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Forecast of weather parameters using time series data

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सार – इस शोध पत्र में उत्तराखंड क्षेत्र के पंतनगर में विशिष्ट मौसम पूर्वानुमान के लिए समय श्रृंखला आँकडों के आधार पर मॉडल विकसित करने के लिए अध्ययन किया गया। यह अध्ययन, 27 वर्षों (1981-82 से 2007-08 तक) के समय श्रृंखला के अनुपूरक मासिक मौसम आँकड़ों का उपयोग करते हुए किया गया। मान-केंडल परीक्षण सांख्यिकी द्वारा मौसम प्राचलों की प्रवृत्ति का विश्लेषण किया गया। इस अध्ययन में जिस पद्धति को अपनाया गया उससे पूर्वानुमान लगाने के लिए शीतकालीन चर घातांकी सहज मॉडल और मौसमी स्वसमाश्रयी समाकलित चल औसत (SARIMA) के मौसम प्राचलों को लिया गया है। पूर्वानुमान त्रुटि प्रतिशत और माध्य वर्ग त्रुटि का उपयोग करते हुए तुलनात्मक अध्ययन किया गया। इस अध्ययन से पता चला है कि प्रवृत्ति की यह जानकारी उद्यमियों को योजना बनाने और फसलों के उत्पादन में सहायक सिद्ध हो सकती है। पूर्वानुमान मॉडल के अध्ययन से पता चलता है कि SARIMA मॉडल मासिक अधिकतम तापमान, मासिक न्यूनतम तापमान और मासिक आर्द्रता-। का पूर्वानुमान करने के लिए सबसे सक्षम मॉडल है। मासिक आर्द्रता-।। का पूर्वानुमान करने के लिए शीतकालीन मॉडल सबसे सक्षम मॉडल है परन्तु कोई भी मॉडल मासिक कुल वर्षा का पूर्वानुमान करने के लिए उपयुक्त नहीं है।

ABSTRACT. The present study is undertaken to develop area specific weather forecasting models based on time series data for Pantnagar, Uttarakhand. The study was carried out by using time series secondary monthly weather data of 27 years (from 1981-82 to 2007-08). The trend analysis of weather parameters was done by Mann-Kendall test statistics. The methodologies adopted to forecast weather parameters were the winter's exponential smoothing model and Seasonal Autoregressive Integrated Moving Average (SARIMA). Comparative study has been carried out by using forecast error percentage and mean square error. The study showed that knowledge of this trend is likely to be helpful in planning and production of enterprises/crops. The study of forecast models revealed that SARIMA model is the most efficient model for forecasting of monthly maximum temperature, monthly minimum temperature and monthly humidity I. The Winter's model was found to be the most efficient model for forecasting Monthly Humidity II but no model was found to be appropriate to forecast monthly total rainfall.

Key words – Weather parameters, Winter's exponential smoothing model, SARIMA.

1. Introduction

Agricultural businesses, associated government systems and farmers depending on agriculture for sustenance, may all be significantly responsive to fluctuations in climate, largely through the impacts of climate on production and associated management intervention. Agro-meteorologists have tough challenges ahead in understanding the impact of weather and climate on growth and yield of crops. The more concerted efforts are essential to realize the present day needs of the farmers by the agricultural community of the country and also meet the demands of the poorer section of the country. Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and at a given location. In agriculture industry weather forecasting provides the opportunity to the farmers for enhancing input efficiency that enhances the chance for increasing productivity and reducing cost of production. Knowledge of seasonal climatic forecasts allows farmers to develop seasonal management strategies leading to potential improvements in productivity. It helps them in determining planting dates, irrigation needs, crop types, fertilization, and planting materials. Farmers can take many macro and micro level decisions within time and avoiding belated farm operations. Several studies of climate variability on both short and long time scales have been carried out in India and abroad to establish climate changes over India. Kripalani *et al*., 1996, studied monthly rainfall data for 14 stations over Bangladesh for the period 1901-1977 are used to investigate and understand the inter annual variability of the summer monsoon rainfall. Also Kumar *et al*., 2007 used an Artificial Intelligence approach to handle the highly non-linear and complex behavior of the climatic variables for regional rainfall forecasting for Orissa, India on monthly and seasonal time scales. Gadgil *et al*., 2002, worked on forecasting of Indian summer monsoon and Asin 2005, introduced a statistical procedure for obtaining long-term local daily precipitation forecasts in a climate change scenario. Two major groups, at the India Meteorological Department and at the Indian Institute of Tropical Meteorology, have mainly dealt with the analysis of long term temperature and precipitation records. Most of the studies of temperature analysis dealt with the analysis of surface temperature records of some individual observatory stations in the country. However, very few studies have been made of surface temperature trends in the country as a whole (Hingane *et al*., 1985). The present paper described the area specific weather forecasting models based on time series data.

2. Data and methodology

The present study was carried out to apply forecast models for predicting the weather parameters at the Pantnagar, Uttarakhand, India. It is situated in the Shivalik range of Himalayan foot hills at approximately 243.89 meters above mean sea level at 29° N latitude and 79.3° E longitudes. The time series data on monthly weather of 27 years (1981 to 2008) were collected from Agro-meteorological Observatory situated at the Crop Research Centre (C. R. C) of G. B. Pant University of Agriculture and Technology, Pantnagar. Five weather parameters were included in the study; namely average monthly maximum temperature, average monthly minimum temperature, average monthly relative humidity at 7.12 hrs (IST) (Humidity I), average monthly relative humidity at 14.12 hrs (IST) (Humidity II) and total monthly rainfall.

2.1. *Statistical techniques*

The methodology applied for development of forecast model was winter's exponential smoothing and Seasonal Autoregressive Integrated Moving Average (SARIMA). The trend analysis was done through Mann-Kendall test. The detailed of the procedure explained under different subheads.

