Original Research Article

Prediction of rainfall pattern using Holt winters method in Bungoma County, Western Kenya

Abstract

Rainfall is termed as a meteorological phenomenon which is very useful for daily human activities. Most of the population depend on it for domestic purpose and agriculture, hence it is vital for farmers to know rainfall trends and patterns prevailing in their locality. The main objective of the study was to model rainfall patterns in Bungoma region. Specific objectives were to determine the current rainfall patterns in Bungoma region and to predict the future rainfall patterns in Bungoma region. Holt winters model was used to model the behavior of the rainfall patterns. Data for Monthly and yearly rainfall patterns for the period 1977-2010 was obtained from the Kenya meteorological department. Findings of the study will make it possible to facilitate planning and management of water for both domestic and agricultural use in Bungoma region. Monthly rainfall patterns were forecasted for five years. Rainfall data was found to be seasonal implying that most of the rainfall occurred in a specific period each year. Forecasted rainfall had increasing and decreasing prediction intervals and this implied that rainfall could either start decreasing or increasing. The data was found to be non-stationary due to presence of seasonality and rainfall trends. There were heavy rains in the months of March, April and May. Short rains were also observed in the months of October, November and December.

1.0 Introduction

There is a great challenge in the agricultural sector due to recently noted extremities in rainfall variability and this heavily impacts East African Counties where irrigation schemes are not developed making agriculture to be entirely rain-fed (Eriksen S, Lind J. 2009). In Eastern Africa the mean annual rainfall is more likely to occur and this is contrast to and northern Sahara and Mediterranean since they are likely to experience decrease in rainfall (Chen H, Githeko GF, Zhou JI, Githure, Yan. 2006). Even though the mean annual rainfall in East Africa is expected to increase, the increase might not be uniform across time and space (Recha C, Makokha WG, Traore PS, Shisanya C, Lodoun T, Sako. 2012).

These changes however are uncertain due to under estimation of the warming impacts of Indian Ocean in many general climate models making it possible to overestimate rainfall increase in the region (Eriksen S, Lind J. 2009). Some records shows that there is an upward trend in Kenyan rainfall however there are a range of models and scenarios which suggest both an increase and decrease in rainfall (Chen H, Githeko GF, Zhou JI, Githure, Yan. 2006, Helsel DR, Hirsch RM. 2002).

Many studies have proved that the total rainfall projection in Kenya increases from 0.2-0.4% each year until the 2090s 2090s (Helsel DR, Hirsch RM. 2002, Moazzam MFU, Lee BG, Rahman G, Waqas T. 2020). There is an increase in heavy rainfall and there is likely to be more frequent extreme events and this results to greater rainfall variability (Macenzie F. Zamani. 1974, Hamed KH, Rao AR. 1998). Correct forecasting of future rainfall will not only play a major role in the management of water resources but also assist in boosting agriculture since farmers will plant most crops during rainy seasons, Oyamakin (2010).

2.0 Research Methodology

2.1 Data source

Bungoma county monthly and yearly rainfall data was obtained from Kenya meteorological department for the period 1977-2010 which was used in the study.

2.2 Method of analysis

Collected data was analyzed using R software. The analyzed data is presented in graphical forms where features such as rainfall trends and seasonality component are observed. In this study Holt-Winters forecasting method was used to predict the future rainfall trends in Bungoma region. Holt-Winters' multiplicative method was the preferred model because the data had seasonality component, and this implied that there are changes in the widths of the seasonal periods over time. The basic equations of overall smoothing, Trend smoothing and Seasonal smoothing are as follows,

Overall smoothing: $L_t = \alpha X_t / s_{t-m} + (1-\alpha)(m_{t-1} + b_{t-1})$

Trend smoothing: $b_t = \beta(m_t - m_{t-1}) + (1-\beta) b_{t-1}$

Seasonal smoothing: $S_t = \gamma Xt / (m_t + b_{t-1}) + (1 - \gamma) S_{t-m}$

Forecast: $\hat{Y}_{t+1} = (m_t + b_t h) S_{t-m} + h^{+}_{m}$

These three parameter smoothing provides a good framework in order to forecast a time series data which contains level, trend and seasonality.

