthesis is the associated p-value.
2. Standard errors are heteroscedasticity and autocorrelation consistent (HAC).
Source: RBI Staff calculations.

One-year ahead projections[7] carried out by using model (1) suggest that MPRNs have lower forecast errors as compared to PRN and IMD in all the cases. Relative Root Mean Square Percentage Error (RMSPE)[8] of MPRN over IMD indicate that there is significant improvement in the forecasting performance of the model. Among the MPRNs with different thresholds selected under study, the MPRN at threshold 105 outperforms all the others. In the last 5 years, the RMSPE for *kharif* foodgrain production using MPRN (threshold 105) is lower by 21.3 per cent and 38.3 per cent, than the RMSPE based on IMD under time trend and HP trend, respectively (Table 5.1).

Incorporating the month-wise rainfall dynamics in the model [regression model (2)] in place of total rainfall during SWM season does not help in improving the forecasting performance for the last 5 years (Table 5.2).

Further, the model which factors in the adverse impact of excess rainfall [model (3)] seems to be improving the overall in-sample fit (Adj. R Square) when compared to the model only with annual rainfall [model (1)]. MPRN at 105 stands out to be having the best in-sample fit. The negative and statistically significant regression coefficient of the excess rainfall suggests unfavourable output conditions for *kharif* foodgrain production. As the threshold setting for excess rainfall increases, the negative impact of the excess part also magnifies (Annexure 2). The adverse impact comes out to be significant at 10 per cent and 5 per cent level of significance under time trend and HP trend, respectively. The forecast performance for *kharif* foodgrain production seem to be improving only marginally when compared to model (1) in the case of Time Trend. However, no such improvement was observed in the case of HP trend (Table 5.3).

[7] The projections are generated recursively, *i.e.*, the model was first estimated using data till time 't', then using the estimated model and the rainfall index observed for time 't+1', foodgrain production for time 't+1' was projected.

[8] $RMSPE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left\{\left(\frac{P_t - \hat{P}_t}{P_t}\right) * 100\right\}^2}$, where P_t is the actual *kharif* production in year 't' and $\hat{P}_t$ is the estimated *kharif* production for year 't'.

Table 5: Out-of-Sample RMSPE in the Last Five Years (FY2019 to FY2023)

(Per cent)

	Time Trend	HP Filter -Trend
RMSPE of IMD	6.72	4.89
5.1: Relative RMSPE over IMD: Annual Rainfall (Model 1)		
PRN	85.9	74.9
MPRN105	**78.7**	**61.7**
MPRN106	79.4	62.6
MPRN107	80.0	63.5
MPRN108	80.6	64.3
MPRN109	81.1	65.1
MPRN110	81.6	65.9
MPRN115	84.3	69.6
5.2: Relative RMSPE: Monthly Rainfall (Model 2) over Annual Rainfall (Model 1)		
IMD	107.7	109.0
PRN	119.8	128.9
MPRN105	110.8	110.7
MPRN106	110.9	111.0
MPRN107	111.0	111.2
MPRN108	111.0	111.3
MPRN109	111.1	111.4
MPRN110	111.1	111.6
MPRN115	111.4	112.3
5.3: Relative RMSPE: Model 3 Over Model 1		
MPRN105+DMPRN105	100.1	104.4
MPRN106+DMPRN106	99.9	103.7
MPRN107+DMPRN107	99.8	103.1
MPRN108+DMPRN108	99.7	102.6
MPRN109+DMPRN109	99.7	102.3
MPRN110+DMPRN110	99.7	101.9
MPRN115+DMPRN115	100.7	102.3

Source: RBI Staff calculations.

V. Conclusion

An assessment of the impact of the quantum, spatial and temporal distribution of SWM rainfall on the production of *kharif* foodgrains reaffirms the positive and statistically significant impact of SWM rainfall on *kharif* production prospects. Among the SWM months, July rainfall has the highest impact on production followed by June, September and August, indicating that the adverse impact of delay in onset or subdued performance of monsoon in June may be somewhat mitigated if the monsoon picks-up in the subsequent month.

The MPRN derived by applying a one-sided winsorisation on the actual state-wise rainfall was constructed for various thresholds starting from 105. While PRN performs better than IMD index in terms of better in-sample fit and lower forecast error, MPRN proves to be a further improvement over PRN. As the threshold of MPRN increases after 105, the in-sample fit of the model decreases and the impact gradually diminishes, indicating that rainfall around 105 per cent of LPA has the highest and significant impact on *kharif* foodgrain production. Also, MPRN at 105 has better forecasting performance over PRN, IMD and MPRN with other thresholds. Incorporating the temporal distribution of SWM rainfall (based on month-wise rainfall index) over annual rainfall, however, does not help in improving the forecasting performance of production at least in the last five years. Further, the excess rainfall was found to have a significant and negative impact on *kharif* foodgrain production.

