

Testing the accuracy of rainfall forecast for its usability in planning smart agricultural practices and its user response

A.N. Islam^{1*}, R.L. Deka², K. Medhi² and K. Sarmah²

¹Department of Natural Resource Management, College of Horticulture and Farming System Research (Assam Agricultural University), Nalbari-781 336, India

²Department of Agricultural Meteorology, College of Agriculture (Assam Agricultural University), Jorhat-785 013, India

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*Corresponding Author Email: athar.islam@aau.ac.in

*ORCID: <https://orcid.org/0009-0001-7712-1682>

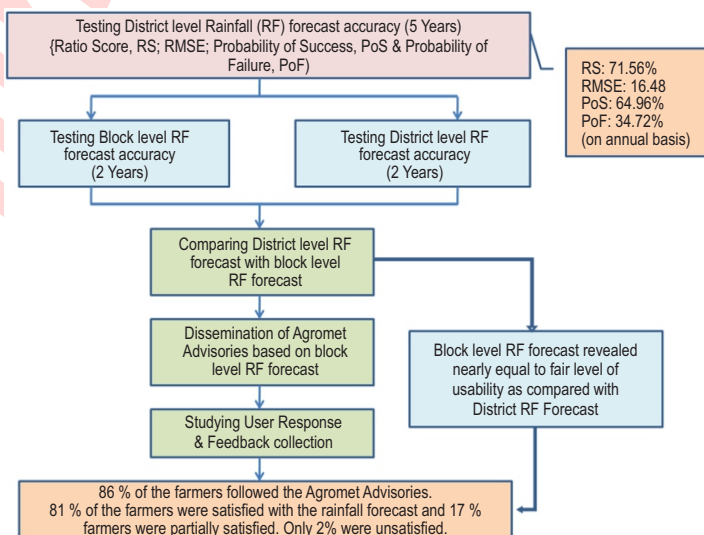
Abstract

Aim: Compute the accuracy of district level rainfall forecast issued during last five years and compare its accuracy with the block level forecast and evaluate its usability by farmers.

Methodology: 5-years rainfall forecasts were verified qualitatively by using Ratio Score (RS) and quantitatively by using statistical technique like RMSE. The error structures for verification of quantitative precipitation were also followed to discriminate between probability of success and failure forecasts. 5-Day Block level forecasted rainfall was also verified for three blocks viz., Kaliapani, Jorhat and Titabor, and the accuracy was compared with the district level forecasted data for assessing its practical utility. Further, based on the agromet advisory bulletins (AABs) disseminated, feedback were collected from 700 respondents regarding the field level usability of the AABs and the weather forecasts issued during the study period.

Results: Qualitative verification of district level rainfall forecasts from 2018-19 to 2022-23 showed that, Ratio Score (RS) had a good acceptability with a mean score of 72% on annual basis and 80%, 76%, 67% and 66% during winter, post-monsoon, monsoon and pre-monsoon seasons, respectively. Quantitatively, 65% rainfall forecasts were found correct and usable on an annual basis with highest probability of success during winter (96%; i.e., highly accurate) and lowest during monsoon (30%). Probability of success along with the RS of the block level rainfall forecasts were somewhat fair when compared with the district level forecast. Further, feedback analysis from 700 respondents revealed that 86% of the farmers followed the agromet advisories and out of the total sample, 81% were satisfied with the rainfall forecast and 17% farmers were partially satisfied.

Interpretation: District level rainfall forecast had a good acceptability with fair quantitative and qualitative forecast accuracy. Though the qualitative acceptability of rainfall forecast during monsoon was satisfactory, there was a lag in forecast of the exact quantum of rainfall occurred, which resulted in reduced probability of success with high RMSE values for the season. Further, Block level forecast accuracy showed slightly better results in most of the cases and therefore it can be effectively utilized over district level rainfall forecast for formulation and dissemination of micro level smart weather-based advisories.



Key words: Accuracy, Agromet Advisory Bulletins, Block level, District level, Qualitative, Quantitative, Rainfall forecast



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Introduction

Agriculture in Assam is primarily rainfed and therefore, uniform distribution of rainfall during a crop season plays vital role in defining the crop acreage and yield. The Northern part of the state is surrounded by Arunachal Pradesh and Bhutan, the eastern part by Nagaland, some parts of Arunachal Pradesh and Myanmar, the southern part by Mizoram, Tripura and Bangladesh, and western region by Meghalaya and West Bengal. The diverse topographic and orographic characteristics of the region plays a key role in the region's rainfall variations (Sinha *et al.*, 1982; Goswami *et al.*, 2010; Mahanta *et al.*, 2013; Mohapatra *et al.*, 2008) which eventually gets amplified due to the anticipated impact of climate variabilities, thereby triggering serious concerns to the agrarian community over the region. Slight variations in the rainfall could be vulnerable as major part of the region is comprised of valley flood plains (Gogoi and Rao, 2022) which support a large chunk of the principal crop areas. Under different GHG emission scenarios (Shared Socioeconomic Pathways), the variability of rainfall is projected to increase with more weightage in the frequency of heavy rainfall and drought events (IPCC, 2021), and such consequences may lead to an estimated crop loss of 10-40% in India by 2080-2100 (IPCC, 2007).

