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Research Article

INNOVATIVE TREND ANALYSIS OF HYDRO-METEOROLOGICAL VARIABLES IN IBADAN, NIGERIA

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Abstract

Analysis of trend in hydro-meteorological variables is extremely important for improving water resources planning and management. This study examines trend in monthly rainfall and temperature using the recently developed Innovative Trend Analysis Method (ITAM) and Mann-Kendall (M-K) with Sen's slope test. Record of precipitation and temperature data was obtained from the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria for the period of 1973-2018. The precipitation trend during the period of 45years has been analyzed using the ITAM and M-K test. Most of the results obtained from these two methods for detecting trend are found to be matching. The result of this study shown that precipitation for the month of February, March, April, May, June, July, August and September indicated an increasing trend with the rate of 0.01, 0.01, 0.004, 0.025, 0.063, 0.028, 0.006 and 0.061 mm / year respectively. A significant increasing trend was shown in June and September at 1% and 10% significance level. The result of temperature obtained over the study area shown that almost all the months indicated increasing trend. The month of February, April, May and November shown an increasing trend at 10% significance level.

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The comparison of the ITAM and M-K methods support the reliability of ITAM. In fact, ITAM detected some trend properties which could not be observed from the M-K test. Therefore, in climate change scenarios the ITAM can be effectively used and can provide useful information for precise management and planning of water resources.

Keywords: Trend analysis; Rainfall; Temperature; Climate change; Innovative Trend Analysis Method; Sen's Slope test; Mann-Kendall test; Ibadan.

1. INTRODUCTION

Changes in climate variability, its impacts and vulnerabilities have attracted great global attention and become increasingly unpredictable each year, especially in Nigeria [1]. According to Burn and Hag-Elnur [2], a compendious overview of the possible impacts of changes in climate is provided in Inter-Governmental Panel on Climate Change [3]. It is clearly shown in the report that change in climate in areas of greater latitude is likely to increase runoff due to increased precipitation. Some locations are also expected to change the frequency of flooding, specifically in floodplain watersheds and in the northern latitudes. The frequency and flinty of drought episodes could be increased by changes in precipitation and evaporation.

Oloruntunde *et al.* [4], noted that forecasting future climatic conditions and impacts associated with it has become uncertain due to increase in universal variability of the hydrological cycle caused by climate change; therefore, studies of long-term agro-climatic variables are becoming increasingly necessary. In addition, most design, planning and management of water reservoirs are on the basis of historical model of water demand and availability, assuming that normal behavior of climate can no longer be contained under the climate change [5]. In view of this, most recent information on the behavior of agro-climatic variables through statistical analysis is needed by water resources and hydrology engineers. According to Forootan [6], accurate and reliable forecasts and water management projects depend on historical hydrological and climatic data that required strong analytical techniques to determine the hydrological behavior of the basin. Estimating precipitation and temperature trends can simultaneously declare the drivers of some of these trends, since the presence of rain corresponds to temperature changes in large amount of the area [7].

Trend analysis is widely used by various researchers globally to assess the change in hydrological time series and the possible impacts of climate change. The tests use to determine trend analyses are grouped into parametric, non-parametric and mixed types. To detect significant trends in climatic variables, parametric tests are more sensitive and stronger than the non-parametric tests, particularly for small samples [6]. There are many techniques in hydro-meteorological studies to determine the trends in climatic variables for efficient water resource management which includes multiple regression models, Sen's slope estimator and non-parametric Mann-Kendall test, but the Mann-Kendall test is ultimately used [8].

To date, numerous studies on the analysis of hydro-meteorological extremes to determine the trend of pan evaporation and regional precipitation on seasonally, annually, monthly and daily basis have been carried-out by applying Mann-Kendall (M-K) test, regression analysis and test for estimating the Sen's slope [6,9]. For example, Sen's slope and Mann-Kendall tests has been used by Pingale *et al.* [10] to inspect the spatio-temporal trends in extreme temperatures and precipitation in Rajasthan region of India. The result of their study implies that urban centers of the state of Rajasthan show negative and positive trends.

The results of the study of Oguntunde *et al*. [11] on the changeability and trends in evaporation and other hydro-meteorological variables in Ibadan, Nigeria by applying the Sen slope and Mann-Kendall (M-K) tests showed that solar radiation, wind speed and evaporation were significantly reduced ($P < 0.001$), while rain, temperature and relative humidity were not significant increasing trends over the past four decades. Akinbile *et al.* [1] also studied the impact of climatic variations and the trend of rice cultivation and yield in Nigeria. The result of their study showed that negative and significantly decreased at $P < 0.001$ was observed for yield in rice, relative humidity (RH) and temperature (T) while statistically insignificant trends was observed for solar radiation and rainfall over the past three decades (1980 - 2010).

In addition, application of non-parametric Mann-Kendall test on the implications of trends and precipitation cycles in agricultural and water resources of the tropical climate of Nigeria was carried-out by Fasinmirin *et al.* [12]. The result showed that at different rates precipitation return peaks was dominant and this implies different spatial effects on ecosystems and agriculture. Some of the possible future effect of these trends in water resources and agriculture differ from station to station, depending on the trends and the extent of the return period of precipitation. Much success has been obtained in literature by using various statistical methods, however, the methods mentioned above have certain drawbacks, for example, the data to be used for the linear regression are required to be normally distributed and independent, which contrasts with the hydrological and meteorological time series models (in most cases positive or negative biased data); The Mann-Kendall and Spearman's rho tests are qualified for a set of circumstances where normally distributed and monotonous trend can be assumed [13]. The application of these traditional methods still have some negative aspects in detecting variations in trend for hydrological and meteorological time series.

Sen, [14] [15] recently introduced a method of analyzing trend called innovative trend analysis method (ITAM); To study trends and impact of hydrological and metrological variables of water resources, this method of trend analysis has been successfully applied [9,16]. Many researchers have applied Mann-Kendall test alongside the innovative trend analysis method to analyze time series data. For example, Kisi [9], studied the trend analysis of monthly pan evaporations of six different locations in Turkey by employing the Mann-Kendall and the innovative trend analysis method (ITAM). The ITAM was also used by Ahmad *et al*. [15] to study trends in monthly rainfall for 25 stations and an increasing trend was found towards the southern parts while in the northern part of the Macta river basin in Algeria, declining trend was observed between the period of 1970 and 2011. Furthermore, the variability of seasonal and yearly precipitation in the regional state of Amhara, Ethiopia was studied using ITAM by Mohammed *et al.* [17]. Therefore, in comparison with the linear regression (LR), Mann-Kendall method (M-K) and Spearman's rho tests which some of their assumptions are restrictive (seasonal cycle, independent series, normally distributed data and time series duration), the innovative trend analysis method (ITAM) has been widely applied. Furthermore, graphical representations of significant sub-sectoral trends can be noticed when applying the ITA method.

