Statistical analysis of rainfall data at Iranamadu reservoir catchment in Kilinochchi, Sri Lanka.

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Abstract -Iranamadu reservoir is the largest reservoir in Northern Province of Sri Lanka, which is located in Kilinochchi. Iranamadu tank is one of the ancient reservoir in Sri Lanka, which was built in 5th century. Capacity of the reservoir is 132 MCM and the catchment area of the reservoir is 588 km2. The reservoir was enlarged during the British era, and bund was raised up three times. Objective of the study was to analyze rainfall data and check whether data is statically suitable for further hydrological modeling. Numbers of rain gauge stations, which are available at Kanagarayan Aru river basin, were selected for the study including Iranamadu, Vavuniya, Vavunikulam, Mankulam, and Muthiyankaddu. Missing rainfall data is estimated using simple arithmetic mean and normal ratio method. Daily rainfall data from 2010 – 2016 was statically check for screening and consistency. Outlier test and Spearman's rank correlation test also carried out for the data set. Results of the study are revealed that rainfall data are statistically distributed and suitable for further hydrological analysis.

Keywords: Consistency check, Iranamadu reservoir, Screening check, Spearman's rank correlation test, Outlier test.

I. INTRODUCTION

Iranamadu reservoir is located in Kilinochchi, Northern Province of Sri Lanka. The reservoir, which was built by King Dhathusena during Anuradhapura era, is very important irrigation systems in the Kanagarayan Aru river basin. The reservoir was enlarged during the British era between 1902 1920 and the bund height was increased three times in 1951, 1954 and 1975 to increase the capacity of the tank up to 88 MCM, 101 MCM, and 132 MCM respectively.

The Iranamadu reservoir with basin area of 588 km2 stores the water for the irrigation requirements in downstream areas. It has two irrigation canals, Right Bank (RB) canal and Left Bank (LB) canal to distribute water to the downstream irrigable areas. Iranamadu reservoir receives inflow from its own basin via Kanagarayan Aru River. Today, approximately 8500 hectares of paddy cultivation and subsidiary crops fields are irrigated under Iranamadu reservoir irrigation scheme. Precipitation varies geographically, temporally and seasonally. Both regional and temporal variations in precipitation are important in water resources planning and hydrologic studies. Rainfall runoff model and water allocation and distribution models are required to study the water balance, reservoir simulations, reservoir operations, and optimization of the reservoir operations etc. Above models are required statistically verified daily rainfall data.

This study is aim to analyse daily rainfall data statistically and verify for further analysis.

II. LITERATURE REVIEW

Screening and consistency checked can be carried out for selected data to check accuracy of the data. Screening check will allow visual detection of whether the observations have been consistently or accidentally credited to the wrong day, whether they show gross errors, or whether they contain misplaced decimal points [1]. Double mass analysis is a test for consistency of data. Changes in gauge location, exposure, instrumentation, or observational procedure may cause relative change in the precipitation catch. Double mass tests the consistency of the record at a station by comparing its accumulated annual or seasonal precipitation with the concurrent accumulated values of mean precipitation for a group of surrounding stations. The consistency of the record for each of the base stations should be tested and those showing inconsistent records should be dropped before other stations are tested or adjusted [2]. Therefore, double mass analysis is known as test for consistency (conforming to a regular pattern or style). Spearman's rank correlation coefficient is used to identify and test the strength of a relationship between two sets of data. It is often used as a statistical method to aid with either proving or disproving a hypothesis [3]. Outlier test can be used to find an observation that lies an abnormal distance from other values in a random sample from the data set. The lower quartile (q1) is the 25th percentile, and the upper quartile (q3) is the 75th percentile of the data and the inter-quartile range (IQR) is defined as the interval between q1 and q3 in outlier test [4].