The Ministry of Environment and Forests, Government of India (INCCA, 2010) has projected future climate change scenario over the NE region using regional climate model (PRECIS) and forecasted annual increase in mean rainfall by up to 0.3 to 3 per cent and temperature by 1.8°C to 2.1°C by the end of 2030. Such amplifications in rainfall (Gharphalia *et al.*, 2018) and temperature (Deka *et al.*, 2009) may likely aggravate the occurrence of frequent and extreme weather events, thus provoking a major threat to agriculture and allied sectors in near future. Rainfall is a natural process, and its variability is uncontrollable at farmers end and therefore, adaptation to such situation by proper utilization of quality forecast for crop panning is one of the most feasible options for assuring food security. Accurate quantitative as well as qualitative rainfall forecast is crucial for taking up various management and intercultural operations thereby, strengthening timely crop plannings for improved yields and profits for farmers (Arulmathi *et al.*, 2023). Since, the region is experiencing high anomaly in seasonal and day-to-day weather pattern, strategic action plan with contingency measures need to be framed adequately and inclusively for timely implementation. Farmers' exposure to the ever-escalating possibility of rainfall variability can be minimized through agricultural techniques customized with timely and accurate weather forecasts.

The ability to communicate timely and accurate weather predictions offer possibility to reduce the exposure of people to the deleterious impacts of atmospheric events (Singh *et al.*, 2018). Timely communicated weather information can be utilized by cultivators for taking critical farm decisions like, selection of crop along with its variety, nursery bed preparation, optimizing

sowing time, main field preparation, scheduling irrigation and fertilizer applications, intercultural practices, planning pesticide spraying operations for pest and disease control, deciding suitable time for crop harvest and its market transportation and management of the allied sectors like, livestock, poultry and fishery (Islam *et al.*, 2024).

It is evident that farmers who received timely weather warnings made significantly more efficient farm management decisions and obtained enhanced crop yields than the non-users of weather-climate information services (Chiputwa *et al.*, 2022). Since, the impact of weather in crops like rice can result in yield variability up to nearly 70 per cent (Islam *et al.*, 2017), therefore, weather smart farming in India can reduce the cost of production by nearly 5 per cent, approximately, with enhanced yield levels up to 15 per cent through judicious and timely utilization of inputs (Maini and Rathore, 2011). Such an increase in the yield levels and reduction in the cost of production can lead to an increase in net returns up to 10 to 29 per cent. The National Council of Applied Economic Research, in their report revealed that, India's investment of nearly 1,000 crores in weather forecasting related research in agriculture could facilitate benefits worth rupees 50 thousand crores in the future farming sector (NCAER, 2020).

Since the genesis of India's Agromet Advisory Services in 1976 under India Meteorological Department, Government of India, New Delhi and National Centre for Medium Range Weather Forecasting, Gol, Noida, in 1991 and its subsequent advancement in the weather forecasting techniques, the initial spatial resolution of forecasts have been substantially upgraded to finer levels. Over the stretch of time, the resolutions of medium range weather predictions used for Agromet services got fine-tuned from 250 km resolution in the year 1991 to 150 kms in 1993, 75 kms in 1999, 22 km in 2009 and gradually up to 12 kms in 2019 and the short range forecast resolutions up to 1-3 kms. Such advancements in weather forecasting have revolutionized human ability to predict and prepare for weather-related events, improving safety, resource management, and overall resilience in the face of changing weather patterns (IMD, 2021). Currently, such outputs are being utilized to prepare Agromet Advisory Bulletin (AAB) on every Tuesday and Friday for its dissemination to the farming community through a single window of Gramin Krishi Mausam Sewa (GKMS).

Generation of multiple block and district level AABs within a short span of time has been made possible with the evolution of Agromet Decision Support System (Agro-DSS) having customized tools to integrate weather and crop information in a dedicated web portal, and display the output in form of bulletins and mobile applications (Islam *et al.*, 2024). Such information gets disseminated to the farmers on real time basis through multiple platforms. Under the present scenario, where nearly 75% of Indian districts are facing different levels of climatic hazards (Bal *et al.*, 2021) along with changes in the rainfall pattern during different seasons of the year (Deka *et al.*, 2015; Gharphalia *et al.*,

2018), generating adaptation and mitigation measures using Agromet Advisory Services will prove to be one of the key ways to address the sweltering issue of climate change and variability.

With the intent of proliferating the services under GKMS up to micro level, block level weather forecasts are being issued by IMD to prepare Block Level Agromet Advisories on an experimental basis. However, the dynamic nature of weather phenomenon at micro level is predominant and, limited work has been done for UBZ of Assam on the usability of block level weather forecast over district level weather forecast for agricultural planning. The UBZ is a largely farming based region of the state which is characterized by predominantly rain-fed agriculture, with limited irrigation infrastructure, making crop production highly dependent on monsoon rainfall. The major crops in the region include *Sal* rice, tea, sugarcane, mustard, pulses, maize, and a variety of vegetables, fruits along with other agri-allied sectors, each exhibiting specific seasonal requirements and distinct sensitivities to variations in precipitation. To understand the strengths and weaknesses of the rainfall forecasts on the farming practices of the region, and to indicate the model developers where improvements need to be made in the model, regular regional verification is necessary (Ebert and McBride, 2000). Therefore, the current study was conducted for verification of district level medium-range rainfall forecast delivered during last five years and compare its accuracy with block level forecast and evaluate its field level usability by farmers.

