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Forecast verification analysis of rainfall and temperature for Malkangiri district of Odisha

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Abstract
Medium range weather forecast and weather based agro advisories help in farming community by minimize the production losses due to unfavourable conditions. So, there is need to study reliability and suitability of the medium range weather forecasts for further improvement. In this study verification of medium range weather forecast of Malkangiri, Odisha during the period of 2017-18 are discussed in respect to rainfall and temperature. Usability based on quantity of rainfall was higher in winter season (100%) and very less in monsoon season (17.02%). Except monsoon season, the quantitative forecast of rainfall revealed higher reliability over percent forecast accuracy (ratio score). Higher Root Mean Square Error (RMSE) of rainfall in monsoon season (18.48) indicated lower accuracy in prediction. Annual usability of forecasted maximum temperature and minimum temperature were 71.11 and 76.19%, respectively. The highest percentage of usability for maximum and minimum temperature was observed in winter season. The RMSE for minimum temperature was found lower than maximum temperature indicating higher accuracy. Furthermore, there is scope of improvement in usability of rainfall mainly for monsoon season as well as temperature for more income of farming community of Malkangiri district of Odisha by following weather based agro advisories.

Keywords: forecast verification, rainfall, temperature, usability, weather

Introduction
Agriculture in India mainly depends on weather and climatic conditions. Weather condition plays a great role for modifying agricultural production. A great portion of loss in agricultural sector was contributed by aberrant weather condition. In this regard timely weather information allows farmers to plan their farm operations in a way that helps in exploiting the yield levels as well as reduction in crop loss. Agro-meteorological Field Unit (AMFU) under the project of Gramin Krishi Mausam Sewa (GKMS) is operational in the South Eastern Ghat agro climatic zone of Odisha. It comprises of Malkangiri district and parts of Koraput (Jeypore). Medium range weather forecast is received from India Meteorological department, New Delhi on each Tuesday and Friday. The data were clarified by a team of experts on every Tuesday and Friday and Agro-advisory bulletin is prepared with the help of expert members based on the information on weather forecast, crop condition obtained from the farmers' field (such as crop growth stage, incidence of pest attack and diseases and water stress) and weather condition of previous days. The information is disseminated for the farmers of the district on the various agronomic practices to be followed to increase crop production and minimize the production losses due to unfavourable conditions including pest and diseases by using suitable plant protection measures. For effective planning and management of agricultural practices such as selection of cultivar, sowing, need-based application of fertilizer, pesticides and efficient irrigation as well as harvesting. Medium range weather forecast greatly contribute towards making short-term adjustments in daily agricultural operations which minimize losses resulting from adverse weather conditions and improve yield and quantity as well as quality of agricultural productions. Rana *et al.* [1] reported an increase in net return by 4.0 - 5.7% for rice, 2.1 - 4.4% for maize and 3.2 - 4.6% for wheat in diffrenet district of Himachal Pradesh due to intervention of weather forecast based agro advisory services (AAS). The AAS farmers have gained 5.26 – 25.00% more income over non AAS farmers from different crops [2]. So, there is a need to study reliability and suitability of the medium range weather forecasts. With these backgrounds the present study has been made to verify reliability and suitability of rainfall and temperature for Malkangiri district of Odisha.

Materials and Methods

The weather parameters forecasted by India Meteorological Department, New Delhi for Malkangiri district of Odisha were rainfall, cloud cover, maximum temperature, minimum temperature, relative humidity and wind speed as well as wind direction. Different verification methods were used to assess the reliability and suitability of forecast values of weather parameters. In this study, forecast of rainfall and temperature (maximum and minimum) have been verified by calculating the error structure and used to categorize the forecast given as correct, usable or unusable based on the percent deviation in the forecast values as compared to observed values as per the guidelines of National Centre for medium range weather forecasting [3]. Sum of correct and usable events were considered as usability of forecast. Criteria for obtaining usability for rainfall and temperature are given in Table 1. Different verification scores [3] that have been used for verification of rainfall and temperature are-

Table 1: Criteria for obtaining usability for rainfall and temperature

Category	Error structure for verification		
	Quantitative rainfall		Temperature
	If observed rainfall ≤ 10 mm	If observed rainfall > 10 mm	
Correct	≤ 0.2 mm variation	≤ 2% variation in observed	≤ 1 ^{0}C difference
Usable	0.2 to 2.0 mm variation	2 – 20% variation in observed	1 – 2 ^{0}C difference
Unusable	> 2 mm variation	> 20% variation in observed	> 2 ^{0}C difference

Source: (3)

Measures of obtaining skill of yes/no rainfall

If total number of cases is M then, M = YY+NN+YN+NY

Where, YY = Number of days when rain was forecasted and also observed, NN = Number of days when rain was not observed and also not forecasted, YN = Number of days when rain was observed but not forecasted and NY = Number of days when rain was not observed but forecasted.