III. Materials and Methods

Methodology of the study is shown in the Fig. 1. Numbers of rain gauge stations are available at Kanagarayan Aru river basin. Fig. 2 is shown Iranamadu, Vavuniya, Vavunikulam, Mankulam, and Muthiyankaddu gauge stations that were selected for the study based on their geographical distribution. Selected period was 2010 to 2016. Iranamadu, Muthiyankaddu and Vavunikulam rain gauge stations used during missing data estimation based on data availability and distance between stations.

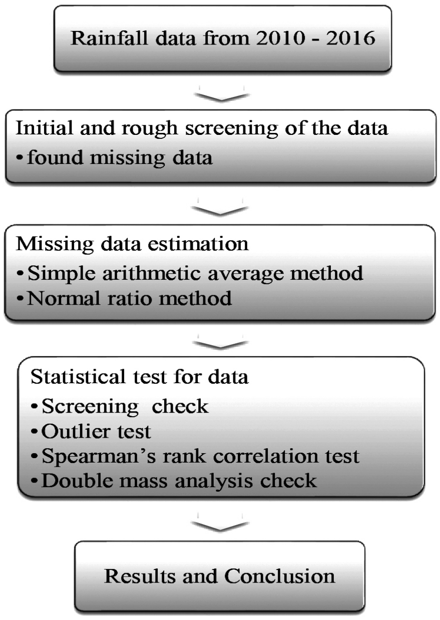

Fig. 1: Methodology of the study

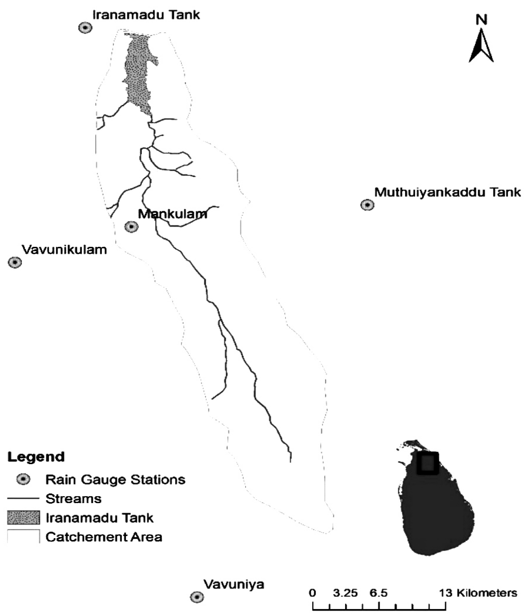

Fig. 2: Rain gauge stations close to Iranamadu catchment area

The basic procedure begins with an initial, rough screening of the data. Missing data were estimated using two different methods. If the average annual precipitation at each of the three adjacent stations differs from the average at the missing data station by less than 10%, the following equation (1) is used to estimate the missing daily data. This method is called simple arithmetic averaging method.

$$P_x = \left(\frac{P_A+P_B+P_C}{3}\right)$$

Where,
P_x = estimated daily precipitation volume at the missing data site X
P_A,P_B,P_C = estimated daily precipitation volume at the adjacent stations, A, B and C

If the difference between the average annual precipitation at any of the adjacent stations and the missing data station is greater than 10%, a normal ratio method is used. Normal is used as it refers to the arithmetic average. The method consists of weighting each adjacent station daily value by a ratio of the normal annual precipitation value and then average the numbers, or using equation (2).

$$P_X = \frac{1}{3}\left[\left(\frac{N_X}{N_A}\right)P_A + \left(\frac{N_X}{N_B}\right)P_B + \left(\frac{N_X}{N_C}\right)P_C\right]$$

Where,
N_x = average annual precipitation at the missing data site X,
N_i = average annual precipitation at the adjacent sites (i = A, B, & C).

Then screening check has performed for the monthly rainfall data. Testing for the outliers was done by using calculation of quartiles; the quartile 1 and quartile 3 and then IQR and the lower fence and upper fence for the data set. Spearman's rank correlation test was done by using XLSTAT software.

