Overcoming Economic Impact of Rainfall Variability in Mahailuppallama by Using Gamma Distribution

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Introduction

Climate change is a major factor that significantly affects the world economy with extreme changes in climatic variables such as precipitation, temperature, winds, relative humidity etc. Agriculture is an economic endeavor that depends on both climatic and weather situations on which its extremes direct to failure in agronomic activities switching deficit in the economy. Parallel circumstance exists in Sri Lanka, where the primary income source is agriculture.

With the high geographic and climatic variability in Sri Lanka, different kinds of crops are cultivated in different regions, harmonizing their unique characteristics of topography and climate. The mean annual rainfall in Sri Lanka varies from under 900mm to over 5000mm from the driest part to the wettest part. The 3 climatic zones that have been classified according to the mean annual rainfall are further divided into 46 Agro-ecological regions having different amount of rainfall.

Crops, cultivars and implementation of agronomic practices are planned as per the forecast climatic variables all over the country. In addition to that, irrigation planning is executed mainly considering rainfall where irrigated farming is performed. Thus, rainfall variability is crucial in agricultural activity, water management, food security and energy production. According to the annual reports of Central Bank of Sri Lanka from 2010 to 2019, paddy production in *yala* season of 2012, 2014, 2017, 2018 and 2019 has declined due to the drought conditions existing in those years whereas it has increased in 2010, 2011, 2013, 2015, 2016 and 2018 due to the favorable weather conditions and proper irrigation plannning. It generates fluctuations in the economy since mainly drought conditions prevail in the Dry Zone, where paddy production is concentrated in Sri Lanka. Therefore, realization of rainfall distribution is vital in order to accomplish proper policy planning, decision making and risk management.

Hence, location specific range and likelihood of rainfall is essential in achieving those strategies. Therefore, modeling of rainfall variability with probability distribution is a useful tool. The information regarding rainfall accumulation in time and space for an area and the foundation for fitting and testing distribution models is given by historical rainfall data (Husak et al., 2007). Along with that the gamma distribution has been recommended as the best fitted distribution in order to describe the annual, monthly or seasonal rainfall (Aksoy, 1999; Sen and Eljadid, 1999; Husak et al., 2007; Sivajothi and Karthikeyan, 2016).

Objectives

The primary objective of this study is to estimate the parameters of the gamma probability distribution and explain the monthly rainfall variability in the location.

Methodology

The daily rainfall data for the 40 years from 1980 to 2019 of Mahailuppallama (80.47^0N of longitude and 8.12^0E of latitude) was obtained where agricultural activities are carried out at research level, farmer level and industry level. The missing values were filled with parallel time point of the recent past. Monthly data were employed for the analysis. For the non-zero monthly rainfall data, probability distribution function of two parameter Gamma distribution (equation 1) was constructed. The complete gamma function is given by equation 2.

$$f(x) = \frac{(x/\beta)^{\alpha-1} e^{-x/\beta}}{\beta \Gamma(\alpha)} \qquad (1)$$

$$\Gamma(\alpha) = \int_0^{\infty} e^{-t} t^{\alpha-1} dt \qquad (2)$$

The two parameters are: shape parameters (α) which determine the skewness of the distribution and scale parameter (β) that determines the spread of the values. These two parameters are estimated through maximum likelihood estimation. For that the value of A (equation 3) is to be determined which is then used to calculate α (equation 4) followed by β (equation 5) (Thom, 1958).

$$A = \ln(\bar{x}) - \frac{\sum_{i=1}^{n_p} \ln(x_i)}{n_p} \qquad (3)$$

$$\hat{\alpha} = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \qquad (4)$$

$$\hat{\beta} = \frac{\bar{x}}{\hat{\alpha}} \qquad (5)$$

Where, x_i is non-zero values of the rainfall data and $\bar{x}$ is the arithmetic mean of the non-zero values.

