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Accuracy of Weather Forecast for Semi-arid Climate of Delhi for Agricultural Management Practices

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ABSTRACT

Weather forecast received from India meteorological department, New Delhi and actual weather data recorded at Agrometerological Observatory IARI, New Delhi were compared to assess the validity and accuracy of weather forecast during 2007-08 and 2008-09 using statistical procedures and skill scores. Quantitative verification and usability analyses for the weather parameters were carried out using skill scores and critical values for the error structure for the different seasons. The ratio scores derived between the forecasted and observed values during post monsoon and winter seasons were observed to be relatively higher as compared to those for the monsoon seasons during both 2007-08 and 2008-09, indicating the performance of ensemble model under semi arid climatic conditions at Delhi region to be better in post monsoon and winter seasons than in the summer and monsoon seasons. The relatively higher usability of maximum temperature and minimum temperature was observed during post monsoon season, which are important to the farmers for the pre-sowing operations of the *rabi* crop. Forecasting of wind speed plays an important role in saving the crop from lodging especially in the *Rabi* crop season and it was observed that in this season (2007-08) the wind speed prediction was 90 per cent correct. Similarly during summer when irrigation water is scarce for growing vegetables the usable prediction was 18 per cent while in 79 per cent of the cases the predictions were correct. The accuracy of forecast of weather parameters in advance is found to be useful for farmers for doing appropriate field operations and crop management practices.

Key words: Medium range weather forecast, Ratio score, Skill score

Introduction

The agricultural production in India depends on the South-West monsoon between June to September. Forecasting the onset of monsoon is therefore important for crop management and for sowing. Prediction of rainfall during winter season is also considerable importance for the *rabi* crops in the northern and central parts 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. The supercomputer facility at the National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi has further made it possible to run a global spectral model for medium range operational weather prediction for three days and beyond.

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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, labor and energy and reduce pollution with judicious use of agricultural chemicals. Rathore *et al.* (2001) discussed the weather forecasting scheme operational at 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.* (2001) reported that the statistical interpretation methods are used to increase the reliability of the precipitation forecast. Acurate 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. The performance of prediction models and reliability of weather forecast for making farm-level decisions at IARI, New Delhi have been discussed in this paper.

Materials and Methods

Weather forecast received from India Meteorological Department (IMD), New Delhi and actual weather data recorded at the agromet observatory located at the farm of Indian Agricultural Research Institute, New Delhi were compared to assess the validity of weather forecast. During the Year 2007-08 and 2008-09 forecast on rainfall, wind speed maximum and minimum temperature received from IMD were compared with IARI observed weather data by using following statistical tools.

For the analysis of the verification of the forecast data, the year is divided into four groups on seasonal basis viz., summer, (April –June), monsoon (July-September), Post monsoon (October- November), winter (December-march) and annual (April – march). Different scores such as threat score, H.S. score, true skill score and ratio score were calculated to test the weather forecast for rainfall during 2007-08 and 2008-09. These scores are explained as below:

Threat Score

Threat score (TS) measured the fraction of observed and / or forecast events that were correctly predicted. Threat core was calculated using the following formula:

TS = hits/ (hits +misses + false alarms).

where Hits means forecast for rainfall was yes and it was observed, miss means no forecast for rainfall but it was observed, false alarm means forecast for rainfall was yes but it was not observed and correct negative means no forecast for rainfall and it was not observed.

The value of threat score ranges between 0 to 1, 0 indicates least accuracy of forecast, and 1 indicate perfect forecast. It explains about how well did the forecast yes event correspond to observed yes events.

Heidke Skill Score (H.S. Score)

Heidke skill score (H.S. SCORE) measured the fraction of correct forecasts after eliminating those forecasts which would be correct due purely to random chance. Its value ranges between minus infinity to 1, 0 indicates no skill and 1 indicates perfect score. The H.S. score was calculated as follows:

H.S. Score = {(hits + correct negative)-(expected correct)$_{random}$}/{N-(expected correct)$_{random}$}

(Expected correct) $_{random}$ = {(hits+ misses) (hits +false alarms) + (correct negative + misses) (correct negative +false alarms)}/N

H. S. score explain the accuracy of the forecast relative to that of random chance.

Hanssen and Kuipers (True skill score)

Hanssen and Kuipers (True skill score) was calculated as follows:

HK score = {hits/ (hits + misses)} – {false alarms / (false alarms + correct negatives)}

The value of HK score ranges between -1 to 1, 0 indicates no skill and 1 indicate perfect score. It explain how well did the forecast separate the yes event from the no event

Ratio Score

Ratio score was calculated as follows:

Ratio score = (hits+ correct negative)/ N

It range between 0 to 1, 0 indicates no skill and 1 indicate perfect score.

