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Analysis Of Rainfall And Its Future Trend In Relation To Climatic Change For Krishna District

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Abstract:Climatic change is always one of the most important topics in the world and it has significant impacts on ecological and hydrological processes. Understanding of rainfall variability helps in proper planning of agriculture and decision management. In this present study, seasonal forecasting models namely Box Jenkins and Winters additive models were used for the period of 1988 to 2012 in Krishna district and finally, regarding the comparison of error between models, Seasonal ARIMA approach was chosen as the most appropriate method for forecasting and then the monthly rainfall forecast from 2013-2015 years have been investigated by selected ARIMA (1,0,0)(1,1,2)s.

Keywords:ARIMA, Rainfall, Winters additive and correlation

I.INTRODUCTION

Forecasting of climate processes makes available appropriate tools for managers in various fields, mainly to optimize costs and maximize productivity features. Rainfall forecast is very important for agriculture, because Rain-fed agriculture plays a major role in India's food security and sustainable economic growth. India ranks first among the countries that practice rain-fed agriculture both in terms of extent and value of production. Out of an estimated 140.3 m ha net cultivated area, 79.44 m ha (57%) is rainfed, contributing 44% of the total foodgrain production. It is estimated that even after achieving the full irrigation potential; nearly 50% of the net cultivated area will remain dependent on rainfall. Rain-fed agriculture supports nearly 40% of India's estimated population of 1210 million in 2011. Cultivation of coarse cereals (91%), pulses (91%), oilseeds (80%) and cotton (65%) predominates in these rain-fed regions there are large opportunities for gains from adaptation and new investments in water management for meeting the targets under the proposed National Food Security Act (Sharma, 2011).

Krishna District is one of the agriculturally productive coastal districts of Andhra Pradesh. It is located on the east coast of India between 15 ° 43'N. latitude and 17° 10'N. Latitude and between 80° E. longitude and 81° 33'E. Longitude, covering an area of about 8,727 Sq.Km. The only major river in the district is Krishna. Average Normal Rainfall of the district is 1034 mm and 67 % (686 mm) of this is received through South – West monsoon, 24 % (250 mm) is contributed by North - East monsoon, while remaining 9 % (98 mm) is shared by winter and summer showers. The district occupies an important place in Agriculture, which is the most important occupation and Paddy is the main food crop produced. Apart from Paddy, Jowar, Cotton, Turmeric, Maize, Arhar, Chillies, Sugarcane & Sesame,..etc are grown in this district. Most of the crop yields are much depend on the rainfall. The main aim of this study is to investigate changes in the time of Rainfall pattern of Krishna district by using time series models and forecasting for future water management.

Nail and Momani (2009) applied Box-Jenkins methodology for forecasting of Rainfall in Jordan, with respect to time period of 1922-1999. He reported as ARIMA (1,0,0)(0,1,1)12 was the best model for forecasting to upcoming years on the basis of AIC and SBC criteria. Abdul et al. (2013) examined rainfall pattern over period of 1974 to 2010 in Ashanti region of Ghana by Seasonal ARIMA (0,0,0)(2,1,0)12. He concluded that the rainfall pattern was significantly changing over time and there was slight decrease in rainfall from August to December. Firozi et al. (2013) studied on precipitation in Shiraz station for the period 1977 to 2010 to investigate changes for studying drought and wet years for water management by using time models i.e., Box Jenkins, Decomposition and Holt Winters models. Based on errors, forecasting was made by SARIMA (1,0,1)(0,1,1)12 & SARIMA (0,0,1)(0,1,1)4 for monthly, annual precipitation for this station respectively. It was found that Shiraz pre-province have been in drought period 20 years out of 33 years with 51% weak drought and 9% severe drought and these droughts have been occurred especially in recent years.

MATERIALS AND METHODS

Monthly Rainfall data of Krishna district for a period of 25 years from 1988-2012 and annual rainfall, temperature (maximum and minimum) and Relative humidity (08:30

&17:30 hrs IST) have been collected from Hand Book of Statistics and IMD website. Before analysis, as the study is dealing with time series data, so present series has been verified for existence of outlier in the data set.

Test for Outlier: Several tests are available to test the outliers, Grubbs test is one, which can be used for large sample. Grubbs test is particularly easy to follow and is also called the ESD (Extreme Studentized Deviate) method. (Graph pad-2005) for outliers i.e., to detect the existence of any outlier or not; if found, have been replaced by the median of respective series (Sahu, 2010).

