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Forecasting Temporal and Spatial Climatological Influence for Land Suitability Evaluation in Bentota Sri Lanka

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ABSTRACT

Climate change has raised much concern regarding its impacts on future land use planning, varying by region, time, and socio-economic development path. The principle purpose of land suitability evaluation is to predict the potential and limitation of the land for crop production and other land uses. This study was carried out to predict the temperature and rainfall trends as one of the major factor for evaluating land suitability. Climatic data such as monthly mean temperature, total monthly rainfall, maximum daily rainfall and total annual rainfall during last 30 years of all weather stations located in Bentota River basin was collected and analyzed applying time series analysis, correlation analysis and Manna Kendall trend test methods. Spatial distribution of forecast rainfall values was illustrated applying Arc GIS software. The findings revealed that monthly mean temperature and maximum daily rainfall had a general increasing trend whereas, total monthly rainfall and total annual rainfall showed a general decreasing trend in Bentota area. It was indicated relatively high rainfall situations during May and October while low rainfall situations during January and February by occurring flood situation in once per five year. During Yala season the area will be received comparatively more rainfall (331mm) than Maha season (300mm) in future. Community and the farmers in this area can be aware about the anticipated spatial distribution of total monthly rainfall during two major seasons and flood occurrence periods. Decision makers should evaluate land suitability of Bentota area by considering above climatological influences and its spatial distribution pattern that identified as major outcome of this research. The approach and the methodology adopted in this study will be useful for other researchers, agriculturalist and planners to identify the future climatological influences and its spatial distribution pattern for land suitability evaluations and other decision making purposes for other areas.

1. Introduction

Appropriate land use decisions are vital to achieve optimum productivity of the land and to ensure environmental sustainability. Land should be used based on its capacity to meet human needs and ensure the sustainability of ecosystems (Amiri and Shariff, 2012). The amount of land is fixed and the kinds of use that the land can support and the competition among these uses vary over time. The intensity of the competition is often proportion to the density of the population and in the demands of the population on the land (Jafarzadeh et al, 2005). Relatively scarcity of land resources for agriculture and insufficient food security of the world's population require that the land be used in an optimum way in the context of climate change (Liambila, Kibret, 2016). Thus, land evaluation is a vital link in the chain leading to sustainable management of land resources (FAO, 2007). Land evaluation is only part of the process of land use planning. Land evaluation is the selection of suitable land, and suitable cropping, irrigation and management alternatives that are physically and financially practicable and economically viable (FAO, 1984) and it is also the process of making predictions of land performance over the time based on specific types of uses considering soil, climatic, land form and socio economic conditions of an area (Al-Mashreki et al., 2011). These predictions are then used as a guide in strategic land use decision making. With the increase of demand for land, land suitability evaluation has become more important as people strive to make better use of the limited land resources. The principle purpose of land suitability evaluation is to predict the potential and limitation of the land for crop production and other land uses (Pan and Pan, 2012). Therefore, suitability is a function of crop requirements and land characteristics. Land suitability analysis is a prerequisite to achieve optimum utilization of available land resource in a sustainable manner (Mustafa,et al, 2011). In this manner, land suitability evaluation plays very important role in order to help developers and agriculturists to match the land optimum use and optimizing the use of a land piece for a specified use (Sys, Van and Debaveye, 1991).

Identification of the factors and related measures on land qualities and characteristics that use to evaluate the land suitability is the first step in the process of land suitability analysis. Ritung et al,(2007) show that land quality has the complex attributes of lands and contains more land characteristics. The land quality could either be directly observed in the field or estimated based on land characteristics and land evaluation requirements involve not only soil but also climatic, land form and socio economic conditions (FAO, 1976). Important land characteristics in any land evaluation include topography, soil, and climate (Ritung et al., 2007). Kamkar, Dorri and Silva (2014) identify that the climatic conditions and soil quality of an area are the most important factors of land suitability evaluations. Forecasting temporal and spatial rainfall and temperature trends is necessary for examining the climatological factor in land suitability evaluations. The climate and meteorological conditions in the world have been changed considerably by their intensity, term and duration due to the changing pattern of the human lifestyles and environment pollution.

Therefore identification of future climatic conditions of an area is one of the major factors of land suitability evaluations. Many studies on land suitability evaluations have been considered prevailing climate condition of an area along with its spatial distribution but not based on future climate change scenario. In this background, this study intends to forecast temporal and spatial rainfall and temperature trends in Bentota River basin for examining future climatic conditions in the area as one of the major factor that should be taken in to account in studies on land suitability evaluations. For land evaluation, the required climate data are monthly mean temperature, total monthly rainfall, maximum daily rainfall value for each month, total annual rainfall and number of dry and wet months which are generated either from weather stations or from climatic maps (Liambila and Kibret, 2016).

2. Methodology

Weather forecasting is a scientific appraisal of the weather conditions in a particular area during a specified time period (Buckle, 1996). Various methods are used to forecast weather such as Time series analysis (Box and Jenkins, 1976), Autoregressive (Hurrell, 1995) and Moving Average Model (Kaushik and Singh, 2008), Autoregressive-Moving-Average Modeling (Walker, 1933), Seasonal ARIMA Model (Aziz et al, 2013), etc. Box & Jenkins (1970) defined as a time series is a collection of quantitative observations that are evenly spaced in time and measured successively. Kim and Jaun (2003) show that time series are analyzed in order to understand the underlying structure and function that produce the observations. Aziz et al (2013) shows that time series analysis can be applied by assuming that a time series data set has at least one systematic pattern. Box & Jenkins (1970) show that time series analysis has two most common patterns as trends and seasonality. Trends are generally linear or quadratic and moving averages or regression analysis is often used to derive trend line. Seasonality is a trend that repeats itself systematically over the time. Understanding the mechanisms of a time series allows a mathematical model to be developed that explains the data in such a way that prediction or monitoring can occur. Hence, to describe a trend of time series, Mann–Kendall trend test was used to see whether there is a decreasing or increasing trend. Mann–Kendall statistics (S) is one of the non-parametric statistical tests used for detecting trends of climatic elements. Mann–Kendall trend test is also the most widely used methods since it is less sensitive to outliers (extraordinary high values within time series data) and it is the most robust as well as suitable for detecting trends in rainfall (Keradin et al. 2013). Mann–Kendall nonparametric trend test has first been proposed by Mann (1945) then further studied by Kendall (1975) and improved by Hirsch and James (1984) who allowed taking into account seasonality. The null hypothesis H0 for these tests is that there is no trend in the series. The three alternative hypotheses that there is a negative, non-null, or positive trend can be chosen. The Mann-Kendall tests are based on the calculation of Kendall's tau measure of association between two samples, which is itself based on the ranks with the samples. In Mann-Kendall trend test, the first series is an increasing time indicator generated automatically for which ranks are obvious, which simplifies the calculations. To calculate the p-value of this test, XLSTAT can calculate as in the case of the Kendall tau test, an exact p-value if there are no ties in the series and if the sample size is less than 50.

