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RESEARCH ARTICLE

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Validation of medium range weather forecast for Keonjhar district of Odisha

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ABSTRACT : The validity of medium range weather forecast issued from National Centre for Medium Range Weather Forecast (NCMRWF) on various weather parameters for Keonjhar district of Odisha state during the period 2015 is discussed in this paper. The validity of weather forecast for monsoon and post-monsoon season was tested separately with real time data observed from station observatory. The ratio scores on Yes/No basis *viz.*, Forecast Accuracy (ACC), Critical Success Index (CSI), Heidke Skill score (HSS), Hansen and Kuiper's (HK) scores were used for testing of only rainfall prediction. The predicted rainfall on Yes/No basis for the total seasons was 85.1 per cent correct, whereas it was 92.1 per cent correct for monsoon and 88.6 per cent correct for pre- monsoon period. The weather forecast for other parameters was tested with Critical Values for Error Structure as suggested by NCMRWF. On annual basis, the prediction of cumulative rainfall (84.6%), rainfall (77.7%), Total cloud cover (61.6 %), and Tmin (52.2 %) were having maximum correct events, whereas the predicted Wind direction (63.2 %), RH I (36.3%) and Wind speed (35.0 %) were having maximum number of failure events. On seasonal basis, the predictions for rain (83.5%), Cumulative rainfall (79.6%), wind speed (44.8 %) and total cloud cover (44.6%) during monsoon period and cumulative rainfall (88.7%), rainfall (84.9%), wind speed (51.2%), and Tmin (50.4%) during pre- monsoon period were having higher percentage of correct events. However, the wind direction (71.1%) and RH II (60.6%) during monsoon and wind direction (53.6 %) and RH II (52.9%) during post monsoon period were having maximum number of failure events. The value (0.89) of co-efficient of determination (r^2) for rainfall during monsoon period indicated that the values of predicted rainfall were almost matching with the observed ones. It means that prediction of rainfall are near to accurate. The values of co-efficient of determination $r^2 = 0.93$ in the regression analysis during pre monsoon period indicated accuracy in prediction of minimum temperature. The accurate weather forecasting with respect to various weather parameters is important as this can be used to facilitate the farmers to make broad decision on the crop management operations.

KEY WORDS : Weather forecast, Validity testing, Ratio scores, NCMRWF

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INTRODUCTION

Agricultural productivity largely depends upon weather. Out of the total annual crop losses, a substantial portion is because of aberrant weather. The loss could be minimized by making adjustment with coming weather through timely and accurate weather forecasting. Agricultural operations can be advanced or delayed with the help of advanced weather forecast from three to ten

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days. An agriculturally relevant forecast is not only useful for efficient management of farm inputs but also leads to precise impact assessment (Gadgil, 1989). Weather forecasts in all temporal ranges are desirable for effective planning and management of agricultural practices. The development of response strategy (Stewart, 1988) helped farmers realize the potential benefits of using weather-based agrometeorological information in minimizing the losses due to adverse weather conditions, thereby improving yield, quantity and quality of agricultural productions. In fact, short and medium-range weather forecasts play a significant role in making short-term adjustments in daily agricultural operations. Some of the early works that appeared in the late 1960s concentrated on effectiveness of agrometeorological information (Bagrov, 1966; Ehrendorfer and Murphy, 1987 and Gandin and Zhukovsky, 1972). From a farmer's perspective, the forecast value increases if the weather and climate forecasts are capable of influencing their decisions on key farm management operations (Everingham *et al.*, 2002; Gadgil *et al.*, 2002 and Ingram *et al.*, 2002). Thus, it becomes essential to relate with the requirements of farmers (Hansen, 2002), understand their needs and give the forecast in appropriate spatial and temporal range (Hammer *et al.*, 2001; Hansen, 2002; Nicholls, 1991 and Nicholls, 2000). This ultimately helps in increasing the reliability of the forecast and thus in better adoption of the weather-based advisory (Stone and Meinke, 2006). Therefore the importance of forecast evaluation for scientific, administrative and economic purposes (Panofsky and Brier, 1958) has been widely accepted (Brier and Allen, 1952 and Dobryshman, 1972).

