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INVITED REVIEW

A REVIEW OF RECENT CHANGES IN RAINFALL TREND IN SRI LANKA

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Abstract

The rainfall trend provides useful information for effective planning, and management of water resources and agriculture which also gives an insight into the climate change of a region. The rainfall trend varies with the use of different data periods, and therefore, this review attempted to analyse only the recent rainfall trend over Sri Lanka using published literature. The review examined 15 recently published manuscripts for monotonic trends and statistical tests used. Overall, the review identified the increasing tendency of rainfall in the entire country prominently towards the eastern segment. The review also comprehends upward trends of First Inter-Monsoon and North-East monsoon over the country. It is proposed to introduce effective water management measures to harness the opportunities created by increased rainfall and preparedness measures to reduce the anticipated risk.

Keywords: Rainfall, Agriculture, Climate change, Effective water management

INTRODUCTION

Agriculture, particularly crop production, predominantly depends on the climate and natural resources. Water, one of the main natural resource inputs to agriculture, is under pressure with increasing demand from other sectors, impairment of water quality, and climate change and variability. The availability of appropriate quality and quantity of freshwater depends on the intensity, frequency, and variability of precipitation in Sri Lanka. According to AQUASTAT of FAO database, agriculture sector in Sri Lanka in 2018 withdrew 87.4 % of freshwater (FAO 2018). Water demand of crop irrigation, mainly for paddy cultivation, is high in the dry and intermediate zones of the country. Changing rainfall pattern, drought, and floods influence water availability for crop production and the entire Sri Lankan economy.

In general, higher temperature results in greater evaporation and surface drying potentially contributing to high intensity and duration of droughts. However, as the air warms, its water-holding capacity increases, particularly over the oceans. Clausius-Clapeyron equation indicates that the air can generally hold around 7% more moisture for every 1°C of temperature rise (Ingram 2016). Hence, a warmer world would have more water vapor in the atmosphere and can have potentially higher precipitation (Ingram 2016). At present, some areas of the world experience increased precipitation, while some areas are expected less due to shifting weather patterns and some other regional factors. Global Climate Models (GCM) simulates a 1.5 to 2 % K^{-1} increase in global mean rainfall as a result of surface warming of the Earth (Dey *et al*. 2018). Even in Sri Lanka, a significant warming trend is recorded at most places of the country (Sheikh *et al*. 2014). According to some past studies (Chandrapala1996; Jayatillake *et al*. 2005; De Costa 2008), precipitation changes are not that prominent or statistically significant though considerable variability had been recorded. Reviewing the precipitation changes delivers

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insights on reducing the risk and vulnerability of precipitation-related phenomena and agricultural planning in the future.

Rainfall change assessments in the near term can be based on understanding long-term trends from the observational records. Appropriate general circulation models can be used to project the rainfall status of the future. This article reviews the recent scientific literature on rainfall trends and variability in Sri Lanka to identify overall trends over the country. However, the review does not attempt to analyze the possible attributes for the change.

MATERIALS AND METHODS

The study collected 15 manuscripts on rainfall trend analysis which are recently published (2015 to 2021) using comparatively recent data set (at least up to 2010) from google scholar. These manuscripts were comprehensively analyzed for rainfall trends on an annual and seasonal scale (Table 1). Other than these 15 manuscripts, past research published in index journals was also considered when writing the discussion. Conference papers and abstracts published in relation to rainfall trend assessment were not considered. Rainfall trend assessment in Sri Lanka has been done occasionally, yet some instances without using a systematic approach. Thus, methodologies used by different authors were also reviewed in this article. Before discussing the trends, the article is organized to summarize the average accepted rainfall pattern in Sri Lanka so that the reader would understand the rainfall status over the country. Thereafter, the article is arranged to discuss the methodologies used and overall annual and seasonal rainfall trends by reviewing the recently published articles.