3.0 Results and Discussion

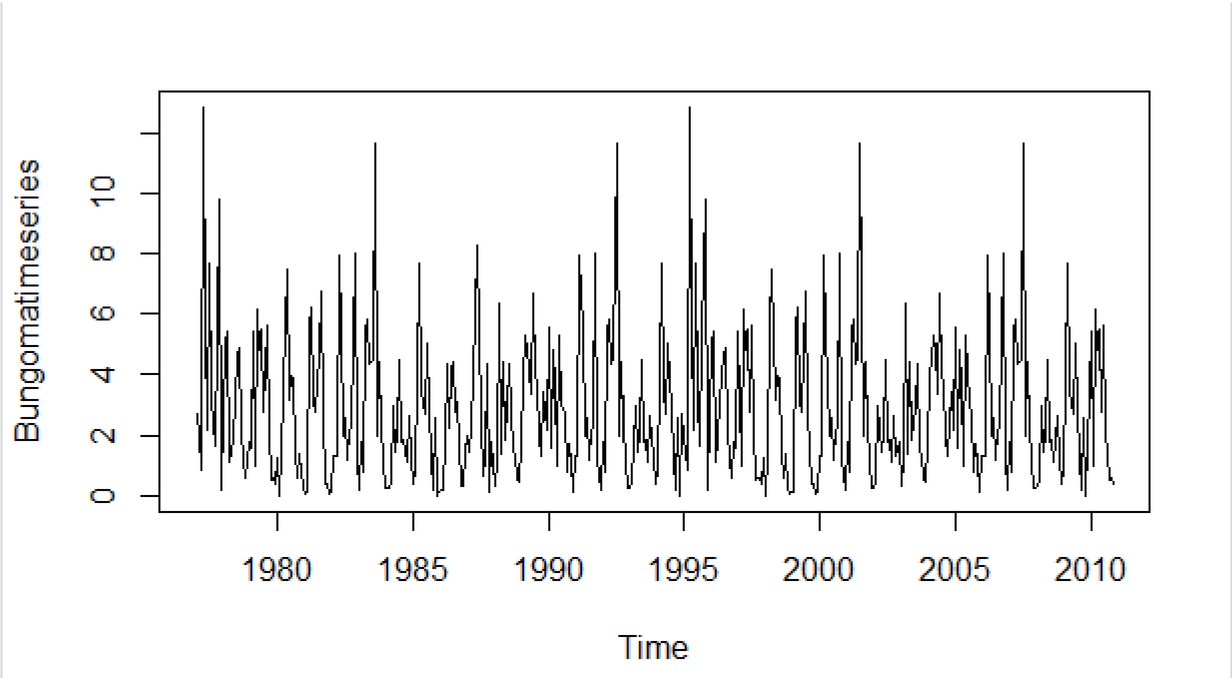

Figure 1: Plot of average monthly rainfall of Bungoma region from 1977-2010.

Figure1 displays average monthly rainfall data of Bungoma region from 1977-2010. Seasonality component can be observed from the graph. This is because there is an irregular distribution of rainfall patterns during the years. Most of the rainfall occurs in specific period in each year. In this plot there is no specific trend of the rainfall pattern in Bungoma County. In order to have a clearer vision of this, the rainfall data was decomposed so that features such as trends and seasonality can be observed. The smoothing parameters that were observed are;

Table 1: Smoothing Parameters

Smoothing Parameters	
Alpha	0.07712996
Betta	0.3836055
Gamma	0.2416752

An alpha (level smoothing factor) level of 0.07712996 was observed, this indicates that much weight is given to the latest values when being included in the current level estimate. Beta (trend) level of 0.3836055 was observed, this indicates that much weight is given to the older values. Gamma (seasonal smoothing) level of 0.2416752 was observed. Gamma specifies how smooth the seasonal component of the time series is. From this gamma value it's evident that older values weighted more heavily.

