Vol. 23, No. 1, pp. 120-131 (2023)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Evaluation of Usability Gap of Medium Range Weather Forecast in Agriculture Risk Management in Central India

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ABSTRACT

The forecasted and observed daily weather data from 2011 to 2021 were evaluated using different verification criteria during sowing, reproductive and harvesting period during *kharif* and *rabi* seasons respectively at Tikamgarh. The ratio and threat scores varied from 0.31 to 0.77 and 0.31 to 0.68 respectively during *kharif* sowing. The root mean square (RMSE) error for maximum temperature was ranged from 0.24 to 3.6 and minimum temperature from 2.3 to 4.0 during *kharif* and *rabi* sowing periods. The usability percentage (correct + usable) of rainfall varied from 45 to 87 per cent during the *kharif* sowing period. The simple success of forecasted rainfall varied from 0 to 13 per cent during the sowing and from 0 to 64 per cent during the harvesting period of the *rabi* season. The usability of rainfall during the harvesting period of *kharif* and *rabi* varied from 9 to 79 and 96 to 100 respectively. Similarly, the usability of minimum temperature during the reproductive periods of *rabi* varied from 36 to 65. The RMSE of maximum and minimum temperature during reproductive, harvesting periods of *rabi* varied from 1.9 to 3.2 and 2.7 to 4.6. The minimum temperature usability was 17 to 66 and 35 to 65 per cent during the *rabi* sowing and reproductive period. It was found the usability percentage of rainfall during the *kharif* sowing and temperature during the *rabi* sowing were lower as compared to other crop growth stages. It was observed that ratio score is not the truly represent the rainfall forecast success as compared to true score. The lower accuracy limits the usability of weather forecasting in farm decision-making and thus the economic value too.

Key words: Weather forecast, Verification, Usefulness, Agromet advisory, Crop management

Introduction

Agriculture is highly exposed to weather and climate risks (Kumar, 2011; Schlenker and Lobell, 2010). Farmers are in search of appropriate options to minimize these risks to stabilize their farm income. The prior information about the behavior of weather parameters is not only useful but also economically beneficial for farmers in their day to-day crop management (Kushwaha *et al*., 2010). The weather forecast information is useful to undertake suitable strategic and tactical crop management operations (Rathore *et al*., 2001). The quantitative weather forecast provides choices to take decisions about whether to undertake or withhold the sowing, harvesting, irrigation, pesticide and insecticide operations (Rathore *et al*., 2009).Skillful weather forecasts offer an opportunity to minimize the input cost and maximize the income (Hansen, 2002).

Venkataraman (1992) has reported that many crops are highly sensitive to weather parameters throughout their growth, while many others are sensitive to weather parameters during certain growth stages. Therefore in this study, three important crop growth stages *i.e.* sowing, reproductive and harvesting, have been selected for different forecast verification and usability gap analysis. The critical

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crop growth stages (sowing, reproductive and harvesting) play an important role in crop production. Hence, efficient crop management decisions during these critical periods have significant impacts on crop yield. The weather forecast accuracy supports empathy for its utilization in tactical decisions taken by farmers to save their crops from aberrant weather and minimize their input cost. The weather forecast accuracy of medium range was studied by several authors (Tripathi *et al.*, 2008; Lunagaria *et al.*, 2009; Chaudhri *et al.*, 2010; Khichar *et al.*, 2010; Mishra *et al.*, 2010; Rathore, 2013) at annual and seasonal basis in different Agro-climatic zones of India. However, the purpose of weather usability verification does not provide good empathy for farmers and hence created a usability gap.

The value of forecasted weather enhanced; if it has capability to influence the farmers' decisions on key farm management operations (Gadgil *et al.*, 2002). It was observed from the literature survey that most of the studies have been performed to show the usefulness and economic benefits of the weather forecast at annual and seasonal basis. The accuracy of the weather forecast during critical crop growth stages (sowing, reproductive and harvesting), has not been attempted in India. Keeping this in view, the medium range forecast during sowing, reproductive and harvesting periods of *rabi* and *kharif* crops from 2011 to 2021 has been tested using different skills for its accuracy and usability at Tikamgarh district of Madhya Pradesh. In addition to the credibility of the weather forecast in general, farmers need precise weather forecast during the critical crop growth period, during which an appropriate decision has more economical value.

In this present investigation, the important weather parameters (rainfall, temperature and wind speed) were verified for the accuracy and usability of Tikamgarh district, situated in Bundelkahnd Agro-climatic Zone, of Madhya Pradesh in central India. The reported usability of the forecasted weather information in the farm decision is also discussed in this paper.

