International Journal of Civil Engineering and Technology (IJCIET)
Volume 9, Issue 7, July 2018, pp. 403–411, Article ID: IJCIET_09_07_041
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=7
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

ANALYSIS OF RAINFALL BY INTENSITY-DURATION- FREQUENCY (IDF) CURVES FOR VAMANAPURAM RIVER BASIN, KERALA

Anie John. S
Research Scholar, Karunya Institute of Technology and Sciences, Coimbatore, India

Dr. Brema. J
Professor and Programme Co-ordinator,
Karunya Institute of Technology and Sciences, Coimbatore, India

ABSTRACT

Climate change impact related to water resources can be characterized by changes in temperature and precipitation. The rainfall Intensity Duration Frequency (IDF) relationship is one of the most commonly used tools in water resources engineering particularly to identify design storm event of various magnitude, duration and return period simultaneously. The objective of the present study is to develop IDF curves for the Vamanapuram river basin area, Kerala. Thirty years (1982-2012) of peak rainstorm intensity values with their corresponding durations were extracted and analysed using Microsoft Excel software. The frequency analysis technique used in this study is Gumbel Distribution Method. The linear regression goodness of fit by Microsoft Excel is used to determine the best fit probability distribution. The parameters of the IDF equation and coefficient of correlation for different return periods (2, 5,10,25,50 & 100) are calculated. The IDF curves are recommended for the prediction of rainfall intensities for the selected river basin.

Key words: Rainfall Intensity, Rainfall Duration, Intensity-Duration-Frequency (IDF) Curves.

Cite this Article: Anie John. S and Dr. Brema. J, Analysis of Rainfall by Intensity-Duration- Frequency (IDF) Curves For Vamanapuram River Basin, Kerala, International Journal of Civil Engineering and Technology, 9(7), 2018, pp. 403–411.
http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=7

1. INTRODUCTION

Climate change impact related to water resources can be characterized by changes in temperature and precipitation. The rainfall Intensity Duration Frequency (IDF) relationship is a mathematical relationship between the rainfall intensity, the duration and the return period

[1]. It is one of the most commonly used tools in water resources engineering particularly to identify design storm event of various magnitude, duration and return period simultaneously [2]. The establishment of such relationship was done as early as 1932 [3]. Analysis of rainfall is usually done by Intensity Duration Frequency (IDF) curves and isopluvial maps [4]. The IDF formulae are the empirical equations representing a relationship among maximum rainfall intensity (as dependant variable) and other parameters of interest such as rainfall duration and frequency (as independent variables). Koutsoyiannis et al. [5] developed a mathematical relationship between the rainfall intensity *i,* the duration d, and the return period T for IDF curves.

There are several commonly used functions found in the literature of hydrology applications [6]. All functions have been widely applied in hydrology. The IDF relation is mathematically as follows:

$$i=f\,(T, d) \tag{1}$$

Where *T* is the return period (years) and *d* is the duration (minutes). The typical generalized IDF relationship for a specific return period is as given in equation (2)

$$T = \frac{a}{\left(a^{v} + b\right)^{e}} \tag{2}$$

Where *a, b, e* and v are non-negative coefficients. Thus, the equation that is more general: with *v*=1 and *e*=1 it will be Talbot equation; *v*=1 and *b*=0 is Sherman; *e*=1 is Kimijima equation and *v*=1 is Sherman. This expression is an empirical formula that summarizes the experience from several studies. There has been considerable attention and research on the IDF relationship: Hershfield [7] developed various rainfall contour maps to provide the design rain depths for various return periods and durations. Bell [8] proposed a generalized IDF formula using the one hour, 10 years rainfall depths; P_1^{10}, as an index. Chen [9] further developed a generalized IDF formula for any location in the United States using three base rainfall depths: P_1^{10}, P_{24}^{10}, P_1^{100}, which describe the geographical variation of rainfall. Kothyari and Garde [10] presented a relationship between rainfall intensity and P_{24}^{2} for India. The engineering application of rainfall intensity is mainly in the estimation of design discharge for flood control structures. The main aim of this work is to understand and quantify uncertainties in series of extreme rainfall at several durations (1, 2, 6, 12, 24 h) collected at three rain gauge stations in

Vamanapuram river basin, Kerala from the point of view of climatologically factors, streamflow response and as regards the impact on the dimensions of hydraulic works designed for flood protection.

