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ANALYSIS OF RAINFALL TREND USING MANN– KENDALL TEST AND THE SEN'S SLOPE ESTIMATOR: A CASE STUDY IN MATALE DISTRICT IN SRI LANKA

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ABSTRACT

Analysis of precipitation trends is important in studying the impacts of climate change for water resources planning and management. The present study entitled analysis of changes in precipitation trends in four administrative divisions in the Matale District Sri Lanka by examining the trends in monthly, annual and seasonal total rainfall of The daily rainfall data for the period of 33 years (1981-2013) from the records of the three rain gauging stations were analyzed using Modified Mann-Kendall Test (MKT) together with the Sen's Slope Estimator for determination of trend and slope magnitude of monthly, seasonal and annual rainfalls. The results indicated that there is an increasing trends for seasonal rainfall of 14.1 mm/year at Nalanda station and 6.4 mm/year at Dewahuwa station, while a decreasing trend of 2.3 mm/year at Dewahuwa and o 4.3 mm/year at Nalanda station. The highest annual trend of 21.3 mm/year was noted in the Nalanda station while lowest; 9.7 mm/year in the Pelwehera station. Observed trends indicate that increased annual rainfall could be expected in the Matale District in the future.

Keywords: Rainfall Trend, Mann-Kendall Test, Sen's Slope Estimator, Sri Lanka

1. INTRODUCTION

The dry zone of Sri Lanka consists of nearly 63% (501,000 ha) of the paddy lands of the country and about 65% (878,000 ha) of the other croplands. Of the paddy lands, about 89% is irrigated whereas the croplands are mainly rain fed (Nayakakorale, 1998). Rainfall in the dry zone is confined to two seasons namely Yala (March to August) and Maha (September to

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February).Annual rainfall of the dry zone is less than 1500mm. Therefore, acute water shortage during the dry period from June to September has been the major constraint for agricultural development in this region. In this context, the groundwater evolved as a supplementary source of water for agriculture in the dry zone of Sri Lanka.

Use of groundwater for agriculture in Sri Lanka has been confined traditionally to the northern and eastern provinces which lack in perennial surface water resources. Systematic exploitation of shallow and deep aquifers of the north started in early 1960s. Since 1970s, farmers in the central dry zone also have started to use groundwater of hard rock aquifers for cultivation through shallow large-diameter dug-wells (S. Pathmarajah, 2007). Agro-wells, defined as wells used at least partially for agriculture, are typically shallow and are of three types as lined dug-wells, unlined dug-wells, and tube-wells. The National Agro-well Program launched in 1989 by the Agricultural Development Authority (ADA) has promoted the use of agro-wells through a subsidy scheme. Since then, agro-wells gained popularity as the farmer has high flexibility in the selection of crop and time of cultivation. Also, the farmer has full control over the irrigation, which allows him to irrigate on demand basis. Consequently, various governmental and non-governmental agencies have started to promote the use of agro-wells through subsidy schemes. Since then, the development of agro-wells has been taking place in an ad hoc manner without a proper assessment of the hydrogeological properties including safe yield and recharge potential of a particular area. It is now known that the groundwater potential in this region is limited due to shallow depths, low groundwater storage capacity and low transmissivity of the underlying crystalline basement hard rock aquifer. The major challenge today is therefore, to formulate and implement a rational methodology for managing the available water resources in the areas. In this context expecting amount of rainfall for the crop period is very important factor in water management. Therefore, determination and identification of trends of precipitation is a key element for this process.

