Journal of Agrometeorology 15 (2) : 129-134 (December 2013)

Trend analysis of weather data in shrimp farming areas of Nagapattinam district of Tamil Nadu*

J. ASHOK KUMAR, M. MURALIDHAR, M. JAYANTHI and M. KUMARAN

Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, R.A.Puram, Chennai - 600 028
Email: ashok@ciba.res.in

ABSTRACT

Examining the trends and building the forecasting models for the meteorological parameters has got significance in climate research. An attempt was made to study the trends of temperature and rainfall of Nagapattinam District, a main shrimp farming area in Tamil Nadu. Surface weather data of the study area obtained from Indian Meteorological Department, Pune were analysed using Mann–Kendall trend test (MK test) for the weather parameters viz., maximum, minimum, highest maximum (HMax), lowest minimum (LMin) and mean temperatures, rainfall and number of rainy days. Month-wise, season-wise (winter, summer and rainy) and year-wise trends were computed for the monthly data from 1961 to 2000. Results of analysis revealed a significant trend for maximum temperature for all the cases of experimentation, whereas the trend was significant for few months or seasons for minimum, mean, highest and lowest temperatures and number of rainy days. Trend does not exist for rainfall of the region. Time series forecasting model was built for monthly maximum temperatures using the data from 1961 to 1980 for building the model and evaluated with the data from 1981 to 2000. Autoregressive integrated moving average model (ARIMA) (2, 0, 1) (1, 1, 1) s was found to be suitable model with highest R^2 value of 0.94 and lowest Root Mean Square Error. Model predictions were reassessed with Willmott's index and found to be reasonably good (0.95) for the study area. The forecasting model for temperature in the study area can be used for shrimp farming crop calendar planning.

Key words: Shrimp farming, trend analysis, Mann-Kendall test, ARIMA models

Successful shrimp farming primarily depends on weather and environmental parameters. Favourable weather conditions are required at each stage from stocking to harvesting of shrimp crop. Major weather parameters that affect shrimp farming are temperature and rainfall. These parameters are responsible for rise and fall of water quality parameters like salinity, pH, and dissolved oxygen which subsequently influence the growth of shrimp in ponds. Hence, study of the weather parameters and forecasting these parameters before cropping season would help the farmers in providing necessary information for planning the crop calendar.

Trend analysis, an important activity undertaken by climate researchers, provides clue on patterns in historical data of weather parameters. Mann-Kendall trend test (MK test) is a nonparametric test used for finding the trends in time series data of weather parameters. MK test has been used by many researchers and some of the recent works include Arun *et al*. (2012), and Subash *et al*. (2012). If the trend is identified for the variable under study further step would be to build a forecasting model. A reasonably good forecasting model provides a realistic estimate of the variable for a given future time based on past data. Autoregressive integrated moving average model (ARIMA) procedure used in this study is frequently used for developing time series forecasting models (Shamsnia *et al*., 2011; Syeda *et al*., 2012; Elias *et al*., 2012). Nagapattinam, a coastal district of Tamil Nadu is chosen for the study as it is one of the major shrimp farming areas in the state. The objectives of the study are to evaluate the trends in weather parameters of Nagapattinam district and developing a forecasting model for the variables showing significant trend. Implementation of trend analysis as well as developing forecasting models for the selected area is explained in the present study.

MATERIALS AND METHODS

Study area

Nagapattinam is located between 10°16'19" N to

* Paper presented in national seminar on "Climate change and Indian Agriculture : Slicing down the Uncertainty" held at CRIDA, Hyderabad during 22-23 January-2013 and reviewed for special issue of the Journal.

11°25'9" N Latitude and 79°29'25" to 79°53'3" East Longitude. The total geographical area of the district is about 3536.38 sq. km. The district has a coast line of 187.9 km, constituting about 15 percent of the coastline of Tamil Nadu (http://www.nagapattinam.tn.nic.in). Eighty seven per cent of the population in the district are fishermen signifying the domination of fisheries related activities. Several extreme and disastrous climatic events were witnessed in the district during the last Century - ranging from storm surges in the year 1952 to Nisha cycone in 2008 and a rare event like tsunami in the year 2004. These extreme conditions have not only affected agriculture and aquaculture activities in the distric,t but also have taken lives of several coastal poor. Hence, the climate change related studies have got great significance in Nagapattinam district.