2.1.1. *Trend analysis of weather parameters*

The Mann-Kendall rank correlation coefficient (Mann, 1945; Kendall, 1975) is commonly used to assess the significance of trends in hydro-meteorological time series and has been used in this study. The Mann-Kendall test statistics (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k)$$

and

$$\text{if } \theta > 0 \quad \operatorname{sgn}(\theta) = 1$$

$$\text{if } \theta = 0 \quad \operatorname{sgn}(\theta) = 0$$

$$\text{if } \theta < 0 \quad \operatorname{sgn}(\theta) = -1$$

where, n is the data set record length, x_j and x_k are the sequential data values.

The Mann-Kendall test has two parameters that are of importance for trend detection: the significance level, which indicates the trend strength, and the slope estimate, which indicates the direction as well as the rate of change.

(a) *Hypothesis*

H_0: There is no trend in the data.

H_1: There is trend in the data.

(b) *Test statistics*

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & \text{if } S \neq 0 \\ 0 & \text{if } S = 0 \end{cases}$$

Note : Under null hypothesis the distribution of S is then expected to have a mean of zero and a variance of

$$Var(S) = \frac{n(n-1)(2n-5)}{18}$$

(c) *Critical region*

The null hypothesis H_0 is rejected at level of significance α, if $|Z| > Z_{\alpha/2}$, otherwise accepted.

Note : A positive value of Z indicates an upward trend while a negative value of Z indicates a downward trend.

2.1.2. *Estimation of trend magnitude*

Trend magnitude is estimated using a nonparametric median based slope method proposed by Sen (1968) and extended by Hirsch *et al*. (1982).

β = Median $(X_j - X_k / j - k)$ for all $k < j$

where, $1 < k < j < n$ and β is median of all possible combinations of pairs for the whole data set.

Mathematical software, MATLAB was used for the estimation of trend magnitude and testing of its significance using Mann-Kendall test.

2.1.3. *Winter's forecasting model*

The winter's forecasting procedure is a simple and widely used projection model which can cope with trend and seasonal variations (Makridakis *et al*., 1998). This model is particularly suitable for production planning and stock control. This generalizes simple exponential smoothing so as to cope with trend and seasonal variation (Chatfield 1978).

Let us assume that the time series was adequately represented by the model

$$X_t = (b_1 + b_2\, t)\, c_t + \varepsilon_t$$

where,

b_1 = The base signal, usually called the permanent component,

b_2 = A liner trend component,

c_t = A multiplicative seasonal factor,

ε_t = The usual random error component.

2.1.4. *Seasonal Autoregressive Integrated Moving Average (SARIMA)*

This forecasting procedure has been developed by G.E.P. Box and G. M. Jenkins in early 1970's. The importance of this model is that a stationary time series can be modeled by it with fewer parameters than a pure moving average process or autoregressive process (Cooray, 2008). It deals with the seasonality of time series data hence named Box and Jenkins seasonal model (SARIMA) and it is a general multiplicative Seasonal Autoregressive Integrated Moving Average Model. The estimation of parameters involves iterative procedures.

A time series $\{X_t\}$ is a seasonal ARIMA (p, d, q) (P, D, Q)s process with period s if d and D are nonnegative integers and if the differenced series

$$Y_t = (1 - B)^d\, (1 - B^S)^D\, X_t$$

TABLE 1

Trend in monthly maximum temperature (1981-2008)

Months	Z-statistic	Slope (β)	Sig. value
Jan	-2.05	-0.065	**0.039***
Feb	-0.29	-0.015	0.766
Mar	0.75	0.034	0.452
Apr	0.61	0.025	0.539
May	-1.52	-0.083	0.127
Jun	-1.89	-0.105	0.057
Jul	-1.60	-0.047	0.108
Aug	-1.14	-0.024	0.250
Sep	-1.82	-0.033	0.068
Oct	-0.65	-0.016	0.513
Nov	-0.27	-0.005	0.781
Dec	-0.89	-0.020	0.373
Annual	-1.18	-0.205	0.235

*P < 0.05

is a stationary autoregressive moving average (ARMA) process defined by the expression

$$\varphi(B)\, \Phi(B^S)\, Y_t = \theta(B)\, \Theta(B^S) e_t$$

where, B = backshift operator defined by

$$B^a X_t = X_{t-a}\,;$$

$$\varphi(z) = 1 - \varphi_1 z - \ldots - \varphi_p z^p\ ,$$

$$\Phi(z) = 1 - \Phi_1 z - \ldots - \Phi_P z^P\ ;$$

$$\theta(z) = 1 - \theta_1 z\ - \ldots - \theta_q z^q\ ,$$

$$\Theta(z) = 1 - \Theta_1 z - \ldots - \Theta_Q z^Q;$$

e_t is identically and normally distributed with mean zero, variance σ^2 and

$$\mathrm{cov}(e_t\ , e_{t-k}) = 0 \quad \text{for all } k \neq 0,$$

i.e., $\{e_t\} \sim N\ (0,\ \sigma^2)$. The parameters p and P represent the non-seasonal and seasonal autoregressive polynomial order, respectively, and the parameters q and Q represent the non-seasonal and seasonal moving average polynomial order, respectively. The parameter d represents the order of normal differencing, and the parameter D represents the order of seasonal differencing. From a practical perspective, fitted seasonal ARIMA models provide linear state transition equations that can be applied recursively to produce single and multiple interval forecasts.

2.2. *Model comparison*

The Root Mean Square Error (RMSE) of each forecasting model was calculated for the testing of different forecasting models. The model having the smallest RMSE value was preferred.

$$\text{Root mean square error} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\text{Forecasted value} - \text{Actual value}\right)^{2}}$$

In addition to RMSE, the Forecast Error was calculated for each month of the year 2008 by using forecasted value and actual value to test efficiency of the forecasting models. The formula is give below:

$$\text{Forecast Error (\%)} = \frac{\text{Actual value} - \text{Forecasted value}}{\text{Actual value}} \times 100$$

3. Results and discussion

3.1. *Identification of trend in different weather parameters*

In this section monthly trends in four weather parameters, *viz*., monthly maximum temperature, monthly minimum temperature, monthly average temperature and monthly total rainfall over the years (1981 to 2008) were examined. Significance of trends was tested using Mann-Kendall's test.