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

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Sgn\left(x_j - x_i\right)$$

$$Var(S) = \frac{n(n-1)(2n+5)}{18}$$

Where n is the number of observations and xi (i=1…n) are the independent observations.

In the case of seasonal Mann-Kendall test, the seasonality of the series is taken into account. This means that for monthly data with seasonality of 12 months, one will not try to find out if there is a trend in the overall series, but if from one month of January to another, and from one month February and another, and so on, there is a trend. For this test, first all Kendall's tau for each season is calculated then calculate an average Kendall's tau. The variance of the statistic can be calculated assuming that the series are independent (eg values of January and February are independent) or dependent, which requires the calculation of a covariance. To calculate the p-value of this test, XLSTAT uses a normal approximation to the distribution of the average Kendall tau. Finally, the Inverse Distance Weighted interpolation method in Arc GIS 10.3 was used to estimates cell values by averaging the values of forecasted rainfall of all whether stations in the neighborhood of each processing cell. The closer a point is to the center of the cell being estimated, the more influence or weight and it has in the averaging process.

For this study, Bentota river basin located in the southwest region of Sri Lanka is considered since Bentota river valley is facing the natural phenomena of flooding in the rainy season and saltwater intrusion in the dry season annually and at present more than 80% of paddy lands in of Bentota river basin have been abandon and converted for other uses which are not productive due to contrasting degrees of saltwater intrusion. Weather data on monthly mean temperature, total monthly rainfall, and maximum daily rainfall value for each month and total annual rainfall from year 1986 to 2015 that recorded at three weather stations located in Bentota River basin was obtained from the Metrological Department of Sri Lanka. According to Aziz (2013) weather station data provide accurate information on weather condition around the vicinity of the instrument. Therefore, it is assumed that the data recorded from available all three weather stations in Bentota River basin are perfectly very similar to the weather conditions of the area.

3. Data Analysis and Results

The temporal distribution of average total monthly rainfall and average maximum daily rainfall value during each month of all three whether stations located in Bentota River basin as Agalawatte, Bentotawatta and Pallegoda can be illustrated by Figure 1. Table 1 shows the descriptive statistics of the temporal distribution of whether data on monthly mean temperature, total monthly rainfall and maximum daily rainfall value from year 1986 to 2015. Accordingly highest temperature in Bentota area is about 29.2 oC during months of March and April and lowest temperature is about 25.6 oC during months of July and August in every year being the mean temperature as 27.3 ^{O}C. There are no more variations among the temperature of that each particular month during last 30 years since the values of coefficient of variation for each month varies from 0.01 to 0.02 for all months. Mean total monthly rainfall in Bentota River basin is 328mm. Bentota River basin has been received relatively high total monthly rainfall (600mm) with effect of southwest monsoon during the month of May and with effect of second inter monsoon during the month of October. The area is not receiving much rainfall from Northeast monsoon. Hare (2003), coefficient of variation (CV) is used to classify the degree of variability of rainfall events as less ($CV < 0.20$), moderate ($0.20 < CV < 0.40$), and high ($CV > 0.40$). Total monthly rainfall values with respect to months of January, February and July show the values of coefficient of variation as 0.65, 0.82 and 0.68 respectively by emphasizing the high degree of variation in total monthly rainfall values during these months from 1986 to 2015. Oldeman (1975) has defined that the wet months are the months which total monthly rainfall is greater than 200 mm and the dry months are the months which total monthly rainfall is lower than 100 mm. This criterion is more applicable for annual crops, especially rain fed rice. Schmidt and Ferguson (1951) used a different criteria, in which the wet months are those with >100 mm total monthly rainfall and the dry months are those with <60 mm total monthly rainfall. This latter criterion is usually used for, but not limited to perennial crops. Since Bentota River basin is located in wet zone of Sri Lanka and area is predominantly based on rain fed agriculture, the first definition was considered. Accordingly months of January and February can be considered as the dry months since the average total monthly rainfall of these two months during last 30 years is approximately less than 100mm and remaining months can be considered as wet month since the average total monthly rainfall during those months during last 30 years is more than 200mm.

Table 1 Descriptive statistics of the temporal distribution of whether data from 1986-2015

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temperature in Bentota River basin from 1986-2015												
Mean	27.1	27.6	28	28.1	27.8	27.3	27	26.9	27	27	27.2	27.1
Median	27.1	27.6	28	28.1	28	27.5	27.1	26.9	27.1	27.1	27.3	27.1
Sd	0.4	0.5	0.5	0.4	0.6	0.5	0.5	0.3	0.4	0.5	0.4	0.5
Minimum	26.2	26.7	27.1	27.2	26.1	26.3	25.6	25.8	25.9	26.2	26.4	26
Maximum	28.1	28.5	29.2	29.2	28.7	27.8	27.7	27.5	27.5	27.8	27.7	28
CV	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.02
Total Monthly Rainfall in Bentota River basin from 1986-2015												
Mean	161.7	122.4	222.3	421.8	562.9	424.4	303.5	296.0	433.1	557.9	391.4	276.7
Median	139.9	114.4	208.1	378.8	562.7	393.4	261.2	277.4	407.6	581.2	383.2	242.4
Sd	91.3	94.2	117.6	151.6	212.3	167.5	178.0	145.1	183.2	195.8	113.4	125.0
Minimum	45.8	0.0	2.6	173.4	88.4	173.6	24.9	46.7	109.2	192.1	170.2	60.7
Maximum	404.1	358.6	458.9	703.1	1069.6	931.9	887.0	729.7	762.5	1069.8	612.0	517.0
CV	0.65	0.82	0.56	0.40	0.38	0.43	0.68	0.52	0.45	0.34	0.30	0.52
Maximum Daily Rainfall in Bentota River basin from 1986-2015												
Mean	57.0	38.8	60.5	92.3	116.7	95.6	75.6	68.2	92.2	98.0	75.1	73.1
Median	51.0	35.5	56.0	89.0	112.0	79.0	54.1	67.8	89.0	94.8	64.0	67.5
Sd	25.2	25.9	30.4	41.0	56.8	82.3	59.2	30.3	46.3	35.8	30.5	31.4
Minimum	19.1	0.0	2.2	41.9	23.2	28.6	8.2	18.7	23.1	39.8	35.8	32.8
Maximum	127.0	107.4	165.5	243.4	308.0	443.8	266.5	145.0	201.6	219.1	164.0	145.0
CV	0.44	0.67	0.50	0.44	0.49	0.86	0.78	0.44	0.50	0.36	0.41	0.43

Mean annual rainfall in the area is 3933mm with a range from 3096mm to 4699mm showing less degree of variations (CV=0.12) and the stable climate conditions during last 30 years. Total Annual Rainfall is greater than 4400mm (mean+SD) in years of 1988, 1993, 1995, 1998, 1999 and 2008. Mean maximum daily rainfall value in the area is 420mm. Coefficient of variation