Materials and Methods

Tikamgarh district (24°38′ N lat., 77°75′ E long. and 345 meters above m.s.l.), of central India is a semi-arid region and has a monsoon climate with mild winters and hot summer. The coldest week and the hottest week have temperatures of 1.2°C and 47°C respectively. More than 85 percent of the annual rainfall is received during the monsoon season (June to September).

The quantitative values of different weather parameters *viz.,* amount of rainfall, maximum and minimum temperature, cloud cover, wind speed and direction of medium range scale (next 5 day forecast) were received from India Meteorological Department, New Delhi and Meteorological Center, Bhopal, twice (Tuesday and Friday) a week during the year. Both types of discrete as well as continuous weather variables are selected for the forecast verification analysis. The medium range weather forecast on rainfall (Rain), maximum temperature (Tmax), minimum temperature (Tmin) and wind speed (WS) from 2011 to 2021 was analyzed and compared with observed weather data. The analysis of the forecast verification was carried out for sowing (15^{th} June to 15^{th} July, 15^{th} October to 15^{th} November), reproductive (1^{st} to 31^{st} August, 1^{st} to 31^{th} January) and harvesting (1^{st} to 30^{th} September, 01^{st} March to 15^{th} April) period of *kharif* and *rabi* seasons. Four criteria were used to test the reliability of forecasted rainfall and they are: (1) Ratio score, (2) HK score or True score (3) HSS score and (4) Threat Score (Anonymous, 1999). The usability was tested compared to the of error structure given in Table 1. Weather forecast verification was carried out utilizing different skill scores and their formulas are given below:

Ratio Score

The ratio score measures the accuracy of a rainfall forecast out of total forecasts issued. The ratio score approaches to zero indicates imperfect forecast and close to 1 indicates perfect forecast. The ratio score varies from 0 to 1. It is calculated by using the equation given below:

$$\text{Ratio score} = \frac{\text{Correct forecast}}{\text{Total number}}$$

$$\text{Ratio score} = \frac{(YY+NN)}{n}$$

Where,

YY = nos. of case forecasted yes and observed yes

NN = nos. of case forecasted no and observed no

n = total nos. of observations

Heidke Skill Score (HSS)

This score provide information about the correct rainfall forecast and calculated by the formula given below:

[2(YY*NN)- (YN *NY)]/{(YY+NY) (NY+NN) + (YY+YN)(YN+NN)}

True Score or HK Score

True Skill Score or Hanssen and Kuipers Scores (HK Score): It is the ratio of economic saving over climatology due to the forecast to that of a set of perfect forecasts. The score varies between -1 and +1. Negative values indicates failure (Zero indicate no skill and positive values indicate success of forecast. If the HK score is closer to 1 the forecast is highly successful, if near to 0.5 it is fairly successful and if zero it is moderately successful and if negative the forecast is failure. It is calculated by the formula given below:

HK Score = [(YYxNN –YNxNY)]/[(YY+NY) (NY+ NN)]

Threat score (TS)

It is a measure of relative rainfall forecasting accuracy and is defined as the ratio of the number of hits to the number of events which occurred plus the number of false alarms (Schafer, 1990).

= YY/[NY+YN+YY]

Where,

YY-Predicted and observed rainfall

YN-Predicted but not observed rainfall

NY-Not predicted but observed rainfall

NN-Neither predicted nor observed

Root Mean Square Error (RMSE)

The root mean square error (RMSE) of forecasted weather parameters was worked out for the absolute error between observed and forecasted values. The lower values of RMSE indicate less difference between observed and forecasted values and are calculated by:

$$RMSE = [\sqrt{\Sigma(F-O)^2}]/n$$

Where,

F = forecasted value,

O = observed value,

n = number of observations

Usability

The critical value for error structure: The forecasted weather parameters viz., rainfall, temperature, and wind speed usability were analyzed by using Critical Value Error Structure as given in Table 1.

Total usability (%) = It is the sum of correct and usable percentages.