Materials and Methods

The study was undertaken at Agromet Field Unit (AMFU), Jorhat, Assam Agricultural University situated in the upper Brahmaputra Valley Zone of Assam, for a period of five years from 2018-19 to 2022-23. A 5-day district level forecasted rainfall data of Jorhat were compared and verified against the observed data recorded by AMFU-Jorhat at ICR Farm of Assam Agricultural University. A 5-day Block level forecasted rainfall was also verified for three blocks viz., Jorhat, Kaliapani and Titabor, and the accuracy was compared with the district level forecasted data for two consecutive years, 2021-22 and 2022-23 based on the availability of data. The observed daily rainfall data were recorded for the said blocks through rain gauges installed under AMFU Jorhat. The error structures for verification of quantitative precipitation as proposed by IMD were also estimated to discriminate between Success (*i.e.*, correct and usable) and Failure (*i.e.*, unusable) forecasts (Singh *et al.*, 1999). Considering the efficiency, as suggested by Singh *et al.* (2005), Khichar *et al.* (2010), Sahu *et al.* (2012) and Sarmah *et al.* (2016), the forecasts were verified qualitatively by using Ratio Score (RS) and quantitatively by using statistical technique like RMSE.

Calculation of error structures (probability of success and failure): An error structure calculation method suggested by IMD was followed to discriminate between the correct, usable and unusable rainfall forecasts (Singh *et al.*, 1999). The error structure used for verifying the Quantitative Precipitation (QP) was,

	Observed rainfall ≤ 10 mm	Observed rainfall > 10 mm
Correct	diff ≤ 0.2 mm	diff ≤ 2% of obs
Usable	0.2 mm < diff ≤ 2.0 mm	2% of obs < diff ≤ 20% of obs
Unusable	diff > 2.0 mm	diff > 20% of obs

Usability (Probability of success) = Correct + Usable; Probability of failure = Unusable

Where, 'diff' stands for absolute difference of forecasted and observed rainfall in mm and 'obs' stands for observed rainfall in 'mm'. Further, based on usability, the nature of forecast accuracy was classified as:

Accuracy	Probability of success
Very high accuracy	: 90-100%
High accuracy	: 80-90%
Moderate accuracy	: 60-80%
Poor accuracy	: <60

Calculation of Ratio Score (RS): "Based on the observed and forecasted rainfall data, a 2 × 2 contingency table was prepared as following. If 'Y' stands for occurrence of rain and 'N' stands for non-occurrence then",

Observed	Forecast	
	Rain	No Rain
Rain	A (YY)	B (YN)
No Rain	C (NY)	D (NN)

Where, 'A' is the number of hits (predicted and observed), 'B' is number of false alarms (predicted but not observed), 'C' is number of misses (observed but not predicted) and "D" is the number of correct predictions of no rain (neither predicted nor observed). The total number of cases is given by, $M = A + B + C + D$; From the contingency table, Ratio Score (RS) is calculated as,

$$\text{"Ratio Score (RS)} = \frac{\text{Correct Forecast}}{\text{Total Forecast}} = \frac{A+D}{M}$$

"Ratio Score (RS), 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 expressed in per cent. It varies from 0 to 100 with 100 indicating perfect forecasts." The forecast was categorized as very good, good, moderate and poor for RS values >80%, 70%-80%, 60-70% and <60%, respectively.

Calculation of Root Mean Square Error (RMSE): The RMSE values indicate the degree of error in the forecast. The sum of squared differences between the forecasted and observed values was divided by the total number of observations, and the square root of that value was taken to calculate the RMSE (Willmott and Matsuura, 2005). Lower the values of RMSE, less is the difference between observed and forecasted values. Perhaps, RMSE values less than half the standard deviation of the

measured data may be deliberated as low, otherwise high (Singh et al., 2004).

$$\text{“RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (f_i - o_i)^2}$$

Where, n is the number of samples; f is the Forecast and o the observed values”

Per cent variation: To study the difference between the accuracy parameters of district level rainfall forecast with that of block level rainfall forecast, per cent variation was calculated using the following formula,

$$\text{Per cent variation (\%)} = \left(\frac{B_i - D_i}{D_i} \right) \times 100$$

Where, B_i is the Block level accuracy parameter (e.g., Probability of Success, Failure, Ratio Score etc.) and D_i is the District level accuracy parameter (e.g., Probability of Success, Failure, Ratio Score etc.)

Study on Users’ Response: Further, based on the agromet advisories disseminated, feedbacks were collected from 700 respondents regarding the usability of the AABs and the weather forecasts issued during the study period. The respondents were target farmers to whom agromet advisories were sent periodically during the study period for three blocks considered in the study. A questionnaire was communicated to the target farmers which comprised of set of queries on the practical usability of AABs and quality of weather forecasts issued. To understand the usability of the agromet advisories, the following queries were communicated to the farmers:

Whether bulletins disseminated to the farmers were relevant or not; If relevant then whether it was followed. If bulletins were not followed, then what might be the most probable reason (options provided: unfavorable weather (forecast did not match), minimum response time, relevant but not prepared intentionally, did not follow advisory due to other reasons not related to advisory). The farmers were also asked about their level of satisfaction with the weather forecast based on their practical usability in farm fields (options provided: satisfied, partially satisfied, not satisfied). Based on the above queries relevant success stories were compiled.

Results and Discussion

From the five-year pooled data of seasonal rainfall forecast accuracy indices, as depicted in Table 1, it was observed that the annual probability of success was moderate (64.96%) with very high accuracy during winter (96.36%) and high accuracy during post-monsoon (82.46%). The predictions were moderately accurate during pre-monsoon (63.31%) and poor during monsoon (30.08%). From annual observations (Fig. 1) it was purely evident that the quantitative forecast of rainfall during all the years from 2018-19 to 2022-23 had higher success values during winter and post monsoon as compared to the pre-monsoon and monsoon seasons. Moreover, possibly due to better forecast accuracy during the pre-monsoon season during 2020-21, 2021-22 and 2022-23, the annual probability of success resulted in better values during the period from 2020-2021 to 2022-2023 than that of 2018-19 and 2019-20 (Fig. 1). Further, the seasonal pooled values of RS (Table 1) signify a good annual score of 71.56% with higher accuracy during winter season (79.98%) and post-monsoon (75.88%) seasons, followed by moderate accuracy during monsoon (66.85%) and pre-monsoon (66.51%) seasons.