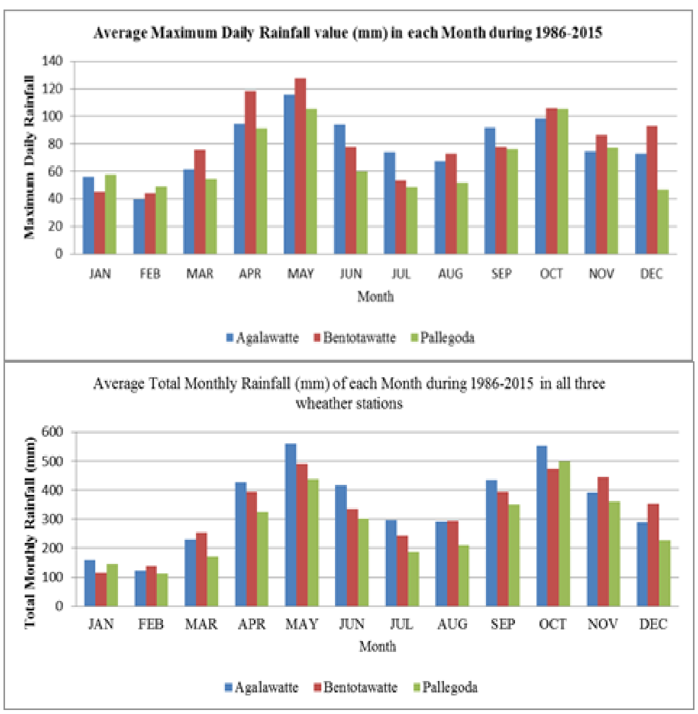

***Figure 1** The temporal distribution of average total monthly rainfall and average maximum daily rainfall value*

values of maximum daily rainfall values with respect to months of February, June and July show as 0.67, 0.86 and 0.78 respectively by emphasizing the high degree of variations in maximum daily rainfall values during these months from year 1986 to 2015. Since the coefficient of variation of maximum daily rainfall with respect to months of May and October show moderate degree of variations, comparatively highest maximum daily rainfall is received in the area during these two months in every year.

The dates which maximum daily rainfall value is more than 200mm in all three whether stations and overall Bentota River Basin from year 1986 to 2015 is shown by Table 2. Here maximum daily rainfall values for Bentota river basin is calculated considering average value of maximum daily rainfall values of all three weather stations. These dates were further more evidenced by the past flood records of the area and comparatively minor flood situations could be observed in year 1993, 1998, 2003, 2008 by indicating flood occurrence period as once in five years and major flood situations could be observed in year 2010 and 2014. According to the past flood records of the area, comparatively minor flood situation can be defined as when maximum daily rainfall of each whether station is in between 200mm to 300mm and major flood situation would be when maximum daily rainfall of each whether station is in between 350-450mm.

The general time series plot of collected weather data indicated a cyclical pattern due to the effect of seasonality component and an irregular way with indicating an increasing or decreasing trend. Weather data was subjected to time series tests were analyzed applying decomposition method which include trend, cycle, seasonal and irregular components using Microsoft Excel 2013. First, Moving Average (MA12) and Centered Moving Average (CMA12) methods were applied sequentially to make the time series in to smooth curve reducing the impacts on seasonality and irregularity. This CMA series can be named as 'base line' which shows the amount of fluctuation to up and down from the base line. Decomposition Method {Yt= f (St, It, Tt)} was applied with multiplicative model to identify trend cycle and seasonal analysis. When applying decomposition method, the patterns of seasonal and irregular

Table 2 *The Dates which Maximum daily rainfall value is more than 200mm in each Month from 1986-2015*

Agalawatte				Bentotawatte				Pallegoda				Overall Bentota River Basin			
Year	Month	Date	MDR	Year	Month	Date	MDR	Year	Month	Date	MDR	Year	Month	Date	MDR
1993	MAY	27	256									1993	MAY	27	256
1998	MAY	17	266									1998	MAY	17	266
2003	MAY	6	308					2003	MAY	6	232	2003	MAY	6	270
2008	MAY	1	259	2008	MAY	1	203	2008	MAY	1	205	2008	MAY	1	222
2010	MAY	23	440	2010	MAY	23	400	2010	MAY	23	420	2010	MAY	23	420
2014	JUN	1	444	2014	JUN	1	364	2014	JUN	1	392	2014	JUN	1	400

MDRV- Maximum Daily Rainfall

component (St, It) were identified by dividing the original observation by the CMA values. The average seasonal data (St) for each month were calculated later on. Then the seasonally adjusted data are computed by dividing the original observation by the seasonal component which can be known as 'de- seasonal data' (Yt/St =Tt × It). The trend line equation was derived applying simple liner regression (SLR) analysis and trend values (Tt) were calculated considering original observation of weather data as dependent variable and time (t) as independent variable. Multiplicative Model (Yt= St × It × Tt) was applied for forecasting weather data. Pearson correlation coefficient value was calculated in order to identify the reliability and the accuracy of the forecasted values comparing them with original observation of weather data. Table 3 illustrates the analysis of total monthly rainfall data for year 1986 only. Same analysis was applied for total monthly rainfall values for other years up to year 2015 and other whether data of all three whether stations and overall values for Bentota river basin. These developed Multiplicative models were used to forecast the rainfall and temperature values from year 2016 to 2025.

Trend component of monthly mean temperature, total monthly rainfall, maximum daily rainfall value for each month and total annual rainfall from year 1986 to 2015 that recorded at three weather stations located in Bentota River basin can be illustrated by Figure 2,3,4 and 5. The relevant equation of each trend line is indicated by respective color on each figure with reference to all three whether stations and overall Bentota river basin. Overall rainfall values for Bentota river basin is calculated considering average value of rainfall values of all three weather stations. Independent variable (x) for total annual rainfall analysis is time (t) which considered as the number of years from year 1986. Independent variable (x) for total monthly rainfall, maximum daily rainfall and temperature analyses is time (t) which considered as number of months from the month of start year for each weather station.

Trend component of time series analysis of monthly mean temperature shows an increasing trend with 0.0011 ^{O}C increment per month (Figure 2). Pearson correlation coefficient value between actual and forecasted monthly mean temperature values for each month indicates a positive strong linear relationship with 0.677 correlation coefficient value and it emphasizes the forecasted values are more or less similar to actual values (Table 3). In Mann–Kendall's Test, the computed p-value (0.0001) is lower than the significance level (alpha=0.0) and the null hypothesis H0 can be rejected and accept the alternative hypothesis Ha says that there is a trend in the series of monthly mean temperature. Seasonal Mann-Kendall test shows that there is a trend from one month to another in each year since p value (0.0001) is lower than the significance level (Table 7 and 8). Deviation of monthly mean temperature values from CMA called as average seasonal component values and average actual temperature values for each month during 1986-2015 was calculated (Table 4). Considering the seasonal component and trend component of time series analysis of monthly mean temperature, average actual temperature for each month during 1986-2015 and average forecasted temperature for each month from year 2016-2025 was calculated (Table 4) and Pearson correlation coefficient value between them is 0.999. It highlights that Area may have high temperature during Month of April and May in future too under the prevailing climate change scenario.