3.1.1. *Trend in monthly maximum temperature (1981-2008)*

The values of test statistic (*Z*), slope (*β*) and significant probability values using Mann-Kendall's test for Monthly Maximum Temperature based on time series data for the years (1981-2008) are given in Table 1.

Table 1 reveals that values of slope varied from -0.205 to 0.034. The most negative slope was observed in annual maximum temperature. The most positive slope was observed in the month of March. Negative non significant trends were observed in all the months except in the months of March and April. However, statistically significant negative trend was found only in the month of January. The rate of change in maximum temperature was -0.06 °C indicates that maximum temperature in January decreased with -0.32% per month over the years 1981-2008. The decreasing trend in the month of January over the years 1981 to 2008 is shown in Fig. 1. Thus, it can be concluded that the month of January appears as a critical month for understanding the behaviour of temperature.

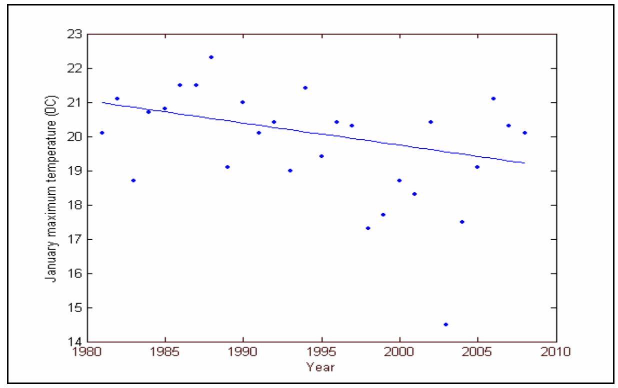

Fig. 1. Decreasing trend in maximum temperature in January (1981 to 2008)

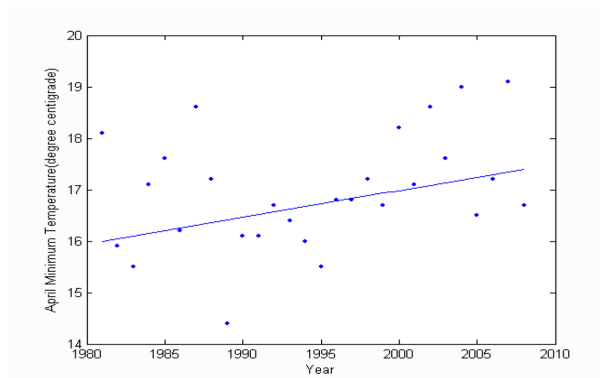

Fig. 2. Increasing trend in minimum temperature in April (1981 to 2008)

Knowledge of this trend is likely to be helpful in planning and production of enterprises/crops which start in the month of January or terminate in the month of January.

3.1.2. *Trend in monthly minimum temperature (1981-2008)*

The values of test statistic (*Z*), slope (*β*) and significant probability values using Mann-Kendall's test for monthly minimum temperature based on time series data for years (1981-2008) are given in Table 2.

It is clear from Table 2 that the values of slope (β) ranged from -0.025 to 0.263. The most negative value was observed in the month of January whereas the most positive value was for annual minimum temperature. Positive non-significant trends have been found in all the months except in the month of January wherein the trend is negative and non-significant. However, statistically significant positive trend was found in the month of April and in annual minimum temperature. The rate of change in April was 0.05 °C which indicates that there was 0.29% increase in minimum temperature in the month of April

TABLE 2

Trend in monthly minimum temperature (1981-2008)

Months	*Z*-statistic	Slope (β)	Sig. value
Jan	-1.24	-0.025	0.212
Feb	1.14	0.037	0.251
Mar	1.22	0.023	0.219
Apr	1.96	0.052	**0.04***
May	0.55	0.023	0.579
Jun	1.08	0.023	0.276
Jul	1.66	0.021	0.095
Aug	0.64	0	0.520
Sep	0.33	0.002	0.735
Oct	1.70	0.036	0.088
Nov	1.32	0.030	0.184
Dec	0.41	0.016	0.677
Annual	2.31	0.263	**0.02***

*P < 0.05

TABLE 3

Trend in monthly average temperature (1981-2008)

Months	*Z*-statistic	Slope (β)	Sig. value
Jan	-2.03	-0.04	**0.04***
Feb	0.33	0.009	0.73
Mar	1.16	0.039	0.24
Apr	1.54	0.051	0.12
May	-0.91	-0.024	0.36
Jun	-1.16	-0.035	0.24
Jul	-0.19	-0.004	0.84
Aug	-0.31	-0.004	0.75
Sep	-0.55	-0.009	0.57
Oct	1.02	0.014	0.30
Nov	0.63	0.010	0.52
Dec	-0.75	-0.012	0.45
Annual	0.23	0.020	0.81

*P < 0.05

over the years 1981-2008. Similarly the rate of change in annual minimum temperature was 0.26 °C which indicates that annual minimum temperature increased with 1.55% per year over the years 1981-2008. The increasing trends over the years 1981 to 2008 in April and in annual minimum temperature are shown in Fig. 2 and Fig. 3 respectively. On the basis of the trends in minimum temperature over the years 1981-2008, it can be concluded that there is general rise in minimum temperature annually. The month of April appears to play a significant role in increasing the minimum temperature. Therefore, the study suggests that future farm planning by the agricultural scientists may be improved, taking into consideration the changes in minimum temperature.