2. MATERIALS AND METHODS

2.1. Study Area

The Vamanapuram river basin with a catchment area of 787 sq. km. is located mainly in Thiruvananthapuram district and a small part falls in Kollam district of Kerala state. Vamanapuram River Basin is bounded by latitudes of8° 35ʹ 24″ N and 8° 49′ 13″ N and longitudes of 76°44′ 24″ E and 77°12′ 45″ E. The Vamanapuram River Basinis bounded by Nedumangad Taluk of Thiruvananthapuram district in the South, Kottarakkara Taluk of Kollam district in the North, Tamil Nadu in the East and Arabian Sea in the West. The area forms part of the midland terrain of the state, characterized by lateritic uplands with undulating topography and intermittent valleys. The river Vamanapuram is a major river in South Kerala with its network of tributaries. The main stream originates from the foothills of the Ponmudi hills (1074 m above msl) and the tributaries from the surrounding hills like Kallar. Theriver then flow through Vamanpuram town and two-branch streams join at Attaramoodu, and at this location the mainstream is called as Kilimanurriver. From there the main stream flows and joins the Kadinamkulam backwater at the northern most extremity. It debouches into the Arabian Sea at Mudalapallipozhi near Perumathura, 25 km north of Thiruvananthapuram city. The two tributaries of this river are the Upper Chittar & Manjaprayar streams. The major portion of the Vamanapuram River flows through midland terrain and the remaining through highlands and lowlands areas. The river basin consists of high to moderate and low flood risk areas.

Figure 1 Location Map of the Vamanapuram River Basin

For the present study, the relevant maps were created using ArcGIS 9.3 and ERDAS Imagine 9.1 software tools. Satellite imagery was used as primary data source. The study area comprising of Vamanapuram River Basin was delineated from Survey of India Topographic maps of scale 1:50000, numbered 58 D/10, 58 D/13, 58 D/14, 58 H/1, and 58 H/2. The location map and base map of the study area is showed in Figs. 1 and 2.