This test starts to quantify how far outlier is from the others. Z ratio is calculated as absolute value of the difference between the outlier and the mean divided by the SD. If Z is greater than 1.96, the value is far from others, this indicates outlier comes from a population.

$$Z - \frac{|x - \bar{x}|}{SD_X}$$

Here, SD_X is Standard deviation of x variable, $\bar{x}$ is mean of that variable and 'i' indicates no of observation, i.e., i=1,2,..

Winters method:

Actually, it is suggested for slow changing and seasonally fluctuated time series modelling and it can be used for short-term and medium term predictions. It is a triple exponential smoothing method because of this technique depends on three smoothing equations- one for level, one for trend and one for seasonality. In fact, there are two different Winters methods i.e., additive and multiplicative method. Winters additive method was used in this study. The basic equations for winters additive method are

Level: $l_t = \alpha\ (y_t - s_{t-m}) + (1-\alpha)(l_{t-1} + b_{t-1})$

Trend: $b_t = \beta\ (l_t - l_{t-1}) + (1-\beta)\ b_{t-1}$

Seasonal: $s_t = \gamma(y_t - l_{t-1} - b_{t-1}) + (1-\gamma)\ s_{t-m}$

Forecast: $y_t(h) = (l_t + b_t\ h) + s_{t-m+h}$

Where m is length of seasonality (number of months) ; yt is observed time series at time t ; α, β, γ- smoothing constants for level, trend and seasonal respectively, whose values lies in between zero and one. The values of these constants are determined based on least Mean Square Error (MSE).

Box-Jenkins Seasonal ARIMA Model:

The ARIMA model building strategy includes iterative identification, estimation, diagnosis and forecasting stages (Box and Jenkins, 1976). Identification of a model may be accomplished on the basis of the data pattern, time series plot and using their autocorrelation function and partial autocorrelation function. The parameters are estimated and tested for statistical significance after identifying the tentative model. If the parameter estimates does not meet the stationary condition then a new model should be identified. After finding the correct model it should be diagnosed (Nirmala and Sundaram, 2010). In the time series research, Selection of appropriate model is an art. There are not any hard and fast rules for selection of appropriate model in the time series studies. Different researchers mentioned different criteria for selection of model. Once the model is selected it is used to forecast the monthly rainfall series. Time series analysis provides great opportunities for detecting, describing and modeling climatic variability and impacts. This can be done by identifying the best time series model using Box – Jenkins Seasonal ARIMA modeling techniques. The Seasonal ARIMA (p,d,q)(P,D,Q)s model is defined as

$$(1-\O_p B)(1-\Phi_P B^s)(1-B)^d (1-B^s)^D (Y_t - \mu) = (1-\theta_q B)(1-\Theta_Q B^s)\ \varepsilon_t$$

Where, B represents back shift operator; εt denotes the error term; Ø's and Φ's are the non seasonal and seasonal autoregressive parameters; θ's and Θ's are the non seasonal and seasonal moving average parameters; 'p' and 'P' are the order of nonseasonal and seasonal auto regression; 'q' and 'Q' are order of nonseasonal and seasonal moving average respectively.

Seasonal differencing: is defined as a difference between a value and a value with lag that is multiple of S, with S=12 (suppose), which may occur with monthly data, a seasonal difference (1-B) Yt = Y -Yt-12.

Nonseasonal differencing: If trend is present in the data, we may also need non seasonal differencing. Often a first nonseasonal difference will detrend the data using (1-B) Yt = Yt -Yt-1 in the presence of trend.

In this present study, Augmented Dickey Fuller test has been used to find unit root in the time series data of variable under consideration. Here, model with minimum values of Akaike information criterion (AIC) and Schwarz's Bayesian Information Criterion (SBC) and with high R-squared values are considered as an appropriate model for forecasting.

RESULTS AND DISCUSSION

Firstly, Monthly Rainfall data of Krishna district in Andhra Pradesh from 1988-2012 was tested for outliers by Grubbs method. From this, it was concluded that the number of outliers in the present data were zero, as presented in Table 1. Before going to forecast by seasonal ARIMA, Winters additive method was applied to monthly Rainfall of Krishna district. Various combinations of 'α', 'β', and 'γ' were tried. Finally based on minimum value of Mean Square Error (MSE), these values were fixed as. 'α=0.02352', 'β=0.001', and 'γ=0.001'. This model fit statistics were shown in Table 2 and forecasting plot was also showed in Fig 1. After the evaluation of trend of Rainfall by Winters triple exponential model i.e., Additive type, forecast by Box –Jenkins methodology was also done.