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Annexure 1: State-wise share in total foodgrain and *kharif* foodgrain production

(Per cent)

States\Year	Total foodgrain share of states					*Kharif* foodgrain share of states				
	2002-03	2007-08	2012-13	2017-18	2020-21	2002-03	2007-08	2012-13	2017-18	2020-21
Andhra Pradesh	6.10	8.36	4.06	4.27	3.64	7.65	9.27	3.74	4.13	3.25
Arunachal Pradesh	0.14	0.11	0.14	0.13	0.12	0.26	0.19	0.27	0.23	0.23
Assam	2.23	1.50	2.05	1.94	1.77	3.60	2.16	3.12	2.99	2.86
Bihar	6.34	4.71	6.20	5.98	4.95	6.22	3.80	6.24	6.09	4.58
Chhattisgarh	1.87	2.73	2.97	2.09	2.65	3.30	4.74	5.41	3.82	5.05
Goa	0.08	0.06	0.05	0.04	0.03	0.16	0.10	0.06	0.05	0.04
Gujarat	2.04	3.56	2.74	2.69	2.89	3.03	3.31	2.80	2.72	2.55
Haryana	7.05	6.63	6.31	5.68	5.89	3.45	4.04	3.78	3.78	3.88
Himachal Pradesh	0.64	0.68	0.58	0.52	0.49	0.67	0.83	0.63	0.60	0.59
Jammu and Kashmir	0.76	0.68	0.71	0.55	0.51	1.05	0.88	1.06	0.77	0.74
Jharkhand	1.08	1.80	1.77	2.11	1.57	2.02	3.20	3.08	3.62	2.53
Karnataka	3.81	5.28	4.22	4.14	4.68	5.59	7.27	6.00	6.02	7.42
Kerala	0.40	0.23	0.20	0.18	0.20	0.67	0.35	0.29	0.28	0.31
Madhya Pradesh	6.15	5.23	9.21	11.74	10.57	4.26	3.26	4.71	8.01	6.51
Maharashtra	6.20	6.58	4.27	4.65	5.07	8.85	7.84	6.00	5.44	5.70
Manipur	0.20	0.18	0.13	0.25	0.22	0.39	0.35	0.07	0.13	0.08
Meghalaya	0.13	0.10	0.10	0.13	0.11	0.23	0.15	0.16	0.20	0.19
Mizoram	0.07	0.01	0.02	0.03	0.03	0.14	0.01	0.03	0.05	0.05
Nagaland	0.22	0.21	0.23	0.19	0.18	0.40	0.37	0.44	0.36	0.34
Odisha	2.04	3.53	3.11	2.51	3.06	3.54	5.93	5.44	4.46	5.45
Punjab	13.44	11.62	11.10	11.12	9.79	10.57	9.12	9.26	9.83	8.76
Rajasthan	4.31	6.96	7.14	7.00	7.81	2.11	6.44	5.38	5.62	6.58
Sikkim	0.06	0.05	0.04	0.03	0.03	0.09	0.08	0.08	0.07	0.06
Tamil Nadu	2.54	2.85	2.18	3.76	3.48	4.33	4.54	3.61	5.99	5.76
Telangana	-	-	3.20	3.31	4.10	-	-	4.29	3.52	4.10
Tripura	0.35	0.27	0.28	0.3	0.28	0.53	0.38	0.43	0.43	0.41
Uttar Pradesh	21.82	18.24	19.74	18.02	18.7	14.06	12.32	14.22	12.32	13.26
Uttarakhand	0.89	0.78	0.71	0.67	0.64	0.87	0.74	0.69	0.65	0.63
West Bengal	8.88	6.95	6.44	5.92	6.44	11.81	8.2	8.61	7.77	8.02
Others	0.13	0.1	0.08	0.07	0.07	0.14	0.11	0.09	0.08	0.06
All India	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Ministry of Agriculture & Farmers Welfare.

Annexure 2: Regression Estimates of Model (3)

	Time Trend		HP Filter Trend	
	Coefficient	Adj. R Sq.	Coefficient	Adj. R Sq.
DMPRN105	-0.260 (0.071)	**0.744**	-0.284 (0.034)	**0.738**
DMPRN106	-0.269 (0.066)	0.742	-0.294 (0.031)	0.737
DMPRN107	-0.274 (0.063)	0.739	-0.300 (0.029)	0.734
DMPRN108	-0.278 (0.060)	0.735	-0.304 (0.027)	0.731
DMPRN109	-0.280 (0.058)	0.731	-0.307 (0.025)	0.727
DMPRN110	-0.282 (0.056)	0.726	-0.309 (0.024)	0.722
DMPRN115	-0.288 (0.045)	0.700	-0.314 (0.015)	0.694

Note: Figure in parenthesis is the associated p-value.
Source: RBI Staff calculations.