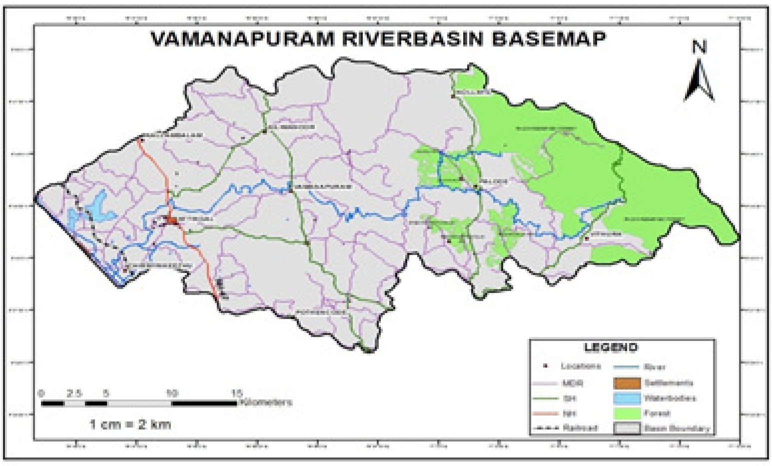

Figure 2 Base map of the Vamanapuram River Basin

Table 1 Rainfall depth (mm) Vs Discharge for the Vamanapuram River Basin

Sl.No	Year	Day	Mean Guage(m)	Discharge (cumecs)	Rainfall (mm)
1	1992	10/10/1992	10.367	974.8	279.1
2	2010	10/4/2010	8.030	522.0	211.8
3	1996	10/18/1996	7.095	506.3	207.4
4	1998	10/12/1998	8.310	500.3	184.3
5	1993	11/11/1993	6.204	365.1	177.4
6	2001	7/9/2001	5.852	360.1	178.4
7	2000	8/26/2000	5.432	341.4	167.2
8	1994	8/3/1994	6.945	340.7	162.5
9	2009	10/2/2009	5.480	331.4	160.4
10	1997	9/16/1997	5.700	326.3	149.5
11	2007	7/17/2007	5.242	323.3	142.8
12	1990	11/4/1990	6.275	305.4	137.5
13	1984	10/3/1984	5.490	298.5	136.7
14	2005	12/12/2005	5.193	296.2	133.4
15	2006	10/30/2006	4.920	287.2	125.6
16	1999	10/17/1999	5.500	272.5	122.3
17	2011	12/31/2011	4.785	252.3	119.8
18	1991	6/8/1991	5.522	251.3	108.4
19	2008	10/25/2008	4.100	223.1	100.5
20	1989	7/22/1989	4.335	213.6	98.0
21	2003	10/7/2003	3.975	207.7	97.5
22	2002	11/9/2002	3.840	204.0	95.6
23	2004	10/4/2004	3.920	201.2	82.4
24	1982	6/9/1982	4.570	196.3	81.9
25	1986	8/8/1986	4.298	185.3	74.5
26	1988	9/3/1988	4.070	165.5	73.0
27	1985	6/24/1985	3.915	141.1	62.4
28	1987	9/24/1987	3.700	138.5	61.7
29	1995	7/31/1995	3.245	116.5	59.1
30	1983	9/23/1983	2.653	93.5	53.4
					SUM= 3844.5
		Average	5.467	311.8	AVERAGE=128.15

2.2. Data Collection

The major data utilized for the study is rainfall data comprising of rainfall durations and intensities in Vamanapuram River Basin, Kerala. Thirty (30) years of hourly rainfall data included data ranging from 1982 to 2012 from the three rain gauge stations namely Nedumangad, Thiruvananthapuram and Varkala. The data were obtained from Indian Meteorological Department (IMD),Thiruvanathapuram, Kerala. The mean rainfall depth is calculated by the use of Arithmetic Mean Method. The corresponding gauge discharge data for the year 1982 to 2012 was collected from Central Water Commission (CWC) Government of India, for the gauge station Ayilamin the study area.

Table 2 Annual maximum intensity of rainfall (mm/hr)

Sl. no	Year	Rainfall Depth (mm)	Duration (hrs)	Rainfall Intensity mm/hr	Duration (minutes)	Rank	Return Period (T) yrs	Probability (1/T)
1	1992	389.7	1.6	243.56	96	3	10.33	0.10
2	2010	211.8	3.8	55.74	228	14	2.21	0.45
3	1996	207.4	1.1	188.55	66	6	5.17	0.19
4	1998	184.3	1.5	122.87	90	9	3.44	0.29
5	1993	179.5	0.3	598.33	18	1	31.00	0.03
6	2001	178.4	1.64	108.78	98.4	10	3.10	0.32
7	2000	167.2	4.5	37.16	270	23	1.35	0.74
8	1994	162.5	3.4	47.79	204	18	1.72	0.58
9	2009	160.4	0.56	286.43	33.6	2	15.50	0.06
10	1997	149.5	0.79	189.24	47.4	5	6.20	0.16
11	2007	142.8	3.1	46.06	186	20	1.55	0.65
12	1990	137.5	0.6	229.17	36	4	7.75	0.13
13	1984	136.7	2.5	54.68	150	15	2.07	0.48
14	2005	133.4	4.3	31.02	258	27	1.15	0.87
15	2006	125.6	2.7	46.52	162	19	1.63	0.61
16	1999	122.3	3.3	37.06	198	24	1.29	0.77
17	2011	119.8	1.45	82.62	87	12	2.58	0.39
18	1991	108.4	0.87	124.60	52.2	8	3.88	0.26
19	2008	100.5	2.54	39.57	152.4	22	1.41	0.71
20	1989	98.0	3.0	32.67	180	26	1.19	0.84
21	2003	97.5	0.97	100.52	58.2	11	2.82	0.35
22	2002	95.6	1.9	50.32	114	17	1.82	0.55
23	2004	82.4	1.3	63.38	78	13	2.38	0.42
24	1982	81.9	2.8	29.25	168	28	1.11	0.90
25	1986	74.5	0.4	186.25	24	7	4.43	0.23
26	1988	73.0	1.7	42.94	102	21	1.48	0.68
27	1985	62.4	1.19	52.44	71.4	16	1.94	0.52
28	1987	61.7	2.2	28.05	132	29	1.07	0.94
29	1995	59.1	3.1	19.06	186	30	1.03	0.97
30	1983	53.4	1.5	35.60	90	25	1.24	0.81

2.3. Data Analysis

The gauge data was analyzed to determine the extreme events and it is used in the present study (Table 1). The data arrangement involved sorting the data according to years of extreme events, rainfall intensities and durations. The extreme rainfall intensity values during the study period were collated and arranged in descending order of magnitude. Annual maximum intensity of rainfall in mm/hr is calculated and presented in table 2.

