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Accuracy of Weather Forecast for Hill Zone of West Bengal for Better Agricultural Management Practices

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ABSTRACT

Weather forecast received from IMD, New Delhi and actual weather data recorded at Agrometeorological Observatory, RRS (Hill Zone), UBKV, Kalimpong, Darjeeling, West Bengal were compared to assess the validity and accuracy of weather forecast during 2011-12 using statistical procedures and skill scores. Quantitative verification and usability analyses for weather parameters were carried out using skill scores and critical values for the error structure for different seasons. The ratio score value was more than 0.71 during all the seasons except during pre-monsoon where it was 0.36. The highest value of H K score (0.59) and false alarm ratio (0.79) were found during post monsoon. The percentage of detection was perfectly predicted during SW monsoon. Critical success index was highest (0.76) during SW monsoon season. The correlation coefficient values for all weather parameters were significantly higher during winter season. For wind direction, the RMSE values were relatively higher as compared to other weather variables. The SW monsoon rainfall prediction was only 10.8 per cent true whereas, winter rainfall prediction was 97.4 per cent true. The correctness of maximum and minimum temperature prediction was relatively very low among four seasons. The correctness of wind speed prediction was 100 per cent during SW and post monsoon season.

KEYWORDS Forecast, accuracy, skill scores, usability, correlation and RMSE

INTRODUCTION

The agricultural production in India depends on the South-West monsoon (SW monsoon) from June to September. Forecasting the onset of monsoon is therefore important for crop management and sowing. Prediction of rainfall during winter season is also considerable importance for the *rabi* crops of the country. Recent advances in the numerical weather prediction models and their reliability have led them for extensive use in the preparation of daily operational weather forecast.

Weather forecast helps to increase agriculture production, reduce losses, risks, reduce costs of inputs, improve quality of yield, increase efficiency in the use of water, labour and energy and reduce pollution with judicious use of agricultural chemicals. Rathore *et al.* (2001) discussed the weather forecasting scheme operational at National Centre for Medium Range Weather Forecasting (NCMRWF) for issuing location specific weather forecast three days in advance to the Agromet Advisory Services units located at different parts of India. Damrath *et al.* (2000) reported that the statistical interpretation methods are used to increase the reliability of the precipitation forecast. Accurate forecasting of rainfall patterns and other weather variables continue to be a major challenge for scientific community. The emerging capacity to provide timely, skillful weather forecasts offers the potential to reduce vulnerability to vagaries of weather (Hansen, 2002). Accuracy of weather forecast for western agroclimatic zone of Haryana during *kharif* season was reported by Khichar and Bishnoi (2003). They have reported that more than 60% farmers realized the weather prediction and agromet advisories to be useful for irrigation time, pest/diseases management and harvesting of crops.

MATERIALS AND METHODS

Weather forecast (medium range weather forecast) for five days was received from India Meteorological Department (IMD), Regional Meteorological Centre, Agromet Advisory Unit, Alipore, Kolkata on every Tuesday and Friday regularly by E-mail. These data were validated with weather data observed at Agrometeorological Observatory, Regional Research Station (RRS Hill Zone), Uttar Banga Krishi Viswavidyalaya (UBVK), Kalimpong, Darjeeling, West Bengal to assess the accuracy of weather forecast during 2011-12 by using different statistical tools. For the analysis of verification of the forecast data, the year is divided into four seasons *viz*., pre-monsoon or summer (April-May), South-West monsoon (June-September), post monsoon (October-December), winter (January-March) and annual (April-March). Different skill scores, ratio, index and probability were calculated to test the qualitative verification of rainfall during 2011-12. These scores are explained as below (Table 1).

Table 1: Forecasted and observed event of rainfall

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*)

Forecast Accuracy (ACC) or Ratio Score or Hit Score: It is the ratio of correct forecasts to the total number of forecasts and was calculated as follows:

$$ACC = \frac{Correct\ fo\ recast}{Total\ fore\ cast} = \frac{A+D}{N} = \frac{YY+NN}{(YY+NN+YN+NY)}$$

The value of ACC ranges between 0 to 1, where 0 indicates no skill and 1 indicates perfect score.