2. MATERIALS AND METHODS

Study Area

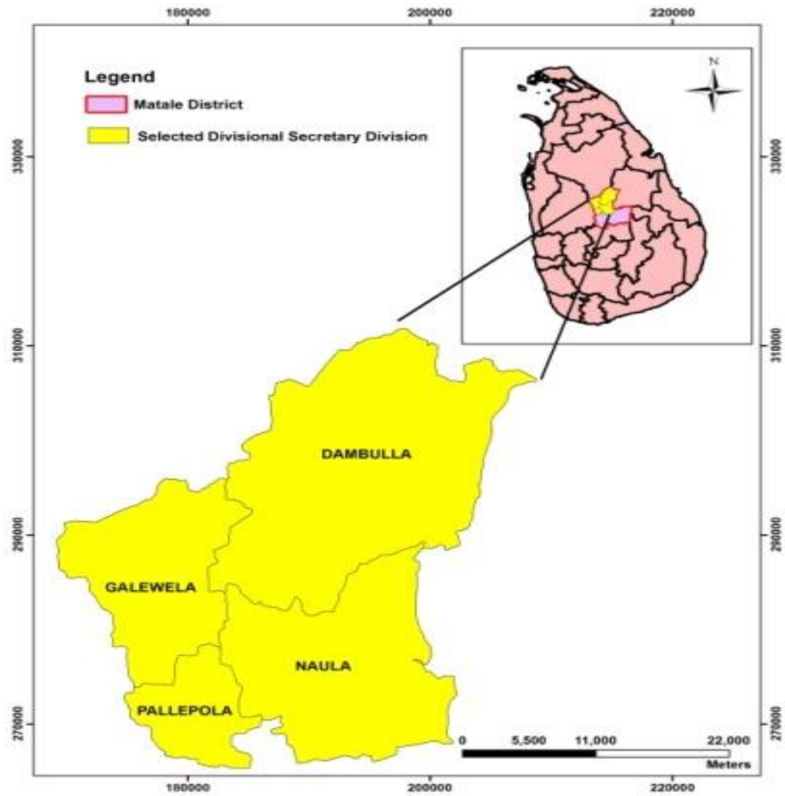

Figure 1: Study area of Matale District

Matale District belongs to the central part of Sri Lanka and is divided in to eleven administrative divisional secretary divisions Four divisions Dambulla, Galewela, Pallepola and Naula with heavy agricultural practices were selected for the present study as shown in Figure 01. The area falls under intermediate climatic zone of the country. Average temperature is 24-26°c and annual rainfall is between 1750 and 2500 mm. There are four rainy seasons bringing precipitation to the study area. The four seasons are, First Inter-Monsoon (March-April), Second Inter-Monsoon (October – November), South West monsoon (May –September) and North East monsoon (December – February) seasons. The area's economy mostly depends on agriculture, therefore, it is very important to analyze the rainfall trend in the area.

Data Collection and Analysis

The daily rainfall data for the period of 33 years (1981-2013) have been collected from Meteorological Department, Colombo and from the Natural Resources Management Center, Department of agriculture, Peradeniya. These data were tabulated as to calculate the monthly, seasonal and annual rainfall for the respective rain gauging stations. The rainfall variation of the

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study area is calculated for collected rainfall data from the records of three rain gauging stations at Pelwehera, Dewahuwa and Nalanda (Figure 02). Descriptive statistics such as mean, median, mode, frequency, standard deviation (SD), kurtosis and skewness, have been computed for estimating the spatial and temporal changes in rainfall and used in data analysis for obtaining a contented tabular & graphical presentation.

