December 31, 2024 Vol. 6 No. 9 E-ISSN 3027-0952 P-ISSN 3027-2033
International Journal of
CONVERGENT AND INFORMATICS SCIENCE RESEARCH (IJCISR)
www.harvardpublications.com

DEVELOPMENT OF A COMPUTER PROGRAM FOR HYDROLOGIC SIMULATION AND PREDICTIONS OF IDF RELATIONSHIPS FOR YOLA AREA USING LEAST-SQUARE REGRESSION METHOD

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DOI: https://doi.org/10.70382/hijcisr.v06i9.014

Abstract
MATLAB software was used to develop a computer program for the hydrologic simulation and prediction of IDF relationships of IDF relationships for Yola area by Least-square regression method of analysis. Rainfall data for a period of 30 years (1981-2010) for Yola. The data was analyzed by sorting and ranking the maximum rainfall depths with their corresponding depths and their return periods. The rainfall depths were converted to rainfall

Keywords: Computer Program, MATLAB Software, Rainfall Data, IDF Curves, Mathematical Model

INTRODUCTION

Computer programs are currently used in solutions to different research and development in several areas of disciplines. Durrans (2010) opined that modern computer softwares for hydrologic simulation and prediction often requires that IDF curves be represented using mathematical equations, though some of such equations predate the computer era. Most of these equations are of the general form

$$i = \frac{aT^d}{t^c + b} \quad (1)$$

where i is the rainfall intensity, t is the duration, T is the return period, and a, b, c and d are station constants that vary from one location to another. Alternative equations are:

$$i = \frac{a}{(t+b)^c} \quad (2)$$

$$i = \frac{aT^d}{(t+b)^c} \quad (3)$$

$$i = a + b(\ln t) + c(\ln t)^2 + d(\ln t)^3$$
(4)

intensities. An algorithm was developed in form of a flowchart which guided the development of computer program using Sherman's method. Values of rainfall intensities with corresponding durations and return periods were exported to the MATLAB program for modelling of station constants and simulation of IDF curves for the area. The station constants were obtained as n = 0.1081, c = 14.1771, and m = 0.5867 for Yola area respectively. These were used to produce IDF curves and mathematical model for Yola area. The IDF curves and mathematical models can be used in conjunction with Rational method for design of hydrologic structures of Yola metropolis.

Durrans asserted that equations (1) and (4) are not explicit functions of the return period, and hence their station constants depend on both location and return period. An alternative to equations such as these for implementation in computer software is to tabulate intensities as a function of duration and return period and to use interpolating equations or splines to obtain values for non-tabulated durations and/or return periods.

According to Gilberto (2002), computer programming is the art of producing code in a standard computer language, such as Fortran, BASIC, Java, etc., to control the computer for calculations, data processing, or controlling a process. Programming languages are artificial sets of rules, vocabulary and syntax used to instruct the computer to execute certain tasks.

Blain and Ouzar (1990) developed IDF curves for Singapore Island using Talbot's model. Eman (2011) developed IDF curves for Ghrandal, EI Timid and EI Godirat in Egypt using Kimijima empirical equation. Kotei *et al.* (2013) asserted that the 2000- 2009 decade witnessed an excessive increasing evidence of more extreme rainfall at various places round the world which according to the 4th assessment report of the International Panel on Climate Change (IPCC), 2007 was blamed on global warming due to an increase in atmospheric vapour and air temperature. They used the graphical and regression methods to develop IDF curves for Mampong –Ashanti Manucipal area of the Ashanti region in Ghana. DHV consultants *et al*. (2002) developed IDF curves on normal scale and double log scale for Chaksman region of Netherlands.

Many researchers made efforts to develop IDF relationships for some parts of Nigeria. These include Oyebande (1980, 1982), Oyegoke and Sonuga (1983), Ojukwu (1983), respectively. Antigha and Ogarekpe (2013) collected twenty hree (23) years rainfall data including data ranging from 1983 to 2010. The data were obtained from Nigeria Meteorological Centre (NIMET) office of the Margaret Ekpo International Airport in Calabar, Cross River State, Nigeria. The data management involved sorting the data according to years, rainfall intensities and durations. The rainfall intensities selected were the maximum values for each month for all the years analysed. They analyzed their data using graphical and regression method. Nwoke and Okoro (2012) developed an IDF mathematical model for Warri South-South of Nigeria using rainfall data (1969-1983) as:

