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Verification and usability of medium range weather forecast for Northern Dry Zone of Karnataka India

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Abstract

A comprehensive verification and usability assessment of the India Meteorological Department's (IMD) location-specific medium-range multi-model ensemble (MME) weather forecast was conducted for Vijayapura district, representing the Northern Dry Zone of Karnataka, India, from March 2019 to February 2025. The forecasts for key weather parameters—including rainfall, temperature, humidity, wind speed, and cloud cover evaluated seasonally using various verification metrics: ratio score, Hanssen and Kuipers (HK) score, probability of detection (POD), false alarm ratio (FAR), critical success index (CSI), Heidke skill score (HSS), root mean square error (RMSE), and correlation coefficients. Results indicated high forecast usability for rainfall during pre-monsoon and winter seasons, with ratio scores exceeding 90%, while monsoon season performance for rainfall remained comparatively poor, reflecting lower correlation and higher RMSE values. Temperature and wind speed forecasts demonstrated generally high accuracy and usability across seasons, though certain parameters, such as afternoon relative humidity and cloud cover, showed greater deviations. Overall, the medium-range weather forecast exhibited satisfactory skill, particularly for operational agricultural advisories, enhancing farmers' decision-making capacity in the region.

Keywords: MME forecast, medium range weather forecast, weather parameter, usability, correlation coefficient

Introduction

Weather is one of the most significant factors affecting crop growth and yield, as it governs critical processes such as germination, flowering, and grain filling (Tripathi *et al.*, 2008)^[15]. The success of agricultural production largely depends on weather conditions, which influence water availability, pest and disease incidence, and overall crop performance (Singh *et al.*, 2005)^[13]. In India, where agriculture remains highly dependent on monsoon rainfall, weather variability directly impacts food security and rural livelihoods (Rathore *et al.*, 1999)^[10]. Given the high sensitivity of crops to weather fluctuations, accurate weather forecasts are essential for optimizing agricultural operations and minimizing climate-related risks (Chaudhary *et al.*, 2010)^[1]. Extreme weather events such as droughts, floods, and heat waves pose substantial threats to agricultural productivity, emphasizing the need for reliable weather information (Sahu *et al.*, 2012)^[11]. Weather cannot be managed in favour of crop growth, but its effects can be minimized by adjusting with the advanced knowledge of unfavorable weather events such as drought, flood, cold wave and heat wave, etc. Agricultural operations can be delayed or advanced with the help of advanced information on weather from 3 to 10 days. (Kushalsharma, *et al.* 2015)^[6]. Under Gramin Krishi Mausam Sewa (GKMS) scheme, value-added medium range weather forecasts for the next five days are generated by IMD (Singh, 2022; IMD, 2023; IMD, 2024)^[13, 3, 4]. Based on the forecast, biweekly Agromet Advisory Services (AAS) bulletins are prepared on every Tuesday and Friday (MoES, 2022) and communicated to the farmers to make decisions on day-to-day agricultural operations based on the bulletin provided (IMD, 2024). Agromet advisory based on prevailing weather condition help in increase the production of farmers' by providing timely weather based management approaches. Weather based agromet advisory services provides the valuable information regarding crop cultivation, land preparation, sowing, irrigation, spray and harvest (Sridhara *et al.*, 2014)^[14]. Accurate, usable and reliable weather

forecast is the only answer/method through which farmers can be advised to save their crops from aberrant weather and minimize their input and labour cost to derive maximum benefit from agriculture. An estimate made by the agri- business, a community in western countries, indicates that the forecast can be put to economical use if it is 50 to 60% correct (Seeley, 1994)^[12]. Hence, the accurate weather forecast based agromet advisories in terms of rainfall and temperature forecast, prepared on the need-based agricultural operations can contribute immensely to benefit the farmers through minimizing the production losses. The forecast verification is essential to judge the usability of the weather forecast for preparation of effective weather based agromet advisories for farmers. The verification of forecast improves the confidence of the farmers for its reliability and applicability in day today field works. (Kushal sarmah *et al.*, 2015). The reliability and accuracy of medium range weather forecast were studied by several authors (Tripathiet *al.*, 2008; Chauhan *et al.*, 2008; Lunagaria *et al.*, 2009; Chaudhari *et al.*, 2010; Khichar *et al.*, 2010; Mishra *et al.*, 2010; Sahu *et al.*, 2012)^[15, 2, 7, 5, 9, 11] for different Agro-climatic zones of India. In this paper, an attempt has been made to verify the accuracy and usability of medium range weather forecast for Northern Dry Zone of Karnataka.