Data

Monthly surface weather data of Nagapattinam District were obtained from Indian Meteorological Department (IMD), Pune. The weather parameters considered for the present study are: maximum, minimum, highest maximum (HMax), lowest minimum (LMin) and mean temperatures, rainfall and number of rainy days. The data were used to compute month-wise, season-wise and year-wise subsets for the period 1961 to 2000 and subjected to MK trend analysis. There were no missing values for the chosen period. For building the time series forecasting models monthly data of 1961 to 1980 were used for model building and 1981 to 2000 were used for model validation.

Analysis of trend

Mann-Kendall trend test (Mann, 1945; Kendall, 1975) is a nonparametric test used in climatological research for finding the trends in the respective variables. Significance of trend was decided through Mann-Kendall Z statistics and magnitude of the trend was calculated through Sen's estimator (Sen, 1968). Expressions for MK test and Sen's estimator are given below.

Mann kendall Score (S) was computed as follows

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(y_j - y_i)$$

Where n is the number of data points. Sgn(è) is calculated between two data points i and j as follows.

$$\mathrm{Sgn}(\theta) = \begin{cases} 1 \text{ if } \theta > 0 \\ 0 \text{ if } \theta = 0 \\ -1 \text{ if } \theta < 0 \end{cases}$$

Variance of the Score (Var(S)) was calculated by

$$\mathrm{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{n} t_k (t_k - 1)(2t_k + 5)}{18}$$

Where n is the number of tied (zero difference between compared values) groups and t_k is the number of data points in the k^{th} tied group. Using Mann-Kendall Score and its variance, standard normal deviate (Z- statistic) was calculated using the following expression (Hirsch *et al*., 1993).

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} \; if S > 0 \\ 0 \quad \text{if } S=0 \\ \dfrac{S+1}{\sqrt{Var(S)}} \; if S > 0 \end{cases}$$

Computed |Z| value was compared with table value at $Z_{á/2}$. If the computed value was more than the table value then the null hypothesis was rejected and inferred that the trend of the series was statistically significant. In the present study null hypothesis was tested at 95% confidence level.

For magnitude of the trend Sen's estimator was computed using the following expression.

$$Ti = \frac{xi - xk}{j - k} \; for i = 1,2,....n \qquad (5)$$

Where T_i is the slopes of all data pairs, x_j and x_k are data values at time j and k respectively. Median of the T_i is considered as Sen's estimator (â). Positive values of Sen's estimate indicate upward/increasing trend and negative values indicate downward/decreasing trend.

Building time series forecasting models

ARIMA models, popularly called Box-Jenkins models, are generally used for analysing and forecasting univariate time series data (Box and Jenkins, 1976). ARIMA models

Table 1: Descriptive statistical measures of temperature parameters in Nagapattinam district

