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Research Article

Usability of monthly ERFS (Extended Range Forecast System) to predict maize yield using DSSAT (Decision Support System for Agro-technology Transfer) model over Erode District of Tamil Nadu

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Abstract
Extended Range of Forecast Service (ERFS) is highly useful for planning of cropping season and midterm correction at the farm level. The medium-range and long-range forecast validation have many studies, whereas ERF has less that needs to be studied. Maize is an important field crop in India after rice and wheat. Therefore, the prediction of maize yield has significant importance. In the present study, ERFS data were validated by correlation analysis using monthly observed rainfall frequency and intensity. This data was imported to DSSAT (Decision Support System for Agro-technology Transfer) to simulate maize yield of Erode district of Tamil Nadu. The model output and actual yield data from Erode were compared. Forecasted monthly total rainfall was correlated at a rate of 0.97r value with that observed. Yield simulation of maize was done using DSSAT by integrating ERFS data and the observed monthly data. Mean per cent deviation among the yields of observed weather and the disaggregated one tended to be -15.7 %. The average deviation between the yields of ERF forecasted weather data and actual yield was very high (-29.7 %) for Erode. Mean % deviation between the yields of observed weather and the actual yield was -14.7 %. Downscaled and accurate weather forecasts could be facilitated for yield prediction of crops by DSSAT model. Yield prediction by the model under observed weather was convenient and usable. Model under-predicted the yields when using ERF data. Both model and ERF forecast need to be improved further for higher resolution.

Keywords: ERFS, DSSAT, Erode district, Rainfall, Maize, Yield prediction

INTRODUCTION

Vital monsoons in India are the southwest monsoon season June–September (JJAS) and also northeast monsoon season, October–December (OND). Utmost states of the country meet their heaviest rainfall during the southwest monsoon season except for the south-eastern portion (Tamil Nadu), which receives maximum rainfall during the northeast monsoon (Attri and Tyagi, 2010). India Meteorological Department (IMD) issues weather forecasts for planning and decision-making in agriculture, water management and policymakers during both monsoon seasons. IMD disseminates weather forecasts at different temporal scales that are short range, medium range, extended range and seasonal scales used for tactical and strategic decisions in agriculture and allied sectors.

Extended Range Forecast Service (ERFS) is highly beneficial for crop planning and midterm correction at the farm level. Another way, it is also useful for the policy maker to assume the food production to choose the best buying and storing options. Inside the agriculture sector, if a precise outlook of monsoon environments is provided in the extended range, farmers will be very much benefited. Conjectures of rainfall on the transitional timescale are perilous for heightened farm planning, such as planting and harvesting (Raleigh *et al.,* 2008). The Extended range weather forecasts have a key role in preparing agromet advisory bulletins for the farmers, which were very useful for scheduling of sowing, irrigation, agricultural operations and management of pests and diseases of field crops. The farmers feel it to be useful since they receive advice on appropriate field operations and management practices depending on suitability of weather conditions (Kaur *et al.,* 2019). Pattanaik and Das (2015) stated that the ERF in the tropics is a tough and utmost challenging task in atmospheric sciences. If this task is carried out, it connects the gap between medium-range weather forecasting and seasonal or long-range forecasting. Based on the feedback from the farmers, it is understood that farmers need prior weather information on extended and seasonal scales to make a comprehensive plan for their farming operations. In this context, it has been tried initially on the experimental scale to use extended and seasonal agriculture forecasts with a modest skill (Chattopadhyay *et al.,* 2018). In the meantime, in 2009, IMD issued an experimental extended range forecast based on available products from statistical and dynamic models' outputs. Spatial scale of the ERFS is still extensive for the farm level decision making and essentially downscaled to the district level to upsurge the exactness of the forecast (Pattanaik, 2022).

Maize (*Zea maize*) is the third most important cereal food crop, cultivated all over the world and having broader production among all the cereal crops. The worldwide production of maize was more than 1134 million metric tons in 2017-2018 and India contributed 26 million metric tonnes to it (Anonymous, 2019). It is an important staple of human food, and livestock feed and is also used in many industrial applications. The crop has massive genetic diversity which allows tropical, subtropical and temperate climates to survive (Anonymous, 2014). In India, Important maize-growing states are Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Rajasthan, Karnataka, Maharashtra, Bihar, Madhya Pradesh and Gujarat. These states account for 85 % of India's maize production and 80 per cent of the area under cultivation. Therefore, the prediction of maize yield has significant importance. Integrating weather forecast and crop models is a novel and faster method among the yield prediction methods. In the present study, the extended range forecasts (ERF) are validated and used to simulate the yield of maize in Erode district of Tamil Nadu by using DSSAT crop simulation model.