Results and Discussion

Different skill scores

The forecasts represent four types of verification events (hits, misses, false alarms and correct negatives), forming a 2×2 contingency table. A value greater than 1 means the event is over forecast, and a value below 1 means it is under forecast. Several scores to evaluate the forecast quality are generally used (Ratio score, threat score, true score, Heidke skill score, etc.). It was observed that these scores

Table 1. Criteria for error structure of the weather forecast were categorized as follow

Rainfall (difference between Obs-For)			Maximum Temperature	Minimum Temperature	Wind speed
	Obs<35mm	Obs>35mm			
Correct	±5mm	±10mm	≤1.0°C	≤1.0°C	Diff≤7.2kmph
Usable	±10mm	0.5obs<For<2*Obs	1.0°C diff≤2.0°C	1.0°C diff≤2.0°C	7.2≤Diff ≤14.4kmph
Unusable	otherwise	otherwise	Diff>2.0°C	Diff>2.0°C	Diff>14.4Kmph

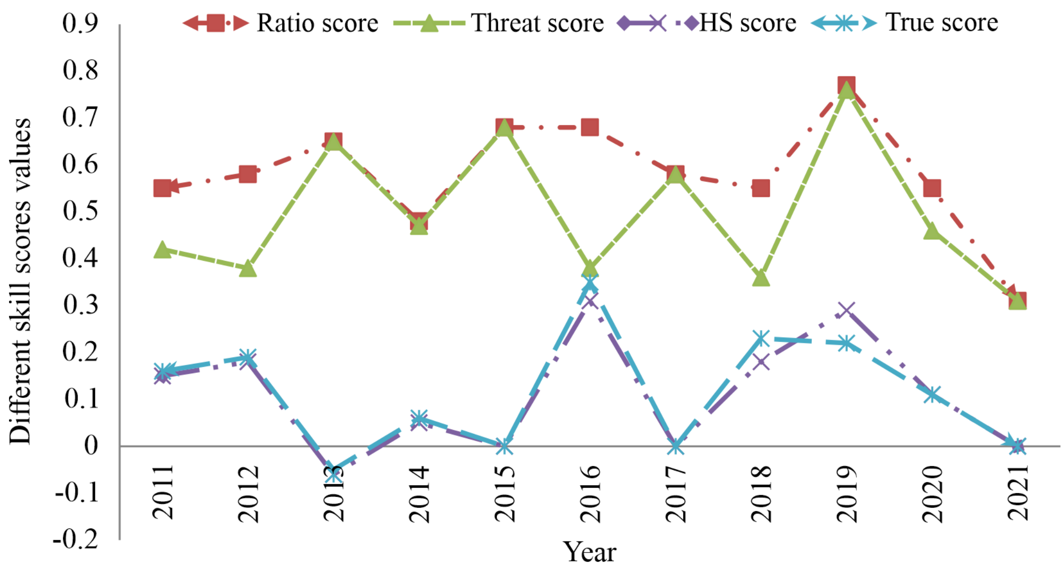

Fig. 1. Different skill scores during *kharif* sowing

approach zero or very small values for rare events (Stephenson *et al*., 2008).

The four skill scores during the *kharif* sowing period (15th June to 15th July) were computed and presented in Figure 1. It was observed that the ratio and threat scores followed almost similar trend. Similarly, the HSS and true scores are also followed a similar pattern. Therefore, only the two score, the ratio and true scores are selected for further analysis in this study.

Crop growth stage wise forecast verification

Sowing (Kharif : 15June to 15 July and rabi : 15 October to 30 November)

The simple success probability of different skills scores, RMSE and usability were analyzed during *kharif* and *rabi* sowing periods and are given in Table 2 (a-e). From Table 2a, it was observed that the simple success (yes or no basis) of the rainfall forecast varied from 10 to 76 per cent during *kharif* and 0 to 13 per cent during *rabi* sowing. Though the no rainfall forecast percentage was high during both the seasons. The rainfall forecast success above 50 percentage event per year was only 45 per cents (Table 2a) during *kharif* and 0.0 percent during *rabi*. However, the ratio score of rainfall forecast was high (0.55 to 1.00) during *rabi* and lower (0.31 to 0.77) during *kharif* sowing (Table 2b). It was found that the two rainfall forecast skills provide different results. But the true score and simple success percentage provide the similar results and thus do not contradicting each other. The root mean square error (RMSE) varied from 8.1 to 21.4 and 0.0 to 3.6 during *kharif* and *rabi* sowing period (Table 2c). This indicates that not only rainfall forecast success is low but also the differences between forecasted and observed values were higher during *kharif* sowing. The RSME vales of wind speed (WS) was also higher (7.5 to 15.7) during *kharif* and lower (3.1 to 7.0) during *rabi* sowing (Table 2c).

The correct and total usability percentage of rainfall (Rain), maximum temperature (Tmax.), minimum temperature (Tmin) and WS are shown in Table 2d and Table 2e. The correct forecast percentage of rainfall and WS were higher during *rabi* and lower during *kharif*. Similar trend was observed for total usability of rainfall, Tmax, and Tmin (Table 2e). The agromet advisory based on the moderately successful rainfall forecast during the sowing period may not have high economic value. Sahu *et al.* (2011), reported through 14 years of medium range weather forecast analysis that during the monsoon season rainfall varied from 29 to 90 per cent. They have also pointed out that during the monsoon season, the ratio score varied from 60 to 81 per cent, HK score from 0.19 to 0.68.