Month	Max			Min			Mean			Hmax			Lmin		
	Average	Range	Std	Average	Range	Std	Average	Range	Std	Average	Range	Std	Average	Range	Std
January	28.30	26.6-30.0	0.64	22.53	20.8-24.1	0.86	25.41	24.1-26.9	0.55	29.42	27.6-32.1	0.79	19.61	16.2-21.8	1.08
February	29.29	27.8-31.2	0.71	23.42	21.1-25.2	0.99	26.35	24.6-27.5	0.66	31.21	29.1-35.0	1.43	20.15	22.6-17.3	1.21
March	31.01	30.0-32.2	0.54	24.88	20.8-26.8	1.07	27.95	25.7-29.5	0.64	33.88	31.3-37.5	1.71	21.40	16.7-24.2	1.53
April	33.12	31.6-34.9	0.76	26.88	25.6-28.1	0.61	30.00	28.7-31.4	0.58	37.29	34.4-40.2	1.65	23.70	20.1-25.7	1.39
May	36.00	34.2 - 38.1	1.07	27.48	26.0-28.7	0.64	31.74	30.2-33.3	0.75	40.05	38.2-41.8	0.87	24.18	21.6-27.6	1.33
June	36.69	33.9-38.0	0.91	27.04	26.1-28.4	0.55	31.86	30.0-33.5	0.67	39.55	38.0-41.4	0.87	24.41	22.4-26.5	1.13
July	35.78	33.8-36.8	0.80	26.44	25.6-27.3	0.46	31.11	29.8-32.0	0.59	38.47	36.1-40.7	0.82	23.88	22.3-33.4	1.70
August	34.91	32.8-36.3	0.83	25.90	24.9-26.7	0.37	30.40	28.8-38.6	0.56	37.37	35.9-38.6	0.78	23.12	20-25.4	1.11
September	33.88	32.1-35.3	0.82	25.63	24.9-26.6	0.37	29.76	28.7-30.7	0.54	36.26	33.6-38.9	1.06	23.00	20.9-24.5	0.74
October	31.62	29.9-33	0.72	25.04	24.2-26.1	0.36	28.33	27.4-29.5	0.47	34.91	33.2-37.6	0.98	22.74	21.3-24	0.64
November	29.50	28.3-30.8	0.62	24.04	22.9-25.1	0.55	26.77	25.7-27.7	0.51	32.36	29.8-38.3	1.44	21.60	18.5-23	0.94
December	28.44	26.7-29.6	0.64	23.04	21.0-25.0	0.81	25.74	24.3-27.2	0.56	30.26	27.9-32.6	1.02	20.39	18.8-22.1	0.99
Summer	34.20	33.3-35.0	0.461	26.57	25.2-27.4	0.52	30.39	29.6-31.1	0.42	40.35	38.4-41.8	0.68	21.28	16.7-23.3	1.44
Rainy	33.14	32.06-34.0	0.44	25.41	24.9-26.1	0.26	29.27	28.5-30.0	0.32	38.52	36.8-40.7	0.75	21.34	18.5-22.5	0.83
Winter	28.67	27.7-29.8	0.54	22.99	21.7-23.9	0.57	25.83	25.0-26.6	0.37	31.45	29.7-35.0	1.31	19.24	16.2-20.7	0.97
Annual	32.00	31.2-32.6	0.39	24.99	24.1-25.5	0.36	28.50	28.0-29.0	0.28	40.39	38.6-41.8	0.66	19.14	16.2-20.7	1.05

Max= Maximum temperature; min=Minimum temperature; mean=Mean temperature; Hmax=Highest maximum temperature; Lmin=Lowest minimum temperature; Std=Standard deviation

Table 2 : Descriptive statistical measures of rainfall parameters in Nagapattinam district

Month	Rainfall			Rainy days		
	Average	Range	Std	Average	Range	Std
January	55.20	0-292.8	74.03	16.93	0-31	10.11
February	22.89	0-331.6	59.02	10.63	0-29	8.97
March	15.83	0-88.7	25.87	10.28	0-28	8.16
April	22.11	0-125.7	36.05	11.58	0-30	9.75
May	37.56	0-140.3	40.60	16.65	1-31	8.75
June	38.44	0-189.7	45.90	15.35	0-30	9.40
July	50.42	0.1-184.2	47.60	18.48	1-31	8.89
August	81.26	0.3-273.6	65.12	18.95	1-31	8.56
September	86.67	0-190.7	46.29	16.90	1-30	8.77
October	238.57	21.9-559.8	140.01	19.63	3-31	7.72
November	381.94	26-836.0	205.68	19.68	1-30	8.95
December	288.26	40-843.1	208.81	15.43	1-31	9.97
Summer	113.93	15.4-312.6	77.16	53.85	16-95	18.91
Rainy	838.85	352.7-1498.3	282.97	93.63	49-127	16.25
Winter	366.34	71.6-959.7	221.62	42.975	13-79	15.51
Annual	1319.13	640-2524.9	368.86	190.45	113-255	27.43

Note: Std-Standard deviation

Table 3: Sen's slope estimator of slope for monthly weather parameters of Nagapattinam district