Ratio score

Ratio score measures the proportion of correct forecast. Value varies between 0 to 100 and 100 indicating accurate forecast. Seasonal and annual ratio score (%) for rainfall was estimated as:

$$\text{Ratio score} = \frac{\text{Correct forecasts}}{\text{Total forecasts}} \times 100 = \frac{(YY + NN)}{M} \times 100$$

Hanssen and Kuipers' Score (HKS)

HKS is the ratio of economic saving over climatology due to forecast to that of a set of perfect forecasts. The value of HKS varies from -1 to +1. If all forecast are perfect then it is +1 and if all forecast are wrong then it is – 1. Annual HKS for rainfall was calculated as:

$$HKS = \frac{[(YY \times NN) - (YN \times NY)]}{(YY + NY)(YN + NN)}$$

Correlation coefficient (r) and Root Mean Square Error (RMSE) are calculated for obtaining the skill of the rainfall and temperatures as (3):

$$r(f_i, o_i) = \frac{\sum(f_i - \bar{f})(o_i - \bar{o})}{\left[\sum(f_i - \bar{f})^2 \sum(o_i - \bar{o})^2\right]^{\frac{1}{2}}}$$

$$RMSE = \left\{\frac{1}{n}\sum(f_i - o_i)^2\right\}^{\frac{1}{2}}$$

Where, f_i = forecast value
o_i = observed value
$\bar{f}$ = mean forecast value
$\bar{o}$ = mean observed value
n = total number of observations

The year (March 2017 to February 2018) was divided into four seasons i.e. pre-monsoon (March – May 2017), monsoon (June – September 2017), post monsoon (October – December 2017) and winter (January – February 2018) for verification analysis.

Results and Discussion

During the study period (March 2017 to February 2018), highest mean maximum temperature of 41.63 ^{0}C was recorded in the month of April and it was varied between 30.00 ^{0}C to 41.63 ^{0}C. The lowest mean minimum temperature of 13.53^{0}C was recorded in the month of January but it was varied between 13.53^{0}C to 26.74 ^{0}C (Fig. 1). The total annual rainfall (average of 7 blocks of the district) received during the study period was 1722.66 mm. Highest rainfall of an amount of 493.84 mm was received in August followed by a rainfall of 454.17 mm in July (Fig. 1). Rainfall during the current year was more than normal (1667.67 mm) by 3.30%.

