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VERIFICATION AND USABILITY ANALYSIS OF MEDIUM RANGE WEATHER FORECAST FOR THE KOKRAJHAR DISTRICT OF LOWER BRAHMAPUTRA VALLEY ZONE OF ASSAM

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ABSTRACT
The moderated weather forecast received from the Regional Meteorological Centre (RMC), Guwahati for Kokrajhar district of Assam during March, 2014 to February, 2019 has been analyzed and verified for its accuracy with the observed weather parameters. The ratio score was found moderate to very good for daily rainfall forecast with highest for winter (91.4%) and lowest for pre-monsoon (67.2%) season. Rainfall forecast was poor during monsoon season with percentage of usability 31.0 per cent to 37.8 per cent with higher RMSE *i.e.*, 30.6 to 45.2 mm as compared with pre-monsoon, post-monsoon and winter season with RMSE 13.5 to 20.8 mm, 2.3 to 17.9 mm and 0.6 to 3.1 mm, respectively. Performance of maximum and minimum temperature forecast was found relatively higher during post-monsoon and monsoon season with usability percentage varies from 62.3 per cent to 85.2 per cent and 69.7 per cent to 88.5 per cent, respectively. For morning and afternoon relative humidity forecast, usability percentage was very good during monsoon and post-monsoon season which varies from 99.1 per cent to 100 per cent and 85.2 per cent to 96.7 per cent, respectively. The correlation study reveals significant association between forecasted and observed weather parameters in most of the season. Overall, the forecast was found widely applicable for all the parameters on seasonal as well as annual basis.

INTRODUCTION

The globally averaged surface temperature has shown warming of 0.89ºC (0.69 to 1.08ºC) over the period of 1901-2012 which is mainly attributed to anthropogenic activities (IPCC, 2013). Additionally, increase in heavy rainfall events and decrease in low and medium rainfall events was also observed over different parts of the Indian sub-continent (Goswami *et al*., 2006). However, the impact of global warming would be severing particularly in the tropical areas, including the developing country like India (Sathaye *et al*., 2006). Increase in the frequency of drought, heat stress and flooding events are expected to have greater influences on sectors with closer links to climate, such as water, agriculture and food security (IPCC, 2012). In an agrarian country like India, the agricultural sector itself contributes up to 14% of gross domestic product of the overall economy (Economic survey, 2016). Despites of several technological developments in the field of agriculture, the effect of weather elements in determining the yield factor of a crop is ineffable and any extreme behaviour of weather elements directly leads to significant loss in the crop yield. Furthermore, weather parameter during the crop development stages also determines the degree of vulnerability of crops to pest and disease epidemics (Patil *et al*., 2016; Dhal *et al*., 2016). Thus, advance information on weather behaviour can be found very useful not only in harnessing the benefits of optimal weather but also in circumventing the ill effect of extreme weather events.

The Medium Range Weather Forecasts (MRWF) generated by India Meteorological Department (IMD) is widely used for preparation and dissemination of weather based Agromet Advisory Service (AAS) for 635 districts in India. The AAS composed of five day's advance information on predicted weather behavior at district level which helps in effective and strategic decision making process in agricultural operations. Chattopadhyay *et al*. (2018) have comprehensively assessed the potential of generating net economic benefit up to 3.3 lakh crores on the four principle crops alone when AAS under the Gramin Krishi Mausam Sewa (GKMS) scheme is fully utilized by 95.4 million agriculture-dependent households. The usefulness of medium range weather forecasts were also studied by several authors over different Agroclimatic zones of India (Rathore *et al*., 2013(a); Lunagaria *et al*., 2009).

An estimate made by the agri-business community in western countries indicates that the forecast can be put to economical use if it is 50-60 per cent correct (Seeley, 1994). Therefore, the forecast verification is essential to judge the usability of the district level weather forecast so as to improve the confidence and its reliability among the end users. In this paper, an attempt has been made to verify the accuracy and usability of medium range weather forecast for the Kokrajhar district of Lower Brahmaputra Valley Zone, Assam.