Rainfall pattern of Sri Lanka

The rainfall of Sri Lanka is the main form of precipitation and is mainly influenced by the Asian monsoonal system (Zubair *et al*. 2008). Further, tropical depressions that are specially generated from the Bay of Bengal, El Niño Southern Oscillation (ENSO), and Indian Ocean Dipole (IOD) like large-scale climatic oscillation influence the rainfall pattern of Sri Lanka. The orography created by central and south-central massif play a major role in the rainfall distribution over the island. The mean annual cycle of rainfall in Sri Lanka is bimodal with a major mode from October to December and a subsidiary mode from April to June (Zubair *et al*. 2008). The peaks of rainfall is mainly associated with the two monsoon seasons which are governed by the monsoon winds reaching from two opposite directions. Apart from two monsoon seasons, Sri Lanka gets rains mainly from convective mechanisms. The two monsoon seasons are referred to as the South-West Monsoon (SWM), which extends from May to September, and the North-East Monsoon (NEM) from December to February. The two inter-monsoon seasons are described as the First Inter-Monsoon (FIM) from March to April and the Second Inter-Monsoon (SIM) from October to November (Malmgren *et al*. 2003). During the FIM period, the entire southwestern section and hill country get over 250 mm of rainfall, with the localized area in the southwestern slopes experiencing rainfall in excess of 700 mm. Rainfall during the SWM period varies from about 100 mm to over 3,000 mm, and the highest rainfall is received in the mid-elevations of the western slopes of central highlands (Punyawardena and Abeysekera 2020). The SIM period is the most evenly balanced distribution of rainfall over Sri Lanka, where almost the entire island receives more than 400 mm of rain during this season, with southwestern slope receiving a higher rainfall in the range of 750 to 1,200 mm. The highest rainfall values are recorded during NEM in the northeastern slopes of the central hills with over 1,200 mm (Punyawardena and and Abeysekera 2020). The two monsoon rainfall seasons correspond to two distinct cropping seasons: the major cultivation season known as *Maha* (October–March) follows the NEM rainfall, and the minor cultivation season known as *Yala* (April–September) coincides with the SWM rainfall (Abeysingha and Rajapaksha 2020). However, climate change has changed the rainfall trend and pattern of Sri Lanka, which is discussed in the review paper. Traditionally, Sri Lanka is climatologically classified into three climatic zones: wet, dry, and intermediate, mainly based on the spatial distribution of rainfall. The area < 1750 mm of annual rain is classified as a dry zone, while the area that receives an annual rainfall between 1750 and 2500 mm is the intermediate zone. The area received > 2500mm of annual rain is classified as a wet zone (Nisansala *et al*. 2019).

Methodological review

Trend analysis is the use of an empirical approach to quantify and explain changes in a system over a period of time (Mozejko 2012). The technique is used to predict future values and movement of variables such as rainfall. It usually uses time-series observations over a significant period to predict the future behavior of that variable. The use of at least 30 years of data is the norm in the climate analysis (WMO 2011). Parametric, Non-parametric, Bayesian, Time series, and Resampling approaches are mainly used in trend detection studies for different hydrologic and climatic variables (Sonali and Kumar 2013). In the Sri Lankan context, Least-squares linear regression, Sen's slope estimator, Mann–Kendall and its modifications, Spearman rank correlation, and Innovative trend analysis approach (Table 1) have been mainly used to detect the monotonic trend of rainfall. Since some studies have not been followed precise approaches, methodologies used by the researchers for rainfall trend analysis were comprehensively analyzed in this review. Steps shown in the flow chart (Fig.1) can be identified as more rational and scientific and are followed by many studies published in high-impact journals (Nisansala *et al*. 2019; Patakamuri *et al*. 2020; Jenifer and Jha 2021).

Most of the rainfall trend studies published in reputed journals used to understand the variability of the data sets as the first step. In general, the variability of the collected data set can be easily visualized if the data set is subjected to scatter plots, box and whiskers plots etc. This gives an overview of the distribution of the collected data. Then, testing the time series data set for homogeneity has become a prerequisite for trend analysis in climate change assessment (Caloiero *et al*. 2020). The rainfall data sets are "homogenous" only when the recorded data are truly due to climatic variations (Lazaro *et al*. 2001) and not due to non-climatic factors (human-made mistakes and instrumental errors). Pettitt Test is one of the non-parametric homogeneity tests commonly used by researchers (Nisansala *et al*. 2019; Khaniya *et al*. 2019). However, it is always advantageous to use more than one homogeneity test in order to get robust decisions. As shown in the flow diagram (Fig.1), checking for missing values in the data series is also necessary, and then filling using appropriate methods is also recommended. Data set is then arranged to time series of annual, both cropping and rainfall seasonal, monthly and daily time scales for analysis. All these time series data set are then subjected to normality tests. If the data set is normally distributed, parametric tests such as linear regression are performed to investigate the monotonic trends. However, when the data set is not normally distributed, non-parametric tests are preferred. However, data transformations such as Box–Cox transformations can be used to achieve normality (Lai and Dzombak 2019). However, some studies were found the use of linear regression without data being transformed and not testing the data set for normality.