Materials and Methodology

Northern Dry Zone (NDZ) of Karnataka consists of seven districts, viz., Vijayapura, Bagalkote, Haveri, Gadag, Belagavi, Haveri and Dharwad. As the crops and cropping pattern of all the districts of NDZ is similar, we took Vijayapura as representing district of NDZ for forecast verification. The all weather parameters of Vijayapura district were compared and verified against the observed weather parameters recorded. Medium range forecast (forecast given for the period of five days) was issued by India Meteorological Department, New Delhi on various weather parameters viz., amount of rainfall (mm), maximum and minimum temperature (°C), surface mean wind speed (kmph) and both morning and afternoon relative humidity (%) and sent to Regional Meteorological Centre, Bangalore on every Tuesday and Friday for value addition. IMD, New Delhi generates these district level forecast from day-1 to day-5 based on a Multi Model Ensemble technique using forecast products available from number of models of India and other countries which include: T-254 model of NCMRWF, T-799 model of European Centre for Medium Range Weather Forecasting (ECMWF), United Kingdom Met Office (UKMO), National Centre for Environmental Prediction (NCEP), USA and Japan Meteorological Agency (JMA). The grid spacing or resolution of these models is 48-50 km. From 2009 onwards, T-574 (resolution - 22 km) model was also introduced and applied in IMD. After receiving the MME forecast, (i) Previous performance history of MME, (ii) prevailing synoptic conditions and (iii) topography and climatic condition of the respective district are considered and accordingly value additions to the MME value are done. After value addition, RMC, Bangalore sent these forecast to the centre on every Tuesday and Friday. This study was conducted at agromet field unit (AMFU), Vijayapura (Karnataka) for five years from March 2020 to February 2025. The daily values of these medium range forecast of weather parameters like rainfall (mm), maximum and minimum temperature (°C), maximum and minimum relative humidity (%) and mean wind speed (kmph) for day -1 to day-5 of Vijayapura during the study period was compared and verified for the four seasons separately as per IMD standard viz., pre-monsoon (Mar- May), monsoon (Jun-Sep), post-monsoon

(Oct-Nov) and winter (Dec-Feb) against the observed weather parameters recorded at Vijayapura.

The forecast were verified using Percent deviation, ratio score, Hanssen and Kuipers (HK) Score, Probability of detection (POD), Heidke Skill Score (HSS), False alarm ratio (FAR), Critical Success index (CSI) and RMSE for rainfall, and RMSE for other parameters. Similar method were used by few researchers (Singh *et al.*, 2005; Tripathi *et al.*, 2008; Chauhan *et al.*, 2008; Lunagaria *et al.*, 2009; Chaudhari *et al.*, 2010; Khichar *et al.*, 2010; Mishra *et al.*, 2010; Sahu *et al.*, 2012)^[13, 15, 2, 7, 5, 9, 11].

Ratio Score (RS), also known as the Accuracy, Hit Rate or Percentage Correct, measures the proportion of correct forecasts. It describes the success rate of correct forecast of occurrence and non-occurrence of rainfall to the total number of events. The RS varies from 0 to 100 with 100 indicating perfect forecasts.

$$\text{Ratio score} = \frac{\text{Correct forecast} - A + D}{\text{Total forecast} \quad M}$$

Hanssen and Kuipers (H.K.) Scores

$$\text{HSK} = A * D - B * C / (A + C) (B + D)$$

These scores are in the range of -1 to +1 with 0 representing no skill. Negative values would associated with “perverse” forecasts and could be convert to positive skill simply by reversing all the yes replaced yes forecasts with no and vice-versa. 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.

Critical success index (threat score) measures relative forecast accuracy (*e.g.*, rain or no rain). It also varies from 0 to 1 with 1 indicating perfect forecast and is defined as the ratio of the number of hits (*i.e.*, correct event forecasts) to the number of events which occurred plus the number of false alarms (incorrect event forecast).

$$\text{Critical Success index (CSI)} = \text{Hits} / (\text{Hits} + \text{False alarms})$$

Probability of detection (POD) is the ratio of correct rain forecast.

$$\text{Probability of detection (POD)} = \frac{\text{Correct rain forecast}}{\text{Rain Observed}}$$

Since POD uses only the observed events A and C, it is sensitive only to missed events and not false alarms. Therefore POD can generally be improved by systematically over-forecasting the occurrence of the event. The POD is incomplete by itself and should be used in conjunction with either the false alarm ratio (FAR) below or the false alarm rate (FA).

$$\text{False alarm ratio (FAR)} = \frac{\text{False alarm}}{\text{Hits} + \text{False alarm}}$$

Since FAR is dependent on A and B only and does not include C, and therefore, is not sensitive to missed events. FAR can be improved by systematically by under forecasting the events. It also incomplete score and should be used in connection with the POD above.

Heidke Skill Score (HSS) is the ratio of correct

$$\text{Heike Skill Score (HSS)} = \frac{\text{Correct Forecast} - \text{Correct Forecast}}{N - (\text{Correct Forecast}) \text{random}}$$

The HSS ranges from negative values to +1, Negative values indicate that the standard forecast is more accurate than the forecast; skill is negative. The HSS represents the fraction by which the forecast improves on the standard forecast. A perfect forecast gives HSS of 1, no matter how good the standard forecast is the error structures as suggested by IMD were followed to discriminate between correct, usable and unusable forecasts (Singh, *et al.*, 1999) ^[13]. The error structure for verification of Quantitative weather parameters Rathore *et al.* (1999) ^[10].

where, diff stands for Absolute difference of observed and forecasted rainfall in mm and obs stands for observed rainfall in 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 for obtaining the skill of the model in forecasting. The RMSE values indicate the degree of error in the forecast. The lower values of RMSE indicate less difference between observed and forecasted values.

$$\text{Root mean square error (RMSE)} = \frac{(F-O)^2}{n}$$

where, *F*=Forecasted value, *O*=observed value, *n*= number of observations.