To test the Stationarity in the monthly data of

Rainfall, Time series plots and Augmented Dickey Fuller (ADF) test was used. Time series plots, clearly indicated as data was non stationary as shown in Fig 2. Time series plot was also showed the data was non stationary; therefore ADF test for unit root was conducted. From this test, data became stationary at 1st seasonal difference (Osabuohein, 2013) as the calculated values were lesser than critical values at 1%, 5% and 10% as shown in Table 3. Time series plot at 1st seasonal difference also cleared as the data has not contained problem of non-stationary, as shown in Fig 3. After fixing the D=1, different tentative models were tried and finally ARIMA (1,0,0)(1,1,2)s was selected as the best model based on least AIC and SBC criterion, as shown in Table 4. Then parameters were estimated to the selected ARIMA (1,0,0)(1,1,2)s model, Which were mentioned at Table 5, from this all parameters of selected model were significant, it indicates as a good fit of selected model. From the residual ACF and PACF plots as shown in Fig 4, it was also cleared that most of autocorrelations and partial autocorrelations lie between 95% control limits and there was no particular pattern observed in case of residual errors (Naill and Momani, 2009). This also indicates the 'good fit' of this selected model. Among all seasonal ARIMA and Winters additive method, ARIMA (1,0,0)(1,1,2)s model was found as best model for forecasting (Hinis, 2011) for monthly rainfall of Krishna district, based on selected criterion i.e., minimum values of AIC and SBC. Finally, forecasting was done to Monthly Rainfall data of Krishna district in Andhra Pradesh by using ARIMA (1,0,0)(1,1,2)s up to 2015. These predicted values (as in mm) were presented in Table-6. It indicated that predicted values were within control limits. Actual & predicted plot was also showed in Fig 5.

Finally, in this present study correlations were calculated between Rainfall and weather parameters like Maximum temperature (Max Temp), Minimum temperature (Min Temp), Relative humidity for 08:30 hrs IST(RH - 08:30) & Relative humidity for 17:30 hrs IST(RH -17:30) of Krishna district, just to check how these variables influences rainfall. From Table-7, it was concluded as rainfall was negatively correlated with both Maximum & Minimum temperature and positively correlated with Relative humidity for 08:30 &17:30 hrs IST at (at the a=0.01 significance level). Hence, it was concluded that the rainfall was influenced by certain other weather parameters.

CONCLUSION

Rainfall is natural climatic phenomena whose prediction is challenging and demanding. Present study made an attempt to forecast monthly rainfall of Krishna district in Andhra Pradesh for few coming years. Here, winters additive model and Box Jenkins methodology of seasonal ARIMA models were used for forecasting. This study found ARIMA (1,0,0)(1,1,2)s as an appropriate econometric model among other ARIMA models and Winters model to forecast the monthly rainfall of Krishna district for next 3 years (2013-2015). It was identified that during July, August the district is getting maximum rainfall. From correlation study, weather parameters like temperature and relative humidity were significantly effecting the pattern of rainfall in Krishna district. The results of achieved rainfall forecasting will help to solve several environmental problems of integrated water resources management, with implications for agriculture, climatic change and natural hazards such as floods and droughts. Predicted excess rain can be stored in reservoirs for future plan of this particular region.

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Table 1 - Grubbs test for Outliers

Mean:	89.38
SD:	103.228
No of observations:	300
Outlier detected?	No
Significance level:	0.05 (two-sided)
Critical value of Z:	3.724