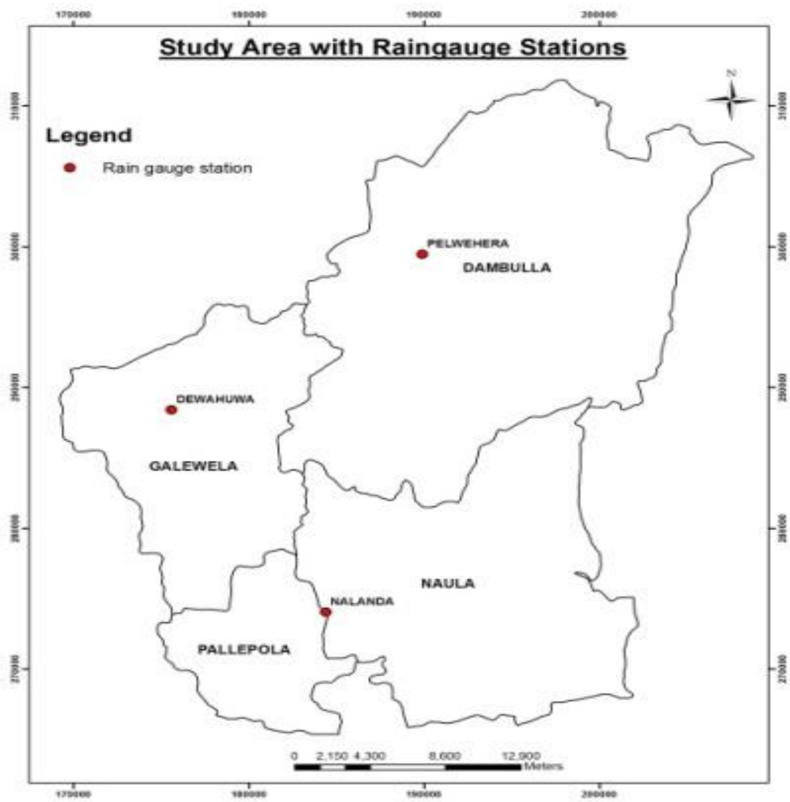

Figure 2: Locations of rain gauging stations in the study area

Trend Analysis

Mann (1945) has first proposed a nonparametric trend test. It was then further studied by Kendall (1975) and improved by Hirsch *et al* (1982, 1984) who allowed taking into account a seasonality. Mann-Kendall test (MK) is widely used to evaluate trends in agro-meteorological and hydrological time series. The purpose of the MK test is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. A monotonic upward or downward trend means that the variable consistently increases or decreases through time, but trend may or may not be linear. The MK test can be used in place of a parametric linear regression analysis, which can be used to test if the slope of the estimated linear regression line is different from zero. The regression analysis requires that the residuals from the fitted regression line be normally distributed; an assumption not required by the MK test, that is, the MK test is a non-parametric (distribution-free) test.

The S statistic was used for the test and its variance is given by

$$S = \sum_{i=1}^{n=1} \sum_{j=i+1}^{n} sgn(\mathrm{xj} - \mathrm{xi}) \qquad [1]$$

Where x_i is the actual time data for a time series of $i = 1,2, \ldots \ldots \ldots \ldots., n$

$$sgn = \begin{cases} +1 > (x_j - \mathrm{x}_i) \\ 0 = (x_j - \mathrm{x}_i) \\ -1 < (x_j - \mathrm{x}_i) \end{cases} \qquad [2]$$

When the data $n \geq 10$ the S statistic follows the normal distribution in a series with the mean of $E(S) = 0$ and the variance.

$$Var(S) = \frac{\mathrm{n(n-1)(2n+5)} - \sum_{i=1}^{m} \mathrm{t(t-1)(2t+5)}}{18} \qquad [3]$$

where t_i are the ties of the sample time series. The test statistics Z_c is given as:

$$Zc = \begin{cases} \frac{\mathrm{S}-1}{\sqrt{\mathrm{Var(S)}}} & \mathrm{S} > 0 \\ 0 & \mathrm{S} = 0 \\ \frac{\mathrm{S}+1}{\sqrt{\mathrm{Var(S)}}} & \mathrm{S} < 0 \end{cases} \qquad [4]$$

where Zc follows normal distribution, a positive Z_c depicts an upward trend and negative Z_c depicts downward trend for the period. At significance level α, where $Z_c \geq Z\alpha/2$, the trend of the data is considered to be significant. The Mann Kendall test checks the null hypothesis of no trend to the alternative hypothesis of existence of trend in data. The above formula is valid when the number of observation $n \geq 10$.

Sen Slope estimator procedure is a simple nonparametric test developed by Sen and presented by Gilbert to estimate the true slope of Mann Kendall's trend analysis. It calculates the magnitude of any significant trend found in the Mann Kendall S test. The Sen Slope estimator can be calculated using equation:

$$T_i = \frac{(\mathrm{xj} - \mathrm{xi})}{\mathrm{j-k}} \qquad i = 1,2, \ldots \ldots \ldots \ldots N \qquad [5]$$

where x_j and x_k is the data values for j and k times of a period where $j > k$. The slope is estimated for each observation. Median is computed from N observations of the slope to estimate the Sen's Slope estimator

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & \text{N is Odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+1}{2}}\right) & \text{N is Even} \end{cases} \quad [6]$$

When the N Slope observations are shown as Odd the Sen's Estimator is computed as $Qmed = (N+1)/2$ and for Even times of observations the Slope estimate as $Qmed = [(N/2) + (N+2)/2)]/2$. The two sided test is carried out at $100(1 - \alpha)$ % of confidence interval to obtain the true slope for non-parametric test in the series (Mondal et al, 2012). The positive or negative slope *Qi* is obtained as upward (increasing) or downward (decreasing) trend.

3. RESULTS AND DISCUSSION

Monthly Variations

The magnitude of the trend in the time series, as determined using the Sen Estimator, is given in Table 1. The monthly analysis of sub divisional rainfall indicate that all sub divisions have very little or no change in South west monsoon months (June to September). All sub divisions experienced increasing rainfall from January to April and October to December, except for Pelwehera which showed a negative trend of rainfall for the month of March (-0.017 mm/year) and October (-1.384 mm/year). The maximum increases were found for Nalanda in December (4.86mm/year), April (4.48 mm/year) and October (3.721 mm/year), Dewahuwa in December (4.88 mm/year), April (4.506 mm/year) and February(2.894 mm/year), Pelwehera (5.478 mm/year) in November. Maximum reduction was found for Nalanda in May (-2.20 mm/year) and July (-0.38 mm/year) and Dewahuwa in May (-1.23 mm/year) and September (-0.25 mm/year). From June to August a trend couldn't be observed in Pelwehera while no trend could be observed in June and August in Nalanda and July in Dewahuwa stations.