The regular occurrence of an increase in severe agro-climatic events (floods, droughts, heat waves, etc.) has threatened many countries socio-economic development, including Nigeria. Hence, understanding time series changes is of great important for water resources projects planning and management. It is therefore necessary to assess the trends of hydrological variables related to the two hydrological processes to allow an accurate water resources prediction. The study objectives are to: I. Identify recent trends in precipitation and temperature in Ibadan using innovative method of trend analysis (ITAM). II. Analyze and compare the results of the Mann-Kendall with Sen's slope test over the period 1973-2018 with ITAM.

2. MATERIALS AND METHOD

2.1 The study area

The city of Ibadan is located in the south-eastern part of Oyo State, in a wooded area near the border between forest and savannah found in the South-western part of Nigeria. The city is situated about 110 km northeast of Lagos and on seven hills with an average altitude of 200 m and 160 km off the Atlantic coast. The city bordering with the Republic of Benin about 120 km eastward, is known to be the black Africa largest hometown and is sited at 7 ° 22 'N latitude and 3 ° 54' S longitude [18]. The city's population grew very quickly in the mid-19th century, with increasing population from approximately one million in 1963 to approximately 3.6 million in 2007. At the time when Nigeria got her independence, the city was the most populated and largest in Nigeria and third largest city in Africa after El- Cairo and Johannesburg City. Ibadan is naturally drain by four rivers which has many tributaries: in the Northern and Western part by Ona River; Eastward by Ogbere River; The Ogunpa river with catchment area of 54.92 km^2 and canal length of 12.76 km cut across the city and, in the metropolis, central part by the Kudeti river. More so, the climate of the city is dry and tropically humid, which is the climatic classification of Köppen, with an extended raining season and temperatures that's relatively constant all through the year. The city's wet season mostly occurs in the month of March to October, but August sees little calm in the rainfall. This calm almost divides the wet season into two different rainy seasons. The dry season of the city is formed from November to February, during which the city experiences the harmattan typical to West Africa. The weather is mainly monsoon with a bimodal rain pattern. The average temperature on a monthly basis varied from 28.8 ° C in February to 24.5 ° C in August and the mean rainfall is around 1300 mm / year [18]. Coloured luvisols soil species are found in the city and the settlements and vegetation of arable land is moderate [19].

2.2 Data source

Monthly precipitation and temperature data for the period of 45 years (1973-2018) were procured from the database of the International Institute of Tropical Agriculture, Ibadan with 7 ° 30 'N, 3 ° 54' S and 243 m above sea level. The installations of the meteorological instrument meet the World Meteorological Organization standards. In the study of Jagtap and Alabi [19], the site agro-ecological properties and its instrumentation can be found.

2.3 Data analysis

The analysis of trends was carried out using Mann-Kendall with Sen's slope test and innovative trend analysis method. This approach used a series of rainfall and temperature events which were inspected monthly to detect trends and slopes. This statistical trend tests have been used in several similar studies worldwide by various researchers or scientists to determine the time series trends in hydrological and meteorological variables [11,13].

2.3.1 Software packages used

Makesen 1.0, a spreadsheet advanced for estimating and detecting time series trend at the Finnish Meteorological Institute was used to analyze the trend of Mann-Kendall with Sen's slope test [4,20]. R-software package was used to carried-out the analysis on the innovative trend analysis method.

2.3.2 Sen's slope test

In this approach, slope of all pairs of ordinal time points are calculated and then the general slope is evaluated using the average slopes obtained [21]. According to Khan *et al.* [22], a simple non-parametric procedure can be used to evaluate the actual slope (change per unit of time) provided that a linear trend was observed over a series of times. This signify that for an increasing and a decreasing continuous monotonic function of time f(t), then f (t) is described as:

$$(t) = Qt + K \quad (1)$$

Where the slope is represented by Q and K is the constant. Firstly, all the data pair's slopes are calculated in order to obtain the slope "Q" according to:

$$Q' = (X_{t'} - x_t) / (t' - t) \quad (2)$$

Where, Q' in equation 2 is the Slope between the points of $x_{t'}$ and x_t while x_t' and x_t are the time taken to measure data at x_t' and t.

Hence, the Sen's slope estimator is simply given by the average slope,

$$Q = Q'_{(N+1)/2} \text{ for N is odd}$$

$$= \{Q'_{(N+1)/2} + Q'_{(N+2)/2}\}/2 \text{ for N is even}$$

Where slopes number is represented as N. On a slope estimate, a bilateral confidence interval of 100 (1- α) % is obtained using a normally distributed non-parametric test [22].

2.3.3 Mann-Kendall trend test

Mann-Kendall (M-K) is a non-parametric test usually used in climatic or hydrological data sets to determine the presence of monotonic trends. In this study, this trend test was used to estimate the presence of monotonic trend in the precipitation and temperature data examined. In this method, the null hypothesis H_0 which is data ordered randomly in time and distributed identically with the alternative hypothesis H_A is used. Another assumption is that the data follow a monotonous trend. The test statistics used by the Mann-Kendall (M-K) trend test are calculated by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(X_j - X_k) \quad (3)$$

The trend test is applied to the data values in the data of X_j (j = i + 1, 2...n) and X_i (i = 1, 2... n - 1). The data values of each X_i are used as a reference point for comparison with the data values X_j given as:

$$sgn(x) = \begin{cases} +1\ if(x) > 0 \\ 0\ if(x) = 0 \\ -1\ if(x) < 0 \end{cases} \quad (4)$$

The average of *S* is equal to zero and the variance σ^2 is calculated as:

$$\sigma^2 = \{n(n-1)(2n+5) - \sum_{j=1}^{m} t_j(t_j-1)(2t_j+5)\}/18 \quad (5)$$

Where t_j is the data points number in the j^{th} linked group and m is the tied group's number in the data set. The statistic S is almost normally distributed in as much as the following Z transformation is used as follows:

$$z = \begin{cases} \frac{S-1}{\delta} if S>0 \\ 0\ if S = 0 \\ \frac{S+1}{\delta} if S<0 \end{cases} \quad (6)$$

The S statistics are nearly related to Kendall μ, given by:

$$\mu = \frac{S}{T} \quad (7)$$

The Kendall correlation coefficient noted as μ provides a general monotonic connectivity that is measured parametrically. It is said to be monotonic because numerical value of μ does not change when monotonic transformation in X or Y is carried out.

Where $T = [\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{j=1}^{p} t_j(t_j-1)]^{\frac{1}{2}}[\frac{1}{2}n(n-1)]^{\frac{1}{2}}$ (8)

Data values are estimated as a modified time series. All of the subsequent data values are compared to each data value. No trend is implied when the Mann-Kendall S statistic initial value is assumed to be zero. If, however, the value of the data of a subsequent period is greater than the previous period data value, then, Mann-Kendall S statistic is increased by one. If, however, the data value of the subsequent period on the other hand is lower than the value of the previously sampled data, S is reduced by one. The finite value of S is obtained from the net result of all these increases and decreases.