The RS was very good during the months of November (85%) and December (95%) and good during January (78%), March (73%), May (71%) and June (79%) followed by moderate accuracy during February (67%), July (69%), September (61%) and October (67%). It was observed that RS was poor during April (56%) and August (58%) (Fig. 2). These results suggests that the accuracy of qualitative rainfall forecast, i.e., the occurrence of rainfall, irrespective of its quantum, could be satisfactorily done during most months of the year, except for April and August. Based on the findings of five years of consecutive analysis (March, 2009 to February, 2014) over the Sonitpur district of Assam, Sarmah et al. (2016) reported a better performance of rainfall forecast during the pre-monsoon, post-monsoon and winter season with usability percentage varied from 55.0 to 68.9%, 90.0 to 97.6% and 100%, respectively; whereas a relatively lower level of usability percentage was reported for monsoon season (31.0 to 34.6%). Likewise, a higher value of RMSE was observed during the monsoon season (18.3 to 33.6mm), relative to the other three seasons (1.1 to 18.7mm). Throughout the North Bank Plain Zone of Assam, the probability

Table 1: Pooled Seasonal and annual variations in probability of success (%) and failure (%), RS (%) and RMSE over Jorhat districts of Assam during 2018-19 to 2022-23

Season	Success	Failure	Ratio score	RMSE
Pre Monsoon	63.31	36.74	66.51	10.59
Monsoon	30.08	69.78	66.85	25.15
Post Monsoon	82.46	17.04	75.88	7.45
Winter	96.36	3.65	79.98	1.85
Annual	64.96	34.72	71.56	16.48

(PRM: Pre Monsoon; MON: Monsoon; PSM: Post Monsoon; WIN: Winter)

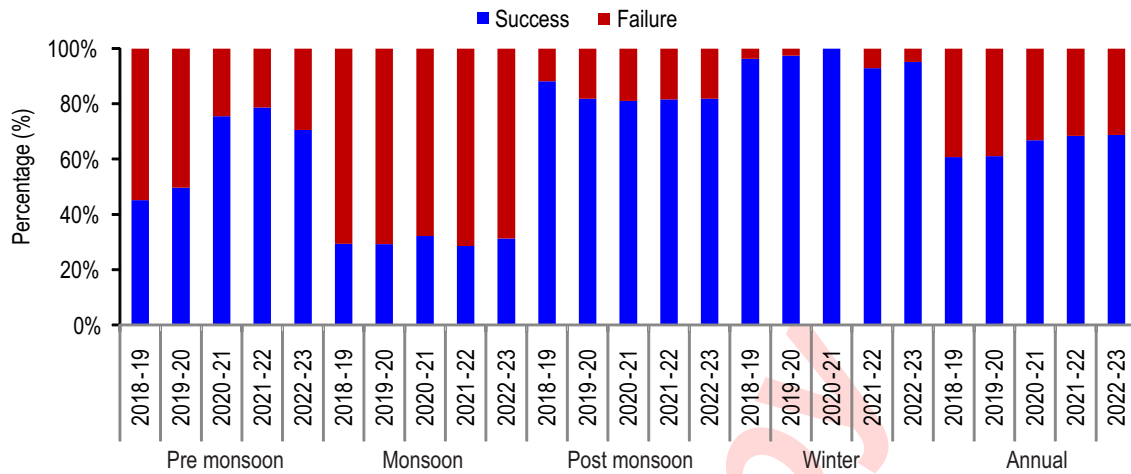


Fig. 1: Seasonal success and failure per cent of rainfall forecast during 2018-19 to 2022-23 over Jorhat district of Assam.

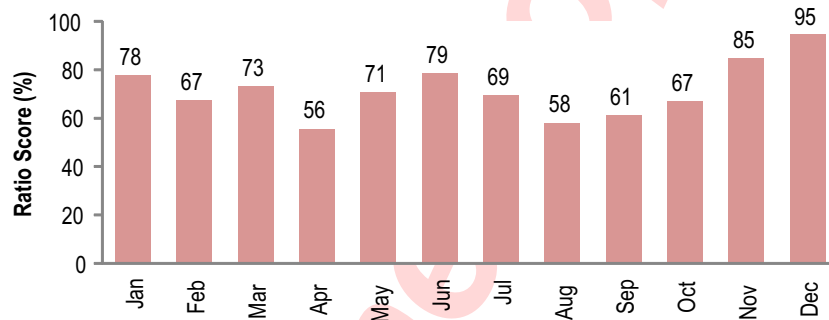


Fig. 2: Five year pooled monthly ratio score (2018-19 to 2022-23) value for rainfall forecast over Jorhat district of Assam.