Seasonal and Annual Variation

Seasonal analysis of sub divisional rainfall showed that all the seasons except South West monsoon rainfall increased in all stations. The maximum increases for First Inter monsoon, Second Inter monsoons and North East Monsoon were 6.491 mm/year and 5.194 mm/year and 14.121 mm/year respectively in Nalanda station. Nalanda showed the maximum decreasing trend of 4.289 mm/year for South West monsoon. The maximum magnitude of trend was found in North East Monsoon (positive) and the minimum in the South West Monsoon (negative).

Figure 3 to 5 show the variability of the mean annual precipitation data for the entire period of study. There is an inclination in annual mean precipitation in the period of 1981-2013. In order to check whether this continues needs further research. As the results of trend analysis show an increasing trend in annual rainfall at all stations in the study area. Maximum increasing trend of 21.296 mm/year was observed in the Nalanda station.

Table 1: Trend analysis of Precipitation data 1981-2013 for three rain gauging stations using Mann-Kendall test (Zc) and Sen's Slope Estimator(Qi)(mm/year) for monthly rainfall.

Rain Gaugeing Station (Sub division)	Nalanda	Pelwehera	Dewahuwa
January	+2.74	+0.6	+0.83
February	+2.43	+1.85	+2.89
March	+2.28	-0.02	+0.46
April	+4.48	+2.99	+4.51
May	-2.2	-1.87	-1.23
June	0	0	-0.08
July	-0.38	0	0
August	0	0	+0.25
September	-0.03	0	-0.25
October	+3.72	-1.38	+2.41
November	+1.76	+5.48	+0.69
December	+4.86	+5.24	+4.88

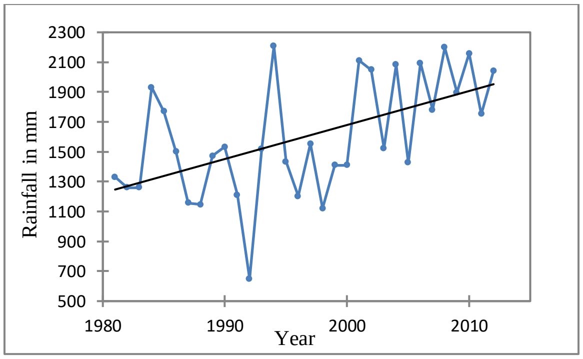

Figure 3: Annual rainfall variation in Nalanda rain gauging station

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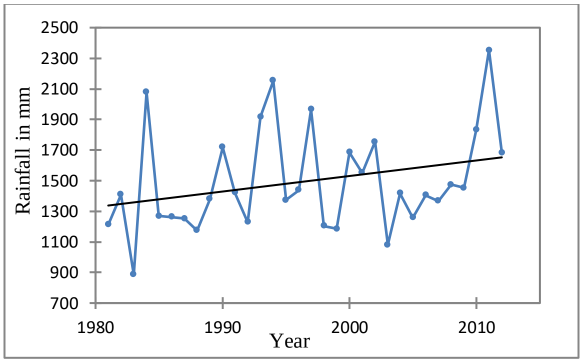

Figure 4: Annual rainfall variation in Pelwehera rain gauging station

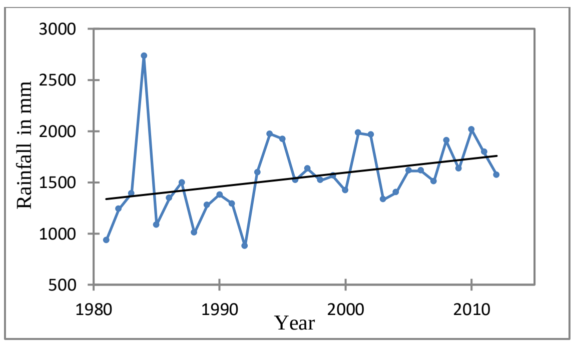

Figure 5: Annual rainfall variation in Dewahuwa rain gauging station

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Table 2: Trend analysis of Precipitation data 1981-2013 for three rain gauge stations using Mann-Kendall test (Zc) and Sen's Slope Estimator (Qi) (mm/year) for annual and seasonal rainfall. Values displayed in bold letters indicate statistical significance at 95% confidence level as per the Mann-Kendall test (+ for increasing and – for decreasing).