In addition, the observations made later in time is great in size than those observed previously and this indicate increasing trend with a very high positive value of S statistics. However, if the observations made later in time is generally smaller than before observations made, then, a downward trend is indicated with very weak negative value. Nevertheless, it is mandatory to calculate the probability closely related with the sample size (n) and S, so that the significance of the trend can be statistically quantified.

2.3.4 Innovative Trend Analysis Method (ITAM)

The innovative trend analysis method (ITAM) concept had been employed in several studies globally to determine trends and impacts of hydro-meteorological variables. The results acquired from the Mann-Kendall method (M-K) was compare with ITAM to verify its accuracy. For the ITAM, hydro-meteorological data time series are first divided equally into two parts and organized independently in ascending order, with the first part presented on the horizontal axis while the second part is presented on the vertical axis based on the Cartesian coordinate system (Figure 1). From the figure it is clearly shown that if in the scatter plot the time series data is located on a 1: 1 straight line (45º), this does not indicate a trend. On the other hand, the trend increases when the data points gather above the ideal 1: 1 triangular area of the straight line and when the data points gather under the 1: 1 triangular area of the straight line, a decreasing trend is observed [14,16].

The ITAM trend pointer is multiplied by 10 in order to make the scale of the Mann-Kendall trend similar to that of the ITAM. Hence, the trend pointer is given as follows:

$$M = \frac{1}{n}\sum_{i=1}^{n}\frac{10(X_j - X_i)}{\theta} \quad (9)$$

Where M = trend pointer

n = observations number in the sub-series

X_i = series of data in the first half of the sub-class

X_j = data series in the second half of the sub-series

θ = average of the series of data in the first half of the sub-class.

When a positive value is obtained, this indicates an upward trend. On the other hand, downward trend is indicated if a negative value is observed. Furthermore, there is no trend when the dispersion comes very close to or on the ideal 1: 1 straight line.

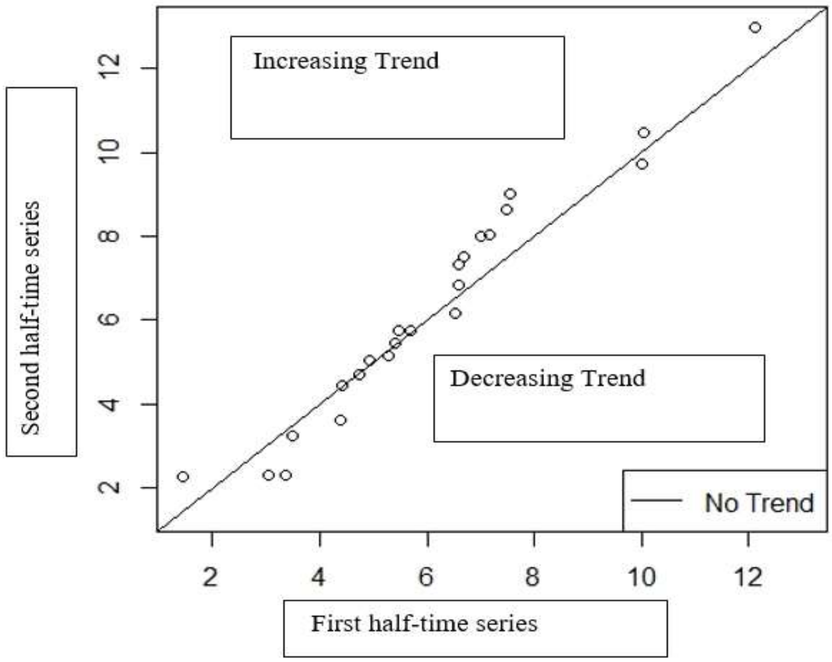


Fig.1. Illustration of an innovative trend analysis method

3. RESULTS AND DISCUSSION

3.1 Trend of precipitation and temperature using Mann-Kendall with Sen's slope test

The Mann-Kendall test has been employed in this study in order to check the reliability of the ITAM and the magnitude of the trend was determined by Sen's slope test. Each monthly rainfall and temperature Mann-Kendall test results are presented in Table 1 and Table 2 respectively conforming to the significance level of 1%, 5% and 10%.

Table 1 clearly shows that the months of January, February, March, April, May, June, July, August, September and November show an upward (increasing) trend while October and December have a downward (decreasing) but not significant trend. It can be visualized from Table 1 that the rainfall for the months of February, March, April, May, June, July, August and September have trend magnitude that increase with 0.01, 0.01, 0.004, 0.025, 0.063, 0.028, 0.006 and 0.061 mm / year respectively. However, only the month of October signify that decreasing trend magnitude was obtained at –0.022 mm / year, while January, November and December months show no trend magnitude. The month of June indicates a significant upward (increasing) trend at a significance level of 1%. The month of September however, shows significantly upward trend at 10% significance level.

The results of the Mann-Kendall trend test for temperature are represented in Table 2. It is apparent from this Table that there is an increasing trend for the month of January, February, March, April, May, June, July, September, October, November and December. While only the month of August shows a decreasing trend which is not significant. February, April, May and November show an increasing trend at 10% significance level (α=0.1). July and October have significant increasing trend at 5% significance level. The month of September and December, on the other hand, have an increasing trend and it's significant at 1% significance level. Out of the twelve months, only January, March and June increase without a significant trend. it can be seen from the Table 2, that the monthly temperature of the month February, April May, July, September, October, November and December show significant increasing slope magnitude with 0.017 ^{0}C/yr, 0.017 ^{0}C/yr, 0.008 ^{0}C/yr, 0.014 ^{0}C/yr, 0.013 ^{0}C/yr, 0.013 ^{0}C/yr, 0.015 ^{0}C/yr and 0.028 ^{0}C/yr respectively while the month of January, March and June show increasing slope magnitude but not significant with 0.012 ^{0}C/yr, 0.010 ^{0}C/yr and 0.007 ^{0}C/yr respectively. However, out of the twelve months, only the month of August show decreasing slope magnitude with 0.002^{0}C/yr. More so, the temperature results for the month of February, April, May and November show significant increase slope at 10% significant level. The month of July and October show an increasing slope magnitude at 0.05 significant level while the month of September and December show increase slope at 0.01 significant level.