Results and Discussion

The seasonal percentage deviation of daily weather parameters, viz., rainfall, maximum and minimum temperature, wind speed, morning and evening relative humidity for four seasons pre-monsoon (Mar-May) monsoon (June-Sep), post-monsoon (Oct-Dec) and Winter (Jan-Feb) for 5 years (March, 2020 to February, 2025) are presented in Table 1 and Fig 1. The daily weather parameters were computed from a contingency table summed for the whole season and worked out the percentage deviation, percent usability, correlation coefficient, Root mean square error compared with observed weather for Vijayapura district and forecasted data received from IMD, are presented in (Table 1 to Table 7)

Pre-monsoon (Mar-May)

The results indicated that rainfall predicted during pre-monsoon season demonstrated excellent accuracy with 100% agreement and no deviation. Whereas, Maximum temperature showed minimum deviation ranging between -0.27 (2020-21) to -2.83 (2024-25), similarly minimum temperature was ranging between -2.10 (2022-23) to 0.32 (2024-25), cloud cover -65.93 (2024-25) to -54.7 (2020-21). Morning and afternoon relative humidity and Wind speed have showed wide variation across the season in the range of up 14.20 to 49.6, 45.4 to 12.02 and -23.2 to -35.20. (Table 1) respectively.

The pre-monsoon usability of rainfall (correct + usable) percent is in the range of 95.0% (2022-23) to 97.0% (2020-21). Indicating the assured events prediction than the amount. The maximum and minimum temperature showed very good percentage of usability upto 80%, and the morning and afternoon relative humidity, cloud cover and wind speed also showed excellent results upto 96%. Representing greater utility of the forecast, for agro advisories and allied sectors.

Correlation coefficient between observed and predicted were analysed the results showed the correlation coefficient during pre-monsoon for rainfall were low in the range of 0.1 (2020-21) to 0.4 (2023-24), whereas for maximum temperature showed higher values ranging from 0.4 (2023-24) to 0.7 (2020-21),

minimum temperature, cloud cover, morning and afternoon relative humidity and wind speed are upto 0.4.

The corresponding qualitative analysis results (ratio score, critical success index, HK score, probability of detection, false alarm ratio and Heidke Skill Score are presented in (Table 6) During pre-monsoon seasons, the ratio score for rainfall ranged from 69.9 to 76.3%, indicating very good forecast skill for event of rain during these seasons. The results revealed that the HK scores were positive during the season are in the range of 0.2 (2021-22). The critical success index is low in the range of 0.1 (2020-21) to 0.3 (2023-24) Likewise the probability of detection (POD) is good during pre-monsoon season in the range of 0.4 to 0.7, however often events (e.g., rainfall) were correctly forecasted when they actually occurred. The False alarm ratio (FAR) is in the range of 0.7 to 0.9. Heidke Skill Score (HSS) is positive in pre-monsoon seasons of the five years ranging from (0.1 to 0.3) Similarly, from the Table 7, it is revealed that the RMSE values for pre-monsoon season for rainfall were lower, varying from 2.1 (2020-21) to 3.7 (2022-23). Indicating low level of errors across years and seasons. Maximum temperature was ranging from 1.5 (2020-21) to 4.3 (2023-24), minimum temperature is ranging from 2.1 to 3.6, morning and relative humidity varied high in the range of 15.2 to 23.8. Wind speed is in the range of 5.7 to 7.3.

Monsoon (Jun-Sep)

The results indicated that percentage deviation between observed and forecasted rainfall during monsoon (Jun-Sep) season five years was good it is in the range of -27.67 (2021-23) to -62.75 (2023-24). Whereas Maximum temperature ranged between -2.78 (2023-24) to 0.82 (2021-22), minimum temperature ranging between -8.33 (2024-25) to 5.16 (2022-23), cloud cover -5.91 (2023-24) to -27.6 (2023-24). Morning and afternoon relative humidity and Wind speed showed wide variation across season in the range of (-2.28 to 5.31), (-4.01 to 26.41) and (-38.5 to 76.0) respectively.

During monsoon usability percentage of rainfall (correct + usable) was excellent as it is in the range of 49.9% (2020-21) to 82.2% (2023-24). Indicating that the assured events prediction than the amount. The maximum and minimum temperature showed very good percentage of 60-90. The morning and afternoon relative humidity, cloud cover and wind speed also showed excellent results upto 100%. Representing greater utility of the forecast.

Correlation coefficient between observed and predicted were analyzed and results showed that the correlation coefficient during monsoon for rainfall was low are in the range of 0.2 (2024-25) to 0.4 (2020-21), whereas for maximum temperature showed values ranging from 0.2 (2024-25) to 0.5 (2022-23), minimum temperature, cloud cover, morning and afternoon relative humidity and wind speed were in the range upto 0.4 indicating moderate correlation between observed and forecast.

The corresponding qualitative analysis results (ratio score, critical success index, HK score, probability of detection, false alarm ratio and Heidke Skill Score) are presented in Table 6 During monsoon, seasons, the ratio score for rainfall ranged from 39.6 to 47.1%, indicating moderate forecast of rain during these seasons. The results revealed that the HK scores were positive during the season. The critical success index is low in the range of 0.3 (2023-24) to 0.4 (2021-22) Likewise the probability of detection (POD) is the excellent during monsoon season in the range of 0.8 to 1.0, The False alarm ratio (FAR) is in the range of 0.6 to 0.7. Heike Skill Score (HSS) is positive in monsoon seasons of the five years ranging from (0 to 0.1)

Similarly, from the Table 7, it is revealed that the RMSE values for monsoon season for rainfall were higher than pre-monsoon, varying from 2.0(2022-23) to 4.3(2023-24). Maximum temperature is ranging from 1.5 (2020-21) to 4.3 (2023-24), minimum temperature is ranging from (1.0 to 2.9), morning and relative humidity were very high are in the range of 6.8 to 13.8. Wind speed is in the range of (6.3-8.8).