Rain gauging station (Sub division)	Nalanda	Dewahuwa	Pelwehera
Annual	**21.296**	**16.683**	9.675
First Inter-Monsoon	**6.491**	**6.415**	2.819
South West Monsoon	**-4.289**	-2.303	-2.589
Second Inter-Monsoon	5.194	2.839	5.028
North East Monsoon	**14.121**	5.485	**8.062**

CONCLUSION

The present study revealed that both positive and negative seasonal trends of precipitation is evident in the Matale district.

Except for South West Monsoon there is a positive trend in all other monsoons precipitations. North East Monsoon represents the highest positive trend with 95% confidence level. Three stations Nalanda, Dewahuwa and Pelwehera show a positive trend for total annual rainfall. Nalanda station represent the highest annual trend with 95% confidence level. Upward trend of seasonal and annual rainfall is a positive indication in view of agriculture in the area. When consider the season wise rainfall, there is a downward trend in South West Monsoon. This could be tackled if control measures are taken by the farmers to limit their cultivation extents.

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REFERENCES

1. Arijit Ganguly, Ranjan Ray Chauhuri & Prateek Sharma (2015). Analysis of trend of the precipitation data: A case study of Kangra District, Himachal Pradesh, 3, 87-95.

2. Arun Mondal, Sananda Kundu & Anirban Mukhopadhyay (2012). Rainfall trend analysis by Mann-Kendall Test: A case study of North-Eastern part of Cuttack district, Orissa, International journal of Geology, Earth and Environmental Sciences, 2(1), 70-78.

3. Blocks, S.J. (1961). Groundwater Hydrology, *C.H.L.* Srimanne memorial volume 07, 90-94.

4. Gabriel Constantino Blain (2013). The Mann-Kendall test: the need to consider the interaction between serial correlation and trend. Acta scientiarum, agronomy, 4, 393-402.

5. Gosselin, D., Sridhar, V., Harvey, F.E. & Goeke, J. (2006). Hydrological effect and groundwater fluctuations in interdunal environments in Nebraska Sandhills. Journal of Natural and Social Sciences, 16**,** 17-28.

6. Mahalingam, B., Ramu, Bharath & Jayashree (2014). Rainfall variability in space and time, a case of Mysore district, Karnataka, India. Current Trends in Technology and Science, 03**,** 205-209.

7. Nayakakorale, H. B. (1998). Climate, water availability and current problems associated with farming systems in the dry zone. In: Nagarajah, S. and Gamage, H (Eds.) Groundwater utilization for crop production in the dry zone of Sri Lanka. Proceedings of a symposium, 2 December 1997, Kandy, Sri Lanka, 1-8.

8. Panabokke, C.R., Perera, A.P.G.R.L. (2005). Groundwater types in relation to physical features, Groundwater Resources of Sri Lanka, 1, 3-10.

9. Pathmarajah, S. & Mowjood, M.I.M. (2007). Review of historical water sector coordination and allocation issues: Prospects and problems for the future. In: Proceedings of Consultation on effective water institution to promote integrated water resources management, Sri Lanka Water Partnership, 08 June 2007, Colombo, Sri Lanka, 9-17.

10. Silva, C.S. & Rushton, K.R. (2009). Interpretation of the behavior of agro well systems in Sri Lanka using radial flow models, Hydrological Sciences Journal, 6, 825-835.

ISSN: 2455-6939

Volume:03, Issue:04 "July-August 2017"

11. Sirimanne, C.H.L. (1964). Ceylon groundwater resources, C.H.L. Srimanne memorial volume 09, 105-116.

12. Taylor, R. G., Owor, M., Tindimugaya, C. & Mwesigwa, D. (2009). Rainfall intensity and groundwater recharge: empirical evidence from the upper Nile Basin, Environmental Research Letters, 4, 3.

13. Thenmozhi, M. & Kottiswaran, S.V. (2016). Analysis of rainfall trend using Mann-Kendall test and the Sen's slope estimator in Udumalpet of Tirupur District in Tamil Nadu. International journal of Agricultural Science and research (IJASR), 6, 131-138.

14. Thilagawathi, N., Subramani, T., Suresh, M. & Ganapathy, C. (2014). Rainfall variation and groundwater fluctuation in Salem Chalk Hills area, Tamil Nadu, India, International Journal of Application or Innovation in Engineering & Management (IJAIEM), 03, 141-161.

