RESEARCH ARTICLE OPEN ACCESS

Statistical and Graphical Comparison of Relative Humidity in the Wet Zone of Sri Lanka

Tharinda.W.M.A[*], Ruwangika,N.R.A.M[**], Jayasingha K.P[***], Aponsu,G.L.M.P[****], Rathnayake.U[*****]

[*](Physical Sciences and Technology, Sabaragamuwa University of Sri Lanka,
Email:anuja.tharinda@gmail.com)

[**](Physical Sciences and Technology, Sabaragamuwa University of Sri Lanka,
Email:ruwangika@appsc.sab.ac.lk)

[***] (Electrical and Electronic Technology, Rajarata University of Sri Lanka,
Email:kpjayasi@tec.rjt.ac.lk)

[****] (Physical Sciences and Technology, Sabaragamuwa University of Sri Lanka,
Email:gmlasanthaaponsu@gmail.com)

[*****] (Civil Engineering, Sri Lanka Institute of Information Technology, Sabaragamuwa University of Sri Lanka,
Email:upaka.r@sliit.lk)

--************************----------------------------------

Abstract:

Abstract

Studying the trend analysis of climatic variables and evaluating their statistical significance in recent times is the greatest evidence about climate change. Climatic warming accompanied by atmospheric humidity is predicted to extend much faster than the entire precipitation amount. Atmospheric moisture is expected to rise with temperature. As a tropical country, Sri Lanka has a variety of different tropical climates. In this study, we received relative humidity data of selected stations in the past 27 years (1990-2017). Accordingly, to analyze the climate variation, we selected five main stations in the Wet Zone of Sri Lanka: Colombo, Katugastota, Bandarawela, Rathnapura, and Nuwara Eliya. To analyze relative humidity data collected over time (1990-2017) for consistently increasing or decreasing trends. The most popular non-parametric test the Mann-Kendall (MK) test was used to identify the trend variation and linear regression analysis was used to analyze statistically. For graphically analyze innovative trend analysis and continuous wavelet transformation methods were used. Data were selected as daytime and nighttime and trends were analyzed annually (1990-2017) using XLSTAT, Minitab, MATLAB, and Excel software. Other than Colombo, all four stations show positive trends in nighttime relative humidity, while the entire district shows a positive trend in daytime relative humidity. According to linear regression analysis, Bandarawela and Colombo show a negative trend in nighttime and only Colombo shows a negative in the daytime. Analyzing a Mann Kendal results shows RathnapuraKatugastota and Colombo shows a negative trend in the nighttime. In terms of CWT data analysis, in one district it shows at least three patterns during the day and four patterns at night.

Keywords —*Relative Humidity, Linear Regression, Mann-Kendall, Trend, wavelet*.

--************************----------------------------------

I. INTRODUCTION

Studying the trend analysis of climatic variables and evaluating their statistical significance in present is the greatest evidence of climate change. Relative humidity is one of the main climatic conditions among various kinds of climate conditions like temperature, rainfall and wind speed. Water vapour on earth is a critical climatological and meteorological parameter that influences global climate change (bleej, 2020). Climatic warming accompanied by atmospheric humidity predicted to extend much faster than the entire precipitation amount. The amount of the atmospheric moisture is guessing to rise with the temperature (xie et al., 2011).

Relative humidity (φ or RH) means the ratio of current absolute humidity to the highest possible absolute humidity at the same current air temperature. On the theoretical side, relative humidity changed with pressure. A change in ratio explained by a change in system temperature, a change in system volume, or a change in these two properties of the system. When the temperature is high, there is more water vapour that the air can handle or absorb. On the contrary, if the temperature is low, then the air will be able to manage a lower amount of water vapour.

Humidity plays an important role in our lifestyle. Humidity affects human comfort and, therefore, the perceived temperature by humans is essentially dependent upon atmospheric moisture content (jamaludin et al., 2015). Wet summer days can sometimes be unbearable. The humidity or humidity in the air can make the temperature warmer as our sweat evaporates more slowly. It can cause overheating of our bodies and be dangerous to our health. Dehydration, fatigue, muscle cramps, heat exhaustion, fainting, and heatstroke identified as health issues. High humidity levels also cause problems for plants (jamaludin et al., 2015) so long-term trend analysis relative humidity will be highly important for human health in the future.

Trend analysis of relative humidity is the central process that provides an overall estimate of the variations in the RH in the future. Therefore, having a good knowledge of trends in RH is very important for the agriculture field, mainly the food-producing field. Since the knowledge of RH variability and trends is important for many aspects, the accurate prediction of humidity variables is also equally important for food distributors. Because if they could have a long-term shipping process, they should be careful about climate change and the packaging.

For some products that require a certain amount of moisture to maintain their quality, the loss of this moisture reduces their value. Some products returned to their original state by returning the moisture. Fruits and vegetables, paintings, art objects, cut flowers, and a variety of foods, on the other hand, cannot be reabsorb to regain their lost quality.

For the assessment of climate variability and trends, different parametric linear regression and nonparametric Mann–Kendall test methods documented in the literature. Over the years, there has been an increasing concern about whether there is an increasing or decreasing trend in relative humidity because of global climate change. Trend extraction is one of the main tasks of your time series analysis. A statistic taken into account as a smooth additive component that contains information about global change (jamaludin et al., 2015). Trend analysis for hydro-meteorological variables like rainfall, mean temperature, ratio, wind speed, and stream flow has been of specific interest to hydrologists and researchers for several years. Previous studies suggest that the most widely used method is the nonparametric mann-kendall test (nema et al., 2016).

Parametric methods are more powerful and their applications are restricted to normally distributed time series. Since most of the climatic time series, specifically precipitation, do not fulfil the normality requirement, nonparametric methods frequently applied in trend analysis. Time series modelling is one of the most important tools for predicting relative humidity changes in a climatic time series, both short and long term.in the different fields of studies, these time-series analyses are widely used.