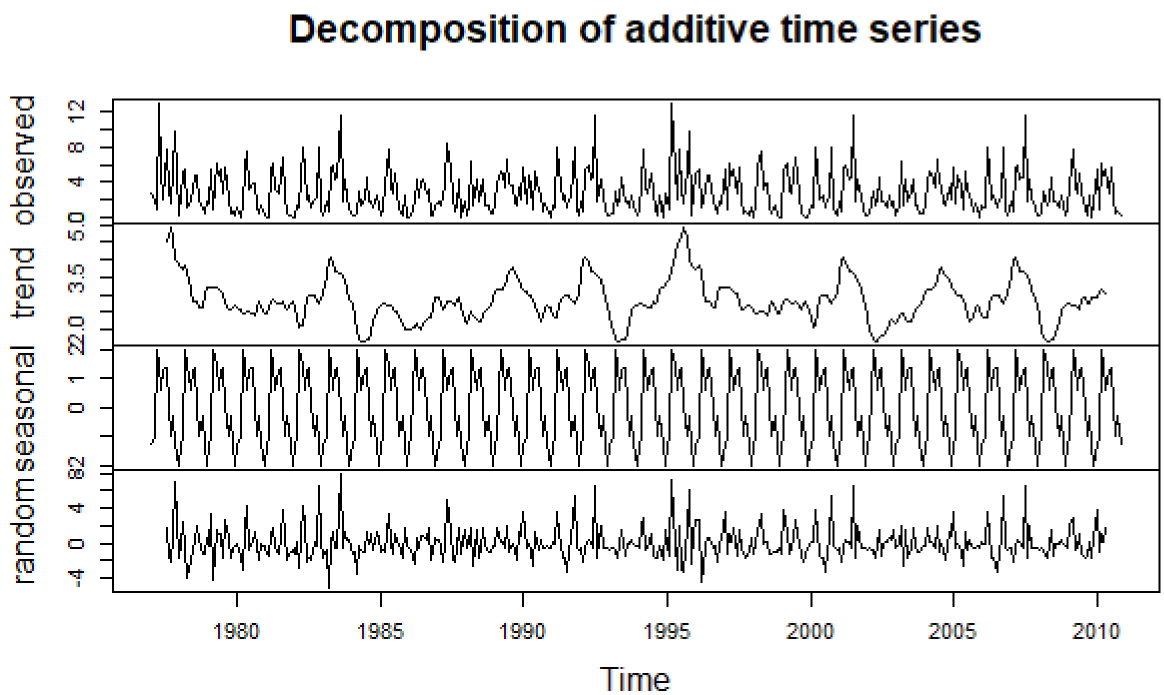

Figure 2: Plot of Rainfall decomposition

Figure 2 displays the decomposed rainfall series data into more detail based on the observed series, trend of the rainfall pattern, seasonality and randomness. This decomposition result will give more precise insight into rainfall behavior during 1977–2010 periods. The first plot shows the observed rainfall trends for the period 1977-2010 in Bungoma County. Under seasonal plot it's observed that there's seasonal fluctuation. This is due to the upward and downward trend. Under the trend, it's observed that there is no specific trend for the rainfall patterns in the period 1977-2010. The last plot shows the randomness of the rainfall patterns.

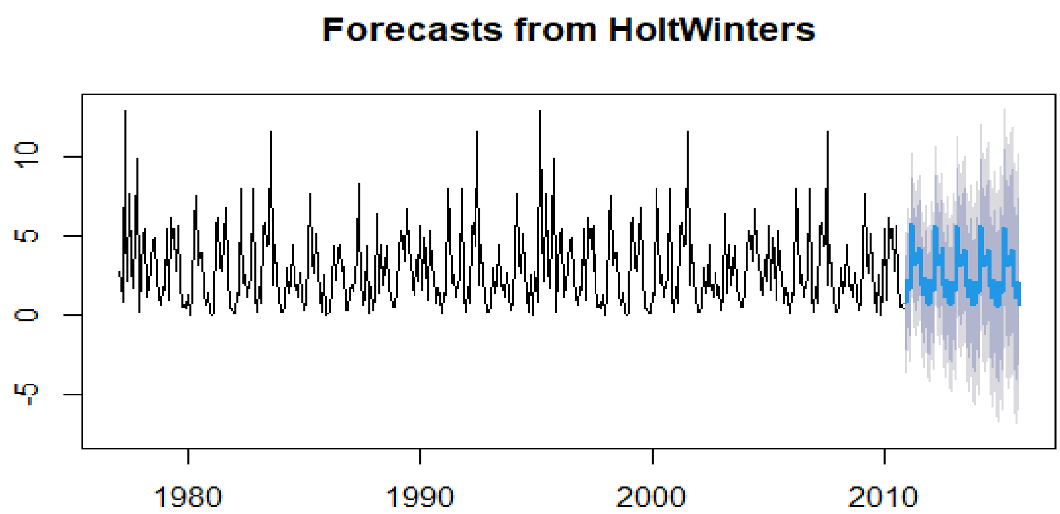

Figure 3: Forecasted rainfall patterns

Figure 3 showed the series followed by the forecast as the blue line and the upper and lower predictions limit as grey lines. Holt-winters was used to model and predict the behavior of Bungoma rainfall patterns this is because it is one the most popular forecasting techniques for time series. The rainfall patterns from 1977 to 2010 was forecasted for the next 5 years up to 2015. The increasing and decreasing prediction intervals showed that rainfall could either start decreasing or increasing. This prediction can be useful for a farmer who wants to know which the best month to start planting and also for the government who need to prepare any policy for preventing flood on rainy season & drought on dry season. The forecasted rainfall patterns is displayed by the blue line.