Table 1. Mann-Kendall and Sen's slope test results of the monthly Rainfall (1973-2018)

Months	First year	Last year	n	Mann-Kendall Z-statics	Sen's slope (Q) value
January	1973	2018	45	0.29	0.000
February	1973	2018	45	1.12	0.010
March	1973	2018	45	0.62	0.010
April	1973	2018	45	0.23	0.004
May	1973	2018	45	1.34	0.025
June	1973	2018	45	2.63**	0.063
July	1973	2018	45	0.87	0.028
August	1973	2018	45	0.28	0.006
September	1973	2018	45	1.91+	0.061
October	1973	2018	45	-0.78	-0.022
November	1973	2018	45	0.01	0.000
December	1973	2018	45	-0.10	0.000

**trend at α= 0.01 level. *trend at α= 0.05 level. +trend at α= 0.1 level.

Table 2. Mann-Kendall and Sen's slope test results of the monthly Temperature (1973-2018)

Months	First year	Last year	n	Mann-Kendall Z-statics	Sen's slope (Q) value
January	1973	2018	45	1.17	0.012
February	1973	2018	45	1.78 +	0.017
March	1973	2018	45	1.25	0.010
April	1973	2018	45	1.82 +	0.017
May	1973	2018	45	1.69 +	0.008
June	1973	2018	45	1.06	0.007
July	1973	2018	45	2.23 *	0.014
August	1973	2018	45	-0.34	-0.002
September	1973	2018	45	2.75 **	0.013
October	1973	2018	45	2.49 *	0.013
November	1973	2018	45	1.84 +	0.015
December	1973	2018	45	2.63 **	0.028

**trend at α= 0.01 level. *trend at α= 0.05 level. +trend at α= 0.1 level.

3.2 ITAM result for precipitation and temperature

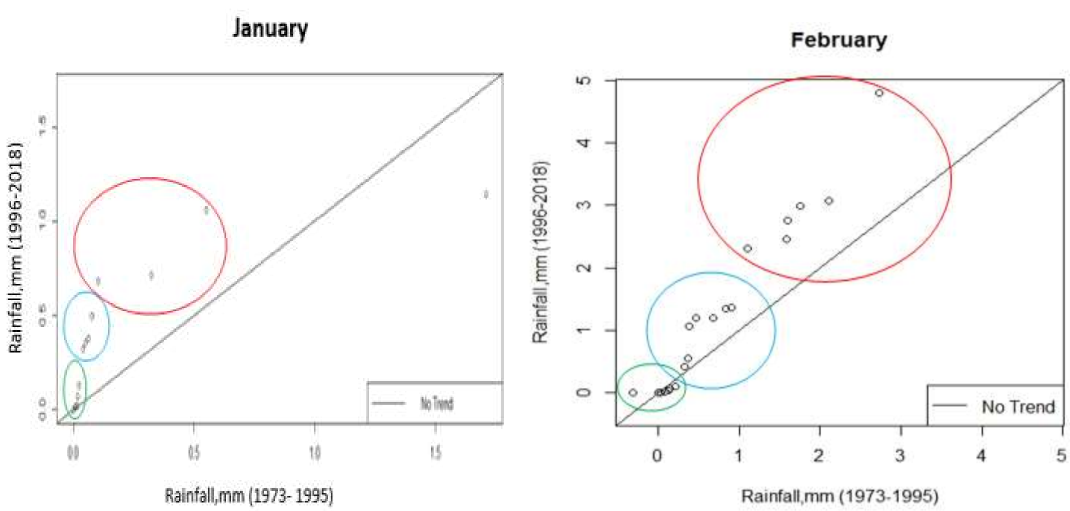
An innovative trend analysis method was utilized in this part of study to evaluate the presence of trend in monthly precipitation and temperature data. According to the study of Sen [14], variable data distributed along the 1: 1 line are grouped into low, medium and high cluster values. The results of ITAM are presented in Figure 2 and 3 for monthly rainfall and temperature. According to Figure 2, which shows the ITAM result for monthly precipitation, it can be seen in the figure that the low cluster values (<0.2 mm) for the months of January and February do not indicate a trend, because the dispersion points are located closely to the 1:1(45^0) straight line, while in the medium and high cluster values, the tendency to a monotonous increase is valid over time (1973-1995) compared to (1996-2018).

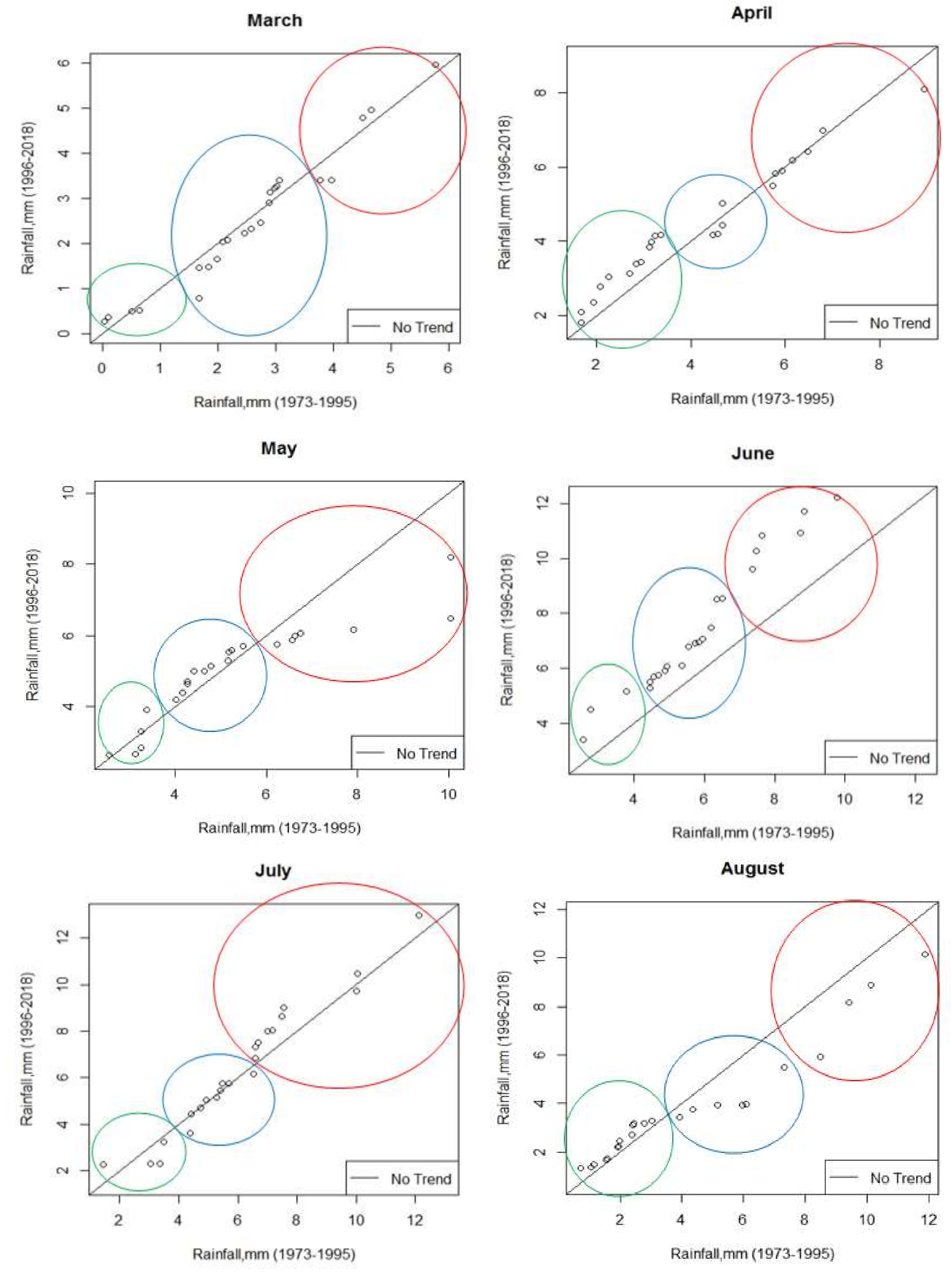
The low values for the month of April show an upward trend with medium values having a downward trend, while no trend was observed for some high value (6 – 7 mm). Comparatively, the duration of the trend in relatively medium rainfall is shorter than that of the low rainfall values and the low cluster rainfall values in April occupied most of the duration.