Table 2a. Simple success probability

Year	*Kharif*		*Rabi*	
	Rainfall forecast Success (%)	No Rainfall forecast Success (%)	Rainfall forecast Success (%)	No Rainfall forecast Success (%)
2011	48	70	0	98
2012	47	71	0	100
2013	67	0	0	100
2014	47	100	0	100
2015	68	0	0	100
2016	46	83	5	96
2017	58	0	0	100
2018	40	82	0	100
2019	76	100	0	100
2020	52	63	0	100
2021	10	0	13	94

Table 2b. Different skill score of rainfall

Year	*Kharif*		*Rabi*	
	Ratio score	True score	Ratio score	True score
2011	0.55	0.16	0.68	0.20
2012	0.58	0.19	1.00	0.00
2013	0.65	-0.05	1.00	0.00
2014	0.48	0.06	1.00	0.00
2015	0.68	0.00	0.83	0.00
2016	0.68	0.35	0.55	0.06
2017	0.58	0.00	1.00	0.00
2018	0.55	0.23	1.00	0.00
2019	0.77	0.22	0.98	0.00
2020	0.55	0.11	0.94	0.00
2021	0.31	0.00	0.83	-0.15

Table 2c. Root mean square error between forecasted and observed weather parameters

Year	Rain		Tmax		Tmin		WS	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
2011	8.6	3.6	3.5	2.7	2.4	3.2	8.7	3.1
2012	35.0	0.0	3.6	1.5	1.1	2.8	7.5	4.1
2013	18.2	0.0	3.4	1.4	3.0	2.7	14.2	3.9
2014	20.9	0.0	2.9	1.6	2.0	3.1	11.4	5.1
2015	7.7	2.9	2.7	1.5	3.2	2.6	12.4	4.2
2016	8.1	1.9	3.2	2.7	1.3	2.6	15.5	5.8
2017	21.4	0.0	3.3	1.3	1.9	3.4	12.8	4.3
2018	19.1	1.1	3.1	1.4	2.7	4.0	15.0	4.4
2019	13.8	0.1	2.4	1.8	2.0	2.3	15.4	6.2
2020	16.0	0.3	2.6	1.5	2.1	2.4	14.8	6.6
2021	10.9	1.8	3.1	2.1	2.4	2.9	15.7	7.0

Table 2d. Correct percentage of forecasted weather parameters

Year	*Kharif*				*Rabi*			
	Rain	Tmax	Tmin	WS	Rain	Tmax	Tmin	WS
2011	61	19	45	32	88	36	32	98
2012	32	23	75	10	95	43	32	100
2013	65	23	23	00	100	51	11	100
2014	13	35	32	06	100	53	30	89
2015	77	29	19	00	94	62	38	96
2016	52	42	58	00	98	49	36	77
2017	26	23	42	00	100	55	11	96
2018	26	48	19	00	100	56	04	94
2019	52	39	65	00	100	53	34	83
2020	61	37	35	00	100	49	34	81
2021	42	25	41	05	96	60	26	74

Table 2e. Total usability percentage of forecasted weather parameters

Year	*Kharif*				*Rabi*			
	Rain	Tmax	Tmin	WS	Rain	Tmax	Tmin	WS
2011	87	39	61	74	87	59	62	100
2012	61	55	94	45	98	90	51	100
2013	75	68	42	03	100	89	37	100
2014	55	55	71	19	100	85	45	98
2015	87	75	38	10	100	77	64	100
2016	84	62	74	06	100	68	51	100
2017	45	45	61	03	100	85	26	100
2018	52	65	51	00	100	85	17	100
2019	65	65	84	03	100	85	66	100
2020	67	77	77	00	100	85	60	100
2021	58	67	71	05	100	81	45	100

Reproductive (kharif :1 to 31 August and rabi: 1 to 31 January)

The simple success rainfall forecast was the highest (45 to 84) during *kharif* reproductive period (Table 3a), the forecast above 50 per cent/ year events was 90 per cent events. Similarly, the simple success of no rainfall forecast was very high (89 to 100), during the *rabi* reproductive period (Table 3a). The true score values were lower (-5.5 to 0.0) during *kharif* and high (0.0 to .90) during *rabi*. The RMSE values of rainfall were the lowest (0.0 to 6.7) during *rabi* and the highest (14.1 to 32.0) during *kharif* (Table 3c) period.