Most commonly used non-parametric test to detect the trend in Sri Lanka is Mann–Kendall (MK) test, and it is combined with the Sen's Slope test as MK test indicates only the trend direction, magnitude of the trend is expressed using Sen's slope estimator (Nisansala *et al*. 2019). However, MK test does not account for the serial correlation that very often exists in a rainfall time series (Abeysingha *et al*. 2017; Naveendrakumar *et al*. 2018). The presence of serial correlation in a data set may enhance the probability of finding a significant trend when actually there is no significant trend. Therefore, each time series rainfall data need to first check for a significant autocorrelation. If a time series does not show a significant autocorrelation, the original MK test analyzes the data. When there is a significant lag-one autocorrelation in a time series, two kinds of statistical procedures are developed to correct the MK-test for autocorrelation. These are

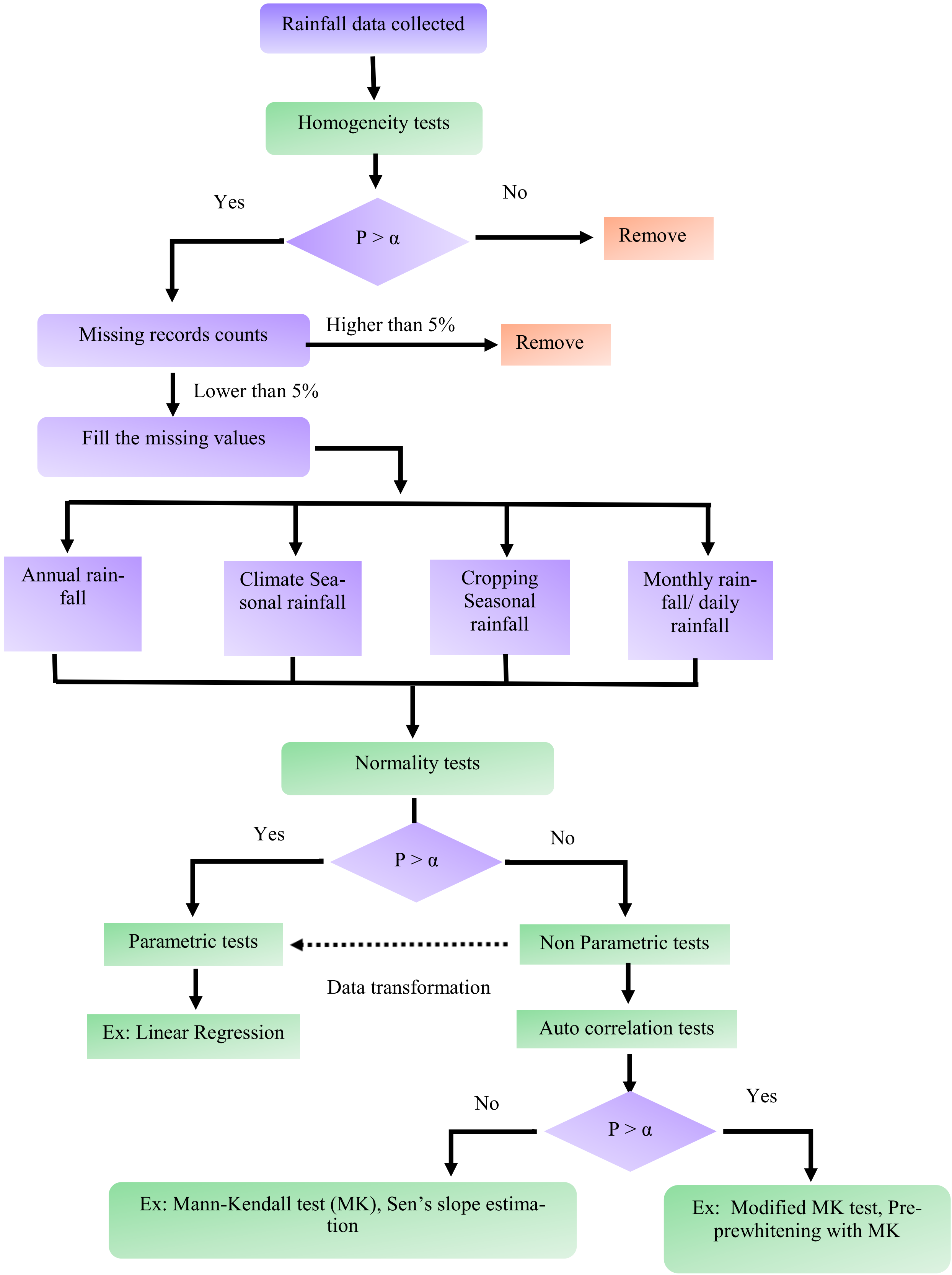

Figure 1: Flow chart to follow the rainfall trend assessment

variance correction approaches and the prewhitening approaches (Coen *et al*. 2020). Both of these approaches have been used in the trend analysis in Sri Lanka (Abeysingha *et al*. 2017; Naveendrakumar *et al*. 2018). In addition, Innovative Trend Analysis (ITA) proposed by Sen (2012) has also been used as a graphical method to test the rainfall trend in Sri Lanka (Nisansala *et al*. 2019; Jayasekara *et al*. 2020; Perera *et al*. 2020). In order to reduce the random fluctuation of the data, moving window averaging with a span of 3 to 5 years is recommended to be taken and then analyses for trend. Moreover, the standardized anomaly is calculated and subjected to trend analysis in order to minimize the spatial bias and helps in comparing spatio-temporal variability in rainfall across the gauging stations (Abeysingha *et al*. 2015; Abeysingha *et al*. 2017).

Rainfall trend

Out of the 15 manuscripts collected, only six (6) manuscripts discussed the rainfall trend over the entire country, while four (4) manuscripts elaborated the regional rainfall trends over wet, dry, northern and coastal zones separately, and one manuscript explained the trend in Colombo district. The rest of the manuscripts were on rainfall trend at river basins scale (Table 1).