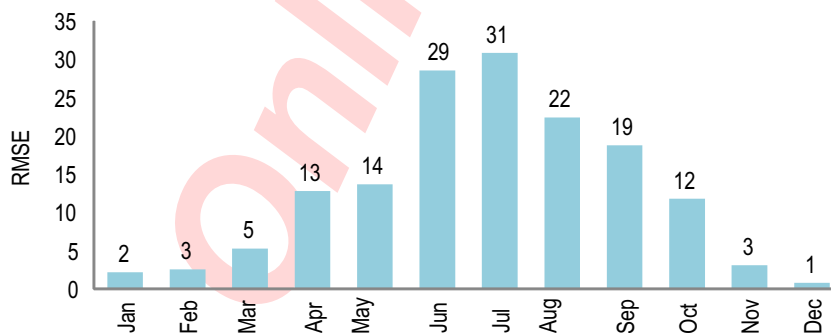


Fig. 3: Five year pooled monthly RMSE (2018-19 to 2022-23) value for rainfall forecast over Jorhat district of Assam.

of success and ratio score indicated very good forecast accuracy during post-monsoon and winter seasons and moderate accuracy during pre-monsoon and monsoon seasons (Sarmah et al., 2016). Similar results of low percent correct in rainfall during the monsoon season was reported by Chaudhari et al. (2010) for the Konkan region of Maharashtra and Lunagaria et al. (2009) for the middle Gujrat region.

Further, the current study depicted high RMSE values of more than 25 mm during the monsoon season precisely during the months of June and July whereas moderate (15-25 mm) during August and September (Fig. 3). On the other hand, RMSE was low (5-15) during March, April, May and October. Very Low RMSE (<5 mm) were manifested during the months of January, February, November and December. Seasonal average values

Table 2: Comparison between district level rainfall forecast and block level rainfall forecast during 2021-22 and 2022-23

Name of the district & block		Medium Range Rainfall Forecast									
		Pre Monsoon		Monsoon		Post Monsoon		Winter		Annual	
		District	Block	District	Block	District	Block	District	Block	District	Block
Probability of Success (%)	Jorhat	69.5	72.9	31.0	32.0	81.8	90.0	95.1	97.0	69.4	73.0
	Kaliapani	70.5	71.0	35.1	41.6	86.9	89.3	95.6	97.2	72.0	74.8
	Titabor	80.1	81.0	19.8	26.4	89.3	99.0	93.7	92.8	70.7	74.8
Probability of Failure (%)	Jorhat	30.5	27.1	69.0	68.0	18.2	10.0	4.9	3.0	30.7	27.0
	Kaliapani	29.5	29.0	64.9	58.4	13.1	10.7	4.4	2.8	28.0	25.2
	Titabor	19.9	19.0	80.2	73.6	10.7	1.0	6.3	6.0	29.3	24.9
Ratio Score (%)	Jorhat	70.0	71.6	65.2	65.7	83.8	86.2	83.7	85.4	75.7	77.2
	Kaliapani	57.0	59.8	41.4	42.3	77.4	81.4	79.7	85.5	63.9	67.3
	Titabor	56.3	69.4	41.8	41.8	70.9	72.5	77.7	79.0	61.7	65.7

(PRM: Pre Monsoon; MON: Monsoon; PSM: Post Monsoon; WIN: Winter; JOR: Jorhat; KAL: Kaliapani & TTB: Titabor)

(Table 1) suggest that the RMSE was high (>25) during monsoon (25.15) followed by pre-monsoon (10.59), post-monsoon (7.45) and winter (1.85). Such results were in consonance with the results of Chauhan *et al.* (2008) for the middle region of Gujarat which depicted higher error values during the monsoon as compared to the pre-monsoon, post-monsoon and winter. It was observed from the current study that, though the RS during the monsoon season was good (66.85%) however, the probability of success forecast was low (30.08) and RMSE was high (25.15) (Table 1; Fig. 3). This suggests that, during the monsoon season, though the occurrence of rainfall events were fairly predicted, the exact quantum was difficult to determine. The highly complex and non-linear dynamics of monsoon weather systems, when coupled with significant topographic heterogeneity of the study area, pose substantial challenges to the weather models in accurately forecasting the precise magnitude of rainfall; nevertheless, the models demonstrate satisfactory skill in reliably predicting the likelihood and occurrence of rainfall events. Occurrence of a rainfall event (qualitative) can be forecasted with fair accuracy using the current forecast models for all the seasons.

Forecasting rainfall occurrence is relatively reliable because it is primarily governed by large-scale atmospheric conditions like moisture availability, synoptic-scale circulation, instability and lifting mechanisms etc., that numerical models can simulate with reasonable accuracy. In contrast, accurately estimating rainfall magnitude remains challenging due to the influence of small-scale, nonlinear processes such as cloud microphysics, convective variability and localized topographic effects etc., that are not fully resolved within the model frameworks. However, since distribution of rainfall during a crop season is essential for its normal growth and development, the quantitative rainfall predictions need further improvement primarily for the monsoon followed by pre-monsoon season. In a similar type of study performed for the Lower Brahmaputra Valley Zone (LBVZ) of Assam (March, 2014 to February, 2019), poor level of monsoon rainfall forecast was observed with a low usability percentage (31-37.8%) and higher RMSE value (30.6-45.2mm) (Medhi *et al.*, 2020).

The ratio scores were higher during post-monsoon (86.2%) and winter (91.4%) seasons than during the monsoon (69.0%) and pre-monsoon (67.2%) seasons, indicating an improved performance of forecasting models during the former two seasons under rainfed climatic conditions over the LBVZ of Assam. Kaur *et al.* (2024) analysed the usability performance of Medium Range Weather Forecast (MRWF) over the Jalandhar district of Punjab, and reported a higher ratio score (94.3%) and Heidke Skill Score (0.56) corresponding to the post-monsoon season, revealing the most skillful rainfall forecast. The results obtained are in corroboration with the findings of Kaur and Singh (2019), who found relatively higher accuracy in post-monsoon rainfall forecasts.