Hanssen and Kuipers (HK) Score or True Skill Score: It is the ratio of economic saving over climatology due to the forecast to that of a set of perfect forecasts and advantage of this score is to give equal emphasis to yes or no-events and was calculated as follows:

$$HK = \frac{Correct\ \ forecast - (Correct\ forecast)_{random}}{N - (Correct\ forecast)_{random,\ unbiased}}$$

$$HK = (Acc)_{events} + (Acc)_{non-events} - 1 = \frac{AD - BC}{(A+C)(B+D)}$$

The value of HK score ranges between -1 to +1, where -1 indicates no skill and 1 indicates perfect score.

Probability of Detection (POD): POD is forecast performance equal to the total number of correct event forecasts divided by the total number of events observed. Simply stated, it is the per cent of events that are forecast and is calculated by using following formula.

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

The value of POD ranges between 0 to 1, where 0 indicates no skill and 1 indicates perfect score.

False Alarm Ratio (FAR): A verification measure of categorical forecast performance equal to the number of false alarms divided by the total number of event forecasts and is calculated by using following formula.

$$FAR = \frac{False\ alarms}{Hits + False\ alarms} = \frac{B}{A+B}$$

The value of FAR ranges between 0 to 1, where 0 indicates no skill and 1 indicates perfect score.

Critical Success Index (CSI) or Threat Score (TS): It is a verification measure of forecast performance equal to the total number of correct event forecasts divided by the total number of storm forecasts plus the number of misses. It explains about how well did the forecasted yes event correspond to observed yes event and is calculated by using following formula.

$$CSI\ or\ TS = \frac{Hits}{Hits + False\ alarms} = \frac{A}{A+B+C}$$

The value of threat score ranges between 0 to 1, where 0 indicates least accuracy of forecast and 1 indicates perfect forecast.

Heidke Skill Score (HSS): HS score measured the fraction of correct forecasts after eliminating those forecasts which would be correct due purely to random chances. The HS score explain the accuracy of the forecast relative to that of random chance and was calculated as follows:

$$HSS = \frac{Correct\ \ forecast - (Correct\ forecasts)_{random}}{N - (Correct\ forecasts)_{random}}$$

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

The value of HSS ranges between -∞ to 1, where 0 indicates no skill and 1 indicates perfect score.

Quantitative verification and usability analyses for the seven weather parameters *viz*., rainfall, maximum and minimum temperature, maximum and minimum relative humidity, wind speed and wind direction were carried out using skill scores and critical values for the error structure for the different seasons (Table 2). The correlation and root mean square error (RMSE) analysis have also been worked out for the different seasons. The RMSE was calculated using the following formula.

RMSE= SQRT (1/N∑ (Fi-Oi) ^{2})

Where, N=Sample size, Fi=Forecasted value and Oi=Observed value

Table 2: Critical value for different weather parameters used for calculating usability

Usability	Rainfall		Temperature °C (Max and Min)	Relative humidity % (Max and Min)	Wind speed km/h	Wind direction °
	Observed rainfall <=10mm	Observed rainfall > 10mm				
Correct	Diff ≤ 2.5mm	Diff≤ 25% of Obs	Diff≤1.0°C	Diff ≤10%	Diff≤ 2m/s (7.2kmph)	Diff≤30°
Usable	2.5mm <Diff≤5.0mm	25% of Obs <Diff≤ 50% of Obs	1.0°C <Diff ≤2.0°C	10% <Diff ≤20%	2m/s<Diff≤4m/s(7.2–14.4kmph)	30° <Diff ≤40°
Unusable	Diff >5.0mm	Diff >50% of Obs	Diff >2.0°C	Diff >20%	Diff>4m/s (14.4kmph)	Diff>40°
Where, Diff=Absolute difference of observed and forecasted value and Obs=Observed value						

RESULTS AND DISCUSSION

Periodic qualitative verification of rainfall

Periodic qualitative analysis of rainfall forecast is presented in Table 3. Out of 366 forecast for rainfall events, 261 forecasts were observed as per predicted *i.e.* 71.3 % accuracy. Rainfall events occurred as per forecasted was 93 during SW monsoon season followed by pre-monsoon, post monsoon and winter. "No Rain" event (no rain forecasted and it didn't occur) was maximum (75) during winter season. Wrong forecast event totaled to 105 out of 366.

Table 3: Periodic qualitative verification of rainfall events during 2011-12

Events or forecast	Season				
	Pre-Monsoon	SW Monsoon	Post Monsoon	Winter	Annual
YY	19	93	6	3	121
YN	34	29	23	8	94
NY	5	0	1	5	11
NN	3	0	62	75	140
Total	**61**	**122**	**92**	**91**	**366**

Skill scores verification for rainfall

For verification of rainfall forecast, 2 X 2 contingency table were made between forecasted daily and observed rainfall events (Table 1) and based upon this table, different skill scores have been computed for quantifying the accuracy of rainfall forecast and presented in the Table 4.