The month of May has medium precipitation values indicating increasing trend over time (1973-1995) compared to (1996-2018) while downward trend was shown by high cluster values. Relatively, medium cluster values occupied most of the duration. The high rainfall with values greater than 6 mm shows a downward trend, which means that water shortages are likely to occur during this time.

A significant increasing monotonous trend was observed for the months of June and September for low, medium and high precipitation values (1973-1995) compared to (1996-2018). Medium cluster values occupied most of the duration, which includes all monthly values greater than 4 mm for the month of June and greater than 5.8 mm for the month of September. In addition, the low rainfall values have a shorter duration than in the medium section of the clusters.

More so, the low values in the months of August and November showed an increasing trend, while a decreasing trend for medium and high rainfall values was indicated in the month of August (4 - 12 mm). Also, the medium cluster values for the month of November shows a decreasing trend, and the high rainfall values signifies slight increasing trend. The two months (August and November) have a longer duration of low rainfall than in periods of medium and high rainfall. In addition, the high values of precipitation in August show a downward trend and hence, water stress will likely occur more frequently in this month. Thus graphical representation of the ITA method allow to have clear identification of the trends within various rainfall months during period of 1976 - 2018.




March
April
May
June
July
August
Rainfall,mm (1996-2018)
Rainfall,mm (1973-1995)
No Trend

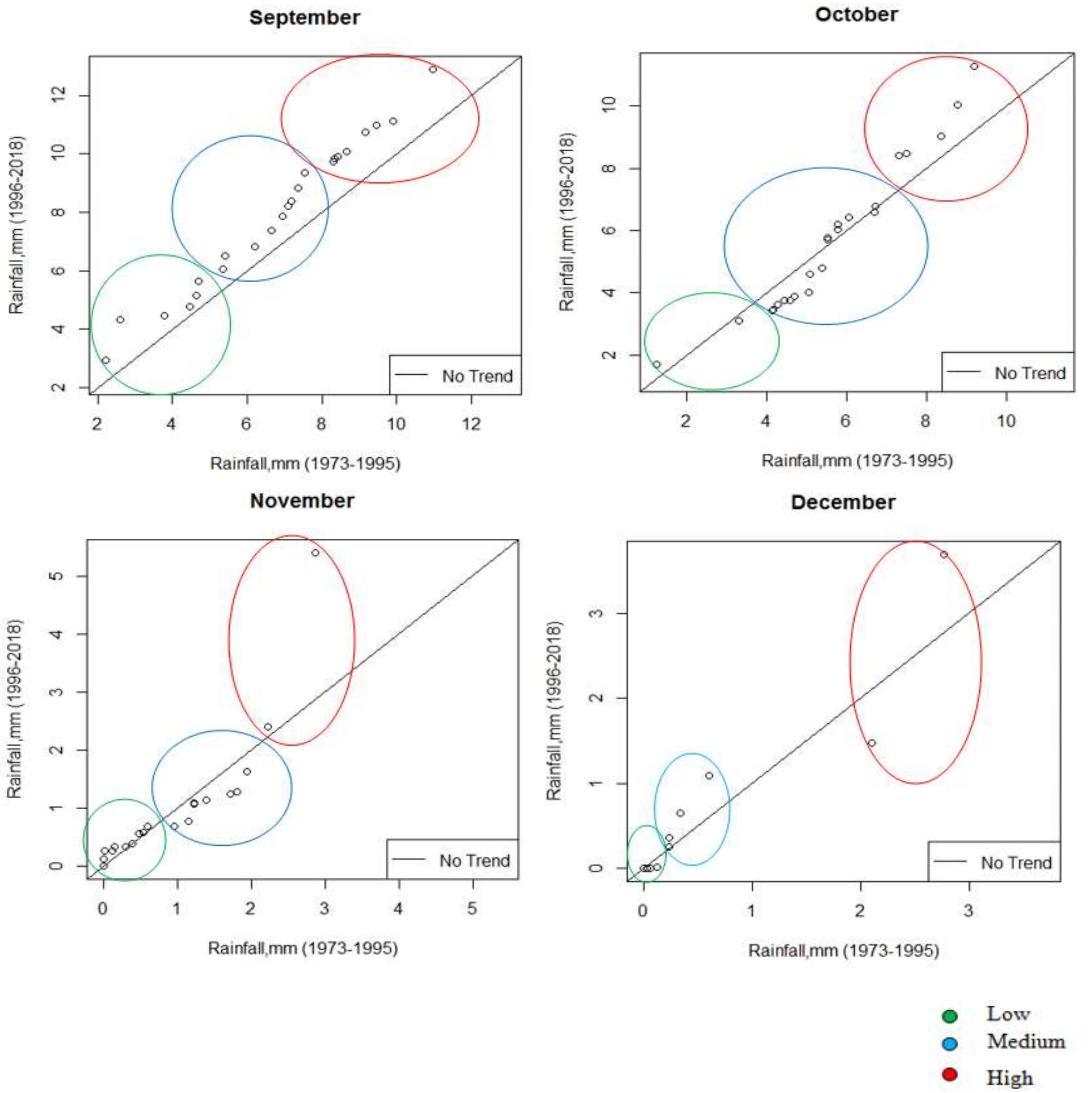


Fig.2. ITAM result for monthly rainfall

ITAM plots for monthly Temperature is presented in figure 3. From this figure, it can be seen that the month of January show a monotonic increasing trend for low, medium and high temperature values because the cluster values is above the 1:1 straight line.

The month of February show an increasing trend for low and medium value, while some high-value show increasing trend for values less than 29.3^{0}C and indicate a decreasing trend for values greater than 29.3^{0}C. More so, the medium cluster values have a longer duration since it occupied most of the temperature values.

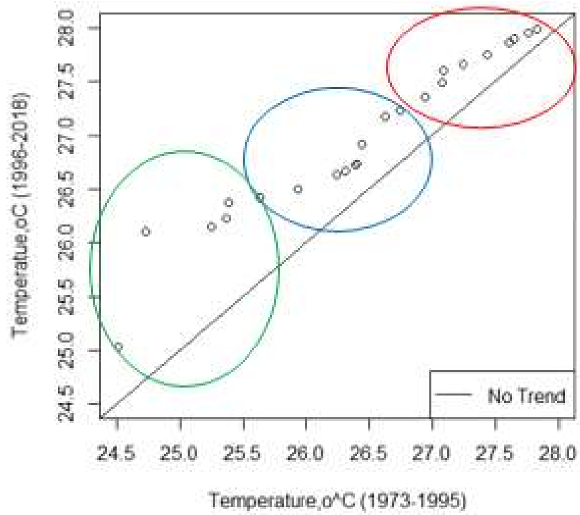
The month of March indicates an increasing trend for low, medium and high-temperature value representing points above the ideal 1:1staright line, which indicates that during the second half of the historic record (1973 – 1995), there is an increase in the low, medium and high temperature with respect to the first half (1996 – 2018).