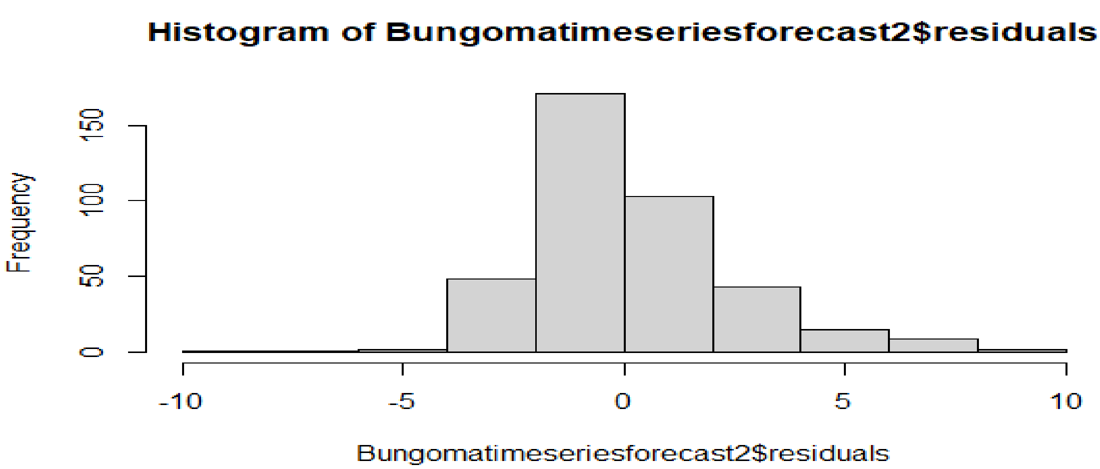

Figure 4: Histogram for Bungoma time series forecast

A histogram was used to show the frequency distributions of the forecasted rainfall patterns in Bungoma. Creating a histogram is important because it provides a visual representation of data distribution. The forecasted rainfall patterns is a right-skewed distribution because a large number of data values occur on the left side with a fewer number of data values on the right side.

4.0 Summary, Conclusion and Recommendation

Rainfall pattern in Bungoma region significantly change over time. There were periods of low variability and others of extreme variability. Bungoma region had long rains in March, April and May and short rains in October, November and December. Rainfall data was found to be non-stationary due to presence of rainfall trends and seasonality. Forecasted rainfall had increasing and decreasing prediction intervals and this implies that rainfall could either start decreasing or increasing. From this study, it can be concluded that, rainfall patterns for Bungoma region would change over time.

REFFERENCES

1) Booranawong T, Booranawong A. 2017. Simple and double exponential smoothing methods with designed input data for forecasting a seasonal time series: in an application for lime prices in Thailand. Suranaree Journal of Science & Technology 24(3).
2) Chen H, Githeko GF, Zhou JI, Githure, Yan. New records of *Anopheles arabiensis* breeding on the Mount Kenya highlands indicate indigenous malaria transmission. Malaria J. 2006;5:5-17.
3) Delleur, J. W., Tao, P. C., &Kavvas, M. L. (1976). An evaluation of the practicality and complexity of some rainfall and runoff time series models. *Water Resources Research*, *12*(5), 953-970.
4) Eriksen S, Lind J. Adaptation as a political process: Adjusting to drought and conflict in Kenya's drylands. Env Manag. 2009;43:817-835.
5) Gregory Nalianya, Jacob Wakhungu, Nicholas Omoyo Nyandiko, (2010). Impact of climatic change and variability on smallholder farmers in Bungoma Kenya.
6) Hamed KH, Rao AR. A modified Mann-Kendall trend test for autocorrelated data. J Hydro. 1998;204:182-196.
7) Helsel DR, Hirsch RM. Hydrological analysis and interpretation: statistical methods in water resources. US Geological Survey, Reston. 2002.
8) Javari,K.& Majida,F. (2016). Trend and Homogeneity Analysis of Precipitation in Iran. *Climate 2016*, 4(3); 44.
9) Matiur, R. M., Shohel, R., Sazzad, M. H. & Naruzzuman ,S.M. (2016). modelling monthly precipitation infaridpur region of bangladesh using ARIMA. *Journal of enviromental science,Toxicology and Food technology*, 22-29.
10) Moazzam MFU, Lee BG, Rahman G, Waqas T. Spatial rainfall variability and an increasing threat of drought according to climate change in Uttaradit Province, Thailand. Atmos Clim Sci. 2020;10:357- 371.

11) Muthama ,N.J. & Manene M. (2008). Simulation of Decadal Precipitation over Nairobi in Kenya. *SQU Journal For Science*, 43-54

12) Oyamakin, S. O, Ayoola,F.J. & Dare, O.T. (2010). Time series analysis of rainfall and temperature in South West Nigeria,Pacific. Journal of sciences and Technology, 552-564.

13) Spipan (2014). Time series analysis of rainfall using Holt winters in Nakhon Ratchasima province, Thailand. Journal of sciences and Technology.

14) Valipour, M., Banihabib, M. E., & Behbahani, S. M. R. (2012). Parameters estimate of autoregressive moving average and autoregressive integrated moving average models and compare their ability for inflow forecasting. J Math Stat, 8(3), 330-338.