The ratio score value was more than 0.71 in all the seasons except during pre-monsoon where it was 0.36, indicating the performance of ensemble multi model under hill climatic conditions of Darjeeling district to be better in SW monsoon, post monsoon and winter seasons during 2011-12. The findings were supported by Vashisth *et al*., 2008. The highest value of Hanssen and Kuipers score was 0.59 during post monsoon and minimum in pre-monsoon season. The percentage of detection value was more than 0.79 in all the seasons except during winter where it was 0.38. It depicts the high rate of accuracy of predicted events throughout the year. The percentage of detection was perfectly predicted during SW monsoon. The highest value of false alarm ratio was 0.79 during post monsoon as compared to other seasons and minimum was 0.24 during SW monsoon season. Critical success index was highest (0.76) dur-

ing SW monsoon season. The value of Heidke skill score was 0.0, recorded during SW monsoon season, indicating HS score was not perfectly predicted the rainfall event during SW monsoon season.

Table 4: Skill scores for verification of rainfall events during 2011-12

Skill scores	Season				
	Pre-Monsoon	SW Monsoon	Post Monsoon	Winter	Annual
Skill or Ratio Score	0.36	0.76	0.74	0.86	0.71
Hanssen and Kuipers Score	-0.13	0.0	0.59	0.28	0.51
Percentage of Detection	0.79	1.0	0.86	0.38	0.92
False Alarm Ratio	0.64	0.24	0.79	0.73	0.44
Critical Success Index	0.33	0.76	0.20	0.19	0.54
Heidke Skill Score	-0.10	0.0	0.24	0.24	0.45

Correlation between observed and forecasted weather parameters

Correlation coefficients were derived between observed and forecasted values for different seasons during 2011-12 (Table 5). The correlation coefficient values were non-significant for most of the weather variables. However, prediction accuracy improved considerably over the year for these parameters. The coefficient values of all weather parameters were significantly higher in the winter season. The highest coefficient values were observed for minimum temperature (0.74) during winter season. The analysis indicates that there was good relationship between observed and forecasted minimum temperature during winter season. In case of wind direction, the RMSE values were relatively higher as compared to other weather variables, indicating less homogeneity among predicted and observed events. Thus, the more fine-tuning is required for wind direction prediction.

Table 5: Quantitative verification of weather parameters during 2011-12

Weather parameters	Season									
	Pre-Monsoon		SW Monsoon		Post Monsoon		Winter		Annual	
	CC	RMSE	CC	RMSE	CC	RMSE	CC	RMSE	CC	RMSE
Rainfall	-0.02	9.26	0.25*	25.4	0.11	4.13	0.02	2.35	0.45*	15.33
Max. Temp.	-0.07	7.45	0.17	6.41	0.42*	5.70	0.48*	6.29	0.52*	6.40
Min. Temp.	0.02	8.92	0.10	8.62	0.52*	8.38	0.74*	5.94	0.60*	8.03
Max. RH	-0.01	22.23	0.02	5.51	0.58*	16.4	0.54*	28.12	0.54*	18.86
Min. RH	-0.17	24.29	0.14	13.26	0.76*	10.02	0.53*	23.44	0.63*	17.85
Wind Speed	0.13	3.36	-0.31*	2.26	-0.05	2.90	-0.16	3.97	-0.13	3.20
Wind Direction	-0.11	83.06	-0.06	95.9	0.43*	85.98	0.02	108.74	0.19	94.97

* Values are significant at 5%

CC: Correlation Coefficient, RMSE: Root Mean Square Error

Correctness and usability of the forecast for different weather parameters

The season-wise correctness and usability verification analysis of the forecast for different weather parameters on daily basis were carried out using various error structures and the values have been depicted in Table 6. The SW monsoon rainfall prediction was only 10.8 per cent true during 2011-12 which is very less whereas, winter rainfall prediction was 97.4 per cent true which was to be beneficial for farmers for management of *rabi* crops. For rainfall forecast events the usable events ranged between 1.3 to 13.6 per cent during all the four seasons. The usable percentage was relatively high in case of rainfall prediction during pre monsoon.