From the study conducted for two consecutive years (*viz.*, 2021-22 and 2022-23) to compare the accuracy of district level forecast with that of the block level forecast for rainfall it was observed that (Table 2; Fig. 4) for all the blocks, the former had nearly equal to fair values of probability of success as that of the latter for all the seasons. The annual probability of success for block level forecast were 73.0%, 74.8% and 74.8% as compared to the district forecast of 69.4%, 72.0% and 70.7% for Jorhat, Kaliapani and Titabor districts, respectively (Table 4). The difference in accuracy with respect to probability of success between the district level and block level rainfall forecast depicted positive to nearly equal per cent variation values (Fig. 4). The difference was <10% in most cases, except for monsoon, where the block level forecast accuracy showed slightly better results. Further, the probability of failure was less in case of block level forecast and thereby, it showed negative variation when compared to the district level forecast. The annual probability of failure in case of block level forecast were 27.0, 25.2 and 24.9 as compared to the district level values of 30.7, 28.0 and 29.3. Moreover, the ratio score indicated nearly equal to slightly better results in case of block level rainfall forecast. The Ratio Score for Jorhat, Kaliapani and Titabor was 77.2, 67.3 and 65.7, respectively for block level forecast and 75.7, 63.9 and 61.7 for district level forecast. It was observed that the difference in

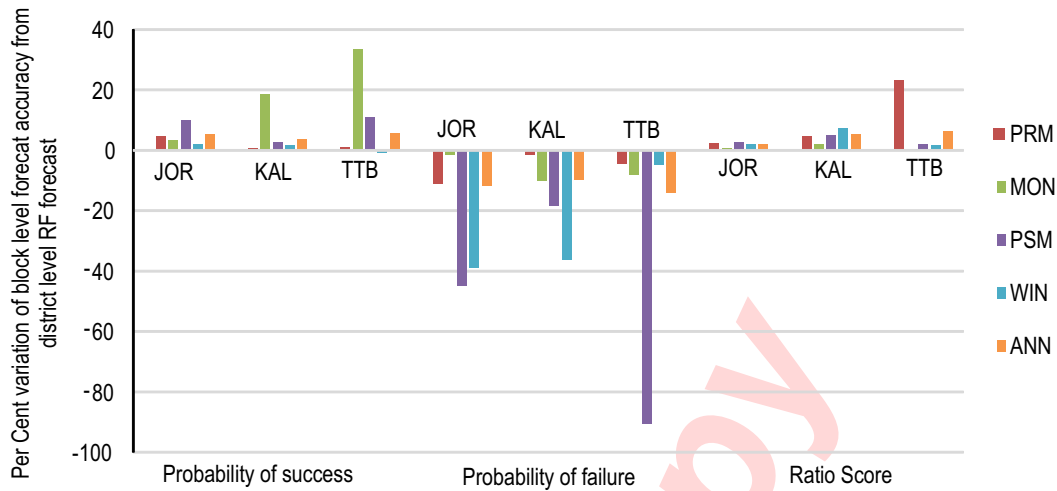


Fig. 4: Per cent variation of block level RF forecast accuracy from district level RF forecast accuracy during 2021-22 and 2022-23. (PRM: Pre Monsoon; MON: Monsoon; PSM: Post Monsoon; WIN: Winter; JOR: Jorhat; KAL: Kaliapani & TTB: Titabor).

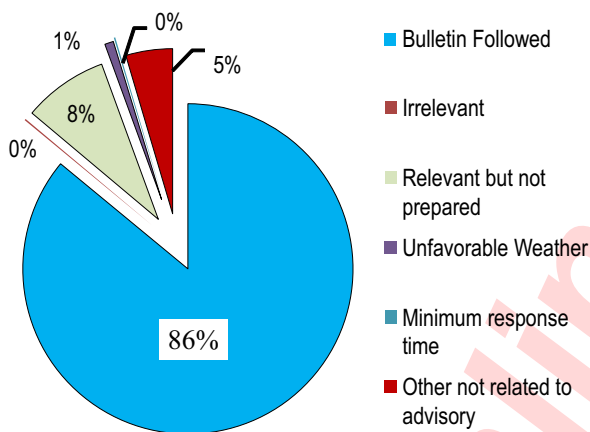


Fig. 5: Feedback on weather-based crop advisories collected from the contact farmers of Jorhat, Assam.

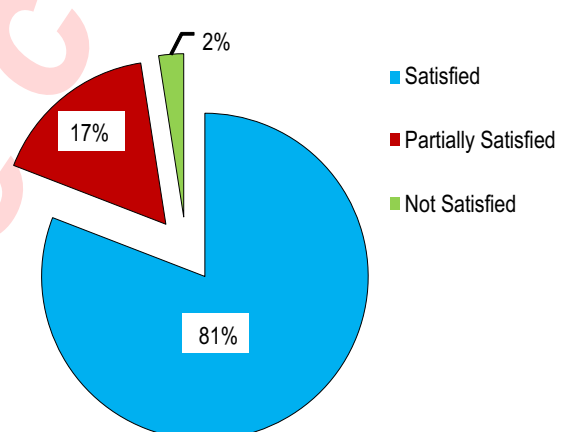


Fig. 6: Feedback on rainfall forecast collected from the contact farmers of Jorhat, Assam.

accuracy between district and block level rainfall forecast as estimated using probability of success and ratio score, was less than 10 per cent in most cases. The block level rainfall forecast showed nearly equal to fair values with reduced probability of failure as compared to the district level rainfall forecast for all the districts during all the seasons of the year.