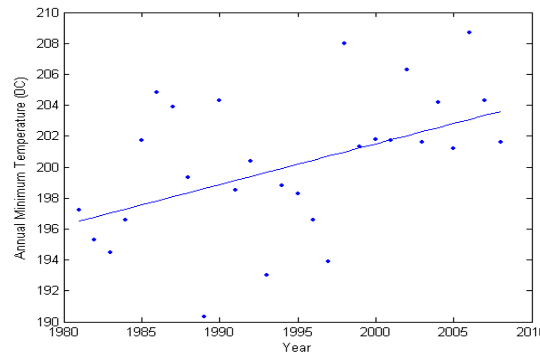

Fig. 3. Increasing trend in annual minimum temperature (1981 to 2008)

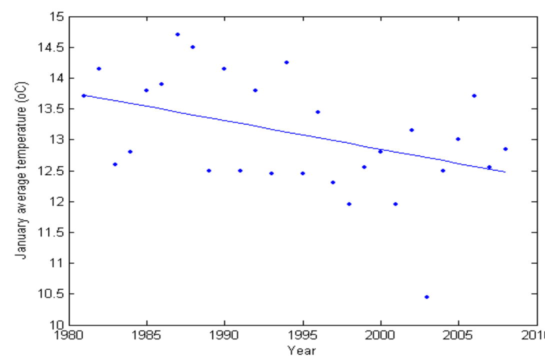

Fig. 4. Decreasing trend in average temperature in January (1981 to 2008)

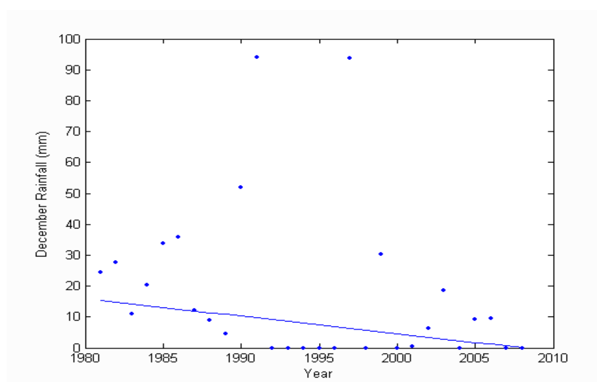

Fig. 5. Decreasing trend in total rainfall in the month of December (1981 to 2008)

3.1.3. *Trend in monthly average temperature (1981-2008)*

The values of test statistic (*Z*), slope (*β*) and significant probability values using Mann-Kendall's test for monthly average temperature based on time series data for years (1981-2008) are given in Table 3.

TABLE 4

Trend in monthly total rainfall (1981-2008)

Months	*Z*-statistic	Slope (β)	Sig. value
Jan	-0.51	-0.195	0.60
Feb	0.65	0.286	0.51
Mar	-0.97	-0.246	0.33
Apr	-0.49	-0.158	0.62
May	1.04	0.777	0.29
Jun	0.81	2.520	0.41
Jul	-0.41	-0.675	0.67
Aug	1.58	8.060	0.11
Sep	0.65	3.000	0.51
Oct	0.43	0	0.66
Nov	-0.63	0	0.52
Dec	-2.14	-0.567	**0.03***
Annual	1.08	15.41	50.61

*P < 0.05

TABLE 5

Forecasted monthly maximum temperature and forecast errors for the year 2008

Year	Month	Max. temp. (Actual) (°C)	Max. temp. (Forecasted) (°C)	Forecast error (%)	RMSE
2008	Jan	20.1	18.97	5.62	1.39
	Feb	21.6	22.7	-5.09	
	Mar	29.4	27.57	6.22	
	Apr	35.2	34.45	2.13	
	May	35.7	35.96	-0.73	
	Jun	32.0	34.74	-8.56	
	Jul	30.6	31.71	-3.63	
	Aug	30.5	31.02	-1.70	
	Sep	31.1	30.64	1.48	
	Oct	30.3	29.71	1.95	
	Nov	27.5	26.20	4.73	
	Dec	23.8	21.50	9.66	

The Table 3 depicted that values of slope (β) raised from -0.04 to 0.051. The most negative value was observed in the month of January whereas the most positive value was for the month of April. Positive but non-significant trends have been found in the months of February, March, April, October and November whereas non-significant negative trends were found in remaining months. Statistically significant negative trend was found in the month of January with the rate of change was -0.04 °C which indicates that monthly decrease in average

TABLE 6

Forecasted monthly minimum temperature and forecast errors for the year 2008

Year	Month	Min. temp. (Actual) (°C)	Min. temp. (Forecasted) (°C)	Forecast error (%)	RMSE
2008	Jan	5.6	6.33	-13.04	1.02
	Feb	7.0	8.90	-27.14	
	Mar	13.0	12.30	5.38	
	Apr	16.7	17.32	-3.71	
	May	21.6	22.31	-3.29	
	Jun	24.8	24.82	-0.08	
	Jul	25.0	25.41	-1.64	
	Aug	24.9	24.95	-0.20	
	Sep	22.9	23.10	-0.87	
	Oct	18.1	17.44	3.65	
	Nov	12.5	11.15	10.80	
	Dec	9.5	7.37	22.42	

temperature was -0.30% in month of January over the years 1981-2008. The decreasing trend in the month of January over the years 1981 to 2008 is shown in Fig. 4. It can be concluded that the month of January is the crucial month indicating a decreasing trend in the average temperature. These findings may be helpful for scientists to reformulate the crop planning, particularly for those crops for which January is the crucial month during its crop season.

3.1.4. *Trend in monthly total rainfall (1981-2008)*

The values of test statistic (Z), slope (β) and significant probability values using Mann-Kendall's test for monthly total rainfall based on time series data for years (1981-2008) are given in Table 4.