The root mean square error (RMSE)

The root mean square error (RMSE) was calculated using the following formula:

RMSE = SQRT (1/N $\sum$(Fi-Oi)^2

where,

N = Sample size

Fi = Forecasted value

Oi = Observed value

Verification of Medium Range Weather Forecast

Weather forecast for four days was received from India Meteorological Department, Regional Meteorological Centre, Agromet Advisory Unit, Safdarjung Airport, New Delhi on every Tuesday and Friday regularly by E-mail. These data were validated with weather data observed at IARI observatory. For the analysis of the verification of the forecast data, each year is divided into four groups on seasonal basis viz., Summer (April-June), Monsoon (July-September), Post monsoon (October-November), Winter (December- March) and the whole year (April-March). Quantitative verification and usability analyses for the six weather parameters viz., cloud cover, rainfall, wind speed, wind direction, temperature maximum and minimum were carried out using skill scores and critical values for the error structure for the different seasons (Table 1). The correlation and RMSE analysis have also been worked out for the different seasons.

Results and Discussion

Weather during Kharif *2007 and 2008*

The maximum temperature during different weeks in the *kharif* 2007 was observed to be almost same as normal except during 23rd, 25th and 39th standard weeks. The minimum temperatures during the *Kharif* season were slightly lower than normal in almost all the weeks barring one or two weeks at the start and end of the season. The rainfall during the *Kharif* season was 30 per cent lower than the normal. However, the rainfall was received in 13 out of 16 weeks of this season. On the whole, this rainfall distribution was satisfactory as far as the crop growth was concerned.

The maximum temperature during different weeks in the *kharif* 2008 was observed to be lower than normal. During 29th, 36th and 39th standard weeks it was equal to normal while during 34th and 35th week it was higher than normal. The minimum temperatures during the *Kharif* season were slightly lower than normal in almost all the weeks except 23rd and 29th week. The rainfall during the *Kharif* season was 22 per cent more than the normal. However, the rainfall was received in 14 out of 17 weeks of this season. Total rainfall during *Kharif* 2008 was 675.6 mm (normal 555 mm) though the distribution was uneven. Bright sunshine hours were found to be lower than normal except 34th, 35th and 38th weeks. Relative humidity measured at 7.21 A. M. was found to be higher than normal except 34th and 38th weeks while at 2.21 P.M. it was found to be higher than normal except 34th, 35th and 38th weeks.

Weather during Rabi *2007-08 and 2008-09*

During *rabi* 2007-08 crop season, the weekly mean maximum temperatures at sowing and crop establishment period were higher than the normal, during the active vegetative, flowering and reproductive stages of wheat and mustard crops, the temperatures were marginally lower than the normal. The minimum temperatures during the *rabi* season were much lower than the normal values. From 48th standard meteorological week till 8th week the minimum temperature was lower than the normal. During this period the temperature even touched lowest of -0.8°C on 2nd January and remained more or less near zero

Table 1. Critical values for different weather parameter used for calculating usability

Usability	Rainfall		Temp °C	Wind speed	Cloud Cover	Wind direction
	<10mm	>10mm	Max/Min	Kmp/h	Okta	Deg.
Correct	0.2mm	2%	1	3	1	10
Usable	2.0mm	20%	2	6	2	13
Unusable	≥ 2.0mm	20%	>2	>6	>2	>30

for over 9 days. These continuous low temperatures during this period were congenial for wheat crop but at the same time the conditions greatly damaged tomato and potato crop in the northern belt due to frost. This low temperature has also affected the fecundity in aphid population thus favouring a good crop of aphid-free mustard.

During *rabi* 2008-09 weekly maximum and minimum temperatures were found to be lower than normal values during vegetative and flowering stages, while they remained higher than normal during pod filling and maturity stages. Total rainfall during crop growing season was 14.6 mm which was less than normal (104 mm). Bright Sunshine hours were found to be lower than normal during vegetative and flowering stages, while they remained higher than normal during pod filling stage. Relative humidity at 7.21 A. M. was found to be more or less same as that of normal while that at afternoon 2.21 P.M. was higher than normal for two weeks during flowering and lower than normal during maturity stage.

Verification of Medium Range Weather Forecast

Skill Scores for Rainfall

For verification of rainfall forecast 2 X 2 contingency table 2 between forecasted daily and observed rainfall events were made and based upon this table, different scores for evaluation the skill rainfall forecast were worked out and presented in the table 3.

The ratio scores during post monsoon and winter seasons were relatively higher as compared to monsoon seasons indicating the performance of ensemble multi model under semi arid climatic conditions at Delhi region to be better in post monsoon and winter. However in 2007-08 ratio scores was also higher for summer season.