Trend component of time series analysis of total monthly rainfall of overall Bentota River basin shows a decreasing trend with -0.0507 mm decline per

Table 3 *Time series Analysis for Total Monthly Rainfall (mm) of Agalawatta weather station in Bentota River Basin 1986-2015*

t (x)	Year	Month	Total Monthly Rainfall (mm) (Yt)	MA(12)	Centered moving Average - CMA(12)	Yt/CMA (12) St,It	St	Deseasonalised data = (Yt/St)	SLR Trend Component of Total Monthly Rainfall (mm) - Tt	Multiplication Forecasted Total Monthly Rainfall (mm) = Stx Tt
1	1986	JAN	94.7				0.47	202.4	329.42	154.12
2		FEB	167.4	339.6	345.4	0.48	0.35	477.7	329.50	115.46
3		MAR	512.2	351.3	344.8	1.49	0.68	755.4	329.59	223.47
4		APR	576.4	338.4	320.2	1.80	1.24	466.5	329.67	407.37
5		MAY	498.1	302.1	297.6	1.67	1.61	309.0	329.75	531.48
6		JUN	192.9	293.2	291.5	0.66	1.19	161.9	329.84	393.02
7		JUL	136.6	289.9	294.8	0.46	0.86	159.4	329.92	282.77
8		AUG	201.2	299.7	295.0	0.68	0.84	240.4	330.00	276.15
9		SEP	482.3	290.4	312.4	1.54	1.24	388.0	330.09	410.30
10		OCT	425.4	334.4	331.3	1.28	1.59	268.3	330.17	523.44
11		NOV	427.8	328.2	339.9	1.26	1.12	382.4	330.26	369.46
12		DEC	359.9	351.7	349.2	1.03	0.83	433.7	330.34	274.11
	.	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.
360	2015	DEC	347.5				0.83	418.8	359.46	

Table 4: Regression and Descriptive statistics of Temperature and Rainfall Data

Climatological Variable	Regression Statistics					Descriptive Statistics						
	r^2	Intercept	Slope	F	Sig	R1	R2	Mean	SD	Min	Max	CV
Temperature	0.065	27.130	0.0011	24.6	0.000	0.677	0.999	27.3	0.61	25.6	29.2	0.02
Agalawatte TMR	0.004	329.33	0.1032	1.6	0.062	0.665	0.999	346.6	198	0.0	1069	0.57
Bentotawate TMR	0.003	350	-0.2378	0.27	0.076	0.698	0.993	330	167	8.0	825	0.51
Pallegoda TMR	0.005	271.59	0.058	0.12	0.080	0.657	0.999	277	176	0	854	0.64
Overall Bentota River Basin TMR	0.001	335.85	-0.0507	0.42	0.057	0.683	0.999	328	190	0	1069	0.58
Agalawatte MDR	0.012	69.77	0.0454	4.5	0.034	0.434	0.997	78.5	48	0	444	0.61
Bentotawate MDR	0.003	85.39	-0.0836	0.33	0.015	0.517	0.996	81	49	5.2	317	0.60
Pallegoda MDR	0.004	69.76	-0.0165	0.15	0.009	0.510	0.998	69	41.5	6	253	0.60
Overall Bentota River Basin MDR	0.002	71.55	0.0166	0.79	0.003	0.479	0.998	75	41	0	420	0.55
Total annual rainfall of Bentota River Basin	0.057	28701.24	-12.38	1.69	0.202	-	-	3933	455.64	3096	4699	0.12

R1- Pearson correlation coefficient value between Actual and Forecasted Values for Each Month from 1986-2015
R2- Pearson correlation coefficient value between Average Actual and Forecasted Values for Each Month
TMR-Total Monthly Rainfall
MDRV Maximum Daily Rainfall value in each Month
SD- Standard Deviation
CV- Coefficient of Variance (=SD/Mean)
Note: independent variable (x) is time (t) which considered as the year from year1986 for total annual rainfall and independent variable (x) is time (t) which considered as number of months from the month of start year of each whether station for other climatological variables

month (Figure 3). Pearson correlation coefficient value between actual and forecasted total monthly rainfall values of overall Bentota River basin for each month indicates a positive strong linear relationship with 0.683 correlation coefficient value and it emphasizes the forecasted values are more or less similar to actual values (Table 4). In MK Test, the computed p-value (0.723) is greater than the significance level (0.05) and one cannot reject the null hypothesis H0 says that there is no trend in the series of total monthly rainfall. In Seasonal Mann-Kendall Test, the computed p-value (0.849) is greater than the significance level (0.05) and one cannot reject the null hypothesis H0 says that there is no trend from one month to another in the series of total monthly rainfall (Table 7 and 8). The computed p-values of two MK tests are greater than the significance level 0.05 for total monthly rainfall of all three whether stations that implying no trend in the series even from one month to another. Considering the seasonal component and trend component of time series analysis of total monthly rainfall; average actual total monthly rainfall for each month during 1986-2015 and average forecasted total monthly rainfall for each month from year 2016- 2025 for all three whether stations and overall Bentota River basin was calculated (Table 5) and Pearson correlation coefficient values between average actual total monthly rainfall and average forecasted total monthly rainfall values for each month of all three whether station and overall Bentota River Basin are near to 0.9 and it highlights the accuracy of the prediction of total monthly rainfall up to year 2025. Bentota area may have high total monthly rainfall during Month of May and October in future under

***Table 5** Average Monthly Mean temperature (oC) of each Month during 1986-2025*

Month	Seasonal component (Deviation of monthly mean temperature values from CMA)	Average actual monthly mean temperature for each month during 1986-2015	Average forecast-ed monthly mean tempera-ture for each month during 2016-2025
JAN	0.991	27.08	27.36
FEB	1.010	27.57	27.88
MAR	1.024	27.97	28.27
APR	1.028	28.07	28.37
MAY	1.016	27.77	28.05
JUN	0.996	27.22	27.49
JUL	0.986	26.98	27.24
AUG	0.984	26.92	27.18
SEP	0.985	26.94	27.21
OCT	0.987	27.01	27.26
NOV	0.994	27.17	27.44
DEC	0.991	27.13	27.38