As shown in Table 4 values of slope (β) varied from -0.675 to 15.41. Most negative value was observed in the month of July whereas the most positive value was observed in annual total rainfall. Decreasing non-significant trends were found in the months of January, March, April, July and December whereas non-significant increasing trends were observed in the remaining months. However, statistically significant negative trend was detected in the month of December. The rate of change was -0.567mm which indicates that Rainfall in the month of December decreased with -3.22% per month over the years 1981-2008. The decreasing trend in the Total Rainfall in the month of December over the years 1981 to 2008 is shown in Fig. 5. Thus, it was found that the trend in Rainfall over the years 1981-2008 is significantly decreasing in the month of December which may affect

TABLE 7

Forecasted Monthly Humidity I and forecast errors for the year 2008

Year	Month	Humidity I (Actual) (%)	Humidity I (Forecasted) (%)	Forecast Error (%)	RMSE
2008	Jan	91	94.90	-4.29	4.33
	Feb	88	92.64	-5.27	
	Mar	82	88.13	-7.48	
	Apr	70	69.52	0.69	
	May	64	65.49	-2.33	
	Jun	82	75.90	7.44	
	Jul	90	89.91	0.10	
	Aug	88	92.27	-4.85	
	Sep	87	92.88	-6.76	
	Oct	83	88.20	-6.27	
	Nov	87	91.42	-5.08	
	Dec	91	94.42	-3.76	

TABLE 8

Forecasted monthly humidity II and forecast errors for the year 2008

Year	Month	Humidity II (Actual) (%)	Humidity II (Forecasted) (%)	Forecast Error (%)	RMSE
2008	Jan	49	57.48	-17.31	5.62
	Feb	47	50.36	-7.15	
	Mar	41	39.52	3.61	
	Apr	21	25.59	-21.86	
	May	31	33.74	-8.84	
	Jun	66	51.53	21.92	
	Jul	75	69.62	7.17	
	Aug	75	72.02	3.97	
	Sep	66	67.61	-2.44	
	Oct	52	50.89	2.13	
	Nov	45	43.66	2.98	
	Dec	53	49.60	6.42	

the production of crops grown/harvest in the month of December. These findings may help the agriculture scientists for reformulating the irrigation management pattern in the month of December.

3.2. *Forecasting of weather parameters using winter's exponential smoothing method*

The obtained results using Winter's model for various weather parameters are presented under different sub heads.

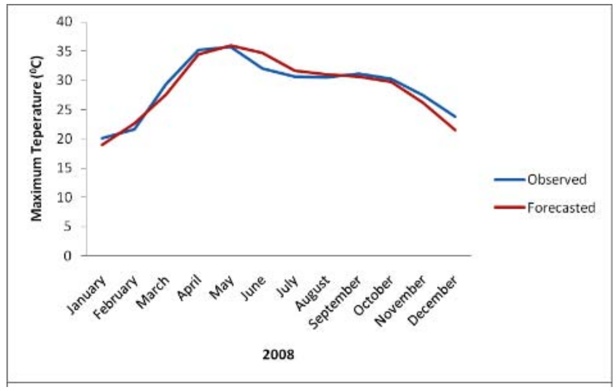

Fig. 6. Comparison of observed and forecasted monthly maximum temperature using Winter's Exponential Smoothing method

3.2.1. *Forecasting of monthly maximum temperature for the years 2008*

The forecasted values of monthly maximum temperature of different months for the years 2008 are given in Table 5 and the comparison of observed and forecasted maximum temperature is also presented graphically in Fig. 6.

The results of Table 5 showed that Forecast errors for the months of the years 2008 are ranging from -8.56% to 9.66% with low RMSE 1.39 which clearly indicates that forecasted values obtained by Winter's model are very close to the actual values of observed monthly maximum temperature. The results are also supported by the Fig. 6. Therefore, it is concluded that Winter's model can be effectively used to forecast monthly maximum temperature.

3.2.2. *Forecasting of monthly minimum temperature for the years 2008*

The forecasted values of monthly minimum temperature of different months for the years 2008 are given in Table 6 and comparison of observed and forecasted minimum temperature is also presented graphically in Fig. 7.

The results presented in Table 6 reveal that Forecast errors for different months for the years 2008 are ranging from -27.14% to 22.42% with RMSE 1.02 which clearly indicates that forecasted values obtained by Winter's model are close to the actual values of observed monthly minimum temperature. The results are also supported by the Fig. 7. Therefore, it can be concluded that Winter's model can be used efficiently to forecast monthly minimum temperature.

TABLE 9

Forecasted monthly total rainfall and forecast errors for the year 2008

Year	Month	Rainfall (Actual)(mm)	Rainfall (Forecasted)(mm)	Forecast Error (%)	RMSE
2008	Jan	1.8	37.98	-2010.00	109.33
	Feb	1.0	57.14	-5614.00	
	Mar	0.0	23.79	----	
	Apr	24.6	18.83	23.46	
	May	34.6	68.20	-97.11	
	Jun	416.4	206.70	50.36	
	Jul	637.2	519.90	18.41	
	Aug	825.2	568.70	31.08	
	Sep	414.4	298.10	28.06	
	Oct	24.4	30.85	-26.43	
	Nov	2.4	3.32	-38.33	
	Dec	0.0	12.81	-	

TABLE 10

Forecasted monthly maximum temperature and forecast errors for the year 2008

Year	Month	Max. temp. (Actual) (°C)	Max. temp. (Forecasted) (°C)	Forecast error (%)	RMSE
2008	Jan	20.1	19.23	4.33	1.38
	Feb	21.6	22.86	-5.83	
	Mar	29.4	27.77	5.54	
	Apr	35.2	34.87	0.94	
	May	35.7	36.69	-2.77	
	Jun	32.0	35.00	-9.38	
	Jul	30.6	32.35	-5.72	
	Aug	30.5	31.68	-3.87	
	Sep	31.1	31.36	-0.84	
	Oct	30.3	30.43	-0.43	
	Nov	27.5	26.89	2.22	
	Dec	23.8	22.12	7.06	

3.2.3. *Forecasting of monthly humidity I for the years 2008*

The forecasted values of monthly humidity I of different months for the years 2008 are given in Table 7. Comparison of observed and forecasted Humidity I is also presented graphically in Fig. 8.

The results given in the Table 7 reveals that forecast errors for different months for the years 2008 are ranging from -7.48% to 7.44% with RMSE 4.33 which clearly indicates that forecasted values of Monthly Humidity I obtained by Winter's model are close to the actual observed values. The results are also supported by the Fig. 8 Therefore, it can be concluded that Winter's model can be used efficiently for forecasting of Monthly Humidity I.