MATERIALS AND METHODS

The extended range weather forecasts issued for Tamil Nadu were downscaled and validated for Erode district. Past 30 years data (1986 to 2015) were collected for the study area for verification purpose. The data consisted of 30 years of monthly data as well as daily data sets for the same location. These monthly data were subjected to a disaggregation process for converting them into daily data. Disaggregation was done using disaggregation tools, a set of console programs that can be called from a DOS command window or a batch file. These console programs required parameter file (*.prm), monthly file (*.mth), and climate file (*.cli), which is produced in DSSAT using Weatherman. These disaggregated daily data were validated with actual daily data sets of the same area to understand the skill of the disaggregation process. The ERFS issued for Tamil Nadu were single values for a month or fortnight and should be disaggregated into daily series using the disaggregation tools and validated for observed Southwest monsoon rainfall of Erode district of Tamil Nadu by correlation analysis done using MATLAB scripts. Validated and disaggregated weather data were facilitated with DSSAT to act out the yield of Maize (TNAU hybrid CO 6). Then, ERFS forecasts for these years were incorporated by replacing observed weather and used in DSSAT for yield simulation. The yields from DSSAT with observed weather data disaggregated weather data and disaggregated ERFS forecast were compared in between and with the observed yield data from crop cutting experiments.

Study area

Erode is a semi-arid land with moderate to high temperatures throughout the year and experiences relatively small rainfall. The usual temperature ranges from 27 °C to 36 °C. Dry climate prevails in the Eastern part of this District and the Western part has a semi-dry climate. The district's average annual rainfall is 775mm, with the maximum rainfall coming from North East monsoon-281 mm. The district receives 228 mm during South west monsoon, 15.5 mm in winter, and 246 during hot weather. While the Southwest monsoon (June to August) brings short rainfall, most of the rainfall is received during the Northeast monsoon from October to December (District report, 2020).

Collection of data

The required data included observed weather data and crop yield data for the Erode as well as the Extended Range Forecast series (ERFS) issued by IMD in collaboration with Indian Institute Technology (IIT), Bhubaneswar. Extended range forecast series were collected from IIT, Bhubaneswar. The rainfall and meteorological data from

1986 to 2015 were collected from State Ground and Surface Water Resources Data Centre, Taramani, Chennai (http://www.groundwatertnpwd.org.in/) and Agro Climatic Research Centre, TNAU, Coimbatore (http://tawn.tnau.ac.in). State Department of Statistics, Chennai, provided the yield data of the district (https://www.tn.gov.in/deptst/agriculture.pdf). The genetic coefficient files for Maize for the variety COH6 were collected from the office of the Directorate of Crop Management, Tamil Nadu Agricultural University, Coimbatore.

Disaggregation process

Disaggregation process was done by using disaggregation tools. It is a set of console programs that can be called from a DOS command window or a batch file. These console programs require parameter file (*.prm), monthly file (*.mth), climate file (*.cli) which were produced in Decision Support System for Agro-technology Transfer (DSSAT) crop simulation model (Sofi *et al*., 2015). First, the observed monthly data should be disaggregated to daily series and check with observed daily data to know whether the disaggregation tools can perform well. The procedure for the disaggregation process is given below. A MATLAB program was used to convert the weather files and correlation analysis.

Analysis of the performance of disaggregated weather data

After disaggregation of monthly series to daily weather series using disaggregation tool, it is needed to check its performance. So, the skill can be checked by comparing these files with the original daily series. Hence, the disaggregated daily series should be compared with the original daily data. For this, the original meteorological file in .prn format was needed. After the file gets open, Matlab script using MATLAB software and checked the correlation between the disaggregated 300 realizations and original daily weather data. After running the MATLAB script, four graphical outputs were obtained

1. Average of correlation coefficients of monthly rainfall frequency of disaggregated daily weather scenarios
2. Average of correlation coefficients of monthly rainfall intensity of disaggregated daily weather scenarios
3. Average of correlation coefficients of monthly rainfall total of disaggregated daily weather scenarios
4. Average of correlation coefficients of seasonal rainfall frequency, intensity and total of disaggregated daily weather scenarios

After analysing the performance of disaggregated observed weather, the disaggregation of ERF forecast data was carried out with the same procedure and compared with the daily observed data by using correlation analysis.