Post-Monsoon (Oct-Dec)

The results indicated that percentage deviation of rainfall during post- monsoon (Oct-Dec) for rainfall was very low it is in the range of -20.5(2022-23) to -89.67 (2023-24). Whereas Maximum temperature ranging between -1.32 (2022-23) to -5.27 (2023-24), minimum temperature ranging between -1.20 (2020-21) to -5.91(2023-24), cloud cover -10.77 (2023-24) to -36.08(2021-22). Morning and afternoon relative humidity and Wind speed are showed wide variation across season in the range of (-1.95 to 4.63), (1.43 to 40.84) and (-21.73 to 26.9) respectively.

During monsoon usability of rainfall (correct + usable) excellent it is in the range of 83.7% (2020-21) to 100% (2023-24). Indicating that the assured events prediction than the amount. The maximum and minimum temperature showed very good percentage 60-90%. then the morning and afternoon relative humidity, cloud cover and wind speed also showed excellent results 71-96%, 65-88%, 60-80%, and 92-100% respectively.

Correlation coefficient between observed and predicted were analyzed and results showed that the correlation coefficient during post- monsoon season for rainfall were low are in the range of 0.1 (2023-24) to 0.4 (2021-22), whereas for maximum temperature, minimum temperature, cloud cover, morning and afternoon relative humidity and wind speed are in the range upto 0.5 indicating moderate correlation between observed and forecast.

The corresponding qualitative analysis results (ratio score, critical success index, HK score, probability of detection, false alarm ratio and Heidke Skill Score) are presented in Table 6 During monsoon, seasons, the ratio score for rainfall ranged from 39.6 to 47.1%, indicating moderate forecast of rain during these seasons. The results revealed that the HK scores were positive during the season. The critical success index is low in the range of 0.3 (2023-24) to 0.4 (2021-22) Likewise the probability of detection (POD) is the excellent during monsoon season in the range of 0.8 to 1.0, The False alarm ratio (FAR) is in the range of 0.6 to 0.7. Heidke Skill Score (HSS) is positive in monsoon seasons of the five years ranging from (0 to 0.1) Similarly, from the Table 7, it is revealed that the RMSE values for monsoon season for rainfall were higher than pre-monsoon, varying from 2.0(2022-23) to 4.3(2023-24). Maximum temperature is ranging from 1.5 (2020-21) to 4.3 (2023-24),

minimum temperature is ranging from (1.0 to 2.9), morning and relative humidity were very high are in the range of 6.8 to 13.8. Wind speed is in the range of (6.3-8.8).

Winter (Jan-Feb)

The results indicated that percentage deviation of rainfall during winter (Jan-Feb) for rainfall was very low or negligible represents more accurate, however there will be no rainfall during the season in the study area. Maximum temperature ranging between -0.19 (2024-25) to -60.18 (2023-24), minimum temperature ranging between -11.25 (2020-21) to -0.4 (2023-24), cloud cover showed very high deviation ranging between -71.75 (2023-24) to -100 (2023-24). Morning and afternoon relative humidity and Wind speed are showed wide variation across season in the range of (-41.93 to 50.45), (-49.5 to 125) and (-76.9 to 47.8) respectively.

During winter season usability of rainfall (correct + usable) excellent it is in the range of 97.2% (2021-22) to 100% (2023-24). Indicating that the assured events prediction than the amount. The maximum and minimum temperature showed good percentage 33.0-98.8, 41.2-69.4 respectively. Then the morning and afternoon relative humidity, cloud cover and wind speed also showed excellent results 67.6-89.4%, 72.9-98.8%, 91.8-94.0%, and 92.0-100% respectively.

Correlation coefficient between observed and predicted were analyzed and results showed that the correlation coefficient during winter season for rainfall were low are in the range of 0 to -0.1 whereas for maximum temperature, (-0.1 to 0.9) minimum temperature (0.1=- to 0.8) cloud cover, morning relative humidity (0.2 to 0.7) and afternoon relative humidity (0 to 0.7) and wind speed are in the range -0.2 to 0.3. Across five years, indicating moderate correlation between observed and forecast.

The corresponding qualitative analysis results (ratio score, critical success index, HK score, probability of detection, false alarm ratio and Heidke Skill Score) are presented in Table 6 During winter seasons, the ratio score for rainfall ranged from 94.0 to 95.3%, indicating excellent forecast skill of rain events during these seasons. The results revealed that the HK scores were negative during the season. The critical success index, the probability of detection (POD), and Heidke Skill Score (HSS) is positive in winter seasons across the five years ranging from (0 to 0.1). The Falsealarm ratio (FAR) is in the range 1.0 Similarly, from the Table 7, it is revealed that the RMSE values for winter season for rainfall were varying from 0.0 (2023-24) to 40.1 (2024-25). Maximum temperature is ranging from 1.3 (2022-23) to 13.3 (2023-24), minimum temperature is ranging from (2.2 to 7.8), morning and relative humidity were very high are in the range of 12.5 to 28.3, and 8.3 to 26.1 respectively.