An increasing trend for high and low temperature values was noticed for the month of April and June but some of the medium value show an increasing trend with no trend for values at 26 ^{0}Cand 28 ^{0}C respectively.

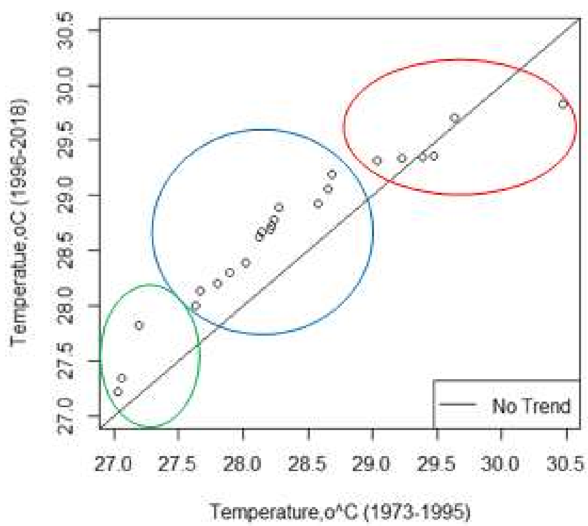
The month of August, on the other hand, shows a decreasing trend for medium and high values and an increasing trend for low cluster values. Comparatively, there is shorter duration for low temperature trends than in the high cluster portion. The medium cluster temperature contained most of the duration with no significant trend property. Moreover, the high-temperature values greater than 25 ^{0}C have decreased in the 1973 – 1995 duration compared with 1996 – 2018.

The month of July, September, October, November and December show a significant increasing monotonic for low, medium and high-temperature value representing points on the upper part of the 1:1 straight line and this implies that during the second half of the historic record (1973 – 1995) there is an increase in the low, medium and high temperature in this months with respect to the first half (1996 – 2018). The trend is said to be significant as the cluster values are distance away from the ideal straight line. More so, medium cluster temperature occupied most of the duration in these months with significant trend component. Comparatively, low-temperature trends have a shorter duration than in the high cluster portion in the month of July, September, October and December.