In order to perform double-mass test for check consistency, annual rainfall was calculated for each year for each stations. Then the accumulated annual rainfall at a one station compared with the concurrent accumulated values of mean precipitation for a group of surrounding stations.

IV. Results and Discussion

Missing data estimated for Mankulam station for year of 2010 using available rainfall data in Vavuniya, Iranamadu, and Vavunikulam adjacent stations. Hence, the different between the average annual precipitation at adjacent stations and Mankulam stations was greater than 10% normal ratio method was used.

Screening curves reveled that rainfall data at each three stations are statistically suitable for further analysis. Screening curves are shown Fig. 3.

Outlier test values are shown in Table 1. According to results, all the data are presented within upper fence and lower fence, so there are no outliers in the selected data set for period of 2010 – 2016.

Double mass curves for Iranamadu, Vavuniya, Vavunikulam, Mankulam, and Muthiyankaddu, which is shown in Fig. 4, shows linear variation. Therefore, the consistency of the records for each of the selected stations are satisfied. Spearman's rank correlation test results are shown in Table 2.

It shows very strong positive relationship between Muthiyankaddu, Vavuniya and Vavunikulam, Iranamadu.

In Further, there is a strong positive relationship between Mankulam, Iranamadu and Mankulam, Vavuniya. Therefore, Spearman's rank correlation test results revealed that data set is statically suitable for further analysis.

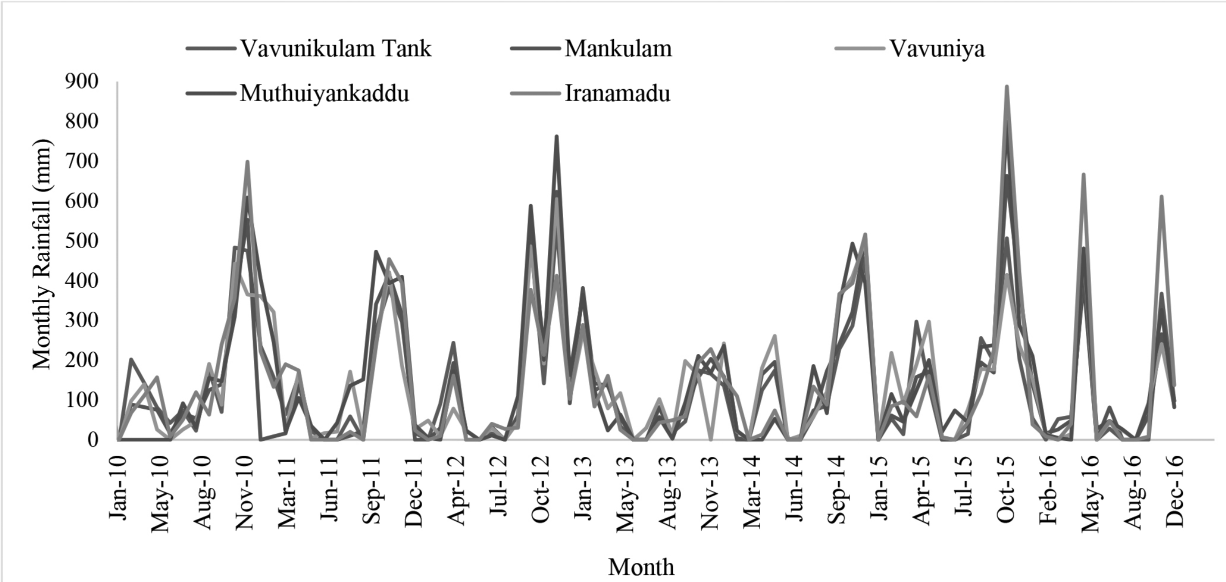

Fig. 3: Screening curves for selected rain gauge stations

Table I
Outlier Test Results

	Iranamadu	Vavuniya	Vavunikulam	Mankulam	Muthiyankaddu
qr1	1427.6	1394.85	1414.275	1321.125	1325.95
qr3	1860.25	1913.7	1663.75	1767	2044.7
IQR	432.65	518.85	249.475	445.875	718.75
IQR*1.5	648.975	778.275	374.2125	668.8125	1078.125
Upper Fence	2509.225	2691.975	2037.9625	2435.8125	3122.825
Lower Fence	778.625	616.575	1040.0625	652.3125	247.825
Outliers	No Outliers	No Outliers	No Outliers	No Outliers	No Outliers