MATERIALS AND METHODS

The Kokrajhar district (situated in latitude 26°42 N, longitude 89°92 E and altitude 48.12 m above MSL) selected for the present study is one of the district among the ten other districts of Lower Brahmaputra Valley Zone (LBVZ) of Assam and falls in region of high monsoonal rainfall with hot summer and cold winter type climatic behaviour. The annual climatological value for rainfall over the district was 3658.5 mm with rainy days of 105 days. The Agromet Field Unit (AMFU) Gossaigaon was established at Regional Agricultural Research Station (RARS), Assam Agricultural University, Gossaigaon with an aim to provide weather related services for the eleven districts *viz*., Baksa, Bongaigaon, Barpeta, Chirang, Dhubri, Goalpara, Kamrup (rural), Kamrup (metro), Kokrajhar, Nalbari and South Shalmara of LBVZ of Assam; which comprises 27.6 percentage (21655.9 sq. km) of total geographical area of Assam *i.e*., 78,438 sq. km. The region is more or less uniform with devoid of steep slope and mountain structures triggering steep variations in weather parameters. The present study was conducted at Agromet Field Unit (AMFU), Gossaigaon, Assam for five years during March, 2014 to February, 2019. The daily values of medium range forecast of weather parameters *viz*., rainfall (mm), maximum and minimum temperature (°C), morning and afternoon relative humidity (%) from day 1 to day 5 was arranged systematically for five consecutive year's individually and thereafter compared and verified for the four seasons separately as per IMD standard *i.e*., pre-monsoon (March to May), monsoon (June to September), post-monsoon (October and November) and winter (December to February) against the observed weather parameters recorded at agro-meteorological observatory located at RARS, Gossaigaon. The skill scores *viz*., ratio score, Hanssen and Kuipers (HK) score, Probability of Detection (POD), Heidke Skill Score (HSS), False Alarm Ration (FAR), Critical Success Index (CSI) were estimated for rainfall (Sarmah *et al*., 2015). The following 2 x 2 contingency table was considered for the analysis of number of occurrence (Y) and non-occurrence (N) events of rain during period under investigation (IMD, 2008).

	Forecasted	
Observed	Rain	No Rain
Rain	A (YY)	B (YN)
No Rain	C (NY)	D (NN)

Where,

A = No. of hits (predicted and observed)

B = No. of false alarms (predicted but not observed)

C = No. of misses (observed but not predicted)

D = No. of correct predictions of no rain (neither predicted nor observed)

The total number of cases (M) is given by,

M = A + B + C + D

Ratio score (RS) also known as the Hit rate. It describes the success rate of correct forecasts of occurrence and non-occurrence of rainfall to the total number of events. The RS varies from 0 to 100 with 100 indicating the perfect forecast.

$$\text{Ratio Score} = \frac{\text{Correct Forecast}}{\text{Total Forecast}} = \frac{A+D}{M} X100$$

Hanssen and Kuipers (HK) Scores also known as true skill statistics. The score has a range of -1 to +1, with 0 representing no skill and negative values representing the "perverse" forecasts. The positive value of HK score indicated the reliability of forecast to be satisfactory in all the season. A drawback of this score is that it tends to converge to the POD for rare events, because the value of "D" becomes very large.

$$HKS = \frac{AxD - BxC}{(A+B)(C+D)}$$

Probability of Detection (POD) is the ratio of correct rain forecast. It is also known as the Hit rate. It ranges from zero (0) at the poor end to one (1) at the good end and can be calculated by using the formula-

$$POD = \frac{\text{Correct rain forecast}}{\text{Rain observation}} = \frac{A}{A+B}$$

False Alarm Ratio (FAR) is the ratio of correct rain forecast. It ranges from zero (0) at the good end and one (1) at the poor end. It also is an incomplete score and should be used in connection with the POD above.

$$FAR = \frac{\text{Correct rain forecast}}{\text{Rain observation}} = \frac{C}{C+A}$$

Critical Success Index (CSI) measures relative forecast accuracy. It varies from 0 to 1 with 1 indicating perfect forecast and 0 indicating no forecast. CSI is a non-linear function of both FAR and POD.

$$CSI = \frac{\text{Hits}}{\text{Hits} + \text{False alarm}} = \frac{A}{A+B+C}$$

HeidkeSkill Score (HSS) is the ratio of correct rain forecast. The HSS represents the fraction by which the forecast improves on the standard forecast. The range of the HSS is -1 to +1. Negative value indicates that the standard forecast is more accurate than the forecast, 0 means no skill and a perfect forecast obtains HSS of 1.

$$HSS = \frac{2(AD - BC)}{(A+C)(C+D)+(A+B)(B+D)}$$

The error structures as suggested by IMD were followed to discriminate between correct, usable and unusable forecasts (Singh *et al*., 1999). The error structure for verification of quantitative precipitation was as follows:

	Error structure for verification of temperature forecast (°C)	Error structure for verification of relative humidity forecast (%)
Correct	diff ≤ 1.0 °C	diff ≤ 10 %
Usable	1.0 0C < diff ≤ 2.0 °C	10% < diff ≤ 20%
Unusable	diff > 2.0 °C	diff > 20%
Usability (Probability of success rate) = Correct + Usable		

Where, "diff" stands for Absolute difference of observed and forecasted rainfall in mm and "obs" stands for observed rainfall in millimeter (mm).

Correlation coefficient (r) and Root Mean Square Error (RMSE) of all-weather parameters were worked out for the absolute error between observed and forecasted data (Kothiyal, 2017). The lower value of RMSE indicates less difference between observed and forecasted values.