There are various kinds of methods used in long-term trend analysis. In this study, there are two main approaches used to compare the relative humidity in both day and night time. First method was statistical method and second method was graphical method. Under the statistical analysis method, there are three sub method used: basic statistical analysis, linear regression analysis and mann-kendall (MK). Under the graphical analysis method, Innovative Trend Analysis method and Continuous Wavelet Transformation methods were used. The relative humidity data were analysed as main two sets as day time relative humidity as well as night-time relative humidity. From 1990 to 2017 (27 years) data were used in this study. Mainly for statistical analysis XLSTAT, Minitab, and excel software were used while for graphical analysis mat lab, excel and r software were used.

II. STUDY AREA

Due to the closeness to the equator, Sri Lanka can classified as tropical and relatively hotcountry.It locate between 5 and 10 north latitude endows the country with year-round warm weather, moderated by ocean winds and considerable moisture. Depending on the precipitation (rainfall) distribution, Sri Lanka classified into three climatic zones the Wet Zone, Dry Zone and Intermediate Zone. The Wet Zone covers the southwestern region including the central hill country and receives relatively high mean annual rainfall over 2,500 mm without pronounced dry periods. The Dry Zone covers predominantly the northern and eastern part of the country; it separated from the Wet Zone by the Intermediate Zone. To analyse the climate variation, we selected five main stations in the wet zone of Sri Lanka: Colombo, Katugastota, Bandarawela, Rathnapura, and Nuwara Eliya

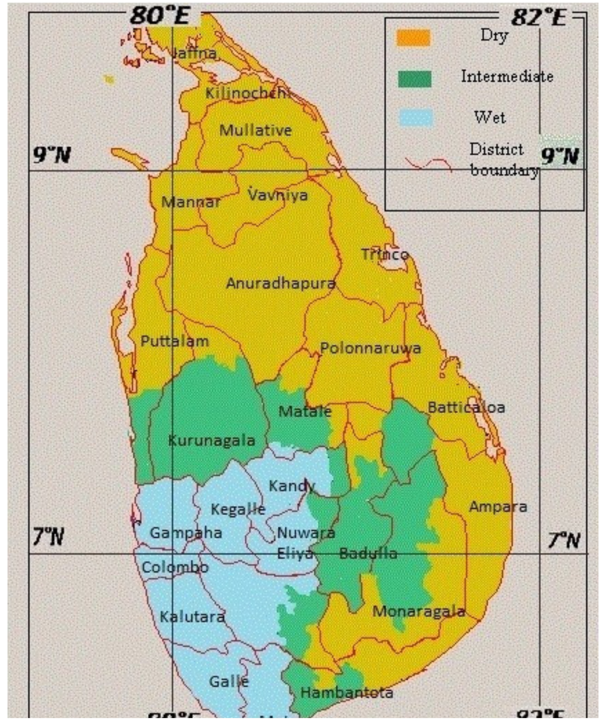


Fig. 1 Three climatic zones in Sri Lanka: wet zone, Intermediate zone and dry zone

III. METHODOLOGY

A. Linear Regression Analysis

In the concept of statistical solving method, simple linear regression is an empirical approach and it can solve the tasks by considering the historical data set of the climate values or parameters. It consists of dependent and independent variable. The simple linear regression model can exist only two variables. The linear regression analysis can be describe;

$$Y = \alpha + \beta X \quad (1)$$

In here Y = dependent variable, X = Independent variable α and β are regression variables. In simple linear regression, we'll implement it by calculating slope and intercept because it'll be like a mathematical equation of slope, intercept line. The strength and direction of the association between the two variables can estimated by using the regression coefficient formula. Similarly, there is

various coefficient of correlation formulas can also be available within the mathematical and statistical evolution processing.
The coefficient determination measures how well data can represented within the regression curve. It can define the strength and direction of the connection between the dependent and independent variables.

B. Mann-Kendall (MK) Analysis

The most popular non-parametric test for analyzing climate data, water quality data, environmental data and hydrological data is Mann-Kendal (MK) test. Mann-Kendall is use to identify monotonically increasing and decreasing trends in a climate data series (Ruwangika at all, 2020). It compares the relative magnitudes of sample data instead of the data values themselves Mann–Kendall test is a two-tailed test. At some probability level, H_0 is reject in favor of H_1 if the absolute value of S equals or exceeds a specified value Sα/2, where Sα/2 is that the smallest S having the probability less than α/2. A positive value of S indicates an upward (downward) trend and a negative value indicates a downward trend. In the Mann-Kendall test Trend study for ratio, the study area covered mainly three steps; the primary was to determine the trend whether increasing, decreasing or no trend by Mann-Kendall (non-parametric) test within the annual as well as seasonal/monthly Rh. The second a part of the study is to estimate the magnitude of the trend by using Sen's slope estimator and third was to develop regression models for the observed data series. The test calculates the Kendall's tau between two data samples based on the ranks. These samples were assumed to be independent. The alternative hypotheses from the test have three outcomes: negative trend, no trend and positive trend. The mathematical formulations of calculating Mann-Kendall statistics S, variance (S) and standard test statistics $ZMK$are given in Equations 1-4.

$$S = \sum_{i=1}^{n} \sum_{j=1}^{i=1} Sgn(x_i - x_j) \qquad (2)$$

Where n is the total length of data, x_i and x_j are two generic sequential data values, and function sign (x_i—x_j) assumes the following values

$$sgn(x_i - x_j) = \begin{Bmatrix} 1, if(x_i - x_j) > 0 \\ 0, if(x_i - x_j) = 0 \\ -1, if(x_i - x_j) < 0 \end{Bmatrix} \qquad (3)$$

$$V(s) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_{p+5})\right] \qquad (4)$$

$$Z_{mk} = \begin{Bmatrix} \frac{S-1}{\sqrt{V(S)}}, if\ S > 0 \\ 0, if\ S = 0 \\ \frac{S+1}{\sqrt{V(S)}}, if\ S < 0 \end{Bmatrix} \qquad (5)$$