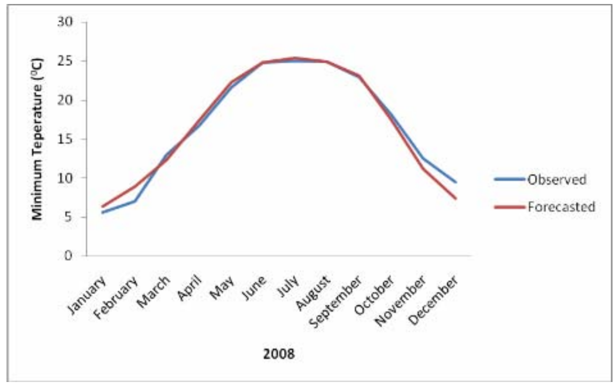

Fig. 7. Comparison of observed and forecasted monthly minimum temperature using winter's exponential smoothing method

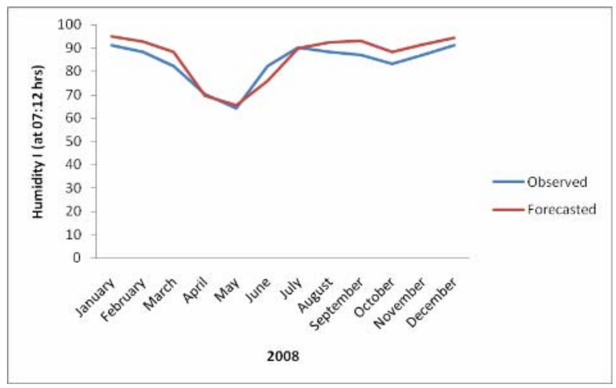

Fig. 8. Comparison of observed and forecasted Monthly Humidity I (at 07:12 hrs) using winter's exponential smoothing method

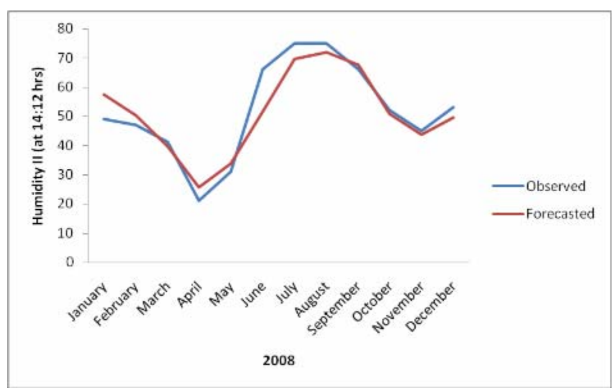

Fig. 9. Comparison of observed and forecasted Monthly Humidity II (at 14:12 hrs) using winter's exponential smoothing method

TABLE 11

Forecasted monthly minimum temperature and forecast errors for the year 2008

Year	Month	Min. temp. (Actual) (°C)	Min. temp. (Forecasted) (°C)	Forecast error (%)	RMSE
2008	Jan	5.6	6.40	-14.29	0.95
	Feb	7.0	8.85	-26.43	
	Mar	13.0	12.39	4.69	
	Apr	16.7	17.31	-3.65	
	May	21.6	22.50	-4.17	
	Jun	24.8	25.09	-1.17	
	Jul	25.0	25.66	-2.64	
	Aug	24.9	25.24	-1.37	
	Sep	22.9	23.41	-2.23	
	Oct	18.1	17.67	2.38	
	Nov	12.5	11.49	8.08	
	Dec	9.5	7.74	18.53	

TABLE 12

Forecasted monthly humidity I and forecast errors for the year 2008

Year	Month	Humidity I (Actual) (%)	Humidity I (Forecasted) (%)	Forecast error (%)	RMSE
2008	Jan	91	94.11	-3.42	3.80
	Feb	88	92.26	-4.84	
	Mar	82	87.48	-6.68	
	Apr	70	69.05	1.36	
	May	64	64.90	-1.41	
	Jun	82	75.77	7.60	
	Jul	90	89.72	0.31	
	Aug	88	91.91	-4.44	
	Sep	87	92.12	-5.89	
	Oct	83	87.33	-5.22	
	Nov	87	90.22	-3.70	
	Dec	91	92.99	-2.19	

3.2.4. *Forecasting of monthly humidity II for the years 2008*

Forecasted values of Monthly Humidity II of different months for the years 2008 for each month are given in Table 8. Comparison of observed and forecasted Humidity-II is also presented graphically in Fig. 9.

It is revealed from Table 8 that Forecast errors for different months for the years 2008 and 2009 are ranging from -21.86% to 21.92% with RMSE 5.62 which indicates that forecasted values of Monthly Humidity II obtained by Winter's model are close to the actual observed values. The results are also supported by the Fig. 9. Therefore, it can be interpreted that Winter's model can be used efficiently for forecasting of Monthly Humidity II.

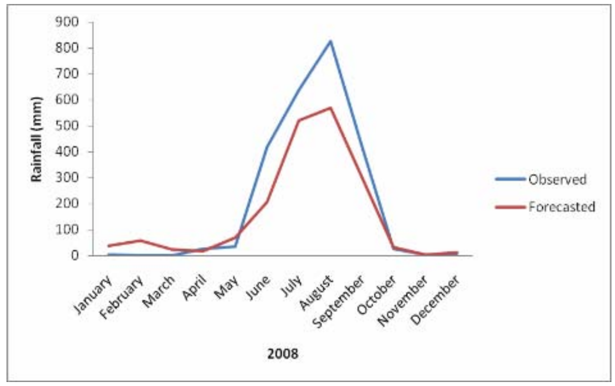

Fig. 10. Comparison of observed and forecasted monthly total rainfall using winter's exponential smoothing method