Where, Fi = forecasted value, Oi = observed value, n = number of observations.

Root Mean Square Error (RMSE) = $\sqrt{\left\{\frac{1}{n}\sum F_i - O_i\right\}}$

In this present study the critical values of error structures given by Rathore *et al*. (1999) were followed to consider success and failure cases for verification of temperature and relative humidity forecast, which mentioned below-

	Observed rainfall d— 10 mm	Observed rainfall > 10 mm
Correct	diff d— 0.2 mm	diff d— 2 % of obs
Usable	0.2 mm < diff d— 2.0 mm	2% of obs < diff d— 20% of obs
Unusable	diff > 2.0 mm	diff > 20% of obs
Usability (Probability of success rate) = Correct + Usable		

Where, "diff" stands for the absolute differences of observed and forecasted weather parameters.

RESULTS AND DISCUSSION

Qualitative analysis of rainfall forecast

The results of qualitative analysis of rainfall forecast based on different skill scores are presented in Fig. 1 to Fig. 6. The values of ratio score during pre-monsoon, monsoon, post-monsoon and winter season ranged from 57.6 to 76.1, 55.7 to 78.7, 75.4 to 96.7 and 81.1 to 100 per cent, respectively (Fig. 1). The highest ratio score value of 100 per cent corresponds to winter season during 2017-18 year. The ratio score was more than 50 per cent for all the season in all five years. The ratio score varies from year to year and higher score indicated a higher value of precision in forecast. The ratio score was recorded relatively higher during the post-monsoon and winter season as compared to monsoon season during all the year indicating a better performance of forecasting model during these two seasons under the rainfed climatic conditions. Overall, the mean ratio score was highest for winter (91.4%) followed by post-monsoon (86.2%) and monsoon (69.0%) and was found lowest for pre-monsoon (67.2%) season and 78.3% for overall period. The result is in corroboration with the findings of Kaur and Singh, 2019.

The positive values of HK score was observed in all the seasons except in the year 2016-17 where negative HK score was recorded for the winter seasons (-0.03) indicating the reliability of forecast on that season was skeptical (Fig. 5). During the monsoon season, HK score was recorded 0 representing no skill forecast during 2014-15 year. The highest HK score (1) was observed in the year 2017-18 during winter season indicates perfect forecast. Similarly, on an annual basis highest HK score was recorded during 2015-16 (0.67) and the lowest (0.54) during 2018-19 year. The HK score was low during the monsoon season indicated low percentage of accuracy of rainfall forecast since relatively higher variability in rainfall occurs during the monsoon season. Similar results were reported by Das and Desai (2018) for the North Gujarat region, where HK score during post-monsoon and winter season was nearly cent percent.

The POD was observed excellent in monsoon season (0.98 to 1.0) followed by pre-monsoon season (0.79 to 0.94) during all the five years of observations (Fig. 4). During the post-monsoon season POD values lies within 0.29 to 0.92 in all five years as shown in Fig. 4. However, lowest value of POD (0.0) was in the winter season during 2016-17 due to non-

Table 1: Seasonal usability percentage (%) between observed and predicted weather parameters during March, 2014 to February, 2019

Season	Year	Rainfall	Max Temperature	Min Temperature	Morning RH	Aftern oon RH
Pre-Monsoon (March- May)	2014-15	80.6	77.2	43.5	47.8	48.9
	2015-16	69.4	45.7	43.5	66.3	63
	2016-17	71.9	58.7	71.7	69.6	67.4
	2017-18	58.7	59.8	84.8	78.3	67.4
	2018-19	64.1	75	81.5	77.1	51
Monsoon (June- Sept.)	2014-15	31	73	69.7	100	94.3
	2015-16	37.5	54.1	77.9	98.4	89.4
	2016-17	33.7	60.7	77.1	99.2	86.9
	2017-18	37.8	76.2	86.1	100	91.8
	2018-19	32.3	73	88.5	99.1	82.7
Post Monsoon (Oct-Nov)	2014-15	100	65.6	47.5	100	95.1
	2015-16	100	82	73.8	96.7	91.8
	2016-17	94.9	62.3	77.1	95.1	96.7
	2017-18	82.6	68.9	60.7	100	85.2
	2018-19	96	85.2	39.3	86.8	88.5
Winter (Dec- Feb)	2014-15	100	46.7	67.8	48.9	38.9
	2015-16	100	70.3	69.2	53.9	87.8
	2016-17	100	83.3	60	32.2	82.2
	2017-18	98.9	74.4	38.9	64.4	46.7
	2018-19	97.2	81.1	41.1	76.6	76.6
Annual (March- Feb)	2014-15	74.8	66.3	58.9	74.3	69.3
	2015-16	73.4	60.7	66.3	79.2	82.7
	2016-17	73.5	66	71.5	74.5	82.5
	2017-18	70.1	70.4	69.9	85.8	73.4
	2018-19	68.9	77.5	66.8	86	74.2