During monsoon season (*kharif* 2008) threat score value was higher compared to other seasons thus indicating that observed rainfall during monsoon was very nearer to the predicted. The interesting observation was that rainfall recorded

Table 2. Forecasted and observed event of rainfall

Forecasted	Observed	
	Observed yes event	Observed no event
Forecasted yes event	Hits	False alarms
Forecasted no event	Misses	Correct negatives

Table 3. Different scores for forecasted and observed rainfall

Skill scores	Ratio Score	Threat Score	H.S. Score	True Score
		2007-08		
Annual	0.82	0.27	0.33	0.43
Summer	0.88	0.31	0.40	0.38
Monsoon	0.57	0.31	0.18	0.24
Post Monsoon	0.85	0.18	0.23	0.24
Winter	0.95	0.00	-0.02	-0.05
		2008-09		
Annual	0.83	0.36	0.40	0.56
Summer	0.62	0.34	0.26	0.36
Monsoon	0.59	0.41	0.24	0.30
Post Monsoon	0.98	0.0	0.0	0.0
Winter	0.93	0.11	0.17	0.28

(IARI agromet observatory) during May and June 2008 was (237.3 mm) much higher than the normal (71.0 mm).

Correlation between Observed and Forecasted Weather Parameters

Correlation coefficients were derived between the forecasted and observed values during 2007-08 for different seasons (Table 4). It was observed that the forecast values were better for cloud cover and wind direction during winter and also with rainfall in summer as compared to other weather parameters. There was a high value of root mean square values (Table 5) for monsoon rainfall as compared to others in both years.

Correlation coefficients derived between the forecasted and observed values during (2008-09) for different seasons (Table 4) was observed that the forecast and observed values were better for maximum and minimum temperature during all the seasons. During monsoon 2008, correlation between forecasted and observed rainfall values were better than other seasons. Correlation between forecasted and observed values for wind speed during post-monsoon was better than other seasons. The analysis indicates that there was

Table 4. Correlation between the observed and forecasted weather parameters

Weather Parameters	Annual	Summer	Monsoon	Post Monsoon	Winter
		2007-08			
Rainfall	0.17	0.64	0.07	-0.01	-0.02
Temp. Maximum	-0.19	-0.14	-0.46	-0.09	-0.10
Temp. Minimum	0.09	-0.08	-0.09	0.09	0.18
Wind speed	-0.14	-0.11	0.16	0.11	0.08
Wind direction	0.33	0.13	0.24	0.27	0.41
Cloud cover	0.41	0.44	0.39	0.01	0.41
		2008-09			
Rainfall	0.50	0.29	0.48	0.0	0.12
Temp. Maximum	0.93	0.82	0.52	0.89	0.87
Temp. Minimum	0.95	0.66	0.30	0.94	0.78
Wind speed	0.10	-0.14	0.22	0.55	0.43
Wind direction	0.40	0.39	0.44	0.32	0.39
Cloud cover	0.36	0.49	0.44	0.08	0.25

Table 5. Root mean square error of different weather parameters

WeatherParameters	Annual	Summer	Monsoon	Post Monsoon	Winter
		2007-08			
Rainfall	9.75	1.72	18.77	5.5	1.17
Maximum Temperature	2.89	3.31	3.37	2.60	2.31
Minimum Temperature	5.19	2.58	2.53	2.92	8.10
Wind speed	2.99	3.09	3.88	2.4	2.39
Cloud cover	1.85	1.6	2.4	1.67	1.60
		2008-09			
Rainfall	6.8	7.01	11.46	0.12	0.86
Temp. Maximum	2.18	2.26	2.39	1.62	2.20
Temp. Minimum	2.41	2.59	2.19	1.86	2.68
Wind speed	5.85	4.77	4.57	5.08	7.63
Cloud cover	2.98	2.71	2.86	2.82	3.37

poor relationship between observed and forecasted in other seasons wind speed.

Correctness and Usability of the Forecast for Different Weather Parameters

Usability analysis of the forecasted weather parameters in relation to observed ones using critical values was carried out. The season-wise analysis is given in Table 6.

Rainfall

The rainfall prediction was found to be more dependable in *kharif* (2007) season. The monsoon rainfall prediction was 77 per cent true in *Kharif*, 2007. The rainfall prediction was found to be highly erratic during *kharif* (2008) season as compared to the previous season (2007). The rainfall during the *kharif* season of 2007 was 193.9 mm which was almost 30 per cent less than the normal. Dry spells during August affected the crops like maize and rice. The rainfall forecast at the time of sowing and transplanting of paddy crop was found to be beneficial to the farmers. During the *rabi* 2007-08 there was almost no rainfall (1.8mm on 1st October 07) whereas forecast during that period was 50mm. The monsoon rainfall prediction was only 29 per cent true in this season (2008) which was very less than previous monsoon (77 percent during 2007).