2.4. Development of Intensity -Duration –Frequency (IDF) curves

For accurate hydrologic analyses, reliable rainfall intensity estimates are necessary. The IDF relationship comprises the estimates of rainfall intensities of different durations and recurrence intervals. There are commonly used theoretical distribution functions that were applied in different regions all over the world; (e.g. Generalized Extreme Value Distribution (GEV), Gumbel, Pearson type III distributions) [11-17]. Two common frequency analysis techniques used to develop the relationship between rainfall intensity, storm duration, and return periods from rainfall data for the regions under studyare: Gumbel distribution and LPT III distribution either may be used as a formula or as a graphical approach. Gumbel distribution frequency analysis technique is used in the present study.

The values are ranked in decreasing order, with the highest intensity taking the value of 1 in the rank. The return periods or recurrence intervals are calculated by the Weibull's formula as stated below:

$$T = \frac{n+1}{m} \quad (3)$$

Where, T is the recurrence interval in years; n is the highest rank; and m is the rank value of each rainfall intensity. The probability was obtained using the following relationship:

$$P = \frac{1}{T} \quad (4)$$

Where P is the probability and T is the return period (recurrence interval)

- Rainfall data intensity was regressed against duration for each year
- After fitting the regression, rainfall intensities for 2minutes, 5 minutes, 10 minutes, 15 minutes, 30 minutes, 60 minutes, 120 minutes, 180 minutes, 240 minute and 320 minutes were estimated. Hence, means and standard deviations of the data for different durations were calculated.

2.4.1. Gumbel Distribution

The Gumbel theory of distribution is the most widely used distribution for IDF analysis owing to its suitability for modelling maxima. Gumbel distribution methodology was selected to perform the flood probability analysis. It is relatively simple and uses only extreme events (maximum values or peak rainfalls). The Gumbel method calculates the 2, 5, 10, 25, 50 and 100- year return intervals for each duration period and requires several calculations. Frequency precipitation P_T (in mm) for each duration with a specified return period T (in year) is given bythe following equation [6].

$$P_T = Pave + KS \quad (5)$$

Where, K is Gumbel frequency factor given by:

$$T = \sqrt{\frac{6}{\pi}}\left[0.5772 + \ln\left[\ln\left[\frac{T}{T-1}\right]\right]\right] \quad (6)$$

Where, P_{ave} is the average of the maximum precipitation corresponding to a specific duration. While applying Gumbel's distribution, the arithmetic average in Eq. (5) is used:

$$Pave = \frac{1}{n}\sum_{i=1}^{n} Pi \quad (7)$$

Where, Pi is the individual extreme value of rainfall and n is the number of events or years of record. The standard deviation is calculated by Eq. (8) computed using the following relation:

$$S = \left\{\frac{1}{n-1}\sum_{i=1}^{n}(Pi - Pave)^2\right\}^{1/2} \quad (8)$$

Where, S is the standard deviation of precipitation data. The frequency factor (K), which is a function of the return period and sample size, when multiplied by the standard deviation gives the departure of a desired return period rainfall from the average.

2.4.2. Goodness of Fit

The aim of the test is to decide how good is a fit between the observed frequency of occurrence in a sample and the expected frequencies obtained from the hypothesized distributions. A goodness-of-fit test between observed and expected frequencies was conducted based on the Linear Regression equation which is as follows.

$Y= a_1x_1+ a_2x_2+a_3x_3+\ldots\ldots+a_nx_n$

y - dependent variable (*experimental value*)

n - number of independent variables (number of coefficients)

X_i (i=1,2, …p) - i^{th} independent variable from total set of p variables

a_i (i=1,2, …p) - i^{th} coefficient corresponding to xi b0 - intercept (or constant).

A good fit leads to the acceptance of null hypothesis, whereas a poor fit leads to its rejection.