Gramin Krishi Mausam Sewa (GKMS) is the sponsored scheme by the India Meteorological Department, Ministry of Earth and Science, New Delhi. It is functioning at Regional Research and Technology Transfer Station, Keonjhar since August 2004. GKMS at Keonjhar is the major centre functioning for North Central Plateau zone of Odisha Having two districts *viz.*, Keonjhar and Mayurbhanj in its jurisdiction. The five-day weather forecast is received through e mail from the IMD on every Tuesday and Friday. It consists of eight weather parameters *viz.*, rainfall (daily and cumulative), wind speed (kmph), wind direction (degrees), change in maximum and minimum temperatures, relative humidity morning and afternoon (%). Once the forecast is received, the experts' opinion from different disciplines is obtained. Based on the advice, the agro advisories are being prepared on every Tuesday and Friday in Odiya as well as in English. These advisories are sent to IMD for preparation of national bulletins and are uploaded on the IMD website in both Odiya and English. Bulletins are regularly communicated to the farmers on real time basis through telephone/ E-mail/SMS. Agro-met advisory bulletins are also sent by E-mail to local Odiya newspapers for publication and uploaded at the websites in both Odiya and English. The bulletins are also sent to, KVK Mayurbhanj, KVK Keonjhar, NGOs, ATMA, State Agriculture offices, DPME, District Agriculture offices, Block level Offices, Krishi Darsan, Annadata, ETV odiya, Different local Newspapers and All India Radio etc. through E-mail messages. The advance knowledge of weather and the action plan suggested is important for the farmers for their farm planning. However its success, depends on the reliability of weather forecast issued by the IMD. The present study deals with the validity testing of weather forecast received from IMD with real time data observed from the station observatory. In this paper an attempt has been made to verify the reliability and suitability of the medium range weather forecasts.

EXPERIMENTAL METHODS

The medium range forecast issued by India Meteorological Department, New Delhi on various weather parameters *viz.*, cloud cover (octa), rainfall (daily and cumulative), wind speed (km/h), wind direction (degrees), change in maximum and minimum temperatures for monsoon (June to September) and post monsoon (October to December) period for the Keonjhar district was compared with the observed values of the respective weather parameters recorded at the Meteorological Observatory located at Regional Research and Technology Transfer Station (RRTTS), Keonjhar under Orissa University of Agriculture and Technology, Odisha. Different verification methods were used to assess the reliability of forecast values of weather parameters. The forecast of rainfall, cloud cover, temperature and direction have been verified by calculating the error structure and used to categorize the forecast given as correct, usable or unusable based on the per cent deviation in the forecast values as compared to observed values as per the guidelines of National Centre for Medium range weather Forecasting

(NCMRWF) (Anonymous, 1999). The correct and usable cases were summed up and the combined values indicate the per cent usability of the forecasts of various parameters to the total events occurred in respective parameter. The verification of weather forecast given was done for four seasons *viz.*, pre-monsoon (April to May), monsoon (June-September), Post-monsoon (October to December) and winter (January and March) as per the guidelines of NCMRWF (Anonymous, 1999). The methods adopted for verification are given as below:

Discrete variable:

The rainfall is a categorical or discrete variable, verified by using the contingency table approach (Murphy and Winkler, 1987; Murphy *et al*., 1989 and Schafer 1990). It gives information about the skill of forecast as well as types of errors that occurs in the forecast. The ratio score (Y/N basis), Critical Success Index (CSI), Heidke Skill Score (HSC) and Hansen and Kuipers Score (HKS) are adopted for verification of predicted rainfall.

– Forecast Accuracy (ACC) or Ratio Score or Hit Score: It is is the ratio of correct forecasts to the total number of forecasts.

$$\mathbf{ACC} = \frac{\mathbf{Correct\ forecast}}{\mathbf{Total\ forecast}} = \frac{\mathbf{YY + NN}}{\mathbf{YY + NN + YN + NY}}$$

– Critical Success Index or Threat Score (CSI): It is a measure of relative 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).

$$\mathbf{CSI} = \frac{\mathbf{YY}}{\mathbf{YY + NY + YN}}$$

– Heidke Skill Score (HSS): It accounts for all correct forecasts that would be made due to chance.

$$\mathbf{HSS} = \frac{\mathbf{(NN * YY) - (NY * YN)}}{\mathbf{[(NN + YN)(YN + YY) + (NN + NY)(NY + YY)]/2}}$$

– Hanssen and Kuipers Scores or True Skill Score (HK Score): It is the ratio of economic saving over climatology due to the forecast to that of a set of perfect forecasts.

$$\mathbf{HK} = \frac{\mathbf{(NN * YY) - (NY * YN)}}{\mathbf{[(NN + NY)(YN + NY)]}}$$

where,
YY-Predicted and observed rainfall
YN-Predicted but not observed rainfall
NY-Not predicted but observed rainfall
NN-Neither predicted nor observed

Critical value for error structure:

The weather parameter *viz.*, Tmax, Tmin, wind speed, wind direction and cumulative rainfall forecasted from NCMREF were analysed by using Critical Value Error Structure as given in Table A.