The correctness of maximum and minimum temperature prediction was relatively very low during four seasons. This might be due to altitudinal variation of hill of Darjeeling. The usability of maximum temperature events ranged between 3.3 to 5.5 per cent during all the four seasons. However, in case of minimum temperature events the usability range was 0.0 to 6.6 per cent in all the seasons.

The maximum relative humidity prediction was 91.0 per cent true during SW monsoon season which was to be beneficial for farmers to take precaution for appearance of pests and disease of *kharif* crops. However, the minimum relative humidity prediction was 65.2 per cent true during post monsoon season. The usable percentage of maximum and minimum relative humidity was relatively considerable.

Forecasting of wind speed plays an important role in saving the crop from lodging and it was observed that the correct wind speed prediction was 100 per cent during SW monsoon and post monsoon season. The wind speed prediction was highly corrected among all seasons. This indicates increase in accuracy of the prediction for wind speed. During summer when irrigation water is scarcely available to the farmer for growing vegetables the usable prediction of wind speed was 1.6 per cent while 98.4 per cent of the cases the predictions were correct. As far as wind direction concerned, the prediction is found to be highly variable. The wind direction events, limit ranged between 2.2 to 9.9 per cent of usable events whereas, the correctness was from 15.6 to 27.1 per cent among all seasons.

Table 6: Usability percentage of forecast for different weather parameters during 2011-12

Weather parameters	Season														
	Pre-Monsoon			SW Monsoon			Post Monsoon			Winter			Annual		
	Correct	Usable	Unusable	Correct	Usable	Unusable	Correct	Usable	Unusable	Correct	Usable	Unusable	Correct	Usable	Unusable
Rainfall	40.9	13.6	45.5	10.8	12.9	74.3	91.2	5.9	2.9	97.4	1.3	1.3	60.7	7.8	31.5
Max. Temp.	1.7	4.9	93.4	4.9	3.3	91.8	14.1	3.3	82.6	15.4	5.5	79.1	9.3	4.1	86.6
Min. Temp.	0.0	1.6	98.4	0.0	0.0	100.0	1.1	3.3	95.6	7.7	6.6	85.7	2.2	2.7	95.1
Max. RH	45.2	22.5	32.3	91.0	9.0	0.0	20.7	64.0	15.3	14.3	25.3	60.4	46.7	29.2	24.1
Min. RH	27.8	27.9	44.3	56.6	32.0	11.4	65.2	33.7	1.1	16.5	36.3	47.2	44.0	32.8	23.2
Wind Speed	98.4	1.6	0.0	100.0	0.0	0.0	100.0	0.0	0.0	95.6	4.4	0.0	98.6	1.4	0.0
Wind Direction	23.0	9.8	67.2	15.6	4.9	79.5	27.1	2.2	70.7	20.9	9.9	69.2	21.1	6.3	72.7

CONCLUSION

The SW monsoon rainfall prediction was very poor whereas, winter rainfall prediction was very good which was to be beneficial for farmers for better management of *rabi* crops. The performance of ensemble multi model under hill climatic conditions of Darjeeling district was to be better during SW monsoon, post monsoon and winter seasons. The medium range weather forecasts were used for preparing agromet advisory bulletins for the farmers of study area which were very useful for scheduling of sowing, irrigation, agricultural operations and management of pest and diseases of field crops. The farmers feel it to be useful since they receive advices on appropriate field operations and management practices depending on suitability of weather conditions.

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REFERENCES

1. Damrath, U., Doms, G., Friihwald, D., Heise, E., Richter, B., & Steppeler, J. (2000). Operational quantitative precipitation forecasting at the German weather service. *Journal of Hydrology, 239,* 260-285.
2. Hansen, J. W. (2002). Realizing the potential benefits of climate prediction to agriculture: issues, approaches and challenges. *Agricultural Systems, 74,* 309-330.
3. Khichar, M. L., & Bishnoi, O. P. (2003). Accuracy of weather forecast for western agroclimatic zone of Haryana during *kharif* season. *Haryana Agricultural University Journal of Research, 33(2),* 97-100.
4. Rathore, L. S., Gupta, A., & Singh, K. K. (2001). Medium range weather forecasting and agricultural production. *Journal of Agricultural Physics, 1(1),* 43-47.
5. Vashisth, A., Das, D. K., Bhagawati, G., & Sharma, P. K. (2008). Accuracy of weather forecast for semi-arid climate of Delhi for agricultural management practices. *Journal of Agricultural Physics, 8,* 51-58.