Annual rainfall trend

The six manuscripts which discussed the rainfall trend of the entire country show signs of an overall increase of annual rainfall during the recent past. All these studies have used MK and Sen's slope methods with its derivatives, sometimes along with some other test such as ITA, except research manuscript by Jayawardena *et al*. (2018). Jayawardena *et al*. (2018) showed that there is an increasing trend at 80% of the tested stations, while manuscripts written by Karunathilaka *et al*. 2017 revealed increasing trends at 66% of stations. Moreover, Naveendrakumar *et al*. (2018) and Nisansala *et al*. (2019) showed increasing annual rainfall trends at 63% and 65% of the rainfall stations tested, respectively. However, stations showing the significant increasing trend is low where these manuscripts used observed rainfall data of the meteorological department of Sri Lanka. For example, 12% of stations out of all showed a statistically significant increase in the manuscript by Naveendrakumar *et al*. (2018), while 14% of stations are indicated to be significant by Nisansala *et al*. in 2019 (Table 1). The first two manuscripts in Table 1 (Alahacoon and Edirisinghe 2021; Amarasinghe 2020) have used Climate Hazards Group Infrared Precipitation (CHIRPS) data for trend analysis over entire Sri Lanka. Those studies also confirmed the significant increase in annual rainfall in Sri Lanka. Alahacoon and Edirisinghe (2021) analyzed the rainfall trend over the 25-districts showed an 84% (21 districts significant out of 25 districts) significant increase (5% significance) of annual rainfall. Moreover, Amarasinghe (2020) investigated the rainfall trend dividing the island into four geographical regions and showed a significant increase in annual rainfall for all four regions. From all these studies, it is clearly evident increases of rainfall during the recent time. Naveendrakumar *et al*. (2018) analyzed the five decadal rainfall trends and showed a decreasing trend of -2.9 mm/decade during 1961–1970 and, in contrast, +0.6 mm/decade increase during 2001–2010 periods. However, these increasing trends are not uniformly distributed in the country.