Table 2: Seasonal RMSE and correlation coefficient between observed and predicted weather parameters during March, 2014 to February, 2019

Season	Year	Rainfall		Max Temperature		Min Temperature		Morning RH		Afternoon RH	
		r	RMSE	r	RMSE	r	RMSE	r	RMSE	r	RMSE
Pre-Monsoon (March- May)	2014-15	0.64**	16.7	0.65**	2.08	0.63**	3.44	0.51**	4.98	0.56**	4.53
	2015-16	0.45**	13.5	0.11	2.87	0.38**	3.22	0.34**	4.1	0.48**	4.13
	2016-17	0.31**	20.8	0.31**	2.9	0.68**	2.48	0.25**	3.92	0.58**	4.28
	2017-18	0.29**	16.9	0.70**	2.52	0.90**	1.75	0.31**	3.43	0.59**	4.03
	2018-19	0.59**	17.88	0.26*	2.42	0.80**	1.87	0.20*	3.49	0.53**	4.52
Monsoon (June- Sept.)	2014-15	0.35**	44.4	0.43**	2.35	0.39**	2.11	0.22**	2.13	0.43**	2.76
	2015-16	0.20**	45.2	0.45**	3.3	0.46**	2.05	0.38**	2.38	0.37**	3.19
	2016-17	0.40**	30.6	0.51**	2.84	0.39**	1.94	0.14	2.12	0.46**	3.25
	2017-18	0.48**	45.2	0.48**	2.22	0.32**	1.68	0.43**	2.12	0.37**	3.24
	2018-19	0.25**	45.23	0.39**	2.29	0.25**	1.4	0.35**	2.08	0.34**	3.47
Post Monsoon (Oct-Nov)	2014-15	0.46**	3.3	0.26**	2.45	0.68**	3.61	0.08	1.61	0.13	2.98
	2015-16	-0.01	2.3	0.66**	2.3	0.85**	2.01	0.23**	2.81	0.44**	2.82
	2016-17	0.83**	6.3	0.69**	2.39	0.88**	2.04	0.36**	3.16	0.74**	2.73
	2017-18	0.27**	17.9	0.47**	2.53	0.88**	2.51	0.35**	2.43	0.61**	3.2
	2018-19	-0.03	7.12	0.74**	1.65	0.93**	2.83	0.29*	3.34	0.45**	3.12
Winter (Dec- Feb)	2014-15	-0.02	1.8	0.15	3.36	0.59**	2.61	-0.06	4.69	0.16	4.88
	2015-16	0.13	1.3	0.60**	2.77	0.59**	2.54	0.1	4.46	0.57**	3.14
	2016-17	-0.02	0.6	0.60**	1.89	0.51**	2.85	0.12	5.31	0.30**	3.53
	2017-18	0.98**	0.6	0.49**	2.62	0.54**	3.34	-0.09	4.11	0.05	4.78
	2018-19	0.68**	3.1	0.36**	2.06	0.66**	3.08	-0.04	3.59	0.54**	3.73
Annual (March- Feb)	2014-15	0.48**	27	0.78**	2.6	0.92**	2.89	0.04	3.69	0.65**	3.88
	2015-16	0.40**	27	0.73**	2.91	0.92**	2.51	0.13**	3.52	0.71**	3.39
	2016-17	0.51**	20.7	0.67**	2.58	0.93**	2.35	0.25**	3.74	0.76**	3.53
	2017-18	0.52**	28.4	0.75**	2.45	0.94**	2.35	0.22**	3.1	0.65**	3.86
	2018-19	0.43**	27.84	0.77**	2.17	0.96**	2.28	0.30**	3.09	0.70**	3.78

(*- Significant at P = 0.05 level; **- Significant at P = 0.01 level)

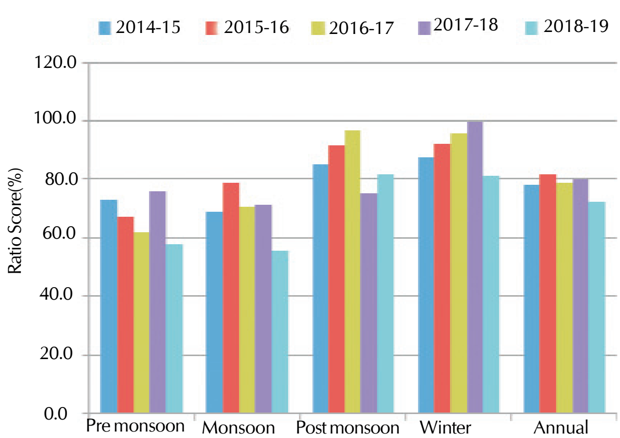

Figure 1: Seasonal qualitative analysis of daily rainfall forecast based on Ratio score