Regression analysis :

The regression analysis between was carried out between observed as a dependent variable (Y) and predicted weather parameters as an independent variable (X). The co-efficients of correlation (r), co-efficient of determination (r^2), root mean square error (RMSE) were worked out for each weather parameters.

Correlation co-efficient :

$$\mathbf{r(f, o_i)} = \frac{\mathbf{\Sigma (f_i - f)(o_i - o)}}{\mathbf{[\Sigma (f_i - f)^2 (o_i - o)^2]^{1/2}}}$$

Root mean square error :

$$\mathbf{RMSE} = \left[\frac{\mathbf{1}}{\mathbf{n}} \Sigma (\mathbf{f_i - o_i})^2\right]^{1/2}$$

where
f_i = Forecast value
f= Mean forecast value
o_i = Observed value
o= Mean observed value
n= Total number of observations / forecast.

Table A : Critical values for error structure as suggested by NCMRWF

Parameter	Cum rainfall	Temperature	Wind speed	Wind direction
Correct (C)	-10 to +10 mm variation	1^0C variation	3	-45^0 to $+45^0$ variation
Usable (U)	-20 to +20mm variation	2^0C variation	6	-60^0 to $+60^0$ variation
Failure (F)	Otherwise	Otherwise	Otherwise	Otherwise

EXPERIMENTAL RESULTS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads :

Analysis of rainfall forecast:

The data of actual and forecasted rainfall were analyzed separately for pre-monsoon, monsoon, post-monsoon and winter period during year 2015 (Table 1).

Forecast accuracy(ACC) or ratio score :

ACC is the ratio of correct forecast to total number of forecast for rainfall events. It is worked out on Yes/ No basis for pre monsoon, monsoon, post monsoon and winter season. It was highest (92.1 %) for monsoon season and lowest (76.4 %) for post-monsoon season, whereas it was 85.1 per cent for overall period.

Critical success index (CSI) or threat score:

It is the relative measure of forecast accuracy (rain or no rain). It varies from 0 to 1. The value 1 indicates perfect forecast. It is the ratio of number of hits (correct events) to number of events that occurred plus number of false events (incorrect events). The CSI values for monsoon period was 0.91. It was 0.84 for whole year (Table 1).

Heidke skill score (HSS) :

It considers all correct forecast events (events and non-events) that would make due to chance. It varies from –1 to +1 with 0 indicating no skill compared with chance forecast. The HSS for monsoon, post-monsoon, pre- monsoon and winter period were 0.65, 0.35, 0.34 and 0.23, respectively. It was 0.42 for whole year (Table 1).

Table 1 : Forecast verification of rainfall at Keonjhar during 2015

Season	Total	YY	YN	NY	NN	ACC score (%)	CSI	HSS	H.K. Disc.
Pre-monsoon (April-May)	53	45	3	3	2	88.6	0.88	0.34	0.27
Monsoon (June-September)	115	96	4	5	10	92.1	0.91	0.65	0.69
Post-Monsoon (Oct-Dec)	85	55	14	6	10	76.4	0.73	0.35	0.14
Winter (Jan-Feb)	90	70	7	9	4	82.2	0.81	0.23	0.10
Total	343	266	28	23	26	85.1	0.84	0.42	0.25

Table 2 : Annual distribution (%) of 'Correct', 'Usable' and ' Failure' of predicted weather parameters at Keonjhar(Year-2015)

Rating of predicted data	T_{max}	T_{min}	Rain	TCC	RH I	RH II	Wind speed	Wind direction	Cumulative rainfall
Correct (C)	41.2	52.2	77.7	61.6	36.3	25.9	37.8	25.5	84.6
Usable (U)	39.9	23.6	7.2	25.0	10.5	20.3	27.2	11.3	7.4
Failure (F)	18.9	24.2	15.1	13.4	53.2	53.8	35.0	63.2	8.0

Table 3 : Seasonal distribution(%) of 'Correct', 'Usable' and ' Failure' of predicted weather parameters at Keonjhar(Year-2015)