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	0.035*	0.026*	0.016	0.018	0.008	0.021	0.020*	0.043*	0.028*	0.016	0.035*	0.037*
Min	-0.009	-0.021	-0.036*	-0.020*	0.006	0.004	0.000	0.007	0.006	0.000	0.005	-0.010
Mean	0.011	0.005	-0.009	-0.002	0.008	0.015	0.012	0.025*	0.017*	0.005	0.020*	0.008
Hmax	0.023*	0.013	0.050*	0.050*	0.000	0.004	0.019	0.031*	0.048*	0.000	0.021	0.032*
Lmin	-0.033*	-0.043*	-0.051*	-0.040*	0.025	0.009	-0.006	0.014	0.005	0.008	0.007	-0.028
Rf	0.076	0.000	0.000	0.000	-0.192	0.035	-0.322	-0.504	0.091	-1.831	4.069	-3.304
Rd	0.268*	-0.103	0.000	0.140	0.071	0.096	-0.063	0.059	0.083	-0.125	0.333*	0.227

* Statistically significance at 95% confidence level as per the Mann–Kendall trend test (+ for increasing and " for decreasing)

Table 4: Sen's slope estimator for seasonal and annual weather parameters of Nagapattinam district

	Season			
Variable	Summer	Rainy	Winter	Annual
Max	0.015*	0.027*	0.035*	0.025*
Min	-0.011	0.005	-0.015	-0.007
Mean	0.001	0.016*	0.009	0.008*
Hmax	0.000	0.020	0.016	0.000
Lmin	-0.047*	0.007	-0.029*	-0.027*
RF	0.866	1.467	-1.240	-1.903
RD	0.348	0.345	0.477	0.837*

* Statistically significant at 95% confidence level as per the Mann–Kendall trend test (+ for increasing and " for decreasing)

predict the future values based on past values and past errors. ARIMA has two forms, one is non seasonal ARIMA (ARIMA (p,d,q)) and seasonal ARIMA (ARIMA (p,d,q) (P,D,Q)). Here p,q and P,Q are non seasonal and seasonal auto regressive and moving average parameters, respectively. Parameters d and D are non seasonal and seasonal differencing parameters, respectively; these are used for checking and satisfying data stationary assumption. Time Series Forecasting System (TSFS) of SAS Ver. 9.3 Software was used for building the ARIMA models in this study. Thorough checking was done to satisfy the assumptions related to stationarity, autocorrelations and partial autocorrelations. Model having lowest Root Mean Square Error and Highest R^2 was selected as the forecasting model for selected weather parameters.

ARIMA Model built in this study was reassessed for its validity by using Willmott's index of agreement (Willmott, 1982) which was computed by using the following expression.

$$d = 1 - \left[\sum_i | P_i - O_i |^2 \right] \left[\sum_i (| Pi - \overline{O} | + | Oi - \overline{O} |)^2 \right]^{-1}$$

Willmott index (d) is considered as more accurate measure than the conventional performance measure (Chattopadhyay and Chattopadhyay, 2008). Values close to 1 indicate that the model predictions are good.

RESULTS AND DISCUSSION

Forty years data on surface weather parameters of Nagapattinam from 1961 - 2000 were first subjected to descriptive statistical analysis (Table 1 for temperature variables and Table 2 for rainfall variables). Summer (March to June), rainy (July to November), winter (December to February) and yearly averages of temperatures and totals for rainfall parameters are also included in the tables. Average maximum temperatures and mean temperatures were high in the month of June even though the peak temperatures were recorded in the month of May (Table 1). Lowest and average minimum temperatures were recorded in the month of January. Annual rainfall of the region ranged from 640 mm to 2524.9 mm. The study area receives maximum rainfall from north-east monsoon and the average monthly maximum rainfall was recorded in the month of November (381.9 mm). Even though number of rainy days in the rainy season ranges from 49-127 days the amount of rainfall received was less in the region.