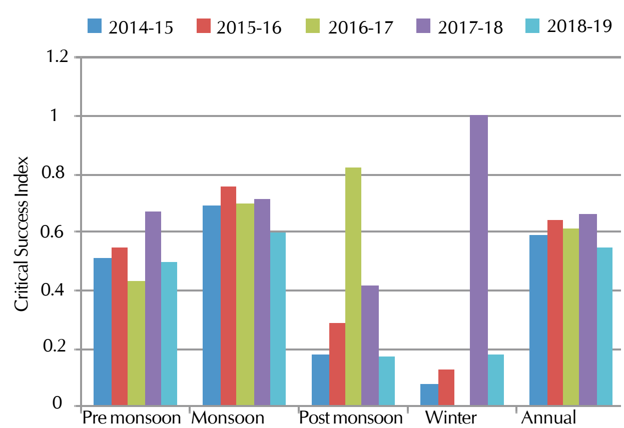

Figure 2: Seasonal qualitative analysis of daily rainfall forecast based on Critical Success Index (CSI)

occurrence of YY or NN events. The highest POD (1.0) was recorded in monsoon and winter season during the year 2014-15 and 2017-18, respectively stated perfect forecast of occurrence and non-occurrence of rainfall events during those defined period. Similarly, the FAR was highest during the winter season except in 2017-18 year and relatively lowest during the monsoon season which ranged from 0.22 to 0.37. Further, it was observed that when POD values are higher (Fig. 4), the FAR values corresponding to same period are reasonably found to be lower (Fig. 3).

Likewise, the CSI during pre-monsoon, monsoon, post-monsoon and winter season varies from 0.43 to 0.67, 0.60 to 0.76, 0.17 to 0.82 and 0.0 to 1.0, respectively (Fig. 2). However, both the highest (1.0) and the lowest (0.0) CSI value was recorded in the winter season, during the year 2017-18 and 2016-17, respectively. Overall, the CSI was highest for monsoon season and lowest for winter season during the five years of observation. Since CSI is a function of both POD and FAR, understanding CSI will help in identifying which component would be more beneficial to target in forecasting. In the present context, the highest POD and lowest FAR corresponds to highest CSI and vice-versa for the winter season.

Heidke Skill Score (HSS) was observed positive in all three season of the five years except in winter where the HSS was detected negative (-0.02) during 2016-17 year, indicates that chance forecast was better (Fig. 6). The HSS was 0.0 during the 2014-15 in monsoon season specifying no skill forecast of rainfall. Perfect forecast with HSS value 1.0 was perceived

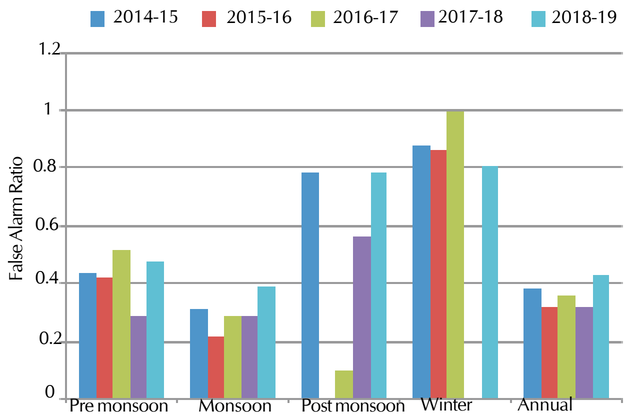

Figure 3 : Seasonal qualitative analysis of daily rainfall forecast based **on False Alarm Ratio (FAR)**

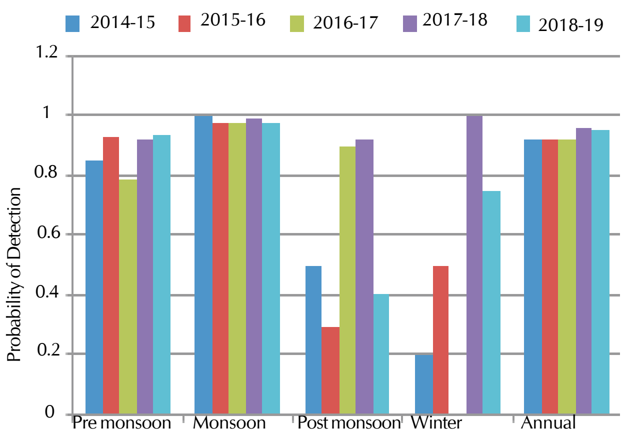

Figure 4: Seasonal qualitative analysis of daily rainfall forecast based on Probability of Detection (POD)