Yield prediction using DSSAT

After disaggregation process, the data were uploaded to DSSAT along with other input files to get yield prediction and outputs were obtained. DSSAT need so many input files which are mentioned below. The flowchart of using DSSAT in the study is given below (Fig 1).

Preparation of DSSAT files

S – file

Soil file for Tamil Nadu at 1:50,000 scales are kept at the Department of Remote Sensing and GIS of TNAU (https://tnau.ac.in/nrm/remote-sensing-and-gis-map-services). These were extracted from the above database using ArcGIS and uploaded into the S Build tool in DSSAT to create a soil file.

DSSAT- Weatherman

Weatherman was used to preparing weather files in DSSAT. Weatherman is an object-oriented tool for importing, analyzing and exporting climate data which was further used in crop simulation modelling and other activities. It is an interactive tool in which one can import the weather files from the different formats that were. ".xls, .csv" *etc.* and convert the data to desirable units. The daily weather data on maximum temperature (°C), minimum temperature (°C), solar radiation (MJ/m^2/day) and rainfall (mm) for the crop period for the concerned district was converted into DSSAT weather file format using Weatherman tool available in DSSAT for running CERES- Rice and Maize calibration experiment.

X- file

Crop management file (X-File) permits the inputs to the models for each experiment to be simulated. Particulars of the experimental conditions and field characteristics were given through X Build tool in DSSAT. X

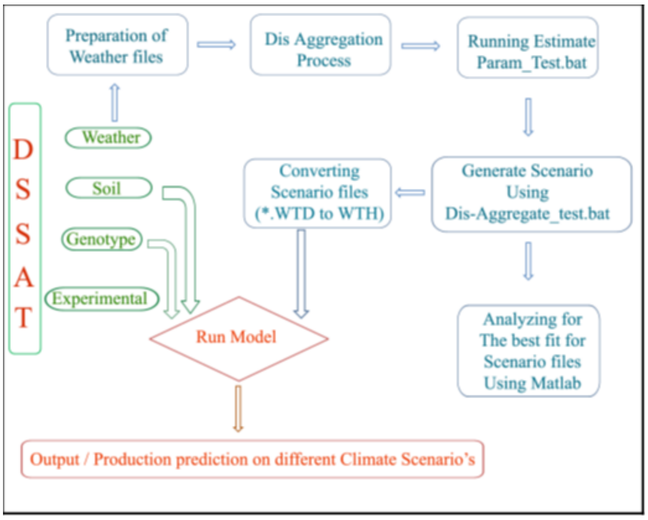

Fig. 1. *Flow chart of usage of DSSAT CSM for the study (Sofi et al., 2015)*

build based on the crop production guide of TNAU (agritech.tnau.ac.in).

Genetic co-efficient

The genetic coefficient files for maize for the variety COH6 were collected from the Directorate of Crop management office, Tamil Nadu Agricultural University, Coimbatore (https://tnau.ac.in/directorate-cm/).

Data analysis

Correlation analysis has been done among disaggregated observed rainfall data and disaggregated ERFS data for computing the skill of forecast. After obtaining skills, these data were used in DSSAT model to bring the output. These model output yields were compared with actual yield data of Erode district. Per cent deviation was worked out between model obtained yields and also with the actual groundnut yield data of Erode.

RESULTS AND DISCUSSION

Skill of disaggregated monthly observed data

From 1986 to 2015 monthly rainfall frequency was decidedly correlated with the observed frequency for June (r = 0.93) and July (r = 0.92) nevertheless for August (r = 0.57), the correlation was low during September (r = 0.36) (Fig 2a). According to total rainfall, correlation was greater for all months (r = 0.99) (Fig. 2b).

The disaggregation was highly skilful in converting the total rainfall amount to daily rainfall. Whereas in the case of rainfall frequency, an excellent correlation was found during June and July, but August and September found a low correlation.