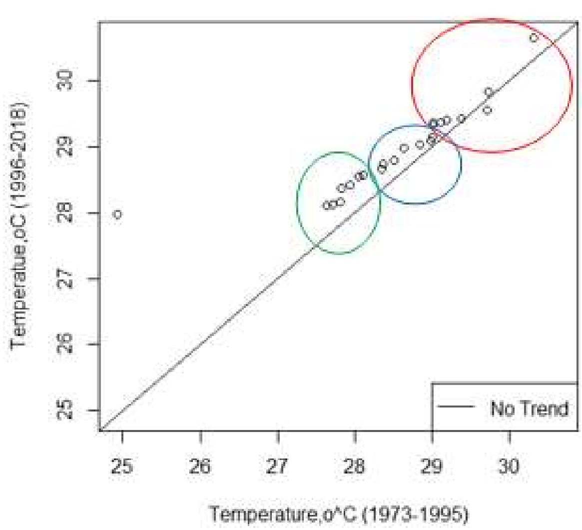
January

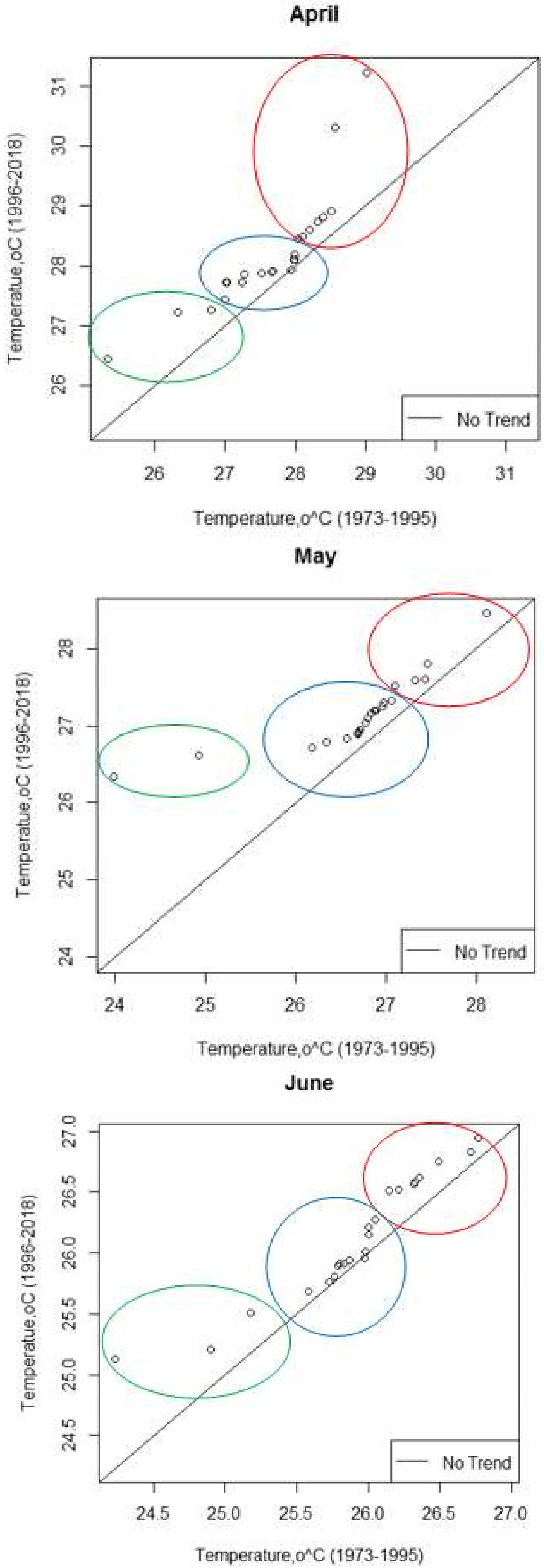


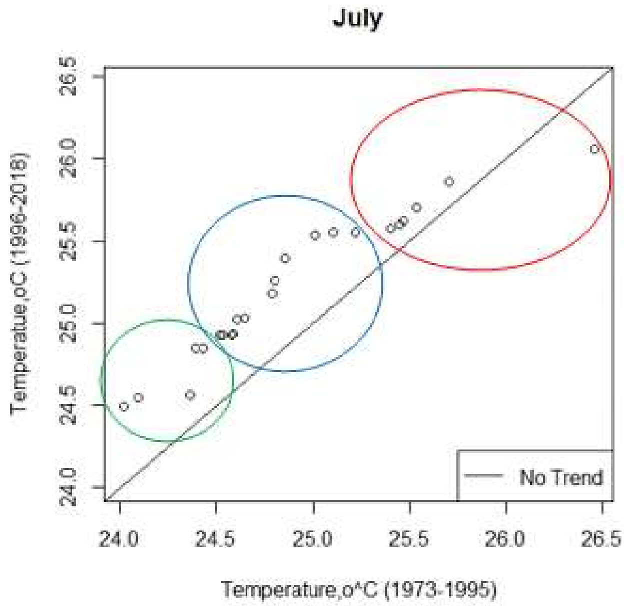
February

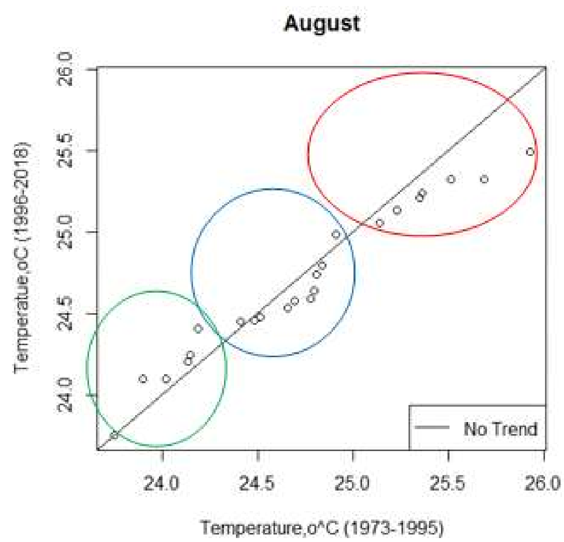


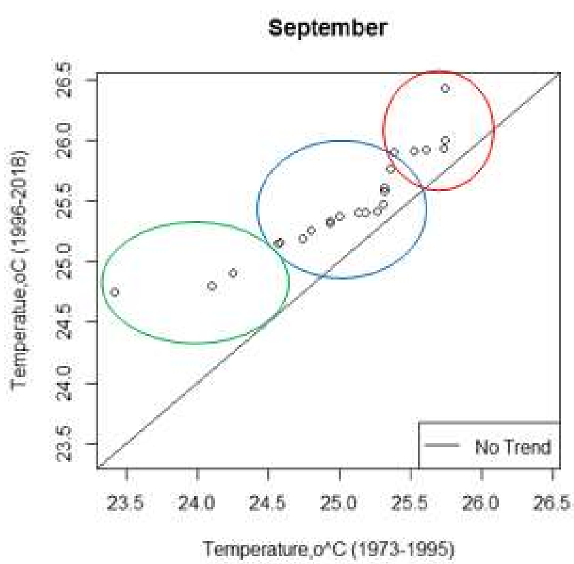
March




April
Temperatue,oC (1996-2018)
Temperature,o^C (1973-1995)
No Trend
May
Temperatue,oC (1996-2018)
Temperature,o^C (1973-1995)
No Trend
June
Temperatue,oC (1996-2018)
Temperature,o^C (1973-1995)
No Trend


July
Temperatue,oC (1996-2018)
24.0
24.5
25.0
25.5
26.0
26.5
No Trend
24.0 24.5 25.0 25.5 26.0 26.5
Temperature,o^C (1973-1995)


August
Temperatue,oC (1996-2018)
24.0
24.5
25.0
25.5
26.0
No Trend
24.0 24.5 25.0 25.5 26.0
Temperature,o^C (1973-1995)


September
Temperatue,oC (1996-2018)
23.5
24.0
24.5
25.0
25.5
26.0
26.5
No Trend
23.5 24.0 24.5 25.0 25.5 26.0 26.5
Temperature,o^C (1973-1995)

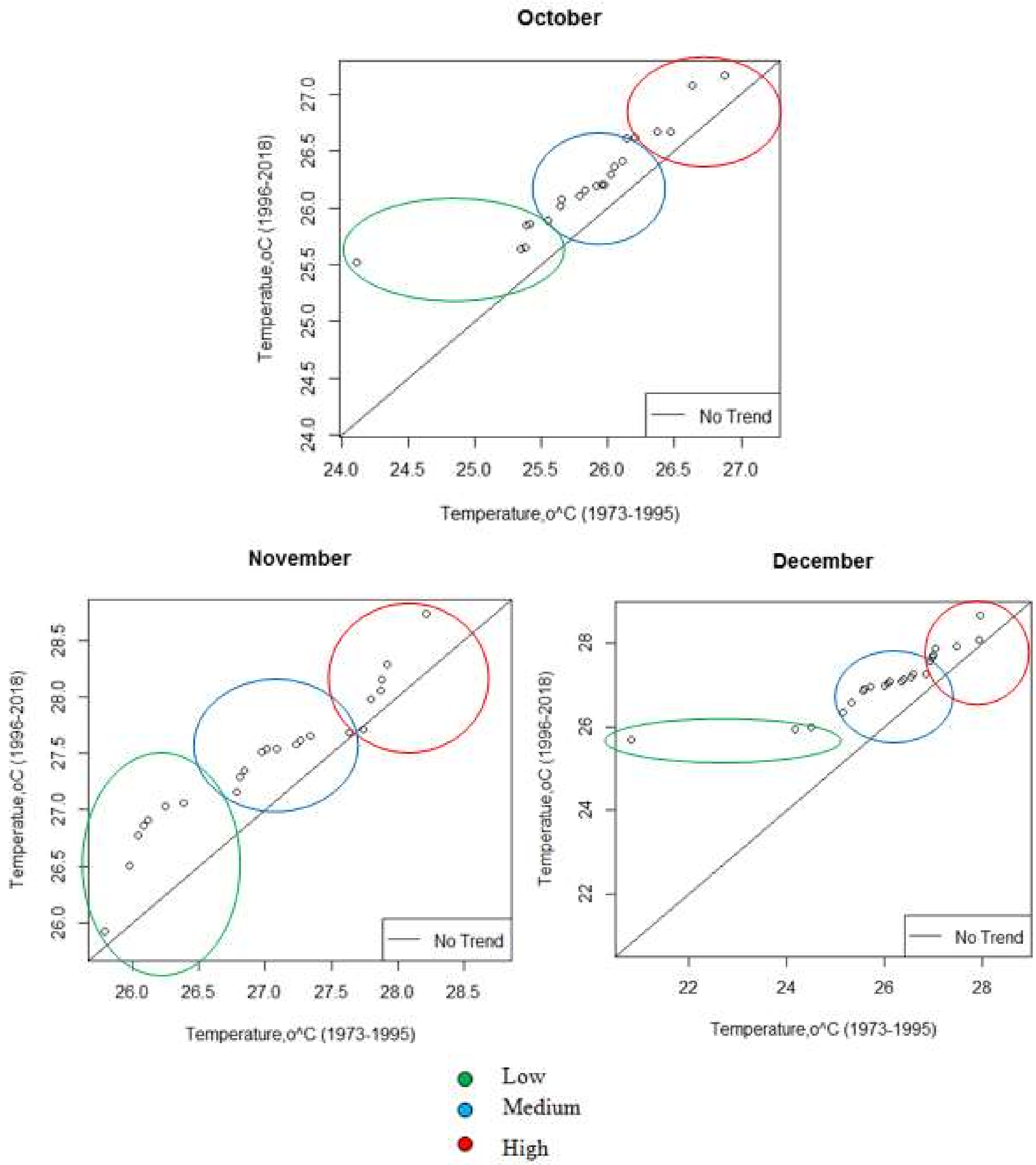


Fig.3. ITAM result for monthly Temperature

3.3 comparison of trends result

The comparison of the trend results obtained from ITAM and M-K test is necessary in order to ascertain the reliability of the innovative trend analysis method (ITAM). This comparison is specifically important because Şen [16] showed that recently, the rate of application of trend analysis has increased unprecedentedly as a result of global warming.