Five manuscripts were also found in google scholar, which analyzed rainfall trends over part of the country. Piratheeparajah *et al*. (2021) studied the rainfall trend over the northern region using the observed data from 1970 to 2019. Abeysekara *et al*. (2015) analyzed the extreme positive rainfall at 13 stations in dry zone from 1990 to 2014. Moreover, rainfall trends over North-Western and Eastern coastal lines were investigated by Wickramaarachchi *et al*. (2020) with the help of 19 stations data, while Perera *et al*. (2020) investigated the Colombo district rainfall trend for the period 1989 to 2018. All these five manuscripts have also used MK and Sens slope except the manuscript by Abeysekara *et al*. (2015). They have analyzed positive rainfall anomalies without mentioning the trend analysis technique used. Moreover,

Table 1: Overall rainfall trends, data periods and methods used by the 15 manuscripts reviewed

No.	Title of the paper with authors	Data period, main method used and part of the country	Overall annual trend	Overall seasonal trends
1	Spatial Variability of Rainfall Trends in Sri Lanka from 1989 to 2019 as an Indication of Climate Change. Alahacoon and Edirisinghe (2021)	1989 to 2019, (CHIRPS) data for entire Sri Lanka. MK test and Sen's slope estimator	An increase in all 25 districts. (Sig: + 84%)	NEM: - 40% of district (Sig:0%) SWM: + in all district, (sig: only in wet zone district) FIM: + in all district (Sig:+68%) SIM: + (Sig: +8%)
2	Analysis of Long-Term Rainfall Trends in Sri Lanka Using CHRIPS Estimates Amarasinghe (2020)	1989 to 2019 (CHIRPS) data for the entire Sri Lanka. MK test and Sen's slope estimator	A significant increase in annual rainfall for the entire country (4 geographical regions)	*Yala*: significant increasing trend. *Maha*: non-significant increase in most of the country
3	Changes in Rainfall in Sri Lanka during 1966 – 2015 Karunathilaka *et al*. 2017	50-year period from 1966 to 2015 for the entire country covering 32 stations MK and Sens slope	66% increasing trends (sig.+ 12%, (Sig: - 9%).	NEW: +84 % (Sig:16%) SWM:- 84 % (Sig:.9%) FIM: + 66% (Sig:13%) SIM:+ 71% (Sig:6%)
4	Recent Trends in Climate Extreme Indices over Sri Lanka. Jayawardena *et al*. 2018	19 met station recorded data (1980 – 2015) 36 years. For entire Sri Lanka	A significant increase and Precipitation indices: 80% of stations showed an increasing trend.	Not given
5	Five Decadal Trends in Averages and Extremes of Rainfall and Temperature in Sri Lanka Naveendrakumar *et al*. 2018	55 years (1961–2015) observed data of 20 stations over the entire country MK test and Sen's slope estimator	Annual: 63% increase (Sig. 5%). Based on island average rainfall, overall increasing rainfall trend.	NEM: + 80% (Sig:5%) SWM: - 78% (Sig: No) FIM, SIM: non-significant increasing tendencies
6	Recent rainfall trend over Sri Lanka (1987–2017) Nisansala *et al*. 2019	1987-2017 37 met stations, entire Sri Lanka MK test and Sen's slope estimator and ITA	Annual 65 % increasing (Sig.14%), 67% increasing for the test ITA	NEM: + 86%(Sig. +19% , no -sig) FIM: +76 % (Sig: +5%; -3%) SWM:- 68% (Sig: +3%; -3%) SIM: +51% (Sig:+ 3%)
7	Trend Analysis of Rainfall in the Northern Region of Sri Lanka from 1970 to 2019. Piratheeparajah *et al*. 2021	1970 to 2019 MK and Sens slope Northern region 16 stations	Annual rainfall of Northern Sri Lanka has increased from 18.76 mm/decade to37.68 mm/decade from 1970 to 2019	SWM: - NEM: - FIM: no variation SIM: -

Note: + increasing trend, -decreasing trend, Sig: Significant percentage of stations, MK: Main-Kendall; ITA: Innovative trend analysis