Table II
Pearson coefficient correlations

Variables	Iranamadu	Vavuniya	Vavunikulam	Mankulam	Muthiyankaddu
Iranamadu	**1**	0.464	0.714	0.536	0.464
Vavuniya	0.464	**1**	0.393	0.571	0.750
Vavunikulam	0.714	0.393	**1**	0.464	0.571
Mankulam	0.536	0.571	0.464	**1**	0.357
Muthiyankaddu	0.464	0.750	0.571	0.357	**1**
	Values in bold are different from 0 with a significance level alpha=0.05				

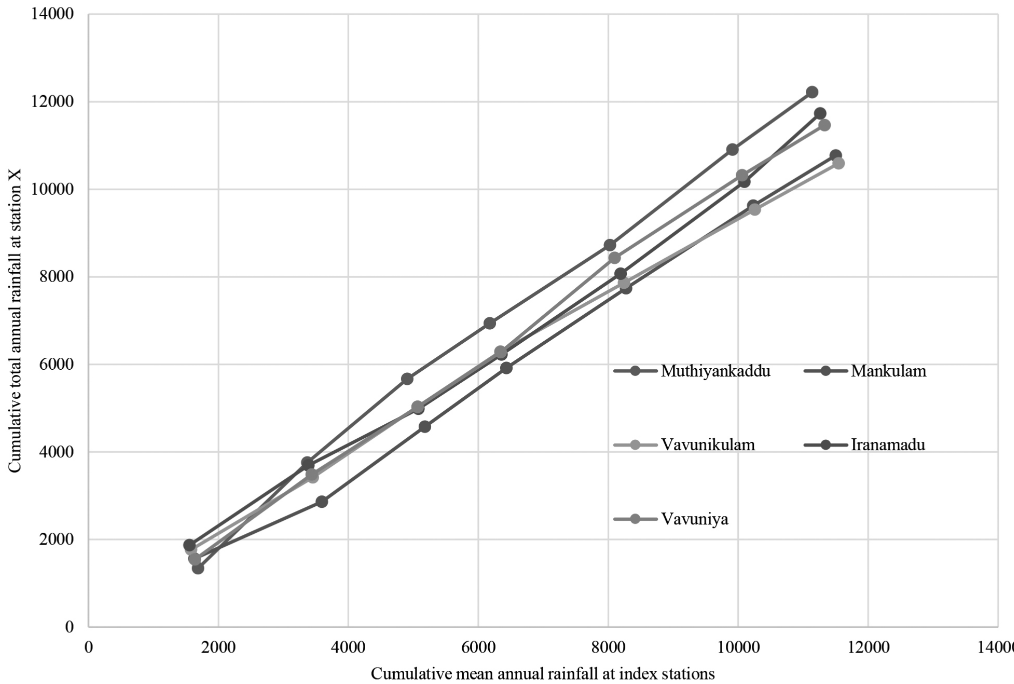

Fig. 4: Double mass curves

V. CONCLUSION

Rainfall runoff model and water allocation and distribution models are required to study the water balance, reservoir simulations, reservoir operations, and optimization of the reservoir operations etc. Above models are required statistically verified daily rainfall data. In this study, screening check, outlier test, Spearman's rank correlation test, and double mass curves were analysed for daily rainfall data from 2010 to 2016 at Iranamadu, Vavuniya, Vavunikulam, Mankulam, and Muthiyankaddu rain gauge stations. Analysis revealed that available daily rainfall data are statistically suitable for further hydrological analysis.

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