$x_i$and$x_j$are chronological time series observations, n is the length of the time series, t_p is the number of ties for p^{th} value, and q is the number of tied values in the above stated equations. An upward trend in the climatological series is given by a positive Z_{MK} value whereas a downward trend is given by a negative Z_{MK} value. Further details regarding Mann-Kendall test can be found in Ahamed et al., (2015)

The second parameter is the Sen's slope estimator. Sen's slope estimator is widely used to quantify the l trends identified from Mann–Kendall test [13–16]. Sen's slope estimator calculated the gradient of the trend line; therefore, it presents the linear magnitude of the trend. Sen's slope calculates using the following equation:

$$m_i = \frac{x_j - x_i}{j - k}, \text{for } i = 1,2,3,..N \qquad (6)$$

Where N is the number of data points in the time series and x_j and x_k are data values at time j and k (where j > k), respectively. The mean value (β) of all slopes is Sen's slope and calculated as given in the following equation:

$$\beta = \begin{Bmatrix} m_{\left(\left(N+\frac{1}{2}\right)\right), if N is Odd} \\ \frac{1}{2}\left(m_{\left(\frac{N}{2}\right)} + m_{\left(\left(N+\frac{1}{2}\right)\right)}\right), if N is even \end{Bmatrix} \quad (7)$$

The trend can be detected as an upward or downward trend based on the + or–behaviour of the β

C. *Innovative Trend Analysis(ITA)*

The Innovative Trend Analysis (ITA) is widely used to study the trends of hydrological and meteorological variables in many areas. Regardless of distribution assumptions, this method is simple, intelligent, usable, and capable of identifying trends in different subtypes. The time series data were divided into two equal parts from the first time series to the end-time series, and both sub-series were separately sorted in ascending order. Then, the first sub-series (xi) were plotted on the horizontal X-axis, and the second sub-series (xj) were plotted on the vertical Y-axis, based on the two-dimensional (2D) Cartesian coordinate system. If the data points in the scatter plot collected on the 1:1 (45°) line, it indicated that they were trendless (data with no trend). If the data points accumulated in the triangular area below the 1:1 line, it could be concluded that there was a decreasing trend present in the time series. If the data points fell above the upper triangular area, the 1:1 line, it could be said that the time series exhibited an increasing trend.

D. *Continuous Wavelet Transformation Test (CWT)*

There are two main Wavelet Transformation methods. Namely Continuous Wavelet Transformation and Discrete Wavelet Transformation. In this section, we will get an algorithm for calculating CWT. The LRA test first identifies the current trend positive or negative, and then ITA test can identify whether the trend is low, high or medium. MK test compares the alpha value and P value and identifies the trend. The CWT test represents the number of all inclinations, large or small, that exist in this time frame. Continuous wavelet transforms use discrete wavelets in the continuous time scale (x (t)). Mathematically, the wavelet function (Ψ (η)) in CWT can be represented as given in equations (8)–(9). More information on these can be found in Chen et al. [71], Nalley et al. [72], and Partal and Kuçuk [30] study:

$$\Psi_{\eta} = \Psi_{(s^*,\gamma)} = \frac{1}{\sqrt{s^*}}\Psi\frac{t-\gamma}{s^*} \quad (8)$$

Where η, c, and s∗ are the no dimensional parameter and the translation factor (time shift) of the wavelet over the time series and the wavelet scale, respectively. The wavelet coefficients $W_{\Psi(s^*,\gamma)}$ can be found from equation (8). Ψ^*Is the complex conjugate function. A scalogram can be produced if the translation factor and the wavelet scale changed smoothly with the time.

$$W_{\Psi(s^*,\gamma)} = \frac{1}{\sqrt{s^*}}\int_{-\infty}^{\infty} x(t)\Psi^*\left(\frac{t-\gamma}{s^*}\right)dt \quad (9)$$

IV. RESULT AND DISCUSSION

A. Linear Regression Analysis

Interesting findings of the wet zone area are presented here. Several months and years were identified with positive trends by all tested methods. However, other than Colombo all four stations show positive trends in daytime relative humidity. Colombo shows negative trends in linear regression analysis, while Rathnapura and Nuwara Eliya show positive trends, also, Katugastota and Bandarawela show a slightly positive trend in linear regression analysis. According to nighttime data in relative humidity, Colombo shows a positive trend and Bandarawela shows a slightly negative trend pattern in linear regression analysis. Considering the nighttime Relative humidity Rathnapura and Katugastota show a slightly positive trend and Nuwara Eliya shows a positive trend in linear regression analysis. Table 1 shows a summary of various relative humidity trend analysis results.