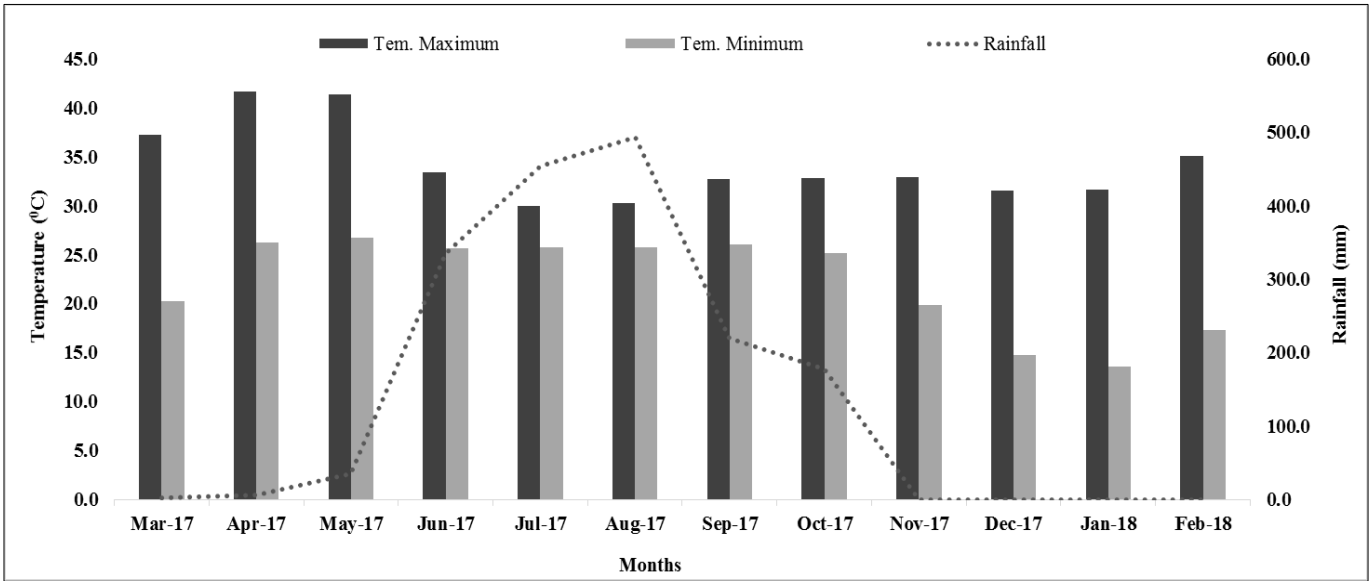

Fig 1: Monthly mean maximum, minimum temperature (^{0}C) and total rainfall (mm) during study period (March 2017 to February 2018)

Rainfall analysis

The seasonal and annual analysis of rainfall verification in relation to rainfall occurrence and amount with predicted values for the period of 2017-18 was compared. Results showed that, number of days when rain was forecasted and also observed (YY) were 4, 88, 16, and 0 days for pre-monsoon, monsoon, post monsoon and winter seasons, respectively. Number of days when rain was not observed and also not forecasted (NN) were 64, 6, 54 and 56 days for pre-monsoon, monsoon, post monsoon and winter seasons, respectively. So, total matching cases (YY+NN) were 68, 94, 70 and 56 days out of 92, 117, 90 and 58 forecasted days during pre-monsoon, monsoon, post monsoon and winter seasons, respectively. Whereas, the annual analysis of rainfall verification revealed that, the number days for YY (forecasted and observed rain) was 108 as well as NN (Not forecasted and also not observed) was 180. But the numbers of non-matching (YN+NY) days were 69 (Table 2).

The seasonal forecast for rainfall were 94.12%, 7.45%, 77.14% and 100% correct during pre-monsoon, monsoon, post monsoon and winter seasons, respectively (Table 2). The data on ratio score indicated that yearly prediction of rainfall was correct in more than 80 cases out of 100 cases. Highest ratio score was observed in winter season (96.55%) followed by monsoon season (80.34%), post-monsoon (77.78%) and pre-monsoon season (73.91%). Usability based on quantity of rainfall was very less in monsoon season. So, there is some scope for improvement in rainfall forecast in terms of quantity though the accuracy of rainfall forecast was more than 80% in monsoon season. Lowest usability in monsoon season was also reported by Kushwaha *et al*. [4]; Manjappa and Yeledalli [2]. The forecast analysis was also revealed that, Root Mean Square Error (RMSE) of 3.55, 18.48, 9.66 and 1.68 for pre-monsoon, monsoon, post monsoon and winter seasons, respectively. It was 11.80 for whole year. The lowest RMSE value was observed in the winter and pre-monsoon season signifying least error between observed and forecasted data. The Hanssen and Kuipers' Score (HKS) for whole year was 0.67 as well as correlation of 0.53. The positive HKS indicated the reliability of forecast to be satisfactory level. The correlation coefficients between observed and forecasted rainfall for year was positive. Manjappa and Yeledalli [2] also reported positive correlation. Except monsoon season, the quantitative forecast revealed higher reliability over percent accuracy of forecast (ratio score) may be due to frequency of rainy days was more in monsoon season.