The correct rainfall forecast percentage was found to be high (87 to 100) during *rabi,* while it varied from 20 to 97 per cent during *kharif*. The correct forecast was observed very low (06 to 48) during *rabi* and higher during *kharif* reproductive period (Table 3d). The total usability of rainfall was noted as higher percentage during *kharif* as well as *rabi* and varied from 35 to 97 and 95 to 100 respectively (Table 3e). It was noted that total usability for both Tmax and Tmin were higher and varied from 33 to 90 and 57 to 100 per cent respectively during *kharif*. It is interesting to note that the WS has 100 usability during reproductive (Table 3e) as well as harvesting period (Table 4e). The total usability percentage of Tmax and Tmin greater than 50 percent /per year basis was only 45.4 and 27.2 percent events during the *rabi* reproductive period (Table 3e). Chatham *et al.* (2008) found that

Table 3a. Simple success probability

Year	*Kharif*		*Rabi*	
	Rainfall forecast Success (%)	No rainfall forecast Success (%)	Rainfall forecast Success (%)	No rainfall forecast Success (%)
2011	68	00	100	97
2012	65	00	38	96
2013	74	00	20	100
2014	45	100	00	100
2015	58	00	00	100
2016	55	00	33	100
2017	57	100	34	89
2018	68	00	45	90
2019	71	00	00	100
2020	84	00	25	100
2021	54	100	00	100

Table 3b. Different skill score of rainfall

Year	*Kharif*		*Rabi*	
	Ratio Score	True Score	Ratio Score	True Score
2011	0.68	0.00	0.97	0.00
2012	0.65	0.00	0.90	0.90
2013	0.74	0.00	1.00	0.00
2014	0.29	-0.55	0.74	0.46
2015	0.58	0.00	0.68	0.35
2016	0.55	0.00	0.87	0.86
2017	0.55	-0.43	0.94	0.00
2018	0.68	0.00	1.00	0.00
2019	0.71	0.00	0.87	0.87
2020	0.84	0.00	0.81	0.56
2021	0.41	-0.46	0.97	0.50

Table 3c. Root mean square error between forecasted and observed weather parameters

Year	Rain		Tmax		Tmin		WS	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
2011	14.1	0.9	1.6	3.4	1.1	4.2	6.1	5.4
2012	17.7	1.5	2.3	2.8	1.5	3.3	8.7	2.1
2013	23.1	0.0	2.8	3.6	1.6	5.5	9.4	5.1
2014	19.2	6.7	2.3	4.0	1.5	2.5	8.9	4.9
2015	15.9	5.2	1.6	4.7	1.2	3.5	13.9	5.3
2016	32.0	1.6	1.7	2.4	1.4	3.6	11.1	4.5
2017	14.4	1.9	1.4	4.3	1.5	3.2	11.7	4.7
2018	16.7	0.0	1.9	1.9	1.2	2.9	13.2	3.8
2019	27.0	1.4	1.9	3.7	1.5	3.1	13.3	7.2
2020	16.0	3.0	2.1	2.5	1.1	3.6	12.7	8.2
2021	22.2	0.7	2.4	2.4	1.2	3.4	13.6	7.9

Table 3d. Correct percentage of forecasted weather parameters

Year	*Kharif*				*Rabi*			
	Rain	Tmax	Tmin	WS	Rain	Tmax	Tmin	WS
2011	60	40	77	70	100	23	32	94
2012	53	20	70	73	97	13	16	100
2013	52	23	83	33	100	25	23	97
2014	97	60	70	23	94	23	39	97
2015	63	47	63	20	87	26	13	87
2016	80	46	23	00	97	39	29	94
2017	43	63	53	33	96	06	16	97
2018	77	43	50	00	100	45	26	90
2019	63	33	37	53	100	26	39	55
2020	20	55	80	05	94	36	23	45
2021	45	53	74	07	100	48	26	46

Table 3e. Total usability percentage of forecasted weather parameters

Year	*Kharif*				*Rabi*			
	Rain	Tmax	Tmin	WS	Rain	Tmax	Tmin	WS
2011	83	65	87	57	100	55	52	100
2012	80	70	90	67	100	52	42	100
2013	73	63	97	50	97	35	36	100
2014	97	33	100	60	95	42	65	100
2015	86	80	90	53	100	29	36	100
2016	90	64	93	50	97	65	52	100
2017	76	77	63	17	100	16	39	100
2018	94	90	90	56	100	80	49	100
2019	80	63	87	23	100	49	65	100
2020	40	76	57	73	97	52	35	100
2021	35	77	93	54	100	74	42	100

there was no significant correlation was observed between observed and forecasted rainfall during the sowing period and maximum temperature during reproductive and harvesting periods.