The rainfall recorded during May and June 2008 was 136.4 and 100.7 mm which was much higher than normal value of 16.9 and 54.1 mm respectively whereas forecasted rainfall during these period were 48 and 196.7 mm.

Temperature

During 2007-08 total usability of maximum temperature was about 65 per cent and minimum temperature was more or less of the same order. The usability of maximum temperature during summer was 60 per cent and about 67 per cent in case of minimum temperature.

During 208-09 total usability of maximum temperature was about 48 per cent and minimum temperature was more or less of the same order. The usability of maximum temperature during summer was 42 per cent and about 41 per cent in case of minimum temperature. Relatively higher usability of maximum and minimum temperature was observed during post monsoon which was of some importance to the farmers as far as the pre-sowing operations of the *rabi* crop are concerned.

Wind Speed and Wind Direction

Forecasting of wind speed plays an important role in saving the crop from lodging especially in the *Rabi* (winter) crop season and it was observed that in this season (2007-08) the correct wind speed prediction was 90 per cent. This indicates increase in accuracy of the prediction. About 19 per cent of wind speed prediction was found to be useful to the farmer during the year. Similarly during summer when irrigation water is scarcely available to the farmer for growing vegetables the usable prediction was 18 per cent while in 79 per cent of the cases the predictions were correct. During 2008-09 about 32 per cent of wind speed prediction was found to be useful to the farmer during the year. As far as wind direction is concerned due to the lack of continuous monitoring/recording of the data the predictions are found to be highly variable since the comparison was made between the predominant wind direction and mean wind direction recorded in the morning and afternoon only.

Cloud Cover

During 2007-08 prediction of cloud cover was correct in almost all the seasons in the order of 46 to 68 per cent and usability ranged between 21 and 27 per cent. However during 2008-09 prediction of cloud cover was correct in almost all the seasons of the order of 36 to 48 per cent and usability ranged between 26 and 33 per cent.

Table 6. Usability percentage of forecast for different weather parameters during 2007-08 and 2008-09

Usability (%)	Annual	Summer	Monsoon	Post monsoon	Winter
		Rainfall (2007-08)			
Correct (%)	92	97	77	93	100
Usable (%)	4	3	12	3	0
Unusable (%)	3	0	11	4	0
		Rainfall (2008-09)			
Correct (%)	67	49	29	100	94
Usable (%)	12	20	21	0	4
Unusable (%)	21	31	50	0	2
		Maximum Temperature (2007-08)			
Correct (%)	37	36	18	39	48
Usable (%)	28	24	32	31	27
Unusable (%)	35	40	50	30	25
		Maximum Temperature (2008-09)			
Correct (%)	48	42	42	64	52
Usable (%)	24	29	25	16	19
Unusable (%)	28	29	33	20	29
		Minimum Temperature (2007-08)			
Correct (%)	35	38	35	38	33
Usable (%)	25	29	28	16	23
Unusable (%)	40	33	37	46	44
		Minimum Temperature (2008-09)			
Correct (%)	46	41	52	56	38
Usable (%)	27	36	26	26	23
Unusable (%)	27	23	22	18	39
		Wind Speed (2007-08)			
Correct (%)	78	79	55	84	90
Usable (%)	19	18	40	16	6
Unusable (%)	3	3	5	0	4
		Wind Speed (2008-09)			
Correct (%)	32	63	35	36	6
Usable (%)	37	15	52	39	38
Unusable (%)	31	22	13	25	56
		Wind Direction (2007-08)			
Correct (%)	35	29	20	33	52
Usable (%)	10	10	9	7	13
Unusable (%)	55	61	71	60	35
		Wind Direction (2008-09)			
Correct (%)	44	43	31	36	59
Usable (%)	10	11	15	5	7
Unusable (%)	46	46	54	57	34
		Cloud cover (2007-08)			
Correct (%)	59	68	46	64	58
Usable (%)	24	21	23	24	27
Unusable (%)	17	11	31	12	15
		Cloud cover (2008-09)			
Correct (%)	43	48	48	39	36
Usable (%)	30	33	29	33	26
Unusable (%)	27	19	23	28	38

Conclusion

The ratio scores during post monsoon and winter seasons were relatively higher as compared to summer and monsoon seasons indicating the performance of multi model (ENSEMBLE) at Delhi region to be better in post monsoon and winter seasons than in the other two seasons. Relatively higher usability of maximum temperature and minimum temperature was observed during post monsoon which was of some importance to the farmers as far as the pre-sowing operations of the *rabi* crop are concerned. 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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