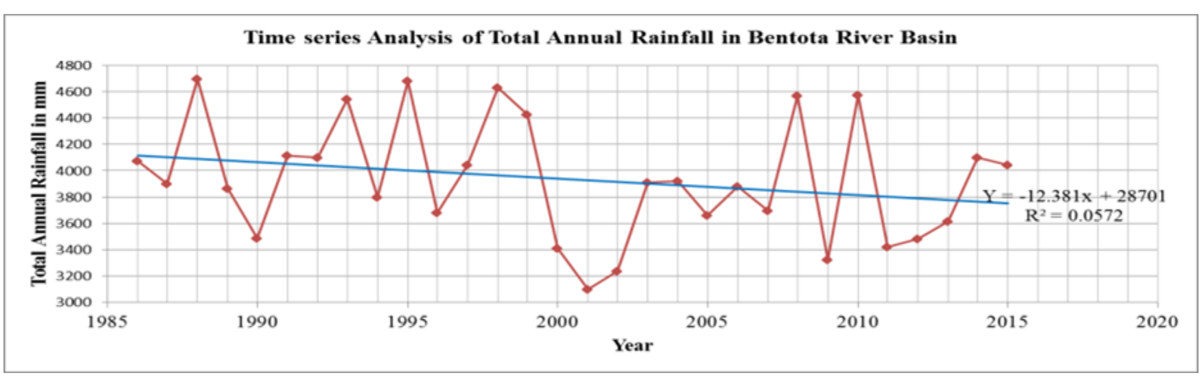

***Figure 5** Time series Analysis for Annual Rainfall Value in Bentota River Basin from 1986 to 2015*

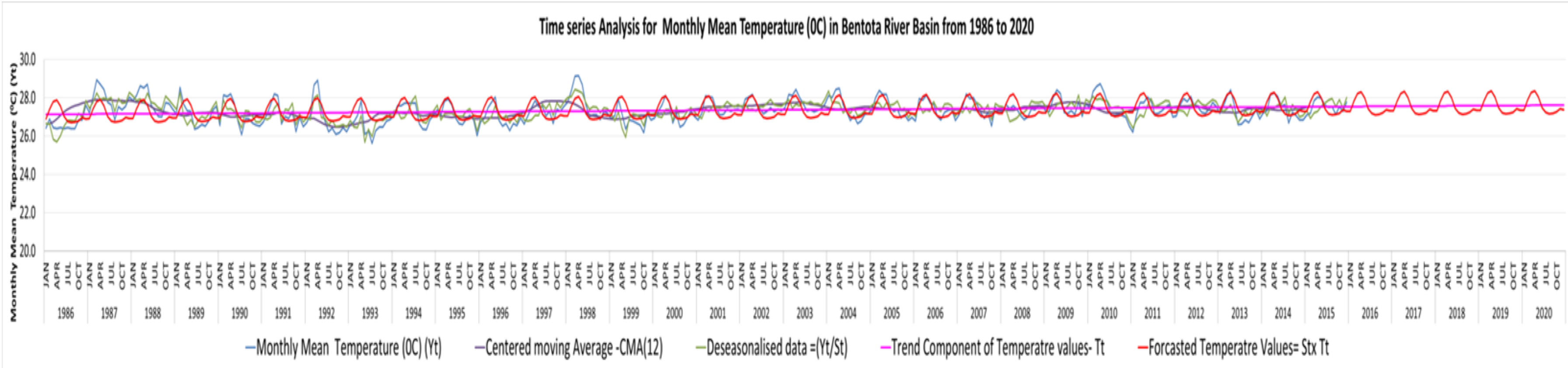

Figure 2 *Time series Analysis for Monthly Mean Temperature (0C) in Bentota River Basin from 1986 to 2020*

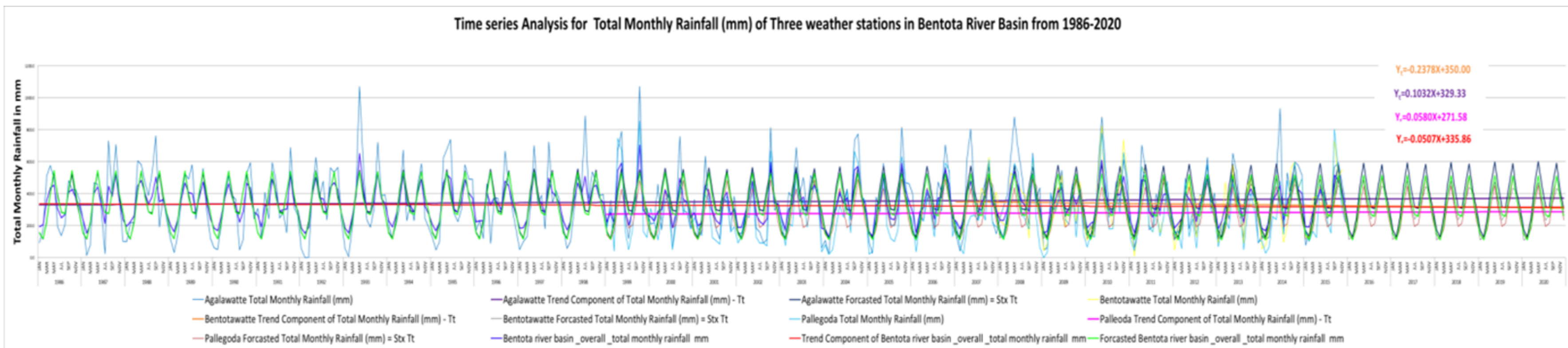

Figure 3 *Time series Analysis for Total Monthly Rainfall (mm) in Bentota River Basin from 1986 to 2020*

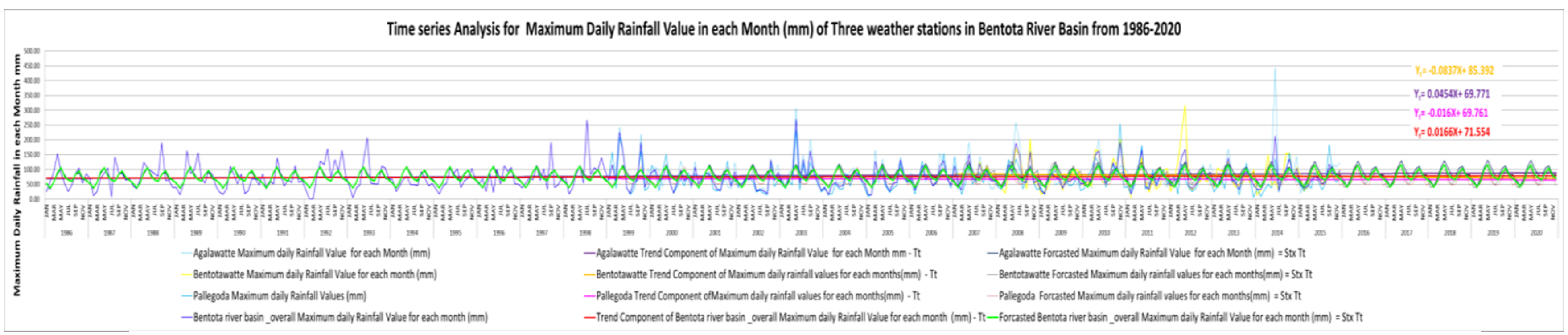

Figure 4 *Time series Analysis for Maximum Daily Rainfall Value in each Month (mm) in Bentota River Basin from 1986 to 2020*