Table 1: Seasonal percentage deviation between observed and predicted weather parameters during March 2020 to February 2025

Season	Years	Rainfall	Maximum temperature	Minimum temperature	Cloud cover	Morning RH	Afternoon RH	Wind speed
Pre-monsoon (Mar-May)	2020-21	0.00	-0.27	-0.34	-54.77	49.96	121.27	-23.91
	2021-22	0.00	-0.30	-0.26	-52.39	48.83	122.26	-23.31
	2022-23	0.0	-0.54	-2.10	-50.42	49.83	55.46	-35.20
	2023-24	0.00	-2.83	-3.13	-64.82	14.20	45.49	39.20
	2024-25	0.00	-2.34	0.32	-65.93	30.61	61.23	-0.59
Monsoon (Jun-Sep)	2020-21	-26.83	0.82	3.53	-6.90	5.31	25.59	-38.85
	2021-22	-27.87	0.73	3.17	-6.96	4.94	25.51	-40.02
	2022-23	-27.67	0.52	5.16	-5.91	3.54	26.41	-50.12
	2023-24	-62.75	-2.78	-8.33	-27.60	-2.28	-4.01	76.00
	2024-25	-18.75	-7.87	-8.18	-19.36	14.49	29.48	-53.42
Post-monsoon	2020-21	-25.95	-1.62	-1.21	-36.08	-2.83	40.84	-25.93

(Oct-Nov)	2021-22	-31.62	-1.42	-1.20	-33.94	-2.95	36.75	-22.73
	2022-23	-20.5	-1.32	-1.60	-31.94	-1.95	32.75	-21.73
	2023-24	-89.67	-5.27	-5.91	-10.77	4.63	1.43	26.19
	2024-25	-38.49	-1.22	-17.70	-52.74	-3.62	35.37	-26.92
Winter (Dec-Feb)	2020-21	0.00	-10.70	-13.17	-71.75	43.67	56.54	-75.31
	2021-22	0.00	-10.18	-11.25	-71.73	38.38	58.93	-76.96
	2022-23	0.00	-12.10	-13.22	-61.71	32.34	48.91	-72.95
	2023-24	0.00	-60.18	-57.78	-100.00	-41.93	-49.50	-38.66
	2024-25	0.00	-0.19	0.40	-82.65	50.45	125.05	47.88

Table 2: Seasonal percentage usability between observed and predicted weather parameters during March 2020 to February 2025

Season	Years	Rainfall	Maximum temperature	Minimum temperature	Cloud cover	Morning RH	Afternoon RH	Wind speed
Pre-monsoon (Mar-May)	2020-21	97.0	86.9	78.7	86.2	56.2	72.3	97.0
	2021-22	97.0	87.0	78.6	87.0	58.0	74.0	97.7
	2022-23	95.0	76.7	69.0	88.8	75.9	85.3	96.5
	2023-24	97.8	80.9	67.8	88.7	86.9	82.5	93.8
	2024-25	96.0	87.0	75.7	79.1	78.2	84.3	93.9
Monsoon (Jun-Sep)	2020-21	49.9	73.0	86.8	89.6	99.4	69.0	94.3
	2021-22	49.3	74.1	86.8	89.7	99.4	68.4	94.3
	2022-23	77.6	77.6	91.7	77.6	100.0	83.9	98.3
	2023-24	82.2	64.0	85.2	71.4	94.2	70.6	93.6
	2024-25	60.2	62.3	82.9	73.7	90.3	49.8	45.7
Post-monsoon (Oct-Nov)	2020-21	83.7	98.8	67.9	78.5	71.6	65.7	100.0
	2021-22	90.9	93.9	61.2	68.6	78.4	69.2	100.0
	2022-23	96.6	87.7	72.9	80.8	89.4	88.5	98.4
	2023-24	100.0	77.4	56.6	61.6	82.5	84.2	93.3
	2024-25	88.6	94.1	26.7	65.6	96.7	77.2	92.5
Winter (Dec-Feb)	2020-21	100.0	49.9	45.5	70.3	71.2	72.9	98.5
	2021-22	97.2	33.0	41.2	81.2	67.6	82.4	97.6
	2022-23	98.2	91.6	72.6	94.0	87.9	96.5	100.0
	2023-24	100.0	74.1	69.4	94.0	78.6	91.7	92.0
	2024-25	100.0	98.8	31.8	91.8	89.4	98.8	98.8

Table 3: Seasonal correlation between observed and predicted weather parameters during March 2020 to February 2025

Season	Years	Rainfall	Maximum temperature	Minimum temperature	Cloud cover	Morning RH	Afternoon RH	Wind speed
Pre-monsoon (Mar-May)	2020-21	0.2	0.8	0.7	0.2	0.4	0.2	0.3
	2021-22	0.0	0.7	0.7	0.0	0.4	0.4	0.3
	2022-23	0.1	0.6	0.6	0.1	0.2	0.1	0.0
	2023-24	0.4	0.4	0.4	0.4	0.4	0.2	0.1
	2024-25	0.4	0.7	0.4	0.4	0.6	0.3	0.2
Monsoon (Jun-Sep)	2020-21	0.0	0.4	0.1	0.1	0.0	0.2	0.2
	2021-22	0.0	0.3	0.0	0.1	15.9	0.1	0.2
	2022-23	0.2	0.5	0.3	0.2	0.5	0.3	0.2
	2023-24	0.3	0.5	0.4	0.4	0.3	0.2	0.3
	2024-25	0.2	0.2	-0.4	0.3	0.4	0.2	0.3
Post-monsoon (Oct-Nov)	2020-21	0.3	0.4	0.7	0.6	0.1	0.2	-0.1
	2021-22	0.4	0.4	0.7	0.5	0.1	0.3	-0.1
	2022-23	0.3	0.5	0.6	0.1	11.6	0.3	0.0
	2023-24	0.1	0.2	0.3	0.0	0.2	0.4	-0.1
	2024-25	0.3	0.6	0.7	0.6	0.8	0.7	0.2
Winter (Dec-Feb)	2020-21	0.0	-0.1	0.3	0.3	0.2	0.4	-0.3
	2021-22	0.0	-0.4	0.1	0.4	0.0	0.0	-0.2
	2022-23	-0.1	0.9	0.8	0.2	0.2	0.2	0.1
	2023-24	0.0	0.7	0.6	0.1	0.8	0.7	0.3
	2024-25	0.0	0.9	0.2	0.3	0.7	0.7	0.1