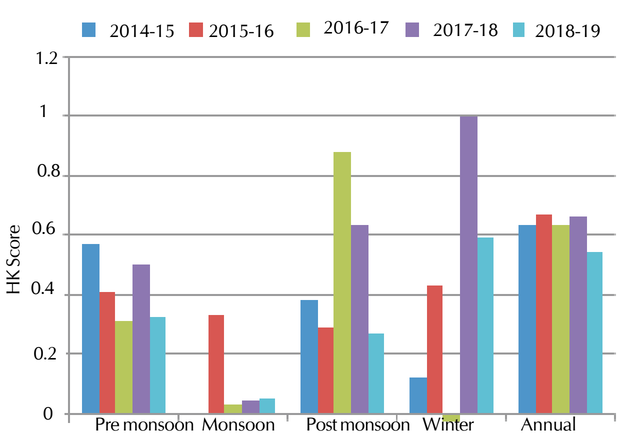

Figure 5: Seasonal qualitative analysis of daily rainfall forecast based on Hanssen and Kuipers Score (HKS)

in the winter season during 2017-18 year.

Rainfall

The verification of rainfall forecast for seasonal usability and correctness indicated that during pre-monsoon, post-monsoon

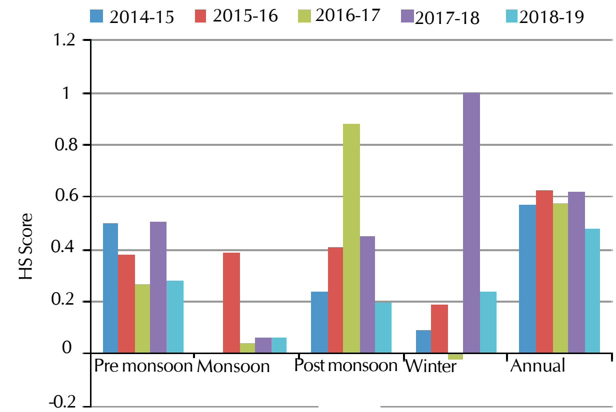

Figure 6: Seasonal qualitative analysis of daily rainfall forecast based on Heidke Skill Score (HSS)

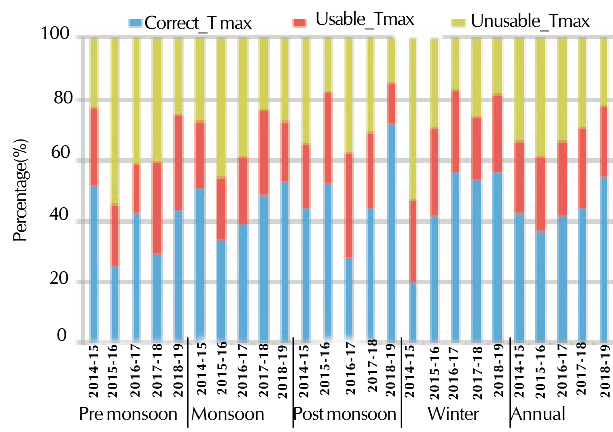

Figure 7: Seasonal verification of daily maximum temperature forecast during March, 2014 to February, 2019

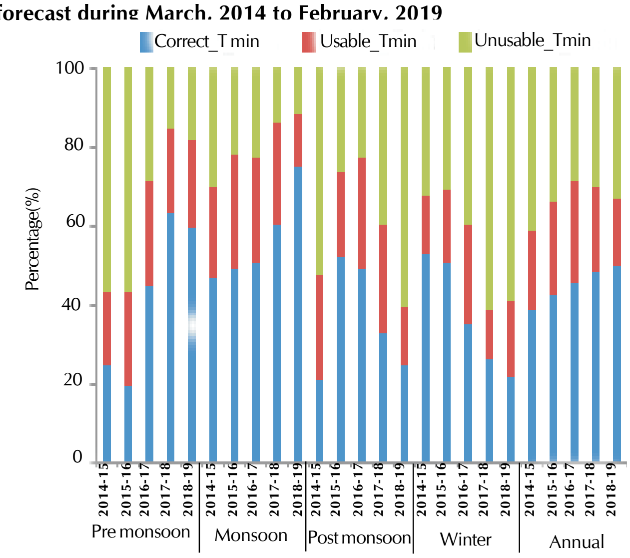

Figure 8: Seasonal verification of daily minimum temperature forecast during March, 2014 to February, 2019

and winter season the usability of forecast was excellent with usability percentage varied from 58.7 to 80.6 per cent, 82.6 to 100 per cent and 97.2 to 100.0 per cent (Table 1) with RMSE 13.5 to 20.8, 2.3 to 17.9 and 0.6 to 3.1 (Table 2), respectively.