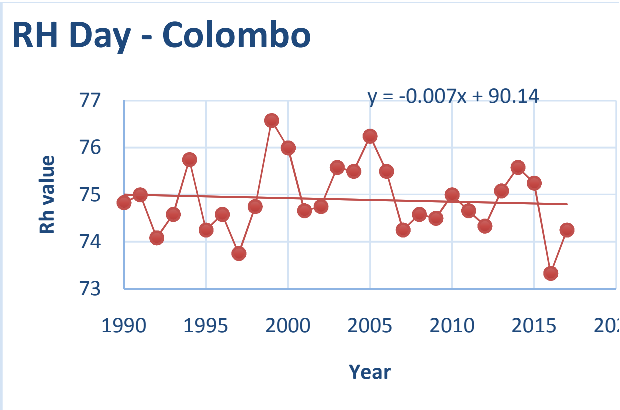


Fig. 2 Day time relative humidity in Colombo district

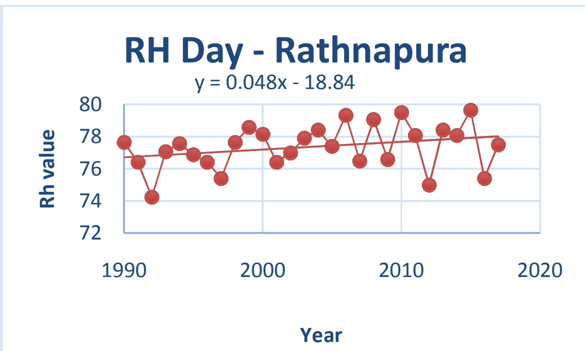


Fig.3:Day time relative humidity in Rathnapura district

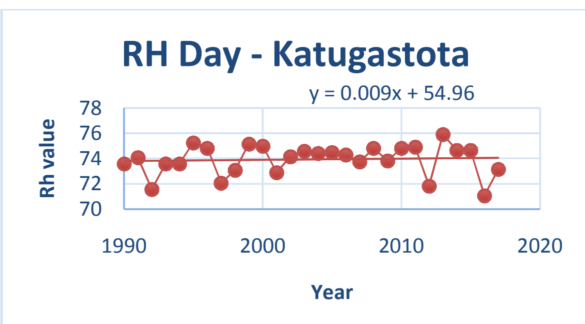


Fig.4:Day time relative humidity in katugasthota district

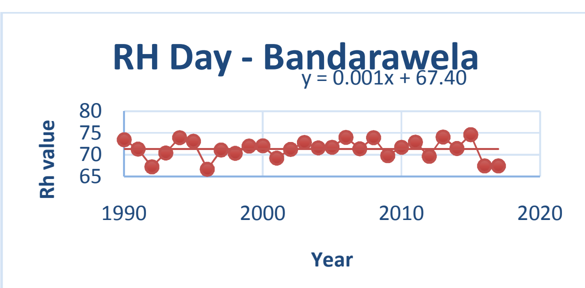


Fig.5:Day time relative humidity in Bandarawela district

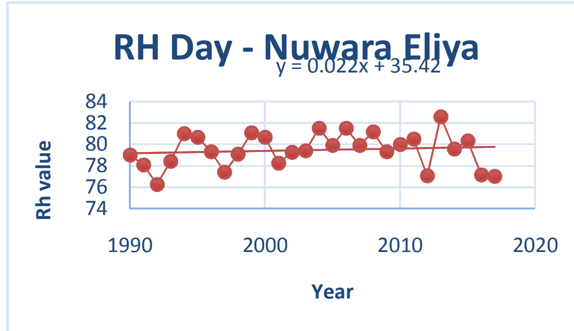


Fig.6:Day time relative humidity in Nuwara Eliya district

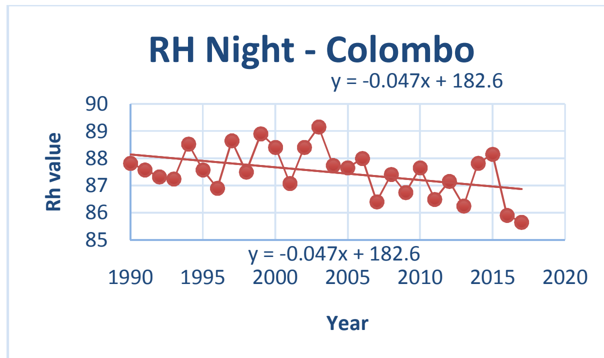


Fig. 7:Night time relative humidity in Colombo district

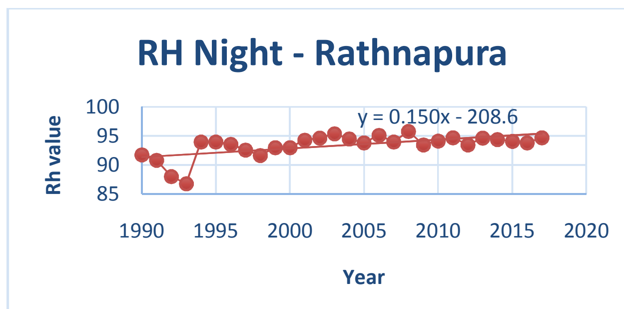


Fig. 8:Night time relative humidity in Rathnapura district

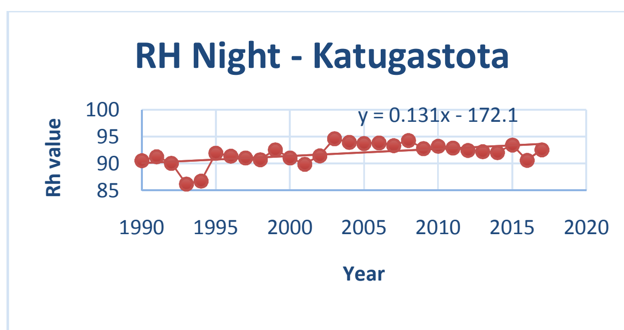


Fig. 9:Night time relative humidity in Katugasthota district

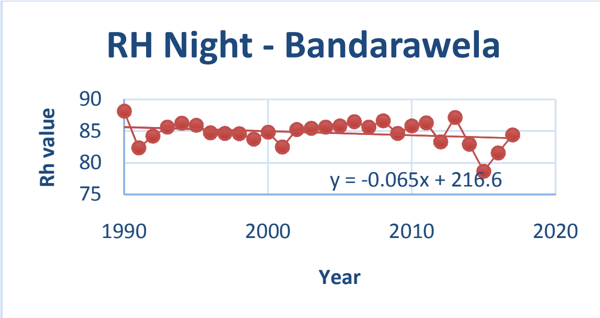


Fig. 10:Night time relative humidity in Bandarawela district

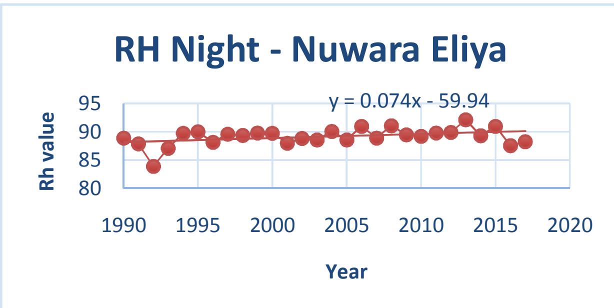


Fig. 11:Night time relative humidity in Nuwara Eliya district

Table 1. Annual, Day and Night relative humidity results for linear regression analysis