Table 1 continuing

No.	Title of the paper with authors	Data period, main method used and part of the country	Overall annual trend	Overall seasonal trends
8	Recent trends of extreme positive rainfall anomalies in the dry zone of Sri Lanka Abeysekera *et al*. 2015	1990 to 2014 from 13 rain gauge stations in Dry zone Extreme indices/Trend method not given	An non-significant increasing trend of extreme events during the last 25 year period	Not given
9	Rainfall Trends in the North-Western and Eastern Coastal Lines of Sri Lanka Using Non – Parametric Analysis Wickramaarachchi *et al*. 2020	1986–2016 MK and Sens slope 19 stations representing northwestern and eastern regions	Eastern costal line: 100 % increasing (36 %,+ sig) North western: 50% decreasing 50% increasing, but not significant	Eastern NEM: + 100% (Sig: +27%) SWM: -100 % (Sig:-18%) FIM: + 72% (non sig) SIM: + 91% (non sig) North western NEM: + 50% (non sig) SWM: - 100% (Sig: -25%) FIM: + 62% (non sig) SIM: - 75% (non sig)
10	Comparison of Different Analyzing Techniques in Identifying Rainfall Trends for Colombo, Sri Lanka Perera *et al*. 2020	Colombo district only 10 gauging stations for 30 years (1989 to 2018) MK and Sens slope and ITA	Annual: + 20% sig. Not given non-significant results	NEM: + SWM: -
11	Analysis of rainfall distribution and variation during the Southwest monsoon in the wet zone of Sri Lanka Samarakoon *et al*. 2021	South West Monsson in Wet Zone 13 stations, 1981 to 2010 MK and Sens slope	Not given	SWM: - 77% (Sig: -31%)
12	Rainfall Trend Analysis in Uma Oya Basin, Sri Lanka, and Future Water Scarcity Problems in Perspective of Climate Variability Khaniya *et al*. 2019	period of 26 years (1992–2017) MK and Sens slope Uma Oya basin	Annual: + (Sig:+40%) (No Significant – trends)	FIM: Sig: +60% SIM, NEM and SWM: non-significant trend
13	Streamflow trends in up and midstream of Kirindi Oya river basin in Sri Lanka and its linkages to rainfall. Abeysingha *et al*. 2017	MK and Sens slope 1980 – 2010 Kirindi Oya	Annual: + sig (Thiesson Polygon) for the entire basin.	SWM: - (Sig. decreasing) FIM;SIM and NEM: non-significant increasing
14	Streamflow trends of Kelani River basin in Sri Lanka (1983-2013). Jayasekara *et al*. 2020	MK and Sens slope and ITA method (1983 – 2013)	Annual: 62%+ (+12% sig) , non sig. decreasing values all.	NEM: + 87% (non sig.) SWM: - 75% (Sig:-25%) FIM: + 87% (Sig: +37%) SIM: + 50% (non sig.)

Note: + increasing trend, -decreasing trend, Sig: Significant percentage of stations, MK: Main-Kendall; ITA: Innovative trend analysis

Table 1 continuing

No.	Title of the paper with authors	Data period, main method used and part of the country	Overall annual trend	Overall seasonal trends
15	Trend and variability of rainfall in two river basins in Sri Lanka: an analysis of meteorological data and farmers' perceptions Muthuwatta *et al*. 2017	Malwathu Oya, and Kalu Ganga River basin. 6 stations at Malwathu Oya basin and 15 at Kaluganga basin 1961 to 2010 MK and Sens'slope	Malwathu Oya: annual rainfall 100% decreases until 1982, and then indicates an increasing trend from 1988 to 2010 (Sig: +50%) Kaluganga: + 66% from 1986 to 2010	Not given

Note: + increasing trend, -decreasing trend, Sig: Significant percentage of stations, MK: Main-Kendall; ITA: Innovative trend analysis

Perera *et al*. 2020 also analyzed the rainfall trends at 10 stations of the Colombo district with an intention of comparing different analytical techniques. Therefore, detailed descriptions such as a number of stations showing increasing and decreasing are not available except for the significant results. As shown in Table 1, these regional analyses also mostly presented the increasing tendency of annual rainfall. Overall annual rainfall of Northern Sri Lanka has increased from 18.76 mm/decade to 37.68 mm/decade from 1970 to 2019 (Piratheeparajah *et al*. 2021). Non-significant increasing trend of extreme rainfall events was also observed in the dry zone (Abeysekara *et al*. 2015). It is interesting to note that 11 rainfall stations in the eastern coastal line showed a 100 % increasing trend, and out of those, 36 % are significant. In contrast, 50% of the stations exhibited a non-significant decreasing trend over the northwestern coastal region (Wickramaarachchi *et al*. 2020). Moreover, Karunathilaka *et al*. (2017) showed increasing rainfall tendency is more towards the eastern, southeastern regions, and Nisansala *et al*. (2019) were also in agreement with the area, but additionally, it is reported to spreads increase towards the northeastern regions. These findings of Wickramaarachchi *et al*. 2020; Karunathilaka *et al*. 2017; and Nisansala *et al*. 2019, overall indicate that increasing annual rainfall trends is more towards the eastern segment of the country.