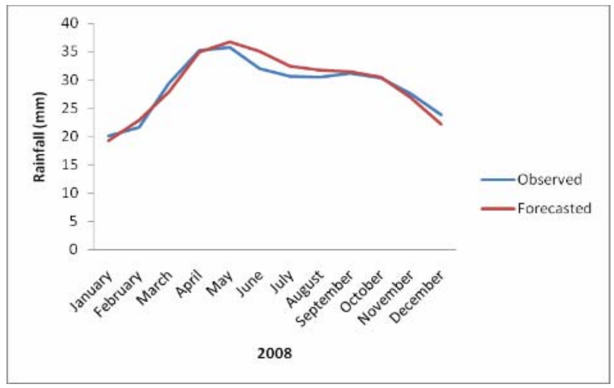

Fig. 11. Comparison of observed and forecasted monthly maximum temperature using SARIMA method

3.2.5. *Forecasting of monthly total rainfall for the years 2008*

Forecasted values of monthly rainfall of different months for the years 2008 for each month are given in Table 9. Comparison of observed and forecasted rainfall is also presented graphically in Fig. 10.

It is revealed from Table 9 that forecast errors for different months for the years 2008 are ranging from -5614.00% to 50.36% with high value RMSE 109.33 which indicates that forecasted values of monthly rainfall obtained by Winter's model are not close to the actual observed values. The results are also supported by the Fig. 10. Therefore, it can be concluded that Winter's model is not suitable for forecasting of monthly total rainfall.

TABLE 13

Forecasted monthly humidity II and forecast errors for the year 2008

Year	Month	Humidity II (Actual) (%)	Humidity II (Forecasted) (%)	Forecast error (%)	RMSE
2008	Jan	49	49.59	-1.20	5.83
	Feb	47	51.96	-10.55	
	Mar	41	41.53	-1.29	
	Apr	21	26.05	-24.05	
	May	31	35.81	-15.52	
	Jun	66	51.09	22.59	
	Jul	75	67.54	9.95	
	Aug	75	69.57	7.24	
	Sep	66	63.98	3.06	
	Oct	52	49.88	4.08	
	Nov	45	44.36	1.42	
	Dec	53	48.81	7.91	

3.3. *Forecasting of weather parameters using SARIMA method*

The forecast obtained through Seasonal Autoregressive Integrated Moving Average (SARIMA) method are presented under following sub heads.

3.3.1. *Forecasting of monthly maximum temperature for the years 2008*

Forecasted values of monthly maximum temperature obtained for each month are given in Table 10. Comparison of observed and forecasted Maximum Temperature is also presented graphically in Fig. 11.

It is revealed from Table 10 that forecast errors for different months for the years 2008 are ranging from -9.38% to 7.06% with low RMSE 1.38 which clearly indicates that forecasted values obtained by SARIMA model are very close to the actual observed values of monthly maximum temperature. The results are also supported by the Fig. 11. Therefore, this model can be used efficiently for forecasting monthly maximum temperature.

3.3.2. *Forecasting of monthly minimum temperature for the years 2008*

Forecasted values of monthly minimum temperature obtained for each month are given in Table 11. Comparison of observed and forecasted minimum temperature is also presented graphically in Fig. 12.

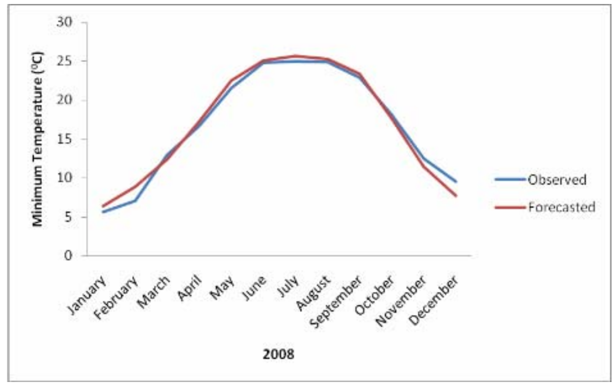

Fig. 12. Comparison of observed and forecasted monthly minimum temperature using SARIMA method

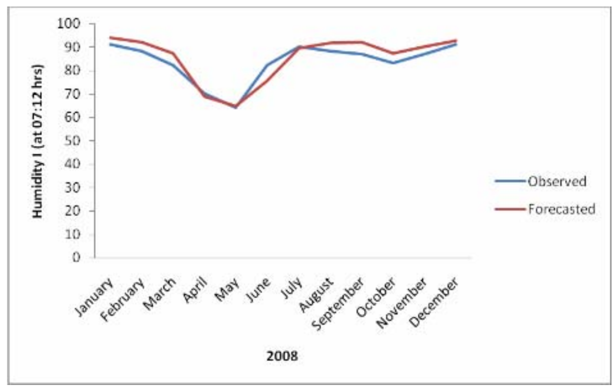

Fig. 13. Comparison of observed and forecasted monthly humidity I (at 07:12 hrs) using SARIMA method

It is revealed from Table 11 that forecast errors for different months for the years 2008 are ranging from -26.43% to 18.53% with low RMSE 0.95 which clearly indicates that forecasted values obtained by SARIMA model are close to the actual observed values of monthly minimum temperature. The results are also supported by the Fig. 12. Therefore, this model can be effectively used to forecast monthly minimum temperature.

3.3.3. *Forecasting of Monthly Humidity I for the years 2008*

Forecasted values of Monthly Humidity I obtained for each month are given in Table 12. Comparison of observed and forecasted Humidity I is also presented graphically in Fig. 13.