Trends in weather parameters were evaluated through Mann-Kendall trend test. Statistical significance of the trends was decided by Mann-Kendall 'Z' statistic and magnitude of the trend was assessed by computing Sen's slope estimator. Monthly Sen's slope estimators and

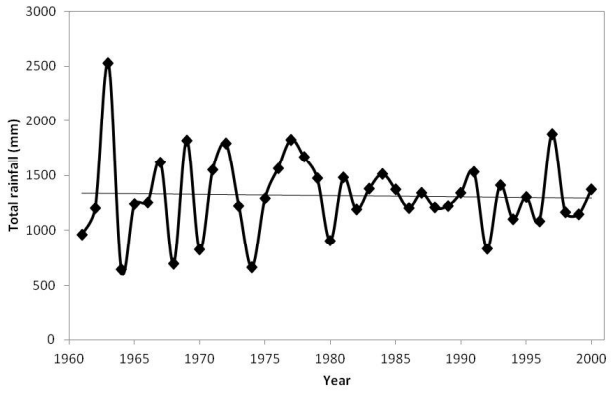

Fig. 1 : Trends in weather parameters of Nagapattinam district

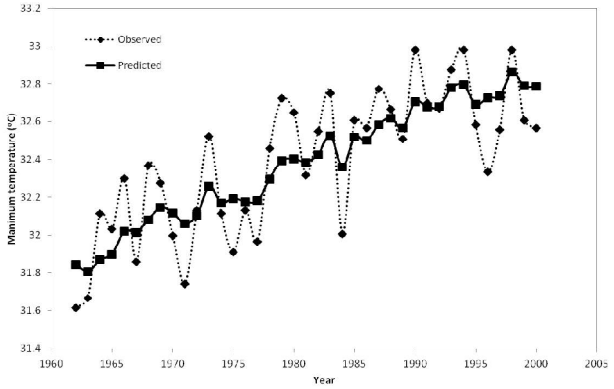

Fig. 2 : Average annual maximum temperature forecast for Nagapattinam district using ARIMA models.

seasonal and annual estimates are given in Tables 3 and 4, respectively. Positive trends in maximum temperatures were observed for seven months, all three seasons and annual values. Minimum temperatures during March and April have shown negative trend over the years. Highest maximum temperatures for the months January, March, April, August, September and December showed positive trend, whereas the lowest minimum temperatures showed significant negative trends for the months January to April. No trends were observed for rainfall of the region even though there was a significant positive trend for the number of the rainy days for the months of January and November. Annual trends are depicted for significant weather parameters along with rainfall in Fig. 1.

ARIMA model was fitted for forecasting the maximum temperatures of the study area as it is the only variable that showed significant trends both seasonally and annually. Seasonal Autoregressive and moving average model of lag 12 (ARIMA $(2,0,1)(1,1,1)_{12}$) was found to be suitable model with R^2 value of 0.94 and Root mean square error of 0.73. Model predictions are shown in Fig.2. These predictions were reassessed with Willmott's index of agreement. The calculated Willmotts index value (0.95) of the model confirmed the model's accuracy in predicting the maximum temperatures of the study area.

Thus, from the analysis it was possible not only to identify the positive trend in maximum temperature, but also to forecast the same for the study area. Further, the increase in maximum temperature coinciding with decrease in the freshwater flow from the upsteram reduces the quality of source waters for shrimp aquaculture, which may reduce the production. Quantification of this component will greatly help in long term planning for shrimp farming and management.

CONCLUSIONS

The present work aimed at analysing trends in surface weather parameters of Nagapattinam District of Tamil Nadu and developing time series forecasting models for the weather parameters that exhibit significant trends. Monthly, seasonal and annual trends were evaluated using Mann-Kendall trend test. Among the seven weather parameters analysed, except total rainfall, all parameters exhibited significant trends in one or more cases, namely, months or seasons. Maximum temperature of the study area has shown significant positive trends for all the seasons and most of the months. Availability of quality source water for shrimp farming in the area may get affected as there is increase in maximum temperatures coupled with no trend in the precipitation over the years.

ACKNOWLEDGEMENTS

Authors are thankful to Director, Central Institute of Brackishwater Aquaculture, Chennai for providing necessary facilities for conducting research, and the Indian Council of Agricultural Research (ICAR), New Delhi for financial support under the project National Initiative on Climate Resilient Agriculture (NICRA).

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