Harvesting (kharif: 1 to 30 September and rabi: 15 March to 15 April)

The simple success of forecasted rainfall above 50 per cent/year during the harvesting periods was only 27.2 and 10 per cent during *kharif* and *rabi* respectively. This was also reflected in true score values and all the values of *kharif* and *rabi* have negative values (Table 4b). It indicates the total failure of the economical rainfall forecast over climatological. The RMSE vales of rainfall during *kharif* varied from 3.1 to 18.7(Table 4c). However, the total usability of rainfall has high values (40 to 97) during *kharif* and it was 100 percent during *rabi* (Table 4e). Similarly, the correct rainfall forecast was higher (20 to 97) during *kharif* and 96 to 100 percent during *rabi*.

The above results indicate that the forecasted weather parameters skill during the critical crop growth periods were low for example, the rainfall during *kharif,* sowing and reproductive period and temperature during *rabi,* sowing and reproductive period. However, their total usability was noted to be very high. Their RMSE values were also high. The present analysis shows that not only correct forecasted weather has the lower success percentage;

Table 4a. Simple success probability

Year	*Kharif*		*Rabi*	
	Rainfall forecast Success (%)	No rainfall forecast Success (%)	Rainfall forecast Success (%)	No rainfall forecast Success (%)
2011	79	100	00	100
2012	60	100	00	100
2013	47	55	50	100
2014	12	100	20	95
2015	25	83	22	89
2016	45	100	64	81
2017	09	79	00	98
2018	36	100	50	98
2019	36	100	00	95
2020	77	100	22	96
2021	05	10	50	93

Table 4b. Different skill score of rainfall

Year	*Kharif*		*Rabi*	
	Ratio Score	True Score	Ratio Score	True Score
2011	0.6	-0.2	0.00	-1.00
2012	0.3	-0.6	0.00	-1.00
2013	0.2	-0.7	0.04	-0.50
2014	0.3	-0.6	0.07	-0.75
2015	0.2	-0.6	0.17	-0.67
2016	0.1	-0.9	0.09	-0.79
2017	0.5	-0.1	0.02	-0.98
2018	0.4	-0.4	0.04	-0.48
2019	0.8	0.3	0.04	-0.95
2020	0.2	-0.8	0.11	-0.74
2021	0.5	-0.5	0.09	-0.43

Table 4c. Root mean square error between forecasted and observed weather parameters

Year	Rain		Tmax		Tmin		WS	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
2011	7.0	1.0	2.0	2.3	1.3	2.7	4.6	5.7
2012	18.7	0.2	2.2	2.2	1.1	4.0	6.5	4.7
2013	11.0	1.1	2.9	1.9	0.8	3.3	6.6	3.7
2014	3.1	0.9	1.7	2.5	1.1	4.1	7.0	4.5
2015	7.2	3.5	1.9	3.0	1.2	3.7	6.5	7.3
2016	8.4	1.3	2.1	2.2	2.4	4.6	10.1	7.5
2017	12.0	1.1	1.6	3.2	1.4	4.5	8.7	7.3
2018	9.6	0.3	2.5	2.2	1.4	2.7	9.2	5.8
2019	11.2	0.8	2.6	2.5	2.6	4.5	7.0	8.9
2020	13.7	1.5	1.9	2.0	1.1	4.1	7.0	8.6
2021	6.8	0.3	1.3	2.7	1.2	4.2	10.9	8.7

Table 4d. Correct percentage of forecasted weather parameters

Year	*Kharif*				*Rabi*			
	Rain	Tmax	Tmin	WS	Rain	Tmax	Tmin	WS
2011	60	40	77	70	100	48	31	91
2012	53	20	70	73	100	54	23	96
2013	53	23	83	33	98	35	28	100
2014	97	60	70	23	98	33	10	98
2015	63	47	63	20	96	22	09	85
2016	80	47	23	00	98	17	16	59
2017	43	63	53	33	98	26	20	67
2018	77	43	50	00	100	35	28	83
2019	63	33	37	53	100	41	13	33
2020	20	53	80	07	98	52	17	26
2021	25	49	75	11	100	35	07	59