Stations	elevation		Height to sea level	RH day trend	RH night trend
	Latitude	Longitude	(ft)	Annually	Annually
Colombo	6.9271	79.8612	29	-0.0076	-0.0475
Rathnapura	6.7056	80.3847	288	0.048	0.1507
Katugasthota	7.336	80.6214	1660	0.0095	0.1318
Bandarawela	6.8259	80.9982	4000	0.0019	-0.0658
NuwaraEliya	6.9497	80.7891	6182	0.022	0.0744

Mann-Kendall Analysis

The Mann–Kendall test is a nonparametric test where the concept of it is simple. It assumes joint distribution of the data, and therefore, the results are minimally affected due to the normality of the series. The summary of the MK test was shown in table 3 and table 4. According to that in daytime relative humidity, no trends were shown; only Colombo shows a negative in Sen.'s slope value. In night-time relative humidity comparatively differs from daytime. Nuwara Eliya and Bandarawela show no trend in daytime relative humidity while Rathnapura and Katugastota show positive trends. The only Colombo shows negative trends in the MK test. Both Colombo and Bandarawela show negative Sen.'s slope value.

Table 2. Monthly daytime relative humidity trend analysis results for MK test.

Stations	Trend	Kendall's tau	P Value	Sen's slope value
Colombo	No	-0.040	0.782	-0.006
Rathnapura	No	0.202	0.133	0.045
Katugasthota	No	0.093	0.501	0.016
Bandarawela	No	0.050	0.722	0.011
NuwaraEliya	No	0.120	0.384	0.038

Table 3. Monthly nighttime relative humidity trend analysis results for MK test.

Stations	Trend	Kendall's tau	P Value	Sen's slope value
Colombo	Yes	-0.277	**0.042**	-0.054
Rathnapura	Yes	0.436	**0.001**	0.106
Katugasthota	Yes	0.312	**0.021**	0.100
Bandarawela	No	-0.056	0.693	-0.019
NuwaraEliya	No	0.237	0.082	0.064

Innovative Trends Analysis (ITA)

The Innovative Trend Analysis (ITA) results are given in Table 4. Innovative trend analysis has data analysis shows that only Colombo shows a negative trendidentified positive trends. Annual daytime analysis shows negative trends in all locations and nighttime.

Table 04: - Results for the Innovative Trends Analysis

Stations	Innovative Trends Analysis	
	Day Time	Night Time
Colombo	Up	Down
Rathnapura	Up	Up
Katugasthota	Up	Up
Bandarawela&Diyathalawa	Up	Up
NuwaraEliya	Up	Up