Table 4: Seasonal correct percentage of forecasted weather parameters during March 2020 to February 2025

Season	Years	Rainfall	Maximum temperature	Minimum temperature	Cloud cover	Morning RH	Afternoon RH	Wind speed
Pre-monsoon (Mar-May)	2020-21	97.0	66.0	53.2	97.0	24.7	31.7	77.6
	2021-22	97.0	65.7	52.7	97.0	26.8	32.7	77.9
	2022-23	248.4	57.8	48.3	248.4	45.8	64.6	74.3
	2023-24	91.0	54.8	43.5	91.0	49.6	67.6	67.8
	2024-25	93.6	56.5	59.1	93.6	58.3	57.4	53.9
Monsoon (Jun-Sep)	2020-21	27.3	43.1	61.5	78.2	75.9	39.7	49.5
	2021-22	27.0	44.2	62.1	81.6	77.0	39.7	48.8
	2022-23	58.2	46.5	75.7	59.2	87.3	58.7	69.5

Post-monsoon (Oct-Nov)	2023-24	74.8	40.0	46.9	41.1	76.3	52.1	64.0
	2024-25	39.5	41.7	54.3	70.3	70.3	19.7	13.7
	2020-21	74.2	69.2	44.1	63.7	56.9	36.3	78.5
	2021-22	86.9	63.3	40.5	56.4	55.8	39.7	76.4
	2022-23	92.2	64.8	47.6	60.3	68.9	70.4	81.1
	2023-24	99.0	56.4	35.8	32.5	55.8	64.2	70.0
Winter (Dec-Feb)	2024-25	83.5	76.7	13.3	54.7	75.8	29.9	76.7
	2020-21	100.0	31.3	27.6	62.6	43.8	46.3	48.5
	2021-22	100.0	20.0	23.5	71.8	36.4	55.4	40.0
	2022-23	100.0	70.4	45.8	84.3	59.3	85.9	73.6
	2023-24	100.0	61.2	55.3	87.0	59.8	70.5	72.4
	2024-25	100.0	91.8	18.8	81.2	69.4	80.0	78.8

Table 5: Seasonal usable percentage of forecasted weather parameters during March 2020 to February 2025

Season	Years	Rainfall	Maximum temperature	Minimum temperature	Cloud cover	Morning RH	Afternoon RH	Wind speed
Pre-monsoon (Mar-May)	2020-21	0.0	20.9	25.4	0.0	31.5	40.6	19.4
	2021-22	0.0	21.3	25.9	0.0	31.3	41.3	19.8
	2022-23	5.0	18.9	20.7	5.0	30.1	20.7	22.2
	2023-24	6.7	26.1	24.3	6.7	37.4	14.9	26.0
	2024-25	2.3	30.4	16.5	2.3	20.0	26.9	40.0
Monsoon (Jun-Sep)	2020-21	22.6	29.9	25.3	11.5	23.5	29.3	44.9
	2021-22	22.4	29.9	24.7	8.1	22.4	28.7	45.4
	2022-23	19.4	31.1	16.0	18.4	12.7	25.2	28.7
	2023-24	7.4	24.0	38.3	30.3	18.0	18.5	29.7
	2024-25	20.7	20.6	28.6	3.4	20.0	30.1	32.0
Post-monsoon (Oct-Nov)	2020-21	9.5	29.6	23.8	14.8	14.7	29.5	21.5
	2021-22	4.0	30.6	20.6	12.2	22.6	29.4	23.6
	2022-23	4.4	23.0	25.3	20.6	20.5	18.1	17.3
	2023-24	1.0	21.0	20.8	29.1	26.7	20.0	23.3
	2024-25	5.2	17.5	13.4	10.9	20.8	47.3	15.8
Winter (Dec-Feb)	2020-21	0.0	18.7	17.9	7.7	27.4	26.6	50.0
	2021-22	0.0	13.0	17.7	9.4	31.2	27.0	57.6
	2022-23	0.0	21.2	26.8	9.7	28.6	10.6	26.4
	2023-24	0.0	13.0	14.1	7.0	18.8	21.1	19.6
	2024-25	0.0	7.1	13.0	10.6	20.0	18.8	20.0

Table 7: Seasonal RMSE of forecasted weather parameters during March 2020 to February 2025