Table 4e. Total usability percentage of forecasted weather parameters

Year	*Kharif*				*Rabi*			
	Rain	Tmax	Tmin	WS	Rain	Tmax	Tmin	WS
2011	83	70	90	87	100	72	48	100
2012	80	63	97	90	100	71	30	100
2013	73	33	100	60	100	76	43	100
2014	97	80	90	53	100	55	30	100
2015	86	64	93	50	100	61	37	96
2016	90	77	63	17	100	60	33	100
2017	76	90	90	56	100	56	41	100
2018	94	63	87	23	100	65	43	100
2019	80	76	57	73	100	48	20	100
2020	40	77	93	54	100	78	28	100
2021	48	68	79	61	100	70	17	92

though the accuracy is required to be high to have economic gain. Therefore, the criteria fixed for total usability percentage must be modified. This was also stated by Anonymous (1999) and justified the changes in critical scores of error structure with time.

From the above results, it was noted that the RMSE and correct percentage of rainfall forecast during *kharif* was high and low respectively as compared to *rabi* season. It seems that the model used for rainfall forecast may be more biased towards a successful no rainfall forecast.

From the forgoing results; it may be concluded that the usability, accuracy and reliability of important weather parameters during critical crop stages for example, rainfall and maximum temperature during *kharif* sowing and minimum temperature in *rabi* sowing have lower correctness. Therefore, there is a need to be improved in weather forecasting, especially with respect to the rainfall because this is the most important weather parameter, which influences other parameters and thus be used to facilitate the farmers to make useful decisions on crop management operations.

Forecast usability and Economic impact

The method of economic impact assessments was generally based on a questionnaire based feedback survey (Rathore and Maini, 2008), which may not demarcate the economic impact is either due to forecasted weather information based advisories use or due to use of general recommendation of agro advisory. Therefore, to assess the economic impact, experimental trials at research farms and in the farmer's field may be undertaken and evaluate both the impact of malevolent and benevolent weather forecast at critical crop growth stages . To assess the precise benefit of the use of forecasted weather information, field experimental results may be obtained rather than the results obtained by a questionnaire based survey. Mostly, the medium range weather forecast (MRWF) and daily observed weather has shown a marginal deviation and in the existing system to formulate the agro met advisory (AAB), there is no specific way to quantify the impact of the marginal deviation from observed; on the specific crop at specific stage at a place. The marginal deviations between observed and forecasted weather; contributing to altering a decision are seldom described and how they are beneficial or usable, still a question. This is illustrated by an example, suppose a MRWF of dry weather with 1 to 2 degrees Celsius increase in maximum and minimum temperature along with a decrease in wind speed by 2 kmph. If a decision based on this MRWF may be recommended then how much its influence on crop growth and development is still not clear. This is argued by earlier worker also. Lal *et al*. (1994) stated that MRWF may not significantly influence irrigation decisions. The weather forecasts are the critical variable affecting tactical decisions, if usable the criteria on decision-making and only when there is no constraints for its implementation. The constraints are availability of advised seed, irrigation water, fertilizer, pesticides, and insecticides etc. in the local market on a real-time basis. Suppose that there may be availability of the advised items in the local market and within the reach of the farmers, the historical data can be used to examine the extent to which the forecasted weather information actually affects the tactical farm decisions (Lal *et al*., 1994). The lower weather forecast accuracy of important weather parameters at different crop growth stages may have also influenced the farmers' tactical decisions.

Conclusions

The usability of weather forecasts was less useful and their usability in tactical decisions during critical crop growth periods was also lower. The credibility for its utilization in cultural operations by farmers may be enhanced if important weather forecasted parameters are more accurate. The quantitative forecasting during sowing, reproductive and harvesting crop period needs to be more precise. There is a need to modify the error structure for the weather forecast usability test. A decreased percentage in precise forecasting during critical crop growth stages of *kharif* and *rabi* seasons creates different perceptions and understandings that create the usability gap, which reflects in the low level of utility of weather forecast in the crop management. The models used for rainfall forecasting are biased towards a successful, no rainfall forecast. To take tactical decisions during the critical crop growth periods, usability gaps also impacts on user's empathy. There is need for further improvement in medium range weather forecasting, as well as on research for its better applicability in farmers' fields.

Acknowledgment

The authors are highly thankful to the Ministry of Earth Sciences and India Meteorological Department (IMD), New Delhi for financial support for the establishment of the Agro meteorological Field Unit at Tikamgarh and providing the medium range weather forecast through the project GRAMIN KRISHI MAUSAM SEWA at Tikamgarh.

References

Anonymous. 1999. Verification of medium range weather forecast. In: *Guide for agrometeorological advisory service*. (Eds.S.V.Singh, L.S.Rathore and H.K,N,Trivedi). pp.73-93, DST, NCMRWF, New Delhi.