Table 2: Verification of forecasted rainfall (March 2017 to February 2018)

Particulars	Seasonal				Yearly
	Pre-monsoon (Mar-May)	Monsoon (Jun-Sep)	Post monsoon (Oct-Dec)	Winter (Jan-Feb)	
Number of days when rain was forecasted and also observed (YY)	4	88	16	0	108
Number of days when rain was not observed and also not forecasted (NN)	64	6	54	56	180
Number of days when rain was observed but not forecasted (YN)	6	4	0	0	10
Number of days when rain was not observed but forecasted (NY)	18	19	20	2	59
Number of matching cases (YY+NN)	68	94	70	56	288
Total number of forecasted days (M)	92	117	90	58	357
No. of missing days (Forecasted data was not available)	0	5	2	1	8
Ratio score (%)	73.91	80.34	77.78	96.55	80.67
Hanssen and Kuipers' Score (HKS)					0.67
Correlation					0.53
Root Mean Square Error (RMSE)	3.55	18.48	9.66	1.68	11.80
Error structure					
Correct	94.12	7.45	77.14	100.00	62.85
Usable	2.94	9.57	4.29	0.00	4.86
Unusable	2.94	82.98	18.57	0.00	32.29

Temperature analysis

Out of 353 forecasted days, the number days with ≤1 ^{0}C absolute values of the difference were 176 for maximum temperature (Table 3). The number days with ≤1 ^{0}C absolute values of the difference were 174 for minimum temperature out of 357 forecasted days (Table 4). The correct and usable cases were summed up and the combined values indicate the percent usability of the forecast. Annual usability of forecasted maximum temperature and minimum temperature were 71.11 and 76.19%, respectively. The highest percentage (86.21) of usability for maximum temperature was observed during winter season and lowest (67.41) in post monsoon season. In case of minimum temperature, usability of minimum temperature was maximum during winter season (89.65%) and minimum during monsoon season (66.67%). More than 70% of annual usability of forecasted maximum temperature and minimum temperature was also reported by Manjappa and Yeledalli [2]; Ray [5]. The Root Mean Square Error (RMSE) for maximum temperature was 2.74, 2.62, 2.56 and 1.74 in pre-monsoon, monsoon, post monsoon and winter seasons, respectively with annual RMSE of 2.51. The RMSE of 2.19, 2.61, 2.15 and 1.68 were recorded in pre-monsoon, monsoon, post monsoon and winter seasons, respectively. The annual temperature analysis showed correlation of 0.85 and 0.91 for maximum and minimum, respectively (Table 3 and 4). Less RMSE with minimum temperature is indicating higher accuracy over maximum temperature.

Table 3: Verification of forecasted maximum temperature (March 2017 to February 2018)

Particulars	Seasonal				Yearly
	Pre-monsoon (Mar-May)	Monsoon (Jun-Sep)	Post monsoon (Oct-Dec)	Winter (Jan-Feb)	
Number of absolute values of the difference ≤ 1 ^{0}C	43	50	43	40	176
Number of absolute values of the difference >1 ^{0}C	46	67	46	18	177
Number of absolute values of the difference > 2 ^{0}C	27	38	29	8	102
Total number of forecasted days	89	117	89	58	353
Number of missing days (Forecasted and/or actual data was not available)	3	5	3	1	12
Root Mean Square Error (RMSE)	2.74	2.62	2.56	1.74	2.51
Correlation					0.85
Error structure					
Correct	48.31	42.74	48.31	68.97	49.86
Usable	21.35	24.79	19.10	17.24	21.25
Unusable	30.34	32.48	32.58	13.79	28.90

Table 4: Verification of forecasted minimum temperature (March 2017 to February 2018)

Particulars	Seasonal				Yearly
	Pre-monsoon (Mar-May)	Monsoon (Jun-Sep)	Post monsoon (Oct-Dec)	Winter (Jan-Feb)	
Number of absolute values of the difference ≤ 1 ^{0}C	43	51	45	35	174
Number of absolute values of the difference >1 ^{0}C	49	66	45	23	183
Number of absolute values of the difference > 2 ^{0}C	21	39	19	6	85
Total number of forecasted days	92	117	90	58	357
Number of missing days (Forecasted and/or actual data was not available)	0	5	2	1	8
Root Mean Square Error (RMSE)	2.19	2.61	2.15	1.68	2.26
Correlation					0.91
Error structure					
Correct	46.74	43.59	50.00	60.34	48.74
Usable	30.43	23.08	28.89	29.31	27.45
Unusable	22.83	33.33	21.11	10.34	23.81

Conclusions

The results showed that, the prediction for rainfall has been found to be quite accurate expect monsoon season and need to be improvement in usability of rainfall mainly for monsoon season because rainfall is an important parameter to make decision on the crop production. Furthermore, there is some scope for improvement in usability of temperature. Improvement in forecast accuracy will definitely provide more benefits to the farming community.

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