3. RESULTS AND DISCUSSION

Frequency precipitation values and intensities for different durations and return periods were computed using Gumbel Type I distribution and presented in table 3. According to the IDF curves, rainfall estimates are increasing with increase in the return period and the rainfall intensities decrease with rainfall duration in all return periods. Rainfall intensities rise in parallel with the rainfall return periods. The results obtained from the two methods have good consistency

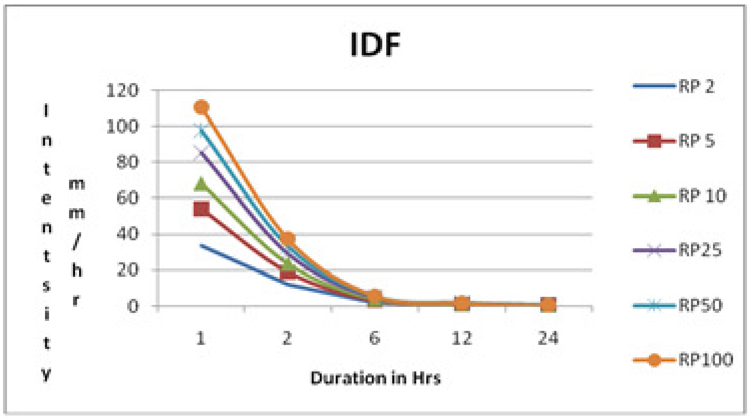

Figure 3 IDF curves for Vamanapuram River basin

Fig. 3 shows the IDF curves developed for the study area. It is clearly understood from the IDF curves that as the duration increases the rainfall intensity decreases and showed a good distribution over the study area. Fig. 4 shows the trend lines and linear equations developed by the use of Microsoft excel. The regression coefficient R^2 value varies from 0.7422 to 0.7566 for different return periods and shows the best fit in the probability analysis.

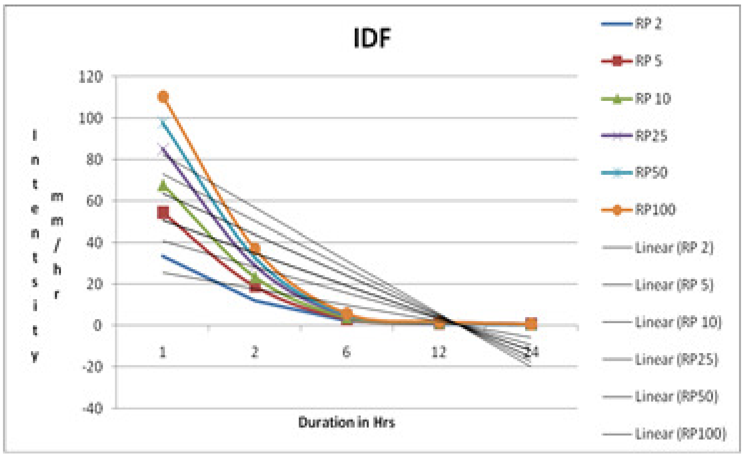

Figure 4 Trend lines developed for the IDF curve of the Vamanapuram River Basin.

Table 4 shows the linear equations for different return periods (2,5,10,25,50&100) and the value of correlation coefficient (R^2). It shows that when the return period increases, the R^2valuedecreases. It also shows the correlation coefficient varies gradually and showed the correct goodness of fit.

Table 4 Linear equations obtained from the trend lines for different return periods.

Sl. No.	Return Period (yrs)	Equation	Correlation Coefficient (R^2)
1	2	-7.809x+33.257	0.7566
2	5	-12.511x+53.117	0.7465
3	10	-15.721x+66.497	0.7473
4	25	-19.689x+83.201	0.7446
5	50	-23.631x+95.589	0.7432
6	100	-25.559x+107.92	0.7422

5. CONCLUSION

The rainfall intensity (mm/hr) was calculated from the rainfall depth of the study area Vamanapuram River Basin.Frequency precipitation values and intensities for different durations and return periods were computed using Gumbel distribution Method. The IDF curve for the different return periods has been developed by Gumbel distribution Type I method. It is showed that as the duration increases, the rainfall intensity decreases.A good fitness is observed from the probability analysis by linear method and the regression values vary from 0.7422 to 0.753 for various return periods.The developed IDF curve is suitable and useful for storm management and for the design of various hydraulic structures in the river basin.

ACKNOWLEDGMENT

The required discharge, rainfall and toposheet provided by the Central Water Commission (CWC), Indian Meteorological Department (IMD) and Survey of India are greatly acknowledged.