Chatham, Vikram, Singh, Chaudhari, Ganesh, B. and Pandey, Vyas. 2008. Medium range weather forecast verification for middle Gujarat region. *Journal of Agrometeorology (Special issue - Part I)*: 90–93.

Chaudhari, J.N., Zagada, M.V., Mahadkar, U.V. and Talathi, M.S. 2010. Assessment of weather based agromet advisories in the high rainfall zone of Konkan in Maharastra. In: Proc. of the Nation seminar on "Agrometeorological Services for Farmers" held at Anand Agricultural University, Gujrat between 10-13 November, 2008, 172-179.

Gadgil, S., Seshagiri Rao, P.R. and Narahari, K. 2002. Use of climate information for farm-level decision-making: rainfed groundnut in southern India. *Agricultural Systems* **74**(3): 431–457.

Hansen, J.W. 2002. Realizing the potential benefits of climate prediction to agriculture: issues, approaches & challenges. *Agricultural Systems* **74**: 309-330.

Khichar, M.L., Singh, Diwan and Ram Niwas. 2010. Verification of medium range weather forecast for Western zone of Haryana, In: *Agro meteorological services for farmers.* (ed. Vyas Pandey), 195-200.

Kumar, K.S.K. 2011. Climate sensitivity of Indian agriculture: Do spatial effects matter?. *Cambridge Journal of Regions, Economy and Society* **4**(2): 221–235.

Kushwaha, H.S., Mehra, M., Rai, H.K. and Singh, R.S. 2010. Economic impact analysis of agro-meteorological services for farmers of Tarai and Bhabar Agro-climatic zone of Uttarakhand. In:Proc. Nation seminar on Agrometeorological Services for Farmers held at Anand Agricultural University, Gujrat during 10-13 November, 2008, 187-194.

Lal Haji, Rao, N.H. and Sarma, P.B.S.1994. Can medium range weather forecasts influence irrigation scheduling?. *Current Science* **60**(1): 60-63.

Lunagaria, Mishra, M.M. and Pandey, S.K. 2009. Verification and usability of medium range weather forecast for Anand region. *Journal of Agrometeorology (Special issue)* **11**: 228-233.

Mishra, S.K., Tripathi, P., Mishra, S.R. and Mishra, A.N. 2010. Seasonal verification of scores for medium range weather forecasting for Eastern Uttar Pradesh, *In Proc: Agro meteorological services for farmers, (ed. Vyas Pandey)*, AAU, Anand, 201-209.

Rathore, L.S. and Parvinder Maini. 2008. Economic impact assessment of agro meteorological advisory service of NCMRWF, Report no. NMRF/PR/01/2008, 2008, p104.

Rathore, L.S., Bhowmik, S.K. Roy and Chattopadhyay, N. 2009. Integrated Agromet Advisory Services in India, *Challenges and Opportunities in Agrometeorology.* Springer Publication, New York, 195-205.

Rathore, L.S., Gupta, Akhilesh and Singh, K.K. 2001. Medium range weather forecasting and agricultural production. *Journal of Agricultural Physics* **1**(1): 43-47.

Rathore, L.S. 2013. Weather information for sustainable agriculture in India. *Journal of Agricultural Physics* **13**(2): 89-105.

Sahu, D.D., Chopada, M.C. and Kacha, H.L. 2011. Verification of medium range rainfall forecast under south Saurashtra agro climatic zone, Gujarat. *Journal of Agrometeorology* **13**(1): 65-67.

Schafer, J.T. 1990. The critical success index as an indicator of warning skill. *Weather & Forecasting* **5**: 570-575.

Schlenker, W. and Lobell, D.B. 2010. Robust negative impacts of climate change on African agriculture. *Environmental Research Letters* **5(**1): 14010, doi: 10.1088/1748-9326/5/1/014010

Stephenson, D.B., Casati, B., Ferro, C.A.T. and Wilson, C.A. 2008. The extreme dependency score: a non-vanishing measure for forecasts of rare events. *Meteorol. Appl.* **15**: 41-50.

Tripathi, P, Mishra, S.R. and Mishra, S.K. 2008. Verification analysis of success probability and usability of medium range weather forecasting in Eastern U.P. *Int. J. Agric. and Stat. Sci*. 4: 437-46.

Venkataraman, S. 1992. Weather relations of crops, (*In:* Crops and weather; Eds: Venkataraman, S. and A. Krishnan). Indian Council of Agricultural Research, New Delhi, 302-457.

Received: December 21, 2022; Accepted: March 13, 2023