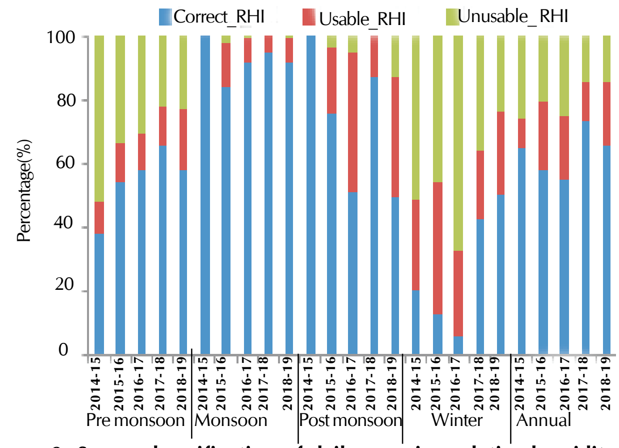

Figure 9: Seasonal verification of daily morning relative humidity during March, 2014 to February, 2019

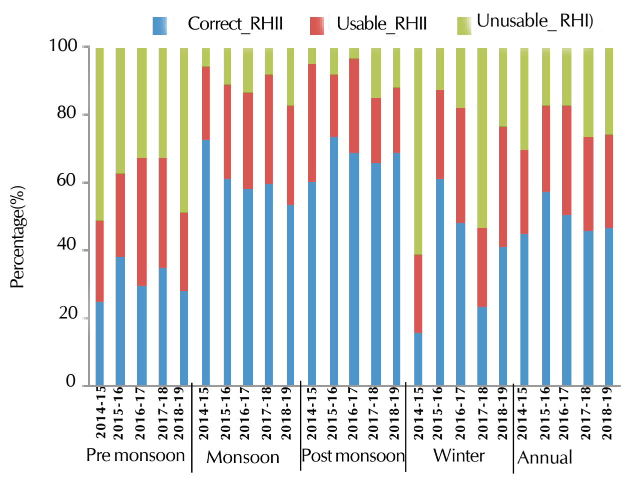

Figure 10: Seasonal verification of daily afternoon relative humidity forecast during March, 2014 to February, 2019

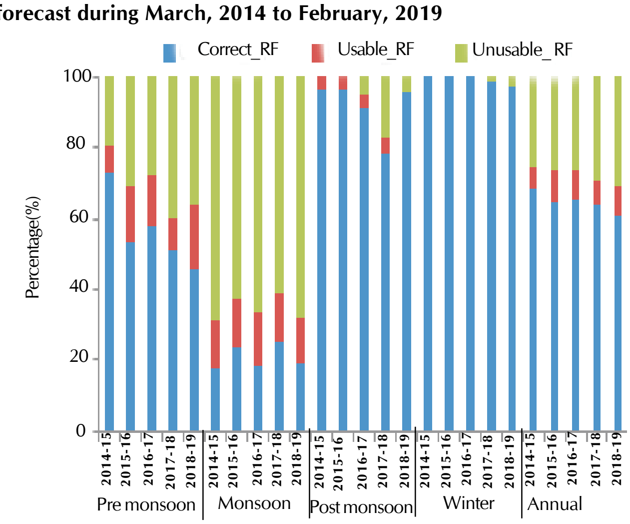

Figure 11: Seasonal verification of daily rainfall forecast during March, 2014 to February, 2019

However, in the peak rainfall receiving season *i.e.* monsoon relatively lower usability percentage was recorded and was varies from 31.0 per cent in 2014-15 to 37.8 per cent in 2017-18 with RMSE values 44.4 and 45.2, respectively. In contrary, the un-usability of rainfall forecast was more during the monsoon season and it varies from 61.0 per cent in 2017-18 to 69.1 per cent in 2014-15 year. Thus, the rainfall forecast during the monsoon season was found erratic and required enhancement in accuracy as it is the most important season for kharif crops in rainfed agricultural areas. During the pre-monsoon and post-monsoon season, un-usable percentage of forecast varies from 19.4 per cent in 2014-15 to 39.7 per cent in 2017-18 and 0 per cent in 2014-15 and 2015-16 to 17.39 per cent in 2017-18 respectively. Similarly, during the winter season, no un-usability percentage was recorded consecutively in first three years followed by 1.1 per cent in 2017-18 and 2.74 per cent in 2018-19 year. Thus, more accuracy in rainfall forecast was observed relatively in winter season followed by post-monsoon and pre-monsoon season. On an annual basis, the usability percentage for overall rainfall forecast was more than 70% except in the year 2018-19 (68.9%). The result is in consonance with the findings of the Chauhan *et al*. (2008) for the middle Gujarat region.