The outcomes of correlation analysis for monthly or seasonal (June, July, August, and September) frequency, the intensity between the IMD observed daily rainfall and disaggregated monthly data when considering the previous studies. The skill was highly significant with values ranging from 0.95 to 0.99. The correlation for total rainfall of disaggregated daily sequences of IMD observed monthly trailed concordance with rainfall intensity (Dhekale *et al.,* 2018). In another study, a small correlation between rainfall frequency and excellent correlation with rainfall intensity was conveyed (Ghosh *et al.,* 2015).

Performance of disaggregated extended range weather forecast

From 1986 to 2015, the frequency of rainfall of the Erode district was highly correlated with the forecast for first two months (June & July) having the r values 0.93 and 0.92, correspondingly for past 30 years (1986 to 2015). Among third and fourth months (August and

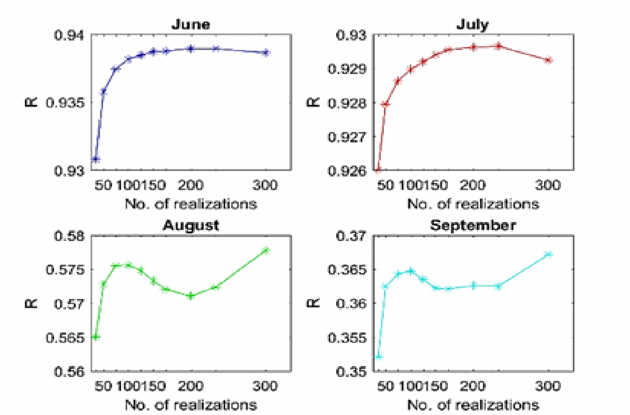

Fig. 2a. *Rainfall frequency*

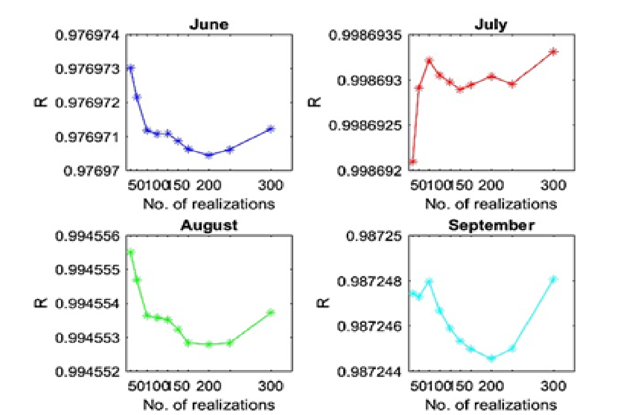

Fig. 2b. *Total monthly rainfall*

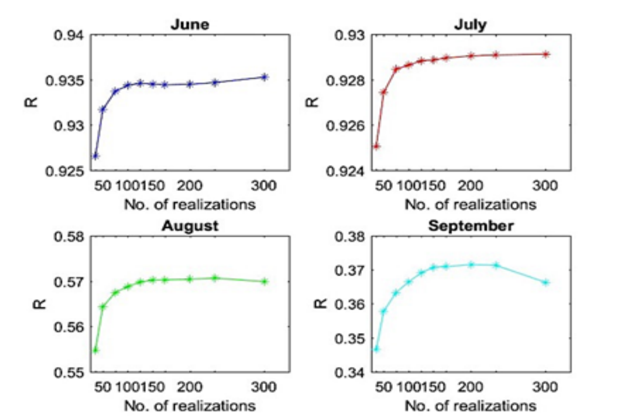

Fig. 3a. *Rainfall intensity*

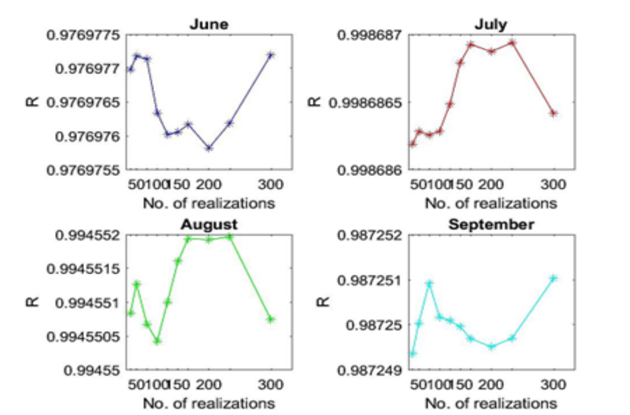

Fig. 3b. *Total monthly rainfall*

September), the correlation was abridged into 0.57 and 0.37, individually (Fig 3a). Correlation for monthly total rainfall showed decent correlation for all the four months (Fig 3b).