The mean of the distribution is $\alpha\beta$ whereas $\alpha\beta^2$ is the variance that was used to explain the rainfall distribution. In order to test the goodness of fit of the fitted distribution, Kolmogorov-Smirnov (KS) test was performed comparing empirical cumulative probability and theoretical cumulative probability. The 'D' that is the KS test statistics and p values were recorded. 'D' is defined as the largest vertical difference between theoretical empirical cumulative distribution function (Sivajothi and Karthikeyan, 2016). The rejection level of 0.01 was used and the null hypothesis was theoretical distribution performs adequately in modeling the historical value for the given month at give location.

Results and Discussion

Gamma parameters and results of the KS test in particular for the months in Mahailuppallama are given in table 1. α values are less than one which means that the gamma distribution is strongly skewed to the right. And the distribution is highly squeezing as β values are larger. The mean rainfalls with standard deviations (SD) in separate stations are presented in the same table as the estimates of the rainfall of a particular month. Relatively dry periods have a higher shape parameter and a lower scale parameter.

Table 1: Gamma Distribution Parameters, Mean and SD of the Rainfall and Results of the KS Test for Mahailuppallama

Month	α	β	Mean	SD	D	p value
January	0.36	258.74	93.53	155.56	0.25	0.16
February	0.46	205.39	93.57	138.63	0.18	0.57
March	0.27	303.06	82.80	158.41	0.33	0.03
April	0.10	1729.63	172.71	546.56	0.68	0.00
May	0.32	359.34	115.83	204.02	0.28	0.10
June	0.44	40.21	17.85	26.79	0.13	0.91
July	0.68	42.50	28.91	35.05	0.23	0.26
August	0.88	46.07	40.49	43.19	0.35	0.01
September	0.31	316.55	98.43	176.52	0.28	0.10
October	0.07	3939.27	268.43	1028.30	0.75	0.00
November	0.04	5958.40	264.53	1255.45	0.83	0.00
December	0.12	1622.20	195.05	562.50	0.63	0.00

The values of D are relatively small, supporting not rejecting the null hypothesis. The p values are greater than 0.01 except for the months of April, October, November and December which also supports non-rejection of the null hypothesis.

Conclusions

According to the results, the empirical rainfall distribution is represented by the gamma distribution adequately for Mahailuppallama in most of the cases. Further, it implies that, when the deviation of rainfall is higher from the mean, it is difficult to project the future since such cases do not follow specific theories. The joint interpretation of monthly shape parameters and scale parameters conveys the distribution of values in the modeled rainfall data in a particular location for a qualitative assessment of the amount and stability of rainfall throughout the season. Likelihood of receiving rainfall amount obtained by the parameters will give the estimation of rainfall in a month at a location, thereby implementation of agronomic practices and water management can be strategically planned.

Since at present in Sri Lanka, this kind of theoretical distribution has not been taken into account for drawing climatological implications, the finding of the study will support forecasting scenarios with policy implication and decision making in order to avoid crop loss affected by farmers and diminish the overall economic loss occuring due to the forthcoming rainfall. Hence, modeling rainfall is of paramount importance since rainfall variability has been identified as a major cause of fluctuations in crop production in the Dry Zone.

References

Aksoy, H. (2000). Use of gamma distribution in hydrological analysis. *Turkish Journal of Engineering and Environmental Sciences*, *24*(6), 419-428.

Husak, G. J., Michaelsen, J. and Funk, C. (2007). Use of the gamma distribution to represent monthly rainfall in Africa for drought monitoring applications. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *27*(7), 935-944.

ŞEN, Z. and Eljadid, A. G. (1999). Rainfall distribution function for Libya and rainfall prediction. *Hydrological Sciences Journal*, *44*(5), 665-680.

Sivajothi, R. and Karthikeyan, K. (2016). Analysis of monthly rainfall data prediction for change of economic environment in Pampadumpara using Gamma distribution. *Research Journal of Pharmacy and Technology*, *9*(9), 1477-1482.

Thom, H. C. (1958). A note on the gamma distribution. *Monthly Weather Review*, *86*(4), 117-122.