Recently published rainfall trends over Uma Oya (Khaniya *et al*. 2019), Kirindi Oya (Abeysingha *et al*. 2017), Kelani river basin (Jayasekara *et al*. 2020), Malwathu Oya and Kaluganga river basins (Muthuwatta *et al*. 2017) in Sri Lanka were also reviewed. Recent annual rainfall trend over all these basins was increasing. Particularly, 40% of the stations in Uma Oya river basin showed a significant increase (Khaniya *et al*. 2019), while Thiesson Polygon average rainfall of Kirindi Oya river basin indicated a significant increase in annual rainfall (Abeysingha *et al*. 2017). Moreover, 12% of the Kelani ganga Ganga river basin stations showed increasing rainfall (Jayasekara *et al*. 2020), while 50% of Malwathu Oya river basin exhibited a significant upward annual rainfall trend (Muthuwatta *et al*. 2017).

Some researchers had the opinion on decreasing trend of rainfall in Sri Lanka (Chandrapala, 2007; De Costa 2008; Jayatillake *et al*. 2005) based on past studies, whereas some researchers view was that there is no significant mean annual rainfall trend during the last century in Sri Lanka. However, all the recent studies used in the present analysis in different geographical scales corroborate that there has been an increasing rainfall tendency over Sri Lanka during the recent past though the significant increasing regions and stations were few. However, it is rare to find significant decreasing annual rainfall stations and regions in the country. Somasundaram *et al*. 2020 studied the spatial and temporal changes in the surface water area of Sri Lanka from 1988 to 2019 and detected a significant increasing trend in permanent water area at a rate of 4.47 km^2 per year and seasonal surface water area at an annual rate of 7.06 km^2. Further, they examined dry zone seasonal water area and showed a significant upward trend of 6.70 km^2. Moreover, Selvarajah *et al.* 2021 analysed rainfall status in Mahaweli river basin using GCM data for the past and also for the future and observed the 19 % increasing trend in the basin average rainfall and indicated very likely experience of more rain in the future. These finding further help to validate the view of rainfall increase over the island and increases of rainfall over the dry zone, particularly towards the eastern zone.

These findings are vital in decision making particularly agricultural planning in the country, and it also needs to be concerned that the coefficient of variation of rainfall (CV) is higher in the dry zone than the wet zone areas (19%) (Nisansala *et al.* 2019).

Seasonal rainfall trend

North-East Monsoon season (NEM)

The studies which were used observed rainfall of the entire country showed increasing rainfall tendency during NEM in which 84% increase is observed by Karunathilaka *et al.* 2017, while Naveendrakumar *et al.* (2018) and Nisansala *et al.* (2019) recorded 80% and 86% increase respectively. Moreover, 16% and 19% of stations showed significant increasing trends by Karunathilaka *et al.* 2017 and Nisansala *et al.* (2019) in their studies. However, Alahacoon and Edirisinghe (2021) observed non-significant decreasing trend of rainfall at 40% of districts. But, they used the CHIRPS data set in their study where the data set may need strong verification with the observed data.

Most of the regional and river basin scale rainfall trend analyses used in this review are in agreement with the Karunathilaka *et al.* 2017; Naveendrakumar *et al.* 2018 and Nisansala *et al.* 2019. Wickramaarachchi *et al.* (2020) pointed out that rain gauge over eastern coastal areas increased during NEM and 27% of stations showed a significant increase. They also demonstrated the 50% increase of NEM rainfall over northwestern coastal areas. As shown in Table 1, Kelani river basin located in the western part and Kirindi Oya river basin, which is partly located in the dry zone, also showed non-significant increasing trend of NEM rainfall. In contrast, NEM over the northern region decreased at some stations (Piratheeparajah *et al.* 2021).

Outcome of this study suggests that there is an increasing tendency of NEM rainfall to Sri Lanka and impact is prominent on the eastern segments of the country. The contribution from NEM to increased annual rainfall is expected to be high.