Similarly, correlation coefficients were also derived between the forecasted and observed values of rainfall for different seasons from March, 2014 to February, 2019 (Table 2) and highly significant association was observed in all the years during the pre-monsoon and monsoon season with correlation coefficient (r) varies from 0.29** (2017-18) to 0.64** (2014-15) and 0.20** (2015-16) to 0.48** (2017-18), respectively. However, non-significant correlation was observed during post-monsoon and winter season in the year 2015-16 (r = -0.01), 2018-19 (r = -0.03) and 2014-15 (r = -0.02), 2015-16 (r = 0.13), 2016-17 (r = -0.02), respectively since relative to monsoon and pre-monsoon season very less rainfall events were recorded during these two season over the region.

Maximum and Minimum temperature

The usability percentage of maximum and minimum temperature was depicted in the Table 1 and Fig. 7 and Fig. 8. The result revealed that the usability percentage of maximum temperature varies from 45.7 to 77.2 per cent with RMSE 2.08 to 2.90 during pre-monsoon; 54.1 to 76.2 per cent with RMSE 2.22 to 3.30 during monsoon; 62.3 to 85.2 per cent with RMSE 1.65 to 2.53 during post-monsoon and 46.7 to 83.3 per cent with RMSE 1.89 to 3.36 during winter season. The usability percentage was relatively more during the post-monsoon season followed by winter season. Similarly, correlation study was also conducted and found significant association between forecasted and observed maximum temperature in all the years during the monsoon (0.39** to 0.51**) and post-monsoon (0.26** to 0.76**) season. However, significant association was also recorded during pre-monsoon and winter season in four years except in 2015-16 (0.11) and 2014-15 (0.15), respectively. On annual basis usability of maximum temperature forecast was gradually improves since 2015-16 and highest in the year 2018-19 (77.5%) with lowest RMSE (2.17) and significant correlation coefficient (0.77**) (Table 1 and 2).

Similarly, the result of the usability analysis for minimum temperature stated a gradual improvement in the usability percentage during the monsoon season from 69.7 per cent with RMSE 2.11 in 2014-15 to 88.5 per cent with RMSE 1.40 in 2018-19 year (Table 1 and Table 2). The usability percentage for minimum temperature during pre-monsoon, post-monsoon and winter season varies from 43.5 to 84.8 per cent, 39.3 to 77.1 per cent and 38.9 to 69.2 per cent with RMSE value 1.75 to 3.44, 2.01 to 3.61 and 2.54 to 3.34, respectively. Thus, the usability percentage for minimum temperature was relatively more during the monsoon season followed by pre-monsoon season. Additionally, the result of the correlation study also revealed a significant association between forecasted and observed minimum temperature during all the seasons over all the years of observation (Table 2).

The overall results obtained represents a good forecast of temperature in all the seasons with relatively higher usability of maximum and minimum temperature during the post-monsoon and monsoon season, respectively. The advance information about any anomaly in the behaviour of maximum and minimum temperature during this period carries substantial agricultural concern as the period coincides with the reproductive stage of principle crop kharif rice over the region which influences the yield and yield attributing characteristics. Kaur and Singh (2019) also reported relatively higher usability percentage for maximum and minimum temperature during the post-monsoon season over the Kandi region of Punjab.

Morning and afternoon relative humidity

The result revealed that the seasonal usability percentage of morning relative humidity varies from 47.8 to 78.3 per cent with RMSE 3.43 to 4.98 during pre-monsoon; 98.4 to 100.0 per cent with RMSE 2.08 to 2.38 during monsoon; 86.8 to 100.0 per cent with RMSE 1.61 to 3.34 during post-monsoon and 32.2 to 76.6 per cent with RMSE 3.59 to 5.31 during winter season (Table 1 and Table 2). Similarly, correlation study was also conducted between forecasted and observed morning relative humidity found significant association in most of the years during the pre-monsoon (0.20* to 0.51**), monsoon(0.14 to 0.43**) and post-monsoon (0.08 to 0.36**) season and no significant association was recorded during the winter season (-0.09 to 0.12).Furthermore, the seasonal usability percentage of afternoon relative humidity varies from 48.9 to 67.4 per cent with RMSE 4.03 to 4.53 during pre-monsoon; 82.7 to 94.3 per cent with RMSE 2.76 to 3.47 during monsoon; 85.2 to 96.7 per cent with RMSE 2.73 to 3.20 during post-monsoon and 38.9 to 87.8 per cent with RMSE 3.14 to 4.88 during winter season (Table 1 and Table 2). Significant association was observed between forecasted and observed values during pre-monsoon (0.48** to 0.59**) and monsoon season (0.34** to 0.46**) in all the five years. The result revealed that overall usability percentage for morning and afternoon relative humidity was relatively more during monsoon and post-monsoon season in all the years under observations. The accuracy in humidity forecast during these seasons will help in understanding the evaporative requirement of atmosphere and also in scheduling the irrigation water in crop field during the dry periods. Similar types of results were also reported by the Sarmah *et al*. (2015) for relative humidity forecast for the north bank plain zone of Assam.

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