The previous studies also indicated that the correlation values for southwest monsoon to the frequency, intensity and total were closely around 0.15. The skill for ERFS forecast is lower than for disaggregated IMD observed June, July, August and September (JJAS) rainfall. This may be because the JJAS forecasts are prepared by seeing the climate situations four months ahead (Dhekale *et al.,* 2018).

Performance of predicted yields using DSSAT crop simulation model

1 Mean per cent deviation amid the yields of observed weather and the actual yield was -14.7 per cent. DSSAT- CERES Maize has extensively predicted the yield during the year 2005, showing a Maximum deviation of 204.4 per cent when considering the deviation between observed weather and actual yield. The minimum deviation under the same consideration was found in 1998 with 4.6 per cent deviation, which can be called accurate. Only 2 years had predicted accurately with a deviation less than 10 Per cent. That was during 1992 (6.7%) and 1998 (-7.1%).

2In the case of observed weather, yield and the disaggregated weather showed a deviation of -15.7 per cent, which was very short. The maximum deviation between the observed and disaggregated weather yield was recorded in 2014 with a deviation of -55.6. The minimum deviation per cent was in 1994 with 0.3 per cent deviation. The model predicted the yield of 2015, 2010, 2004 and 1994 precisely, having deviations -0.5,

Table 1. Per cent deviation of maize yield from actual yield and simulated observed and disaggregated weather data for Erode district

Year	Actual Yield (kg/ha)	Model simulated yield (kg/ha)				
		Yield simulated with Observed weather	Deviation between Observed weather and Actual yield (%)	Yield simulated with Dis aggregated observed weather	Deviation from Dis aggregated and observed weather (%)	Deviation between Dis aggregated and Actual yield (%)
1	**2**	**3**	**4 (3-2)/2*100**	**5**	**6 (5-3)/3*100**	**7 (5-2)/2*100**
1986	4092	2084	-49.1	1604	-23.0	-60.8
1987	3954	1388	-64.9	1184	-14.7	-70.1
1988	3877	1970	-49.2	1585	-19.5	-59.1
1989	3095	1638	-47.1	1348	-17.7	-56.4
1990	4287	1681	-60.8	1288	-23.4	-70.0
1991	3012	1768	-41.3	1409	-20.3	-53.2
1992	3984	3719	-6.7	4019	8.1	0.9
1993	4007	3465	-13.5	2902	-16.2	-27.6
1994	4678	2969	-36.5	2978	0.3	-36.3
1995	3219	4092	27.1	2588	-36.8	-19.6
1996	3678	4795	30.4	4114	-14.2	11.9
1997	4178	3411	-18.4	2666	-21.8	-36.2
1998	4065	4254	4.6	3775	-11.3	-7.1
1999	3186	2587	-18.8	2201	-14.9	-30.9
2000	2286	3529	54.4	3079	-12.8	34.7
2001	2285	4003	75.2	3331	-16.8	45.8
2002	2285	2738	19.8	2427	-11.4	6.2
2003	2285	3080	34.8	2326	-24.5	1.8
2004	2286	3612	58.0	3455	-4.3	51.1
2005	1275	3881	204.4	2822	-27.3	121.4
2006	5897	3265	-44.6	2797	-14.3	-52.6
2007	5198	4170	-19.8	3579	-14.2	-31.1
2008	9856	3644	-63.0	3034	-16.7	-69.2
2009	6736	2636	-60.9	2366	-10.2	-64.9
2010	5944	2899	-51.2	2721	-6.1	-54.2
2011	5068	1995	-60.6	1712	-14.2	-66.2
2012	4593	2251	-51.0	1452	-35.5	-68.4
2013	5237	1581	-69.8	1890	19.5	-63.9
2014	6707	3429	-48.9	1522	-55.6	-77.3
2015	7240	1865	-74.2	1856	-0.5	-74.4
Mean	4283	2947	-14.7	2468	-15.7	-29.2

-6.1, -4.3 and 0.3 %, respectively. Nine years of predictions came under the non-usable category (>20% deviation), which were 2014, 2012, 2005, 2003, 1995, 1991, 1990 and 1986.