***Table 6** Average Total Monthly Rainfall (mm) of each Month during 1986-2025*

Month	Agalawatte			Bentotawatte			Pallegoda			Bentota River Basin		
	SC	ATMR	FTMR	SC	ATMR	FTMR	SC	ATMR	FTMR	SC	ATMR	FTMR
JAN	0.468	159.45	174.12	0.350	115.29	108.98	0.529	145.14	151.60	0.470	149.81	147.94
FEB	0.350	123.91	130.45	0.413	138.67	128.59	0.411	112.36	117.91	0.350	113.58	110.14
MAR	0.678	231.95	252.47	0.775	253.16	240.74	0.636	173.13	182.33	0.648	208.46	204.06
APR	1.236	426.94	460.26	1.208	394.35	375.03	1.168	324.29	334.97	1.225	396.26	385.56
MAY	1.612	560.70	600.50	1.505	490.84	466.94	1.575	437.22	451.76	1.625	529.21	511.32
JUN	1.192	416.70	444.07	1.021	334.26	316.63	1.076	301.15	308.76	1.138	373.21	357.88
JUL	0.857	297.95	319.50	0.748	242.97	231.59	0.682	186.22	195.74	0.851	281.08	267.62
AUG	0.837	292.82	312.03	0.869	293.44	268.93	0.752	211.01	215.93	0.815	268.77	256.32
SEP	1.243	434.76	463.62	1.107	393.56	342.54	1.224	350.57	351.42	1.243	415.78	390.86
OCT	1.585	553.53	591.48	1.391	472.74	430.02	1.774	498.75	509.41	1.624	530.89	510.50
NOV	1.119	392.60	417.49	1.312	446.74	405.32	1.310	361.62	376.13	1.188	390.63	373.27
DEC	0.830	289.19	309.75	0.967	352.96	298.56	0.821	228.34	235.70	0.838	275.16	263.39

SC- Seasonal component (Deviation of Total Monthly Rainfall (mm) values from CMA)
ATMR- Average (Mean) Actual Total Monthly Rainfall (mm) of each Month during 1986-2015
FTMR- Average (Mean) Forecasted Total Monthly Rainfall (mm) of each month during 2016-2025

***Table 7** Average Maximum Daily Rainfall value (mm) in each Month during 1986-2025*

Month	Agalawatte			Bentotawatte			Pallegoda			Bentota River Basin		
	SC	AMDR	FMDR	SC	AMDR	FMDR	SC	AMDR	FMDR	SC	AMDR	FMDR
JAN	0.743	55.93	65.87	0.566	44.81	40.63	0.835	57.54	54.64	0.747	54.42	58.65
FEB	0.496	39.50	43.99	0.536	44.10	38.45	0.690	48.79	45.17	0.529	39.71	41.51
MAR	0.819	61.43	72.66	0.951	75.71	68.09	0.800	54.27	52.32	0.781	56.49	61.27
APR	1.214	94.37	107.75	1.404	118.15	100.37	1.316	91.44	86.09	1.269	94.41	99.62
MAY	1.488	115.77	132.15	1.519	127.85	108.51	1.526	105.51	99.82	1.488	110.37	116.82
JUN	1.176	94.19	104.50	0.965	77.89	68.85	0.872	59.89	57.00	1.075	80.74	84.45
JUL	0.920	73.89	81.82	0.654	53.22	46.63	0.746	48.31	48.76	0.919	70.17	72.23
AUG	0.871	67.53	77.51	0.900	72.78	64.07	0.754	51.81	49.28	0.842	63.31	66.14
SEP	1.183	91.97	105.26	0.947	77.86	67.29	1.124	76.14	73.42	1.161	87.93	91.21
OCT	1.269	98.27	113.00	1.363	106.08	96.74	1.579	105.31	103.14	1.338	98.42	105.22
NOV	0.946	74.40	84.27	1.048	86.56	74.28	1.142	77.31	74.60	1.029	76.83	80.90
DEC	0.929	72.91	82.77	1.157	92.79	81.95	0.708	46.96	46.24	0.883	66.47	69.48

SC- Seasonal component (Deviation of Maximum daily Rainfall (mm) value in each month from CMA)
AMDR- Average Actual Maximum Daily Rainfall value (mm) in each Month during 1986-2015
FMDR- Average Forecasted Maximum Daily Rainfall value (mm) in each Month during 2016-2025

the prevailing climate change scenario (Figure 5). There is comparatively high degree of variations of total monthly rainfall of all three whether stations and there is no difference among them since CV are around 0.6.

Trend component of time series analysis of maximum daily rainfall of overall Bentota River basin shows an increasing trend with 0.0166mm increment per month (Figure 4). Pearson correlation coefficient value between actual and forecasted maximum daily rainfall of overall Bentota River basin for each month indicates a positive moderate linear relationship with 0.479 correlation coefficient value and it emphasizes most of the forecasted values are more or less similar to actual values (Table 4). In Mann–Kendall's Test for maximum daily rainfall of overall Bentota River basin, the computed p-value (0.035) is lower than the significance level 0.05, the null hypothesis H0 should be rejected, and accept the alternative hypothesis Ha says that there is a trend in the series of maximum daily rainfall of overall Bentota River basin. Seasonal Mann-Kendall Test of maximum daily rainfall of overall Bentota River basin shows that there is a trend from one month to another in each year since p value (0.043) is lower than the significance level (Table 8 and 9). The computed p-values of two MK tests are greater than the significance level 0.05 for maximum daily rainfall of Pallegoda and Bentotawatte whether stations that implying no trend in the series even from one month to another. But p value (0.025) of MK test and p value (0.023) of seasonal MK test for maximum daily rainfall of Agalawatte station is lower than the significance level; there is trend in the maximum daily rainfall of Agalawatte station and from one month to another in each year as well. Considering the seasonal component and trend component of time series analysis of maximum daily rainfall, average actual maximum daily rainfall for each month during 1986-2015 and average forecasted maximum daily rainfall for each month during 2016-2025 for all three whether stations and overall Bentota River basin was calculated (Table 6). Pearson correlation coefficient values between average actual maximum daily rainfall and average forecasted maximum daily rainfall values for each month of all three whether station and overall Bentota River Basin are near to 0.9 and it highlights that Bentota area may have high maximum daily rainfall during Month of May and October in future under the prevailing climate change scenario (Figure 5). The degree of variations of maximum daily rainfall of all three whether stations is relatively high and making difference being the highest is at Pallegoda and lowest is at Bentota Watte.