REFERENCES

[1] Al-Dokhayel, A. A. RegionalRainfall Frequency Analysis for Qasim. Riaydh (K.S.A), B.S. Project, Civil Engineering Department, King SaudUniversity, 1986.

[2] El-Sayed, E. H. Generation of Rainfall Intensity Duration Curves for Ungauged Site Nile Basin *Water Science and Engineering Journal*, **4**(1). 2011, pp. 112-124.

[3] Bernard, M. M. Formulas for Rainfall Intensities of long duration. *Transactions, ASCE*, **96** (1801), 1932, pp. 592-624.

[4] Chow, V. T. Handbook of Applied Hydrology. New York: McGraw-Hill Book. 1988, pp. 1-8.

[5] Koutsoyiannis, D., Kozonis, D. and Manetas A. A. mathematical framework for studying rainfall intensity-duration-frequency relationships. *Journal of Hydrology*, **206** (1-2), 1998, pp. 118-135.

[6] Chow, V. A. general formula for hydrologic frequency analysis. Transactions, *American Geophysical Union,* **32** (2), 1951, pp. 231.

[7] Hershfield, D. M. Estimating the Probable Maximum precipitation. *Journal of the Hydraulic Division*, **5**, 1961, pp. 99 - 116.

[8] Bell, F. C. Generalized Rainfall Duration Frequency Relationships. *Journal of Hydraulic Division*, **95**(1), 1969, pp. 311-327.

[9] Chen C. Rainfall Intensity-Duration-Frequency Formulas. *Journal of Hydraulic Engineering*, **109** (12), 1983, pp. 1603-1621.

[10] Kothyari, U. and Garde ,R. Rainfall Intensity-Duration-Frequency Formula for India. *Journal of Hydraulic Engineering*, **118** (2), 1992, pp. 323-336.

[11] Dupont, B. S. and Allen, D. L. Revision of the Rainfall Intensity Duration Curves for the Commonwealth of Kentucky. USA, Kentucky Transportation Center, College of Engineering, University of Kentucky, 2000.

[12] Nhat, L. M., Tachikawa, Y. and Takara K. Establishment of Intensity–Duration–Frequency Curves for Precipitation in the Monsoon Area of Vietnam. Annuals of Disas. Prev. Res. Inst., Kyoto University, 2006.

[13] Hadadin N. A. Rainfall Intensity–Duration–Frequency Relationshipin the MujibBasin in Jordan. *Journal of Applied Science*; **8**(10), 2005, pp. 1777–1784.

[14] Acar, R. and Senocak, S. *Modelling of Short Duration Rainfall Intensity Equations for Ankara*. Proceedings of Third International Scientific Conference on Water Observation and Information Systems for Decision Support, Ohrid, Macedonia, 27, 2008, pp.

[15] Oyebande, L. Deriving rainfall intensity-duration-frequency relationships and estimates for regions with inadequate data. *Hydrological Sciences Journal*, **27** (3), 1982, pp. 353-367.

[16] Raiford, J. P., Aziz, N. M., Khan, A. A. and Powel D. N. Rainfall Depth–Duration–Frequency Relationships for South Carolina and Georgia. *American Journal of Environmental Science,* **3** (2), 200, pp. 78–84.

[17] Al Hassoun, S. Developing an empirical formulae to estimate rainfall intensity in Riyadh region. *Journal of King Saud University - Engineering Sciences*, **23** (2), 2011, pp. 81-88.

[18] Ajin R. S., Krishnamurthy R., Jayaprakash, M. and Vinod, P. G. Flood hazard Assessment of Vamanapuram River Basin, Kerala, India: An approach using Remote Sensing & GIS. *Advances in Applied Science Research*, **4**(3), 2013, pp. 263-274.

[19] Dr. K. H. Jonathan, Dr. P. Suvarna Raju, Analysis of Rainfall Pattern and Temperature Variations in Three Regions of Sultanate of Oman. International Journal of Civil Engineering and Technology, 8(2), 2017, pp. 173–181.

[20] M. Nirmala and S. M. Sundaram, "Modeling and Predicting the Monthly Rainfall in Tamilnadu as a Seasonal Multivariate Arima Process", International Journal of Computer Engineering &Technology (IJCET), Volume 1, Issue 1, 2010, pp. 103 - 111, ISSN Print: 0976 – 6367, ISSN Online: 0976 – 6375