It is revealed from Table 12 that forecast errors for different months for the years 2008 are ranging from -6.68% to 7.60% with RMSE 3.8 which clearly indicates that forecasted values obtained by SARIMA model are very close to the actual observed values of Monthly

TABLE 14

Forecasted monthly total rainfall and forecast errors for the year 2008

Year	Month	Rainfall (Actual)(mm)	Rainfall (Forecasted)(mm)	Forecast error (%)	RMSE
2008	Jan	1.8	29.67	-1548.33	136.64
	Feb	1.0	48.64	-4764.00	
	Mar	0.0	26.44	-	
	Apr	24.6	24.45	0.61	
	May	34.6	72.28	-108.90	
	Jun	416.4	204.41	50.91	
	Jul	637.2	432.94	32.06	
	Aug	825.2	487.03	40.98	
	Sep	414.4	286.28	30.92	
	Oct	24.4	50.77	-108.07	
	Nov	2.4	13.61	-467.08	
	Dec	0.0	24.89	-	

TABLE 15

RMSE and forecast error values for different forecasting models

Parameters	Winter's model		SARIMA model	
	RMSE	Forecast error (range)	RMSE	Forecast error (range)
Max temperature	1.39	1.10	1.38	-2.32
Min temperature	1.02	-4.72	0.95	-7.90
Humidity I	4.33	-0.04	3.80	0.92
Humidity II	5.62	0.06	5.83	-1.46
Total rainfall	109.33	-5563.64	136.64	-4713.09

Humidity I. The results are also supported by the Fig. 13. Therefore, this model can be effectively used for forecasting Monthly Humidity I.

3.3.4. *Forecasting of Monthly Humidity II for the years 2008*

Forecasted values of Monthly Humidity II obtained for each month are given in Table 13. Comparison of observed and forecasted Humidity II is also presented graphically in Fig. 14.

The Table 13 reveals that forecast errors of Monthly Humidity II for different months for the years 2008 are ranging from -24.05% to 22.59% with RMSE 5.83 which clearly indicates that forecasted values obtained by SARIMA model are close to the actual observed values of

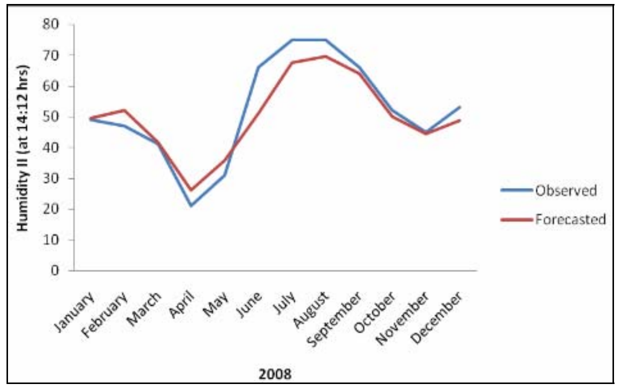

Fig. 14. Comparison of observed and forecasted monthly humidity II (at 14:12 hrs) using SARIMA method

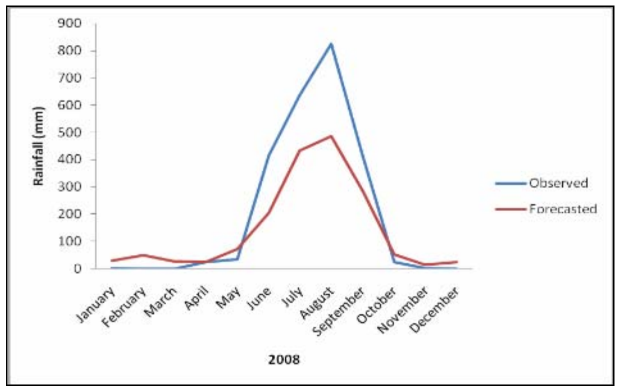

Fig. 15. Comparison of observed and forecasted monthly total rainfall using SARIMA method

Monthly Humidity II. The results are also supported by the Fig. 14. Therefore, this model can be used for forecasting Monthly Humidity II.

3.3.5. *Forecasting of monthly total rainfall for the years 2008*

Forecasted values of monthly total rainfall obtained for each month are given in Table 14. Comparison of observed and forecasted rainfall is also presented graphically in Fig. 15.

It is revealed from Table 14 that forecast errors of monthly rainfall for different months for the years 2008 are ranging from -4764.00 to 50.91% with high value RMSE 136.64 which clearly indicates that forecasted values obtained by SARIMA model are not close to the actual observed values of total monthly rainfall. The results are also supported by the Fig. 15. Therefore, this model is not suitable to forecast monthly total rainfall accurately.

3.4. *Comparison of forecast models*

The comparison of the Winter's model and SARIMA model was done by computing Root Mean Square Error (RMSE) and forecast errors, based on a test data set, *i.e.*, 2008. The results on comparison of models are presented in Table 15.

The results revealed that RMSE values obtained from Winter's model ranged from 1.02 (for minimum temperature) to 109.33 (for Total Rainfall). The RMSE values obtained from SARIMA model had the narrowest range from 0.95 (for minimum temperature) to 136.64 (for total rainfall). On the basis of these results in Table 15, it was found that SARIMA model was the most efficient model for forecasting of, *viz*., monthly maximum temperature, monthly minimum temperature and Monthly Humidity I. However, in case of Monthly Humidity II, Winter's model was the most efficient. These two models used in the study are not appropriate for forecasting of monthly total rainfall since RMSE values and Forecast errors are very large in case of these models. However, out of these models used in the study SARIMA model may be preferred as compared to Winter's model due to its less RMSE value and Forecast error. It was observed that forecasting of total rainfall can't be done on the basis of the past data of only 26 years included in the study. However, the results can be made more conclusive through use of rainfall data on a longer time series.

4. Conclusion

The reliable and well timed forecasts are of vital importance for appropriate up to date planning and execution of farm operations. In India there is a need to develop forecasting models on continuing basis and also for different agro-climatic zones due to visible effects of changing environment conditions and weather shifts at different locations and areas. Therefore, knowledge of trend is likely to be helpful in planning and production of enterprises/crops. The study was undertaken to apply some specific weather forecasting models based on time series data. On the basis of RMSE, (Table 15) the study recommended that SARIMA model is the most efficient model for forecasting of monthly maximum temperature, monthly minimum temperature and Monthly Humidity I. The Winter's model was found to be the most efficient model for forecasting Monthly Humidity II. No model was found to be appropriate to forecast monthly total rainfall.

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