Trend component of time series analysis of annual rainfall of overall Bentota River basin shows a decreasing trend with -12.38 mm per year (Figure 5). In Mann–Kendall's Test for annual rainfall of overall Bentota River basin, the computed p-value (0.201) is greater than the significance level 0.05, one

__Table 6__ Average Total Monthly Rainfall (mm) of each Month during 1986-2025

Month	Agalawatte			Bentotawatte			Pallegoda			Bentota River Basin		
	SC	ATMR	FTMR	SC	ATMR	FTMR	SC	ATMR	FTMR	SC	ATMR	FTMR
JAN	0.468	159.45	174.12	0.350	115.29	108.98	0.529	145.14	151.60	0.470	149.81	147.94
FEB	0.350	123.91	130.45	0.413	138.67	128.59	0.411	112.36	117.91	0.350	113.58	110.14
MAR	0.678	231.95	252.47	0.775	253.16	240.74	0.636	173.13	182.33	0.648	208.46	204.06
APR	1.236	426.94	460.26	1.208	394.35	375.03	1.168	324.29	334.97	1.225	396.26	385.56
MAY	1.612	560.70	600.50	1.505	490.84	466.94	1.575	437.22	451.76	1.625	529.21	511.32
JUN	1.192	416.70	444.07	1.021	334.26	316.63	1.076	301.15	308.76	1.138	373.21	357.88
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AUG	0.837	292.82	312.03	0.869	293.44	268.93	0.752	211.01	215.93	0.815	268.77	256.32
SEP	1.243	434.76	463.62	1.107	393.56	342.54	1.224	350.57	351.42	1.243	415.78	390.86
OCT	1.585	553.53	591.48	1.391	472.74	430.02	1.774	498.75	509.41	1.624	530.89	510.50
NOV	1.119	392.60	417.49	1.312	446.74	405.32	1.310	361.62	376.13	1.188	390.63	373.27
DEC	0.830	289.19	309.75	0.967	352.96	298.56	0.821	228.34	235.70	0.838	275.16	263.39

SC- Seasonal component (Deviation of Total Monthly Rainfall (mm) values from CMA)
ATMR- Average (Mean) Actual Total Monthly Rainfall (mm) of each Month during 1986-2015
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__Table 7__ Average Maximum Daily Rainfall value (mm) in each Month during 1986-2025

Month	Agalawatte			Bentotawatte			Pallegoda			Bentota River Basin		
	SC	AMDR	FMDR	SC	AMDR	FMDR	SC	AMDR	FMDR	SC	AMDR	FMDR
JAN	0.743	55.93	65.87	0.566	44.81	40.63	0.835	57.54	54.64	0.747	54.42	58.65
FEB	0.496	39.50	43.99	0.536	44.10	38.45	0.690	48.79	45.17	0.529	39.71	41.51
MAR	0.819	61.43	72.66	0.951	75.71	68.09	0.800	54.27	52.32	0.781	56.49	61.27
APR	1.214	94.37	107.75	1.404	118.15	100.37	1.316	91.44	86.09	1.269	94.41	99.62
MAY	1.488	115.77	132.15	1.519	127.85	108.51	1.526	105.51	99.82	1.488	110.37	116.82
JUN	1.176	94.19	104.50	0.965	77.89	68.85	0.872	59.89	57.00	1.075	80.74	84.45
JUL	0.920	73.89	81.82	0.654	53.22	46.63	0.746	48.31	48.76	0.919	70.17	72.23
AUG	0.871	67.53	77.51	0.900	72.78	64.07	0.754	51.81	49.28	0.842	63.31	66.14
SEP	1.183	91.97	105.26	0.947	77.86	67.29	1.124	76.14	73.42	1.161	87.93	91.21
OCT	1.269	98.27	113.00	1.363	106.08	96.74	1.579	105.31	103.14	1.338	98.42	105.22
NOV	0.946	74.40	84.27	1.048	86.56	74.28	1.142	77.31	74.60	1.029	76.83	80.90
DEC	0.929	72.91	82.77	1.157	92.79	81.95	0.708	46.96	46.24	0.883	66.47	69.48

SC- Seasonal component (Deviation of Maximum daily Rainfall (mm) value in each month from CMA)
AMDR- Average Actual Maximum Daily Rainfall value (mm) in each Month during 1986-2015
FMDR- Average Forecasted Maximum Daily Rainfall value (mm) in each Month during 2016-2025

cannot reject the null hypothesis H0 says that there is no trend in the series of annual rainfall (Table 8). Inverse Distance Weighted tool in Arc GIS 10.3 was used to estimate cell values by averaging the values of forecasted total monthly rainfall value during Yala and Maha season of all weather stations for year 2016-2025 period. The spatial distribution of forecasted total monthly rainfall during Yala season from March to August and during Maha season from month of September to February during the period of year 2016- 2025 for Bentota Divisional Secretariat division Area can be shown by Figure 6 and Figure 7.

In past, during the Yala season from March to August, the area has been

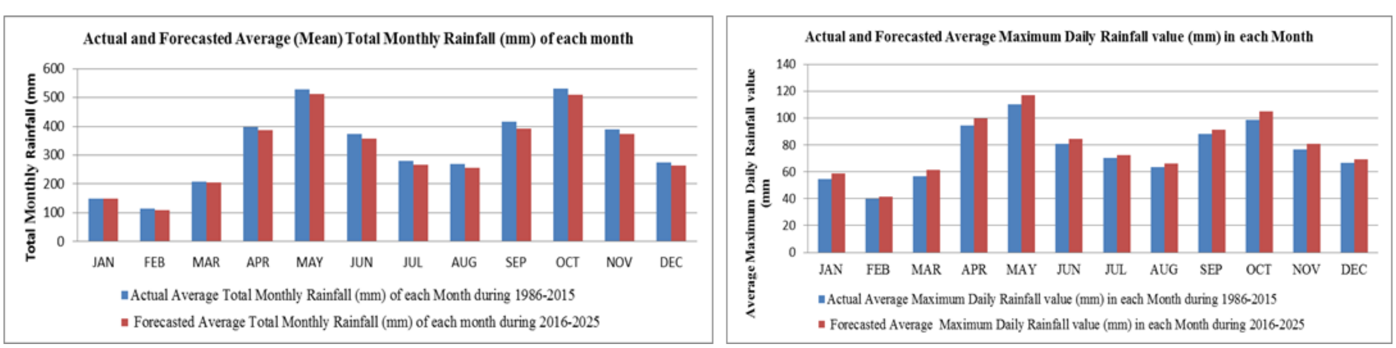

__Figure 6__ Actual and Forecasted total monthly rainfall and maximum daily rainfall from year 1986 to 2015

Table 8 *Mann–Kendall's Test*

Weather Station and data type	No. years	Mann–Kendall's Test H0: there is no trend in the series Ha: There is a trend in the series					
		Mann–Kendall stat (S)	Var. (S)	Kendall's tau	P-value	Sen's slope	Test interpretation
Temperature BRB	30	9604.0	5205482	0.148	0.0001*	0.001	Reject H0, Accept Ha.
Agalawatte TMR	30	1904	5205496	0.029	0.404	0.080	Accept H0.
Bentotawatte TMR	9	50	116145	0.010	0.886	0.073	Accept H0.
Pallegoda TMR	17	838	950173	0.04	0.391	0.168	Accept H0.
BRB: TMR	30	-810	5205500	-0.013	0.723	-0.036	Accept H0.
Agalawatte MDR	30	3492	5205426	0.054	0.025*	0.028	Accept H0.
Bentotawatte MDR	9	-82	119574	-0.016	0.815	-0.024	Accept H0.
Pallegoda MDR	17	105	950085	0.005	0.915	0.004	Accept H0.
BRB: MDR	30	1982	5205466	0.031	0.035*	0.015	Reject H0, accept Ha.
Total annual rainfall BRB	30	-73	0	-0.168	0.201	-12.53	Cannot reject H0.