To understand the practical usability of the agromet products by the end users, an attempt was made to collect feedback from 700 respondents from three blocks viz., Jorhat, Kaliapani and Titabor of Jorhat district. It was observed that 86% of respondents found the weather-based agricultural advisories to be useful and therefore, followed recurrently (Fig. 5). The advisories disseminated to the farmers via different digital, print and other broadcasting media platforms like WhatsApp, radio and

television; not only helped in manipulating the intercultural and other management practices based on the forecasted weather, but also to protect some of the crops from complete damage due to extreme incessant rainfall. However, though 8% of the total respondents found the advisories to be relevant, they could not follow as they were not prepared. On the other hand, only 5% of the respondents found the advisories to be irrelevant.

From the feedback collected on the quality of the rainfall forecast issued (Fig. 6), it was evident that nearly 81% of the farmers found it to be satisfied and 17% to be partially satisfied. Only 2% of the farmers reported to be unsatisfied with the rainfall forecast. Amongst several collected farmers' feedback, two most relevant success stories, especially on the usability of weather forecasts and Agromet Advisories were reported by Mr. Promod



Fig. 7: (a) Before stagnation of rain water in the field, the pumpkins were successfully harvested and safely stored in Mr. Promod Ch. Bora's residence. (b) Water stagnation due to continuous rainfall in the pumpkin orchard after the harvest of the crop



Fig. 8: (a) Rice seedlings destroyed due to water inundation. (b) Poor performance of traditional rice varieties due to water stagnation. (c) Ranjit Sub-1 showed good performance even the crop was under submergence condition during the vegetative stage and had a better harvest.

Ch. Bora (Age 56) from Na-Bora Gaon, Bahona, Jorhat, Assam and Mr. Pankaj Borgohain (Age 47) from Lakhibari, Bharalua Gaon, Jorhat, Assam. Based on the forecast of getting light to moderate rainfall continuously from 1st to 8th May, 2019, Mr. Bora immediately harvested the pumpkins after getting the advisories disseminated through AIR, Jorhat. As a result he was able to save nearly 75 quintals of pumpkin costing around Rs. 15 per kg (Gross income of Rs. 1,12,500.00) from rotting (Fig. 7 a,b).

Mr. Pankaj Borgohain, who repeatedly faced crop loss due to water submergence in his 7 bighas of paddy field, adopted submergence tolerant rice variety, Ranjit, based on the Agromet

Advisories provided to him via GKMS and thereby, was able to harvest around 55 quintals of paddy from the cultivated area of land leading to gross income of nearly Rs. 93,500.00 during 2020 and thereafter (Fig. 8 a,b,c). The results are in corroboration with the findings of Kaur *et al.* (2024), who reported a capital gain of Rs. 4096 and Rs. 6053 per acre for 15th November and 5th December sown wheat crop (Rabi, 2020-21), due to the adoption of AAS compared to the non-adoption group in the Jalandhar district of Punjab.

Qualitative verification of district level RF forecasts revealed that RS had a good acceptability with a score of 72% on annual basis and 80%, 76%, 67% and 66% during winter, post-

monsoon, monsoon and pre-monsoon seasons, respectively. Quantitatively, 65% RF forecasts were found correct and usable on annual basis with highest accuracy during winter (96%) and lowest during monsoon (30%). Verification of block level rainfall forecast for three developmental blocks (Jorhat, Kaliapani and Titabor) indicated that, the probability of success along with the RS was slightly fair for almost all the seasons as compared to that of the district level forecast with reduced probability of failure.

Considering the higher level of usability, agromet advisories based on the block level rainfall forecast can be more effectively utilized in agricultural planning. Feedback analysis from three blocks of the district revealed that- 86% of the farmers followed the agromet advisories as it helped them to smartly plan their farm based activities for attaining higher returns. Out of the total sample, 81% and 17% of the farmers were satisfied and partially satisfied with the rainfall forecast, whereas, only 2% farmers showed dissatisfaction.

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References

- Arulmathi, C., S.A. Prasad, J. Jayakumar, K. Natarajan and M. Vengateswari: Seasonal rainfall forecast verification analysis for Vridhachalam, Tamil Nadu, India. *Int. J. Environ. Clim. Change.*, **13**, 3282-3287 (2023).
- Bal. S.K., K.V. Rao, M.A.S. Chandran, S. Sasmal and V.K. Singh: Weather forecast, agriculture contingency plan and agromet advisory services for climate resilient agriculture. *Ind. J. Agron.*, **66** (5th IAC Special issue), S1-S14 (2021).
- Chaudhari, J.N., M.V. Zagade, U.V. Mahadkar and M.S. Talathi: Assessment of weather based Agromet advisories in high rainfall zone of Konkan in Maharashtra. In: *Agro-meteorological services for farmers* (Eds: Vyas Pandey), AAU, Anand, pp. 172-177 (2010).
- Chauhan, V., G. Chaudhari and V. Pandey: Medium range weather forecast verification for middle Gujarat region. *J. Agrometeorol.*, **10**, 90-93 (2008).
- Chiputwa, B., G. Blundo-Canto, P. Steward, N. Andrieu and O. Ndiaye: Co-Production, uptake of weather and climate services, and welfare impacts on farmers in Senegal: A panel data approach. *Agric. Syst.*, **195**, 103309 (2022).
- Deka, R.L., C. Mahanta and K.K. Nath: Trends and fluctuations of temperature regime of north east India. *ISPRS Archives XXXVIII8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture*, pp. 376-380 (2009).
- Deka, R.L., C. Mahanta, K.K. Nath and M.K. Dutta: Spatio-temporal variability of rainfall regime in the Brahmaputra valley of North East India. *Theor. Appl. Climatol.*, **124**, 793-806 (2015).
- Ebert, E.E. and J.L. McBride: Verification of precipitation in weather systems: determination of systematic errors. *J. Hydrology*, **239**, 179-202 (2000).
- Gharphalia, B.J., R.L. Deka, A.N. Islam, P. Dutta and K. Medhi: Variability and trends of rainfall events in the Brahmaputra valley of Assam. *Int. J. Curr. Microbiol. App. Sci.*, **7**, 1902-1912 (2018).
- Gogoi, K. and K.N. Rao: Analysis of rainfall trends over Assam, North East India. *Curr. World Env.*, **17**, 435-446 (2022).
- Goswami, B.B., P. Mukhopadhyay, R. Mahanta and B.N. Goswami: Multiscale interaction with topography and extreme rainfall events in the northeast Indian region. *J. Geophys. Res.*, **115**, D12114 (2010).
- IMD: Standard Operation Procedure - Weather Forecasting and Warning. India Meteorological Department, Ministry of Earth Sciences, Mausam Bhawan, Govt. of India, New Delhi, pp. 92-135 (2021).
- INCCA: Climate Change and India: a 4x4 Assessment- a Sectorial and Regional Analysis for 2030s. Ministry of Environment and Forests, Government of India, pp. 129-154 (2010).
- IPCC: Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3-32 (2021)
- IPCC: Summary for Policymakers. In: *Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Eds.: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 489-490 (2007).
- Islam, A.N., K. Medhi and R.L. Deka: Paradigm of agromet advisory services and its current advancements, In: *Smart Agriculture: Digital Era in Farming* (Eds.: M. Kachari, H.S. Datta, R. Sarmah