Season	Rating of predict. data	T_{max}	T_{min}	Rain	TCC	RH I	RH II	W.S.	W.D.	Cum. rainfall
Pre-monsoon (Apr-May)	(C)	44.8	50.4	84.9	35.7	41.6	34.8	51.2	25.4	88.7
	(U)	42.7	28.9	3.7	44.8	13.6	12.3	23.5	21.0	2.1
	(F)	12.5	20.7	11.4	19.5	44.8	52.9	25.3	53.6	9.2
Monsoon (June-Sept)	(C)	35.4	73.9	83.5	44.6	27.7	25.5	44.8	18.7	79.6
	(U)	32.7	14.8	8.7	34.1	19.0	13.9	31.6	10.2	9.3
	(F)	31.9	11.3	7.8	21.3	53.3	60.6	23.6	71.1	11.1
Post-Monsoon (October-	(C)	44.9	45.7	64.7	76.2	52.6	18.2	34.1	35.7	78.7
Dec)	(U)	43.6	29.9	11.8	13.4	2.7	21.2	14.9	10.4	16.7
	(F)	11.5	24.4	23.5	10.4	44.7	60.6	49.0	53.9	4.6
Winter (Jan-Mar)	(C)	39.8	38.7	77.7	89.9	23.1	24.9	21.1	22.2	91.4
	(U)	40.4	35.6	4.4	7.8	6.8	33.6	38.9	3.5	1.6
	(F)	19.8	25.7	17.9	2.3	70.1	41.5	40.0	74.3	7.0

Table 4 : The RMSE, per cent error and correlation co-efficients of observed and predicted weather parameters of Keonjhar

Sr. No.	Parameters	RMSE	Per cent error	Correlation co-efficient
1.	T_{max}	02.7	07.0	0.77
2.	T_{min}	02.4	14.2	0.76
3.	RH I	40.1	56.0	0.64
4.	RH II	32.6	54.8	0.44
5.	Wind speed	13.0	71.6	0.51
6.	Wind direction	51.4	52.3	0.57
7.	Rainfall	25.9	527.6	0.45
8.	Total cloud cover	25.5	456.7	0.69
9.	Weekly rainfall	33.6	164.8	0.79

Hansen and Kuiper's score or true skill score (HK Score):

The HK Score is the ratio of economic saving over climatology due to the forecast to that of a set of perfect forecasts. It ranges from –1 to + 1 with 0 indicating no skill. The HK scores for pre-monsoon, monsoon, post monsoon and winter period were 0.27, 0.69, 0.14 and 0.10, respectively. It was 0.25 for whole year (Table 1).

Annual analysis :

The predicted and observed weather parameters were analyzed for Correct (C), Usable (U) and Failure (F) events in terms of percentage (Table 2). The highest percentages of correct events were 84.6 per cent for cumulative rainfall and 77.7 per cent for rainfall. However, the highest percentages of 63.2 per cent failure events was observed for Wind direction. Kumar and Mukesh (2010) also reported similar results for Bundelkhand region of Uttar Pradesh (27.5 to 40.6% of failure in different seasons) in wind direction prediction.

Seasonal analysis:

The analysis presented in (Table 3) shows the seasonal distribution (%) of 'Correct', 'Usable', and 'Failure' events of predicted weather parameters. The highest percentages *i.e.* 84.9 per cent of correct events was observed for rainfall during pre-monsoon period and 91.4 per cent for cumulative rainfall during winter period.

During monsoon period, the highest percentage *i.e.* 83.5 per cent of correct events was observed for Rainfall, 79.6 per cent for cumulative rainfall, 73.9 per cent for T min and 44.8 per cent for Wind speed, whereas 71.1 per cent failure events were observed for Wind direction.

In post monsoon season, the highest percentage 78.7 per cent of correct events was observed for cumulative rainfall. Similarly, highest percentage of failure events was observed for relative humidity II (60.6%).

During winter season 91.4 per cent correct events were observed for cumulative rainfall and 89.9 per cent for total cloud cover whereas highest percentage of failure events was observed for relative wind direction *i.e.* 74.3 per cent.

Regression analysis:

The values of co-efficient of determination were worked out for regression analysis between observed and predicted weather parameters (Table 4). The value (0.89) of co-efficient of determination (r^2) for rainfall during monsoon period indicated that the values of predicted rainfall were almost matching with the observed ones. It means that prediction of rainfall are near to accurate. The highest value (0.93) of co-efficient of determination (r^2) during pre monsoon period indicates the accuracy in prediction of minimum temperature.

Conclusion :

The rainfall is the most important weather parameter in agricultural production and management practices. The prediction of rainfall in qualitative terms on Yes/No basis is 88 per cent accurate for the whole year. Therefore there is a need to be improved in accurate weather forecasting especially with respect to rainfall because this can be used to facilitate the farmers to make broad decision on the crop management operations.

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