South West Monsoon (SWM)

There is a separate study to investigate the SWM rainfall trend over the wet zone of Sri Lanka (Samarakoon *et al.* 2021). They showed that 77% of stations representing a decreasing trend and 31% of stations statistically significant decreasing trend during SWM. The finding is further supported by the results of the studies done by Karunathilaka *et al.* 2017; Naveendrakumar *et al.* 2018 and Nisansala *et al.* 2019. However, the number of significant stations is low. For example, though Nisansala *et al.* (2019) detected decreasing tendency at 68% of the station, only 3% of stations were shown to be statistically significant. The study which used 19 stations representing northwestern and eastern coastal areas showed a similar trend (Wickramaarachchi *et al.* 2020). They showed a 100% decreasing tendency and around 25 % of stations a significant decreasing trend during the period from 1986 to 2016. Most of the river basin studies used in this review also showed a decreasing tendency of SWM, where there was a 25% significant decreasing trend noted in Kelani river basin. Decreasing tendency of SWM is attributed to the delays in monsoon winds or shifting of the seasons as most of the studies observed increased FIM rainfall. In contrast, Alahacoon and Edirisinghe (2021) showed an increase of SWM in all districts in which wet zone are significant using CHIRPS data set. In a summery, overall trend of SWM rainfall is in a decreasing trend.

Rainfall during Inter-monsoon periods
Almost all of the studies considered in the review showed that Sri Lanka receives more rainfall during the inter-monsoon, both FIM and SIM seasons. More studies (Karunathilaka *et al*. 2017; Naveendrakumar *et al*. 2018; Nisansala *et al*. 2019; Wickramaarachchi *et al*.2020; and Alahacoon and Edirisinghe 2021) reported an upward tendency of FIM at a greater percentage of rainfall stations. For example, Nisansala *et al*. 2019 showed an increasing trend at 76% of the station during FIM where 5% of stations were significant, whereas increasing tendency was observed at 51% of stations during SIM in which only 3% were significant. Moreover, 87% of rainfall stations in Kelani river basin are estimated to increase where 37% were significant. However, there were only 50% of stations had increased the SIM rainfall in which none of them were significant over Kelani river basin. Summing of the results of these studies, it is clear that there is an increase in FIM rainfall over the country except the northern region, where this region observed a considerable increase in SIM rainfall (Piratheeparajah *et al*. 2021). According to the studies reviewed, the rainfall trend during SIM is not clear, but FIM is in increasing trend.

Based on the studies analysis (Table 1), when analyzing the rainfall data, it is suggested to select long term and all rainfall observatory data as much as possible. By dividing the data series into two time periods and analyzing the trend help to understand the climate change effect. Rainfall data retrieved by satellite sensors and reanalysis data are used as there is no dense rainfall measuring stations to cover the entire country. However, proper validation using appropriate statistical tests (Mourtzinis *et al*. 2017) are recommended prior to use them for trend detection.

Implications
Increased rainfall during NEM and FIM and also annual scale reported in different studies may be due to high intensity rainfall events (Nisansala *et al*. 2019). Moreover, Jayawardena *et al*. 2018 showed by analyzing the extreme rainfall indices that the intensity of the rainfall has been increasing during the recent past (1980 to 2015). High intensity rainfall may not provide sustained catchment yield and soil moisture. Thus, rainfall increases do not assure water availability for different uses and appropriate planning is recommended to harvest rainwater. In addition, intensive rainfall may aggravate soil erosion, resulting in the siltation of water bodies. Frequent floods are also expected with increased rainfall particularly with high intensity rainfall and there would be frequent drough also with the decreased rainfall during SWM and high rainfall variability in the country. Therefore, proactive risk management strategies for anticipate flood and drought is a must.

As shown in the analysis, rainfall trends are not uniformly distributed over the country, and also it is shown that both annual and NEM rainfall increase is prominent in eastern, southeastern and northeastern area. Therefore, these positive changes can be harnessed for the development of the agriculture sector in the area. The cropping calendar can also be adjusted considering the increases of NEM rainfall that coincide with the *Maha* and increases of FIM in which *Yala* season starts.

Conclusion
Even though past studies had the view of decreasing annual rainfall trend over Sri Lanka, this review analyzing 15 published manuscripts and supporting literature pointed out the increasing trend of rainfall in the recent time periods. All 15 manuscripts reviewed were in an agreement of the increasing tendency of annual rainfall over Sri Lanka. Rainfall during the FIM also showed to be increasing in the entire country. All studies which used observed data of meteorological department of Sri Lanka were in the same view of increasing rainfall during NEM times, particularly toward the eastern zones. In contrast, most of the studied manuscripts indicate the decreasing tendency of SWM rainfall over the country. Thus, increasing rainfall during NEM, FIM and total annual rainfall is most probable in near future time periods. Moreover, the review highlighted the use of appropriate statistical

tests in investigating the monotonic rainfall trend.

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