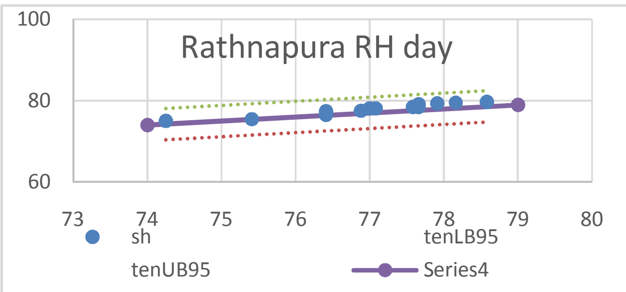


Fig.12: Daytime RH day ITA in Rathnapura

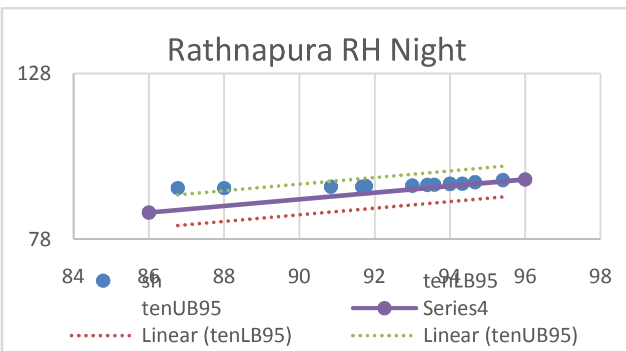


Fig.13: Night time RH day ITA in Rathnapura

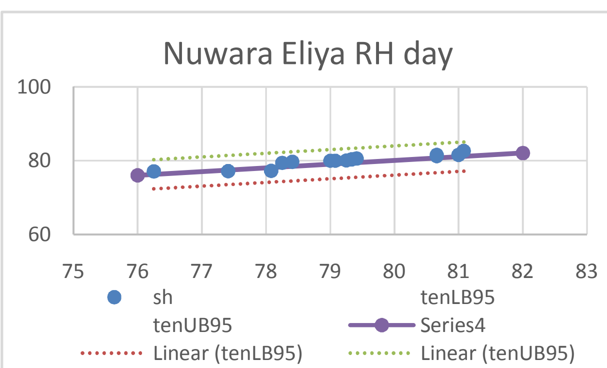


Fig.14: Day time RH day ITA in Nuwara Eliya

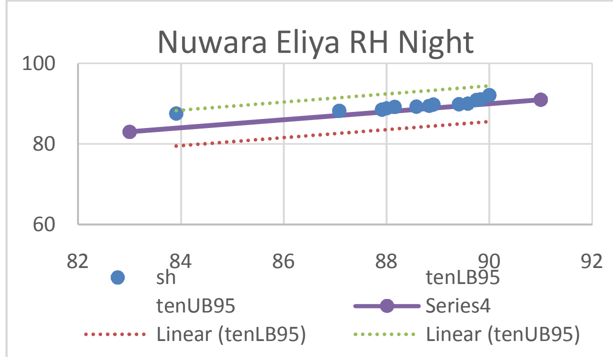


Fig.15: Night time RH day ITA in Nuwara Eliya

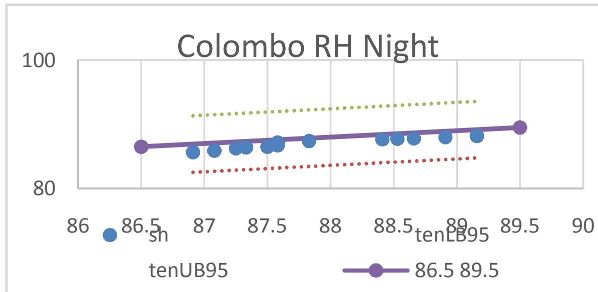


Fig.16: Night time RH day ITA in Colombo

Continuous Wavelet Transformation Test (CWT)

In terms of CWT data analysis, at least one location CWT pattern is represented as at least 3during the day and 4 at night.

Figure 18:Night time CWT Analysis in Colombo

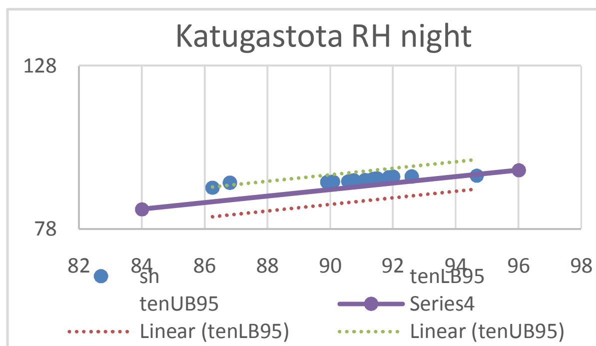
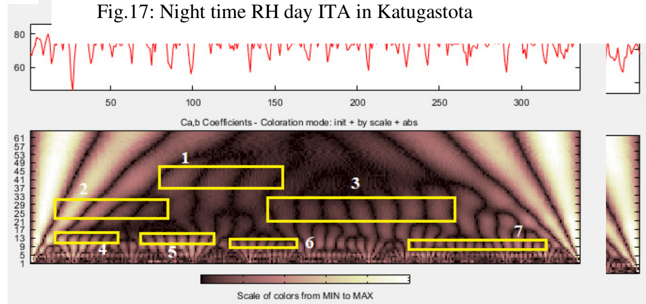