Season	Years	Rainfall	Maximum temperature	Minimum temperature	Cloud cover	Morning RH	Afternoon RH	Wind speed
Pre-monsoon (Mar-May)	2020-21	2.1	1.5	2.1	2.1	23.8	19.5	5.9
	2021-22	2.4	1.7	2.1	2.4	23.4	19.5	5.7
	2022-23	3.7	2.3	2.5	3.7	17.9	15.2	6.5
	2023-24	2.8	4.3	3.6	2.8	16.1	16.0	7.3
	2024-25	2.7	1.9	2.1	2.7	15.7	15.3	8.7
Monsoon (Jun-Sep)	2020-21	16.4	2.3	1.6	2.1	9.6	19.1	8.7
	2021-22	17.4	2.1	1.7	2.1	9.5	18.8	8.8
	2022-23	8.7	2.0	1.0	2.7	6.8	16.1	6.3
	2023-24	6.1	4.3	2.9	3.1	13.8	24.7	7.9
	2024-25	16.4	2.3	1.6	2.1	9.6	19.1	8.7
Post-monsoon (Oct-Nov)	2020-21	12.6	1.2	2.5	2.9	16.4	22.3	6.1
	2021-22	7.9	1.4	2.6	3.3	15.5	20.4	6.3
	2022-23	6.0	1.5	2.3	2.4	11.5	12.2	6.1
	2023-24	0.9	5.6	4.2	3.7	18.8	14.8	13.8
	2024-25	34.5	2.2	4.5	3.2	10.0	17.6	7.6
Winter (Dec-Feb)	2020-21	1.6	3.2	3.4	3.2	24.9	16.3	8.3
	2021-22	0.6	3.5	3.7	2.8	18.3	13.6	9.0
	2022-23	0.1	1.3	2.2	1.8	12.5	8.3	5.8
	2023-24	0.0	13.3	7.8	1.7	28.3	18.9	7.2
	2024-25	40.1	0.6	4.6	2.0	11.2	26.1	5.4

Table 6: Season wise rainfall Verification of weather forecast of Vijayapura district (2019 to 2025)

Winter	Years	R.S	H.K.	POD	FAR	CSI	HSS
Pre-monsoon	2020-21	76.3	0.3	0.4	0.9	0.1	0.1
	2021-22	74.8	0.2	0.4	0.9	0.1	0.1
	2022-23	69.9	0.4	0.7	0.7	0.3	0.3
	2023-24	69.9	0.4	0.7	0.7	0.3	0.3
	2024-25	69.9	0.4	0.7	0.7	0.3	0.3

Monsoon	2020-21	39.6	0.0	1.0	0.6	0.4	0.0
	2021-22	40.2	0.0	1.0	0.6	0.4	0.0
	2022-23	47.1	0.1	0.8	0.7	0.3	0.1
	2023-24	47.1	0.1	0.8	0.7	0.3	0.1
	2024-25	47.1	0.1	0.8	0.7	0.3	0.1
Post monsoon	2020-21	61.4	0.5	1.0	0.7	0.3	0.3
	2021-22	70.2	0.5	0.9	0.8	0.3	0.3
	2022-23	73.7	0.6	0.9	0.8	0.2	0.2
	2023-24	73.7	0.6	0.9	0.8	0.2	0.2
	2024-25	73.7	0.6	0.9	0.8	0.2	0.2
Winter	2020-21	92.3	0.0	0.0	1.0	0.0	0.0
	2021-22	95.3	0.0	0.1	1.0	0.1	0.0
	2022-23	94.0	-0.1	0.0	1.0	0.0	0.0
	2023-24	94.0	-0.1	0.0	1.0	0.0	0.1
	2024-25	94.0	-0.1	0.0	1.0	0.0	0.0

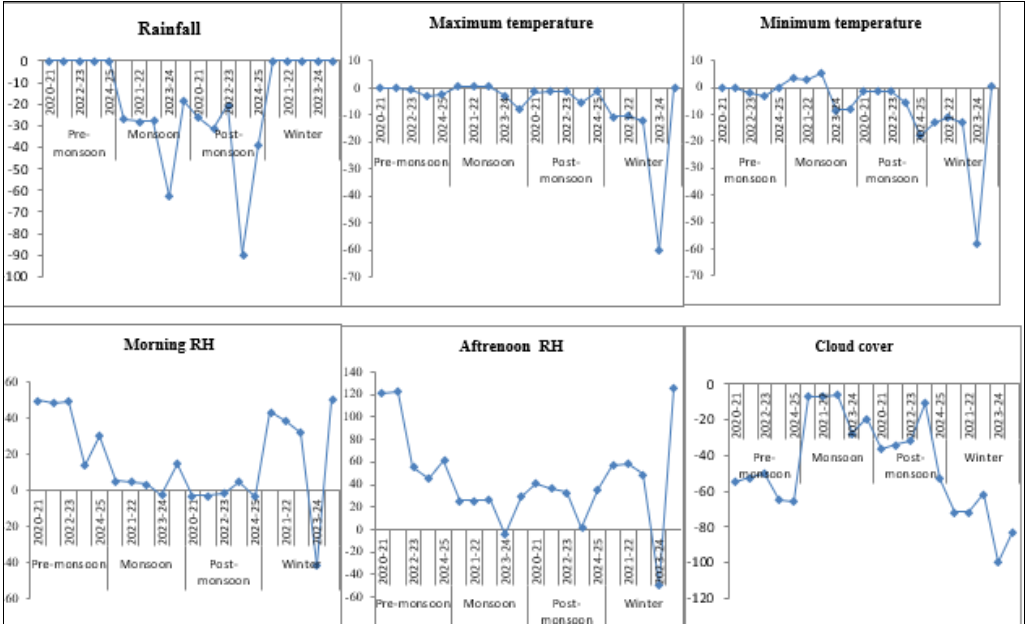


Fig 1: Seasonal percentage deviation between observed and predicted weather parameters during March 2020 to February 2025