Table 9 *Seasonal Mann-Kendall Test*

Weather Station and data type	No. years	Seasonal Mann-Kendall Test / Period = 12 / Serial independence H0: there is no trend in the series Ha: There is a trend in the series				
		Mann–Kendall stat (S)	Ken-dall's tau	P-value	Sen's slope	Test interpretation
Temperature BRB	30	1012	0.194	0.0001*	0.016	Reject H0, and accept Ha.
Agalawatte TMR	30	267	0.051	0.171	0.977	Accept H0.
Bentotawatte TMR	9	-11	-0.033	0.721	-6.09	Accept H0.
Pallegoda TMR	17	60	0.037	0.483	1.967	Accept H0.
Overall BRB:TMR	30	-38	-0.007	0.849	-0.543	Accept H0.
Agalawatte MDR	30	443	0.085	0.023*	0.537	Reject H0, and accept Ha.
Bentotawatte MDR	9	-19	-0.057	0.520	-0.65	Accept H0.
Pallegoda MDR	17	43	0.026	0.617	0.146	Accept H0.
Overall BRB:MDR	30	393	0.075	0.043*	0.5	Reject H0, and accept Ha.

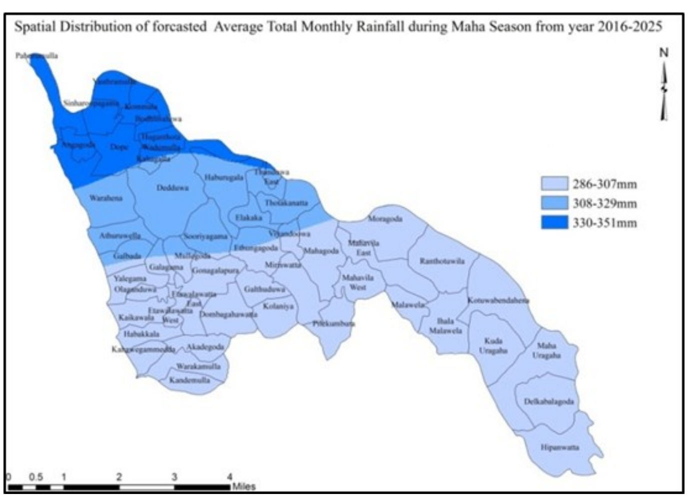

Figure 7 *The spatial distribution of forecasted total monthly rainfall during Yala season from March to August*

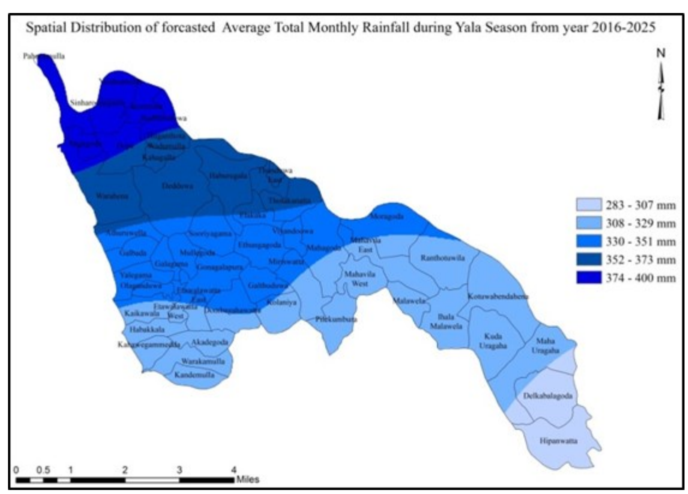

Figure 8 *The spatial distribution of forecasted total monthly rainfall during Maha season from September to February*

received averagely 343mm rainfall and during Maha season from September to February, the area has been received averagely 313mm rainfall. According to time series analysis, during Yala season the area will be received comparatively more rainfall (331mm) than Maha season (300mm) in future. Since the Trend component of time series analysis of total monthly rainfall of overall Bentota River basin shows a decreasing trend, the amount of total monthly rainfall to be received in future will be decreased. Community and the farmers who live in this area can be aware about the anticipated spatial distribution of total monthly rainfall during two major paddy cultivating season of the area and major and minor flood occurrence periods.

4. Conclusions

Identification of the factors and related measures on land qualities and characteristics that use to evaluate the land suitability is the first step in the process of land suitability classification. Forecasting temporal and spatial rainfall and temperature trends is necessary for examining the climatological factor in land suitability evaluations. This study forecasted the temporal and spatial rainfall and temperature trends in Bentota River basin by examining future climatic conditions in the area as one of the major factor that should be taken in to account in studies on land suitability evaluations. Highest temperature in Bentota area is recorded during months of March and April and lowest temperature is recorded during months of June, July and August in every year. Period of rainfall in a year in Sri Lanka has been divided into 4 categories as first inter monsoon period is from March to April, South west monsoon period is from May to September, Second inter monsoon period is from October to November and North east monsoon is from December to February. Bentota River basin receives the highest total monthly rainfall with effect of southwest monsoon during the month of May and with effect of second inter monsoon during the month of October. During the Yala season from March to August, the area is receiving comparatively high rainfall than Maha season from September to February. January and February can be considered as the dry months in the area. Minor flood occurrence period in the area is once in five years. Trend component of time series analysis of monthly mean temperature shows an increasing trend with 0.0011^{O}C increment per month. Maximum daily rainfall of overall Bentota River basin shows an increasing trend with 0.0166mm increment per month. Trend component of time series analysis of total monthly rainfall of overall Bentota River basin shows a decreasing trend with -0.0507 mm of decline per month while annual rainfall of overall Bentota River basin also shows a decreasing trend with -12.38 mm per year. The degree of variations of maximum daily rainfall and total monthly rainfall of all three whether stations are comparatively high and have similar variations of whether changes throughout the year. In future the area may have comparatively high temperature and less rainfall and can be expected extremes daily rainfall during month of May and October occurring minor flood situations. Land use planner, agriculturalists would evaluate the land suitability of the area for selecting specific lands for different types of land use by paying attention to this temporal and spatial climatological influence to the area under the context of future climate change on rainfall and temperature trend as one of the major factor that should be considered in land suitability evaluations. The approach and the methodology adopted in this study will be applied by other researchers, agriculturalist and planners to identify the future climatological influences and its spatial distribution pattern for land suitability evaluations and other decision making purposes for other areas.

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