- and R.C. Boro). 1st Edn., Elite Publishing House, New Delhi, pp. 106-116 (2024).
- Islam, A.N., P.G. Khanikar, R.L. Deka and B. Goswami: Impact of weather parameters on winter rice productivity in the Upper Brahmaputra Valley Zone of Assam. *J. Agrometeorol.*, **19**, 75-79 (2017).
- Kaur, B., S.K. Kataria and K.K. Gill: Assessing medium-range weather forecast and economic impact of agro advisories on wheat in Jalandhar, Punjab. *Mausam*, **75**, 793-800 (2024).
- Kaur, N. and M. J. Singh: Verification of medium range weather forecast for the Kandi region of Punjab. *Mausam*, **70**, 825-832 (2019).
- Khichar, M.L., D. Singh and R. Niwas: Verification of medium range weather forecast for Western zone of Haryana, In: *Agro Meteorological Services for Farmers* (Eds.: Vyas Pandey). 1st Edn., AAU, Anand, pp. 195-200 (2010).
- Lunagaria, M.M., S.K. Mishra and V. Pandey: Verification and usability of medium range weather forecast for Anand region. *J. Agrometeorol.*, **11**, 228-233 (2009).
- Mahanta, R., D. Sarma and A. Choudhury: Heavy rainfall occurrences in northeast India. *Int. J. Clim.*, **33**, 1456-1469 (2013).
- Maini, P. and L.S. Rathore: Economic impact assessment of the Agrometeorological Advisory Service of India. *General Articles. Curr. Sci.*, **101**, 1296-1310 (2011).
- Medhi, K., K. Sarmah, V. Upadhyay, S.K. Paul, A.N. Islam and B.J. Gharphalia: Verification and usability analysis of medium range weather forecast for the Kokrajhar district of Lower Brahmaputra Valley Zone of Assam. *Bioscan*, **15**, 363-370 (2020).
- Mohapatra, M., H.R. Biswas and G.K. Swaisarje: Daily summer rainfall over northeast India due to synoptic scale systems. *Mausam*, **59**, 35-50 (2008).
- NCAER: Estimating the economic benefits of Investment in Monsoon Mission and High Performance Computing facilities. 1stEdn., Annual Report-20200701. National Council of Applied Economic Research, India Centre, 11 New Delhi, India, pp. 1-71 (2020)..
- Sahu, D.D., M.C. Chopada and H.L. Kacha: Assessment of accuracy of medium range weather forecast. *J. Agrometeorol.* (Special issue), **14**, 396-400 (2012).
- Sarmah, K., P. Neog, R. Rajbongshi and A. Sarma: Verification and usability of medium range weather forecast for north bank plain zone of Assam, India. *Mausam*, **66**, 585-594 (2016).
- Singh, C., J. Daron, A. Bazaz, G. Ziervogel, D. Spear and J. Krishnaswamy: The utility of weather and climate information for adaptation decision making: Current uses and future prospects in Africa and India. *Clim. Dev.*, **10**, 389-405 (2018).
- Singh, J., H.V. Knapp and M. Demissie: Hydrologic modelling of the Iroquois river watershed using HSPF and SWAT. 1st Ed., Illinois State Water Survey Contract Report 2004-08, Illinois Department of Natural Resources and Illinois State Geological Survey, Champaign, Illinois, pp. 1-24 (2004).
- Singh, R.R., R. Prasad and S. Kumar: Reliability of medium range weather forecast in mid hill region of Himachal Pradesh. *J. Agrometeorol.*, **7**, 292-303 (2005).
- Singh, S.V., L.S. Rathore and H.K.N. Trivedi: Verification of medium range weather forecasts. In: *Guide for AAS*, Govt. of India, NCMRWF, Mausam Bhavan, New Delhi. pp. 73-93 (1999).
- Sinha, K.C.R., U.S. De and R. Chellapa: Orographic rainfall during southwest monsoon: a dynamical climatological study. *Mausam*, **33**, 99-106 (1982).
- Willmott, C. and K. Matsuura: Advantages of the Mean Absolute Error (MAE) over the Root Mean Square Error (RMSE) in assessing average model performance. *Clim. Res.*, **30**, 79-82 (2005).