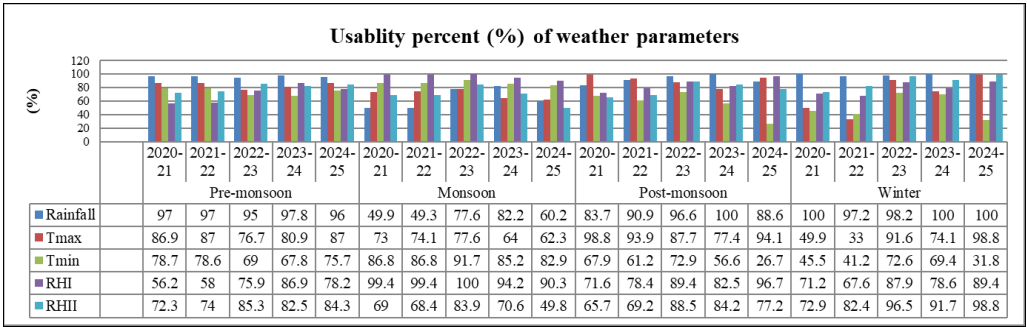


Fig 2: Seasonal percentage usability between observed and predicted weather parameters during March 2020 to February 2025

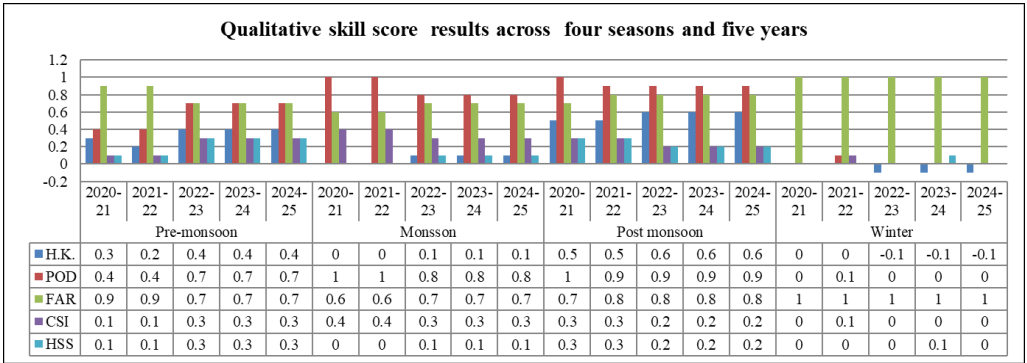


Fig 3: Season wise rainfall Verification of weather forecast of Vijayapura district (2019 to 2025)

Conclusion

The study revealed that the extended range weather forecasts issued by IMD for Vijayapura district during 2020-2025 effectively predicted rainfall occurrences with high usability and probability of detection across all seasons. However, quantitative accuracy, particularly in predicting rainfall amounts, was limited, as indicated by large deviations and moderate to low correlation coefficients. Forecasts for temperature, humidity, wind speed, and cloud cover showed moderate to good accuracy and usability. Overall, despite some quantitative limitations, the forecasts demonstrated sufficient skill to support agricultural advisories and decision-making in the region. Further improvements in quantitative rainfall prediction are recommended to enhance forecast reliability.

References

1. Chaudhary JL, Singh KK, Chattopadhyay N, *et al.* Usability of medium range weather forecast for agromet advisory services over India. *Mausam*. 2010;61:225-34.
2. Chauhan M, Rathi GS. Verification of medium range weather forecast for Pantnagar (Uttarakhand). *Journal of Agrometeorology*. 2008;10(Special Issue):249-52.
3. India Meteorological Department (IMD). Annual Report 2022-23. Ministry of Earth Sciences, Government of India; 2023.
4. India Meteorological Department (IMD). Annual Report 2023-24. Ministry of Earth Sciences, Government of India; 2024.
5. Khichar ML, Soni CP. Accuracy of medium range weather forecast for Hisar (Haryana). *Journal of Agrometeorology*. 2010;12(2):248-51.
6. Sharma K, Chattopadhyay N, Singh KK, Rao G. Medium range weather forecast and its application in Agromet Advisory Services. *Mausam*. 2015;66:577-84.
7. Lunagaria MM, Chauhan M. Accuracy of medium range weather forecast for Anand (Gujarat). *Journal of Agrometeorology*. 2009;11(2):146-50.
8. Ministry of Earth Sciences (MoES). Annual Report 2021-22. Government of India, New Delhi; 2022.
9. Mishra B, Singh KK, Chattopadhyay N, Singh SS. Verification of medium range weather forecast for Ranchi (Jharkhand). *Journal of Agrometeorology*. 2010;12(2):252-5.
10. Rathore LS, Maini P, Singh KK. Evaluation of operational medium range weather forecasts at different stations of India. *Mausam*. 1999;50:279-88.
11. Sahu DD, Singh KK, Chattopadhyay N. Verification of medium range weather forecast and its economic impact on farming community of Gujarat. *Mausam*. 2012;63:133-42.
12. Seeley MW. The use of weather and climate information in farm management. *Climatic Change*. 1994;28:151-67.
13. Singh KK, Chattopadhyay N, Singh KK. Verification of medium range weather forecast for agromet advisory in different agroclimatic zones of India. *Mausam*. 2005;56:655-62.
14. Sridhara S, Bhagat KP, Mallik B. Impact of Agromet Advisory Service (AAS) on farming community: a case study. *Journal of Agrometeorology*. 2014;16(2):138-42.
15. Tripathi KP, Singh KK, Chattopadhyay N. Skill of medium range weather forecast over agroclimatic zones of India. *Mausam*. 2008;59:135-42.