3The average deviation between actual yield and disaggregated weather yield was -29.2 per cent (Table 1). Among these, only 6 years came under the usable category were 2003, 2002, 1998, 1996, 1995 and 1992, with the deviation of 1.8, 6.2, -7.1, 11.9, -19.6 and 0.9, respectively.The mean deviation between ERF forecasted weather data and actual yield yields were -29.7 per cent. Maximum deviation was found on 2005 and minimum deviation found on 1989 with the deviation per cent of 188 and -1.3, respectively. Results indicated the underprediction of model. Total 9 years out of 30 years came under usable category, which are 1986, 1989, 1995, 1999, 2000, 2001, 2002 and 2003 with the deviation of -1.8, -1.3, -7.6, -12.2, -3.2, 14.5, 14.4 and 20 per cent, respectively (Table 2). The maize yields are simulated by the CERES Maize module of DSSAT for the Coimbatore, Erode and Tiruppur districts. The result obtained for the simulated yield for observed weather was less deviated from the yield simulated by disaggregated monthly weather. Whereas the deviation flanked by the simulated crop produced using ERF data and actual yield data had more deviation when compared to the other deviation. The actual yield and observed weather yield of Erode showed greater deviation. The yields predicted by the model for the ERF weather and the actual yield were not usable for the Erode only because it has a deviation of more than 20 per cent. It may be because of the lower skill of the forecast.

4The studies related to CERES Maize yield simulation indicated that, under Indian conditions, the age of tas-

Table 2. Deviation of maize yield from actual yield from yield simulated using ERF forecast data for Erode district

Year	Actual Yield (kg/ha)	Yield simulated with ERF forecast (kg/ha)	Deviation %
1986	4092	4017	-1.8
1987	3954	1714	-56.6
1988	3877	1902	-50.9
1989	3095	3055	-1.3
1990	4287	1287	-70.0
1991	3012	1371	-54.5
1992	3984	1994	-49.9
1993	4007	2148	-46.4
1994	4678	1707	-63.5
1995	3219	2974	-7.6
1996	3678	1854	-49.6
1997	4178	896	-78.6
1998	4065	1569	-61.4
1999	3186	2798	-12.2
2000	2286	2213	-3.2
2001	2285	2616	14.5
2002	2285	2615	14.4
2003	2285	2742	20.0
2004	2286	3742	63.7
2005	1275	3672	188.0
2006	5897	3489	-40.8
2007	5198	1932	-62.8
2008	9856	2154	-78.1
2009	6736	3373	-49.9
2010	5944	2491	-58.1
2011	5068	1780	-64.9
2012	4593	2000	-56.5
2013	5237	3037	-42.0
2014	6707	2130	-68.2
2015	7240	2679	-63.0
Mean	4283	2398	-29.7

selling and grain produce prophesied by the CERES-Maize model exhibited good agreement with the observed values. Model p the biomass yield and harvest index of maize in an unwell manner (He *et al.,* 2009). In Uttar Pradesh, an error of 23.8 per cent among simulated yield when equated with observed stalk yield during *Kharif* season, whereas CERES-Maize model specified its capability to simulate maize dry matter accumulation under finest growth conditions (Kumar *et al*., 2010). Ma et al. (2020) studied DSSAT model calibration on maize. The calibrated DSSAT model was further verified based on additional maize and soybean data from experiments conducted. These results showed that the average calibration and verification values were all less than 15 %. The CERES-maize model was applied to the Fenhe basin, and the measured and simulated
5Another study in China revealed that values of maize yield, aboveground biomass, phenology, leaf area index, and soil moisture are in good agreement. The calibration showed great consistency between the measured and simulated data, with nRMSE (normalized root mean square error) ranging from 0.77% to 21.6%. Model evaluation was found to be satisfactory, with acceptable nRMSE ranging from 1.9% to 25.3% (Rugira *et al.,* 2021).Overall, CERES maize module of DSSAT performed well around the Asian conditions and the same was the conclusion for Erode district also.

Conclusion

1ERF forecast executed an average skill among Erode district and there is a necessity to progress the forecast by exploiting various downscaling tools. Economized and corroborated forecasts could be cast-off to envisage the yields of maize crop by facilitating DSSAT crop simulation model. The model projected the yields under observed weather were truthful and operational ranges but then under-predicted the yields when considering the ERF forecast data. This act would stretch more precision in agro-advisory services. The model and the ERF forecast need to be improved additionally for higher resolution through validation and calibration.

Conflict of interest

The authors declare that they have no conflict of interest.

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