Concerning the monthly precipitation anomalies, the empirical trend analysis results carried out by the ITA method are consistent with the trend analysis results performed by the M-K test, in particular throughout the months of January, February, September and June where low, medium and high values of the clusters indicate an upward (increasing) trend. However, downward (decreasing) trend was observed for the month of October for the M-K results and this contrasts with the result shown by ITAM indicating a downward trend for the low and medium rainfall values while increasing trend occur for some medium values (>6mm) and high precipitation cluster values. The month of April show an upward (increasing) trend for the low cluster values and the medium clusters signifies downward trend while no trend for the high precipitation values and this was in contrast with the result obtained by using Mann-Kendall test, which indicate an upward (increasing) trend. In addition, the ITAM results for the month of December and May indicate a decreasing (downward) trend in low and high rainfall values, while the medium values have an upward trend, but this result is opposite to that obtained using the M-K methods where increasing trend was seen for the month of May. However, there was a downward trend for the month of December when the Mann-Kendal (MK) test was used. Thus, the ITAM traced the presence of increasing trend in medium values for December month which could not be detected by the M-K test. Although, the month of June indicates a significant upward (increasing) trend while September however, shows significantly upward trend. These results obtained for the month of June and September are similar to the one obtained from the M-K test at 1% and 10% significance level respectively. Similarly, trends and variability of precipitation over Onisha in Nigeria were analyzed earlier and the highest monthly contribution to total annual precipitation was recorded in September and June [4]. On the contrary, the results of a study by Oguntunde *et al.* [11] in the same study area indicated that significant trend is not present in any of the months for rainfall. Hence, the certain differences in the results obtained may be as result of the difference in the number of years of climatic variables considered.

The declining trends observed in October and December imply that rainfall has decreased for more than four decades during these months and that this would have possible future effect on agriculture practice that depend on rainfall in Ibadan, hence, to ensure sustainable agricultural production in these months, farmers could have the need to develop better management and planning of water resources. Meanwhile, the significant upward trend observed in June and September implies an increase in precipitation over the decades and, therefore, it can be concluded that the floods which was recorded in Ibadan in the month of September may be due to high precipitation which often occur in the months of June to September.

The result of the ITAM for temperature correspond to the trend result obtained from Mann-Kendall test. The months which indicate a significant increase for the M-K test also concur with the result of ITAM which shows a significant increase for low, medium and high-temperature values. It can be seen from Figure 3 that the month of January, February, March, April, May, June, July, September, October, November and December show increasing trend for low, medium and high values since the clusters is above the ideal line and this correspond to the result obtained from the Mann-Kendall test. The significance trend obtained from the M-K test for the month of February, April, May, July, September, October, November and December conform with the ITAM result. The ITAM result is said to be significance if the cluster value is at a distance away from the ideal 1:1 straight line. On the contrary, the result obtained from the M-K shows decreasing property for August while the ITAM result indicates an increasing trend for low-temperature values and decreasing for medium and high values. Thus, the ITAM reveal what could not have been detected by the M-K test. The increase in temperature obtained in this study agreed with the study of Oguntude *et al.* [11] who carried out similar research on this study area during the period of 1973 - 2008. The overall increment in temperature in this study area is associated with the increase in low and medium temperature values. More so, the increase in temperature result obtained in this study agreed with the study of Asfaw *et al.* [23] who reported an increase in temperature for all months on Woleka sub-basin in North central Ethiopia. Similarly, Abatan *et al.* [24] reported that there is an increase in mean temperature over the study area during the period of 1971 – 2012, which appears to be linked to anthropogenic global warming and this confirms with the observed opinion of the people living in the city on climatic conditions of Ibadan as noted by Taiwo *et al.* [25]. Such increase in Temperature has an adverse effect on agriculture as it makes the growing of some certain crop in the region not advisable and reduce the amount of water available for irrigation. Therefore, the agriculture sector in this study area have to take increase in temperature in to consideration during strategies design, planning and management of water resources.

4. CONCLUSION

The trend of monthly precipitation and temperature were studied by applying the innovative trend analysis method (ITAM) and Mann-Kendall with Sen's slope test during the period of 1973 - 2018.The capability of the ITAM was ascertained by testing it with the Mann-Kendall test.

The monthly rainfall for February, March, April, May, June, July, August and September shown trend magnitude that increase with 0.01, 0.01, 0.004, 0.025, 0.063, 0.028, 0.006 and 0.061 mm / year respectively. However, only the month of October signify a decreasing trend magnitude which was obtained at –0.022 mm / year, while January, November and December months shown no trend magnitude. The significant upward trend observed in June and September implies an increase in precipitation over the decades and therefore, it can be concluded that the floods in the month of September which was recorded in the study area may have been caused by the heavy rainfall that occurs from June to September.

As regards temperature, almost all the months shown increasing trend over the period of 1973 - 2018 apart from August where decreasing trend was observed. The month of February, April May, July, September, October, November and December shown significant increasing slope magnitude with 0.017 ^{0}C/yr, 0.017 ^{0}C/yr, 0.008 ^{0}C/yr, 0.014 ^{0}C/yr, 0.013 ^{0}C/yr, 0.013 ^{0}C/yr, 0.015 ^{0}C/yr and 0.028 ^{0}C/yr respectively while the month of January, March and June shown increasing slope magnitude but not significant with 0.012 ^{0}C/yr, 0.010 ^{0}C/yr and 0.007 ^{0}C/yr respectively. However, the month of August shown decreasing slope magnitude with 0.002^{0}C/yr. The result obtained conform with previous reports on the study area and the increase in temperature appears to be linked to anthropogenic global warming.

The results of the ITAM for monthly precipitation and temperature agreed to a great extent with the one obtained through the Mann-Kendall test. However, certain difference occurring from the comparison of ITAM and Mann-Kendall test confirmed that ITAM is better than the M-K test. In fact, when applying ITAM, some trends were obtained which were not detected by the Mann-Kendall tests. Therefore, ITAM has been shown to have certain advantages over other trend analysis test, as it provides details on trends regarding low, medium and high values which are very essential in the management of water resources.

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