Figure 19:Day time CWT Analysis in Colombo

Fig.17: Night time RH day ITA in Katugastota



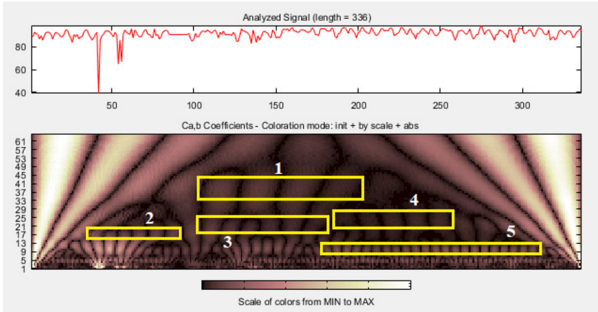


Figure 20:Night time CWT Analysis in Katugastota

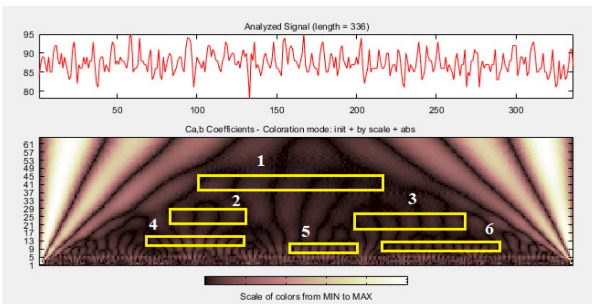


Figure 21:Day time CWT Analysis in Katugastota

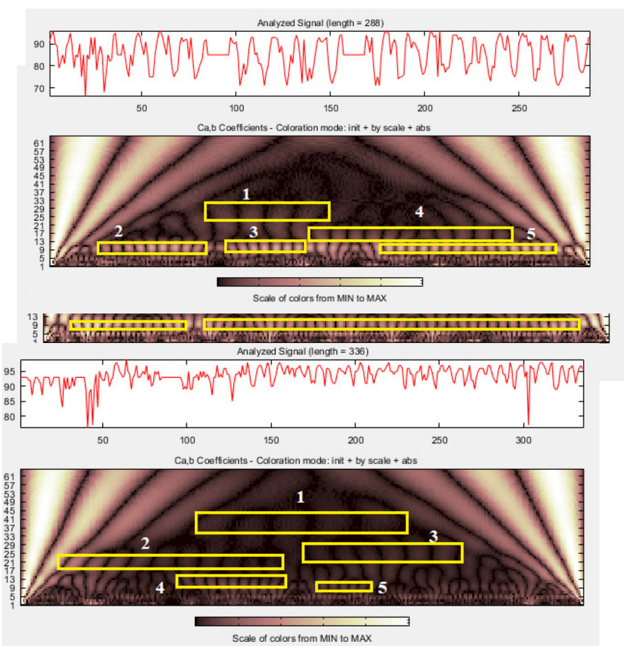


Fig. 22: Nighttime CWT Analysis in Diyathalawa

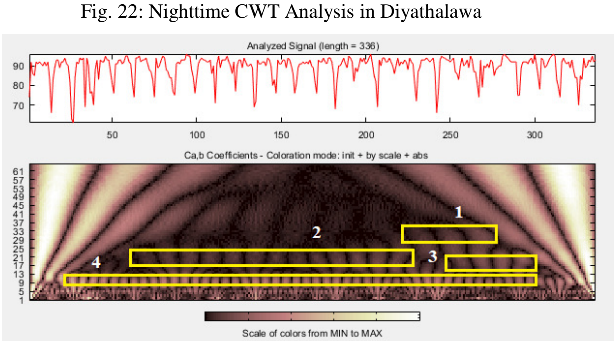
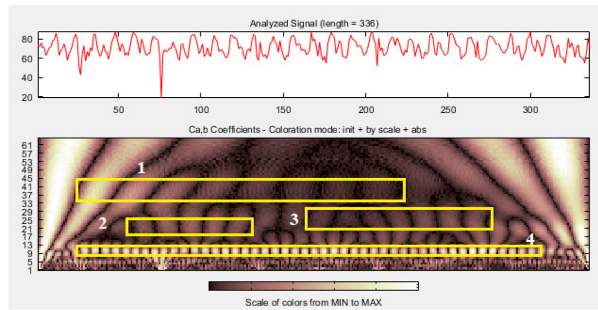


Fig. 23: Daytime CWT Analysis in Diyathalawa

Fig. 24:Nightt time CWT Analysis in Rathnapura



Fig; 25:Dayt time CWT Analysis in Rathnapura

Fig. 26:Nightt time CWT Analysis in Nuwara Eliya

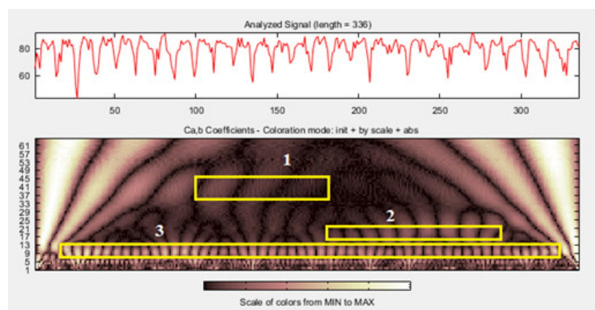


Fig. 27:Day time CWT Analysis in Nuwara Eliya

V. CONCLUSION

The results of this study revealed that there is a positive humidity trend in many areas of the wet zone. This will be a satisfactory outcome for the farming community in the wet zone. However, despite the positive trend, data analysis in many areas of the Colombo district has shown a negative trend because it can be assumed that the area of main economic city of Sri Lanka.In general, we know that urbanization is maximum in districts. On the other hand, the ecosystem around the wet zone may be the main reason for this positive trend as a whole.

Table 05: - Summary for the Results in all tests – Day Time

Location	LRA test	ITA test	MK test	CWT Test (Number of Patterns)
Colombo	Negative	Up	No	3
Rathnapura	Positive	Up	No	5
Katugasthota	Positive	Up	No	7
Bandarawela &Diyathalawa	Positive	Up	No	4
Nuwara Eliya	Positive	Up	No	3

Table 06: - Summary for the Results in all tests – Night Time

Location	LRA test	ITA test	MK test	CWT Test (Number of Patterns)
Colombo	Negative	Down	Yes	6
Rathnapura	Positive	Up	Yes	5
Katugasthota	Positive	Up	Yes	5
Bandarawela &Diyathalawa	Negative	Up	No	5
Nuwara Eliya	Positive	Up	No	4

ACKNOWLEDGEMENT

We are greatly thankful to sriLanka meteorological department,Colombo for providing required data.