$$i = \frac{8130.08}{t + 60.59} \quad (5)$$

Ethelberth (2008) presented IDF curves for Ikeja for rainfall records of the periods 1948-1955 and rainfall model for Enugu city for rainfall records of the periods of 1982-1991. Isikwue *et al*. (2012) and Laudan *et al*. (2012) developed IDF curves for Makurdi and Bauchi areas based on rainfall records of the periods of 1979-2009 as presented in Figure. 8 and Figure.9 respectively. Okonkwo and Mbagiorgu (2010) developed IDF curves for Southeastern Nigeria using both graphical and statistical methods. Omofese and Izinyon (2019) used annual maximum rainfall records from 1965 to 2012 from NIMET for Benin city. They assumed a 3-hour duration of rainfall which they used in computing the maximum annuall rainfall intensities, mathematical models and IDF curves for both computed and predicted rainfall intensities and various return periods. There was close relationship between IDF curves produced using computed rainfall intensities with that produced by predicted rainfall intensities. Sule and Ige (2016) used equation (6) similar to equation (3) to computed equation constants of thirteen locations for rainfall records of 40 years (1971-2010) and 30 years (1981-2010) for Makurdi

$$i = \frac{aT^b}{(t+c)^d} \tag{6}$$

Most researchers used old rainfall data (except for very few) to develop IDF relationships that do not suit the up-to-date climatological realities on ground for their locations. None of the researchers seem to have developed a computer program flexible enough to be used in developing IDF mathematical models and simulation of IDF relationships for any location in Nigeria.

The research seeks to develop a computer program of mathematical models and simulation programs for the establishment of IDF relationships by Sherman's method for Yola area in Nigeria aimed at sizing hydrological structures to contain both natural and artificial floods.

MATERIALS AND METHODS

LOCATIONOF STUY AREA

This work was carried out with data collected from Nigerian Meteorological Agency (NIMET) Lagos for Yola. (Adamawa State). Yola is the capital city of Adamawa State. It has a population of about 847, 582 (National Population commission, 2006) and it is situated in Northeastern region of Nigeria. It is located on latitude 9^0 13'N and longitude 12^0 27'E. Yola is split into two parts. The old town of Yola where the Lamido resides is the traditional city while the new city of Jimeta (about 5 km NW) is the administrative and commercial centre. Generally, the term Yola is now used to mean both the old town of Yola and Jimeta (Brown *et al*., 2005).

Daily rainfall records of 30 years (1981-2010) were collected from Nigerian Meteorological Agency operation office Oshodi, Lagos for Yola, area for analysis. The duration for each rainfall record was extracted using precipitation symbols (symbol for slight rain, medium rain, drizzle, mist) from each weather phenomenon of the meteorological record books. The data collected for each location were partitioned into two data sets. The first were the training sets of data which were used to developed the mathematical models while the second were the validation or testing set of data which were used to validate the mathematical models for each location of the study areas.

Determination of Return Periods of Rainfall Data

The rainfall depths (amount) of training data for Yola, for duration corresponding to each of the following 5 min, 10 min, 15 min, 20 min up to 360 min durations were sorted out respectively using Microsoft excel software. They were ranked in descending order of magnitude to determine the return periods for each duration for the areas respectively. The return periods (recurrence intervals) of the ranked rainfall depths were computed using Weibull's equation for each duration .

$$T = \frac{n+1}{m} \tag{7}$$

where:

T = return period
n = number of observations
m = rank in descending order of magnitude.

Determination of Rainfall Intensities

Maximum rainfall depths with their corresponding durations in Appendices I to IV under each of the computed return period of 1yr to10 yrs for the study areas were sorted out. The rainfall depths were converted to rainfall intensities by dividing each rainfall depth by its corresponding duration for each of the computed return periods.

Computer Programs

Computer programs were developed for rainfall intensity, duration and frequency relationships for the study area. The Least Square regression model, were used with the aid of a MATLAB software.