Table 2 – Model fit Statistics for Winters method

Model	R-squared	SBC	AIC	MSE
Winters Additive	0.5303	2520.8	2509.7	4212.2

Fig 1. Forecasting of monthly Rainfall by Winters method

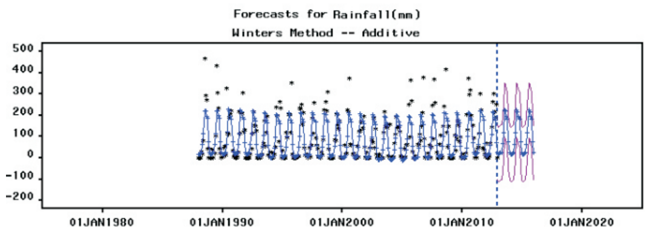

Fig 2. Time series plot for monthly Rainfall

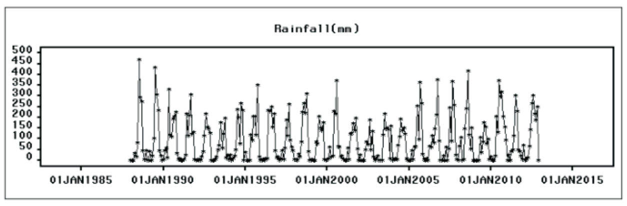

Fig 3. Time series plot for 1st differenced Rainfall

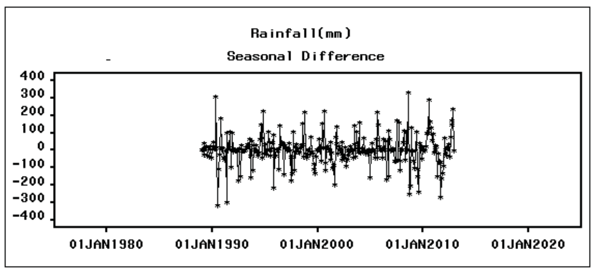

Table 3 - Augmented Dickey Fuller (ADF) test

Test	Decision	ADF statistic	Critical values at			Prob.
			1%	5%	10%	
ADF at level	Data Non-Stationary	-0.5666	-2.573	-1.9419	-1.616	0.4712
ADF at 1st seasonal difference (D=1)	Data became Stationary	-7.78676	-2.57343	-1.94199	-1.61593	0.0001

Table 4 - Tentative Seasonal ARIMA models

ARIMA Model	R-squared	SBC	AIC
(0,0,0) (1,1,0)	0.418	2512.4	2505.1
(0,0,0) (1,1,2)	0.489	2496.2	2471.6
(1,0,0) (1,1,0)	0.423	2517.1	2506.1
(1,0,0) (1,1,2)	**0.529**	**2487.5**	**2469.1**
(1,0,1) (1,1,0)	0.426	2519.5	2504.9
(0,0,1) (2,1,0)	0.447	2508.8	2494.1
(0,0,1) (1,1,2)	0.492	2496	2474
(2,0,0) (2,1,0)	0.448	2514.4	2496
(1,0,2) (1,1,0)	0.421	2528.1	2509.8
(0,0,2) (1,1,2)	0.493	2501.2	2475.6

Table 5 - ARIMA (1,0,0) (1,1,2)s Model Parameters estimation

Model Parameter	Estimate	Std. Error	T	Sig.
Intercept	0.36103	1.2649	0.2854	0.7755
Seasonal MA, Lag 12	-0.24688	0.0495	-4.9829	<.0001
Seasonal MA, Lag 24	0.74959	0.0571	13.1224	<.0001
AR, Lag 1	0.09091	0.0577	1.5765	0.0116
Seasonal AR, Lag 12	-0.99995	0.0015	-656.67	<.0001

Fig 4. Residual ACF and PACF

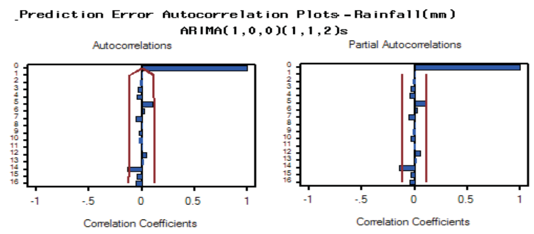

Fig 5. Forecasting of monthlyRainfall by ARIMA (1,0,0)(1,1,2)s

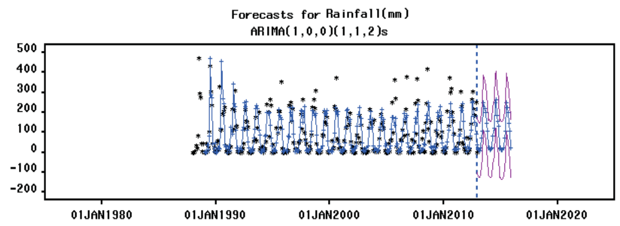

Table 6 – Forecasting Values of monthly Rainfall (mm) with control limits

	2013	2014	2015
Jan	18.9441	22.5503	21.2142
Feb	11.0365	14.9255	11.8994
Mar	9.9716	15.1245	10.7067
Apr	23.7098	22.0851	24.4329
May	69.2812	80.2358	70.0039
Jun	106.5075	120.045	107.23
Jul	249.1135	250.175	249.836
Aug	221.2787	264.219	222.003
Sep	200.6461	185.343	201.367
Oct	146.3962	156.123	147.119
Nov	106.227	130.389	106.95
Dec	20.5097	17.7499	21.2315

Table 7 – Correlation between Rainfall and Weather parameters

	Rainfall
Max Temp	-0.2061
Min Temp	-0.0906
RH -08:30	0.5382
RH-17:30	0.4253