REFERENCES

1. Absolute vs. relative humidity - What is the difference? - Zehnder America*. (2019, December 9). Zehnder America. https://www.zehnderamerica.com/absolute-vs-relative-humidity-whats-the-difference/*
2. *adese M, Kumar L, Koech R, Kogo BK (2020b) Mapping of land-use/land-cover changes and its dynamics in 833 Awash River Basin using remote sensing and GIS. Remote SensApplSoc Environ 19:100352. 834 https://doi.org/10.1016/j.rsase.2020.100352*
3. *Ahmad Roshani, FatemehParak, HosseinEsmaili; Trend analysis of climate change compound indices in Iran.* Journal of Water and Climate Change *1 May 2021; 12 (3): 801–816. doi: https://doi.org/10.2166/wcc.2020.213*
4. *Chapter 2 - post-harvest system and food losses*. (n.d.). Home | Food and Agriculture Organization of the United Nations. https://www.fao.org/3/ac301e/AC301e03.htm
5. *Djamila, H. , Chu, C. and Kumaresan, S. (2014) Effect of Humidity on Thermal Comfort in the Humid Tropics. Journal of Building Construction and Planning Research,* ***2****, 109-117. doi: 10.4236/jbcpr.2014.22010.*
6. *Effects of humidity on the human body*. (2018, August 29). UPMC HealthBeat. https://share.upmc.com/2014/06/effects-humidity-body/
7. *FiazHussain, GhulamNabi, & Muhammad WaseemBoota. (2015). Rainfall Trend Analysis by Using the Mann-*Kendall Test &Sen'S Slope Estimates: a Case Study of District Chakwal*Rain Gauge, Barani Area, and Northern Punjab Province, Pakistan. Science International-Lahore, January.*
8. *Jamaludin, A. R. B., Yusof, F., & Kane, I. L. (2015). Temporal Dynamics of Trend in Relative Humidity with RH-SARIMA Model. Modern Applied Science, 9(3), 281–290. https://doi.org/10.5539/mas.v9n3p281*
9. Javaid M. Dad, M. Muslim, Irfan Rashid, Irfan Rashid, Zafar A. Reshi,Time series analysis of climate variability and trends in Kashmir Himalaya,EcologicalIndicators,Volume 126,2021,107690,ISSN 1470-160X,https://doi.org/10.1016/j.ecolind.2021.107690.
10. *Kashyap, N., & SINHA, G. R. (2012). Image Watermarking Using 3-Level Discrete Wavelet Transform (DWT). International Journal of Modern Education and Computer Science, 4(3), 50–56. https://doi.org/10.5815/ijmecs.2012.03.07*
11. *MdHafijurRahaman Khan, Ananna Rahman, ChuanxiuLuo, Sazal Kumar, G.M. Ariful Islam, Mohammad AkramHossain,Detection of changes and trends in climatic variables in Bangladesh during 1988–2017,Heliyon,Volume 5, Issue 3,2019,e01268,ISSN 2405-8440,https://doi.org/10.1016/j.heliyon.2019.e01268.*
12. *Nema, S., Awasthi, M. ., & Nema, R. K. (2016). Trend Analysis of Annual and Seasonal Rainfall in Tawa command Area. International Journal of Environment, Agriculture and Biotechnology, 1(4), 952–957. https://doi.org/10.22161/ijeab/1.4.46*
13. *Pandey, B. K., Tiwari, H., & Khare, D. (2017). Trend analysis using discrete wavelet transform (DWT) for long-term precipitation (1851–2006) over India. Hydrological Sciences Journal, 62(13),]*
14. *Perera, Anushka & Ranasinghe, Thilini & Gunathilake, Miyuru & Rathnayake, Upaka. (2020). Comparison of Different Analyzing Techniques in Identifying Rainfall Trends for Colombo, Sri Lanka. Advances in Meteorology. August. 10.1155/2020/8844052.*
15. *Ruwangika, A. M., Perera, A., & Rathnayake, U. (2020). Comparison of Statistical, Graphical and Wavelet Transform Analyses for Rainfall Trends and Patterns in BaduluOya Catchment, Sri Lanka. Complexity, 2020(September). https://doi.org/10.1155/2020/7146593*
16. *Sherwood, S. C., Ingram, W., Tsushima, Y., Satoh, M., Roberts, M., Vidale, P. L., & O'Gorman, P. A. (2010). Relative humidity changes in a warmer climate. Journal of Geophysical Research Atmospheres, 115(9). https://doi.org/10.1029/2009JD012585*
17. *Singh, B. R.,& Singh, O. (2012). Study of Impacts of Global Warming on Climate Change: Rise in Sea Level and Disaster Frequency. In (Ed.), Global Warming - Impacts and Future Perspective. IntechOpen.https://doi.org/10.5772/50464*
18. *Wang Fan, Shao Wei, Yu Haijun, Kan Guangyuan, HeXiaoyan, Zhang Dawei, Ren Minglei, Wang Gang TITLE=Re-evaluation of the Power of the Mann-Kendall Test for Detecting Monotonic Trends in Hydrometeorological Time Serie,JOURNAL=Frontiers in Earth Science ,VOLUME=8 YEAR=2020,URL=https://www.frontiersin.org/article/10.3389/feart.2020.00014,DOI=10.3389/feart.2020.00014,ISSN=2296-6463*
19. *Xie, B., Zhang, Q., & Ying, Y. (2011). Trends in precipitable water and relative humidity in China: 1979-2005. Journal of Applied Meteorology and Climatology, 50(10), 1985–1994. https://doi.org/10.1175/2011JAMC2446.1*

20. *D. Labat, J. Ronchail, and J. Guyot, "Recent advances inwavelet analyses: Part 2—Amazon, Parana, Orinoco andCongo discharges time scale variability," Journal of Hydrology,vol. 314, no. 1-4, pp. 289–311, 2005.*
21. *P. P. Nikhil Raj and P. A. Azeez, "Trend analysis of rainfall inBharathapuzha River basin, Kerala, India," InternationalJournal of Climatology, vol. 32, no. 4, pp. 533–539, 2011.*
22. *T. Partal and M. K˙uç˙uk, "Long-term trend analysis usingdiscrete wavelet components of annual precipitations mea-surements in Marmara region (Turkey)," Physics andChemistry of the Earth, Parts A/B/C, vol. 31, no. 18,pp. 1189–1200, 2006.*
23. *Y.-F. Sang, D. Wang, J.-C. Wu, Q.-P. Zhu, and L. Wang,"Entropy-Based Wavelet De-noising Method for Time SeriesAnalysis," Entropy, vol. 11, no. 4, pp. 1123–1147, 2009.[32] R. Mahmood, S. Jia, and W. Zhu, "Analysis of climate vari-ability, trends, and prediction in the most active parts of theLake Chad basin, Africa," Scientific Reports, vol. 9, no. 1, 2019.*
24. *M. Mudelsee, "Trend analysis of climate time series: A reviewof methods," Earth-Science Reviews, vol. 190, pp. 310–322,2019.[34] N. Phojanamongkolkij, S. Kato, B. A. Wielicki, P. C. Taylor,and M. G. Mlynczak, "A Comparison of Climate Signal TrendDetection Uncertainty Analysis Methods," Journal of Climate,vol. 27, no. 9, pp. 3363–3376, 2014.*
25. *C. R. Groves, E. T. Game, M. G. Anderson et al., "Incorpo-rating climate change into systematic conservation planning,"Biodiversity and Conservation, vol. 21, no. 7, pp. 1651–1671,2012.*
26. *K. E. McNamara and H. J. Des Combes, "Planning forCommunity Relocations Due to Climate Change in Fiji,"International Journal of Disaster Risk Science, vol. 6, no. 3,pp. 315–319, 2015.*
27. *A. E. Reside, N. Butt, and V. M. Adams, "Adapting systematicconservation planning for climate change," Biodiversity andConservation, vol. 27, no. 1, pp. 1–29, 2017.*
28. *E. L. Rowland, J. E. Davison, and L. J. Graumlich, "Ap-proaches to Evaluating Climate Change Impacts on Species: AGuide to Initiating the Adaptation Planning Process," Envi-ronmental Management, vol. 47, no. 3, pp. 322–337, 2011.*