The least squares regression line equation is given by Shirley *et al.* (2006) as:

$$y = a + nx \tag{8}$$

where:

y = rainfall intensity (mm/hr)
x = duration of rainfall (min)
n = slope of least square regression line
a = intercept of regression line

The Bernard and Sherman empirical equations according to Trevor and Guillermo (2008;, Isikwue *et al*, 2012 and Laudan, *et al*. 2012) are given by:

$$i = \frac{a}{t^n} \tag{9}$$

where:

$$Log(a) = \frac{\left[\sum\left(Log(I)\right)\right]\left[\sum\left(Log(t)^2\right)\right] - \left[\sum\left(Log(t) * Log(I)\right)\right]\left[\sum\left(Log(t)\right)\right]}{N\left[\sum\left(Log(t)^2\right)\right] - \left[\sum\left(Log(t)\right)\right]\left[\sum\left(Log(t)\right)\right]} \tag{10}$$

$$n = \frac{\left[\sum(Log(I))\right]\left[\sum(Log(t))\right] - \left[\sum(Log(t) * Log(I))\right]N}{N\left[\sum(Log(t)^2)\right] - \left[\sum(Log(t))\right]\left[(Log(t))\right]} \quad (11)$$

and

$$a = cT^m \quad (12)$$

and *c, m, n,* are station constants; *i* is rainfall intensity (mm/hr), *t* is duration (minutes) and *T* is return period in years (Gordon *et al.*, 2005; Isikwue *et al*, 2012 and Laudan, *et al*. 2012).

Developing the computer program for IDF relationships using least square regression model for Yola area

A computer program (Appendix 1) was developed for the establishment of IDF relationships using Least square regression model for the areas employing MATLAB software.

The program was developed to carry out the following modeling and simulation processes:

(i) Loading rainfall data of the study areas from Microsoft excel into the MATLAB program
(ii) Assigning rainfall intensities and durations to rainfall intensities and duration variables
(iii) By calling the linefit function developed in appendix II, the computer program automatically generates regression equations of rainfall intensities *(i)* with their corresponding durations *(t)* for each return period as:

$$i = C_1 t + C_2 \quad (13)$$

where

i = rainfall intensity (mm/hr)
C_1 = slope of regression line
t = duration of rainfall (minutes)
C_2 = intercept of regression line of 10 years of the study areas.

(iv) It computes preliminary rainfall intensities by inputting durations of 5 minutes to 1440 minutes at incremental interval of 5 minutes in each iterations using FOR-LOOP syntax
(v) It generates preliminary IDF tables for 10 years return periods
(vi) It simulates first IDF curves with varying slopes *(n)*for the areas

Because the slopes *n* of the curves produced were not uniform, the averages of their slopes were computed by the program.

The regression equations for the various return periods are of the form

$$y = a - bx \quad (14)$$

which is similar to

$$\log(i) = \log(a) - b\log(t) \tag{15}$$

where $y = log\ (i)$, $x = log\ (t)$ and b = average of slopes of the various regression lines Taking the antilog of each trend line equation (14) for each curves gives

$$i = \frac{a}{t^b} \tag{16}$$

Equation (16) is similar to Bernard and Sherman empirical equation (8), therefore station constant b is the same as station constant n.

The values of a are the values of various intercepts C_2. They are related to return period as in equation (12).

(vii) It computes new rainfall intensities for each of the 10 years return period using individual values of intercepts *(a)* and average values of *(n)* by inputting durations of 5 minutes to 1440 minutes at incremental interval of 5 minutes in each iterations using FOR-LOOP syntax for the study areas.

(viii) It generates IDF tables for Yola, Ilorin, Port Harcourt and Abeokuta areas for 10 years return periods by substituting the durations (t) of rainfall intensities (i) and average slope n into equation (8)

(ix) It simulates IDF curves with average slopes *(n)* for the areas. These IDF tables with average slopes were used to produce tentative IDF curves with average slopes.

(x) It computes logarithms of various return periods and corresponding values of (a) by taking Logarithm on both sides of equation (12). These give regression equations of the form;

$$\log(a) = \log(c) + m\log(T) \tag{17}$$

(xi) It plots the graphs of log(a) against log of return periods with a view to obtaining the values of station constants c and m for the areas respectively. The station constants c and m were obtained from the graphs of Station constant (a) against return period (T) for various values of a and T.

(xii) Having computed the values of station constants c, m and n the final prediction mathematical model was obtained by combining equations (9) and (12) to form the final mathematical model for each location as

$$i = \frac{cT^m}{t^n} \tag{18}$$

Where:

i = rainfall intensity (mm/hr)

t = duration of rainfall (minutes)

T = return period (years)

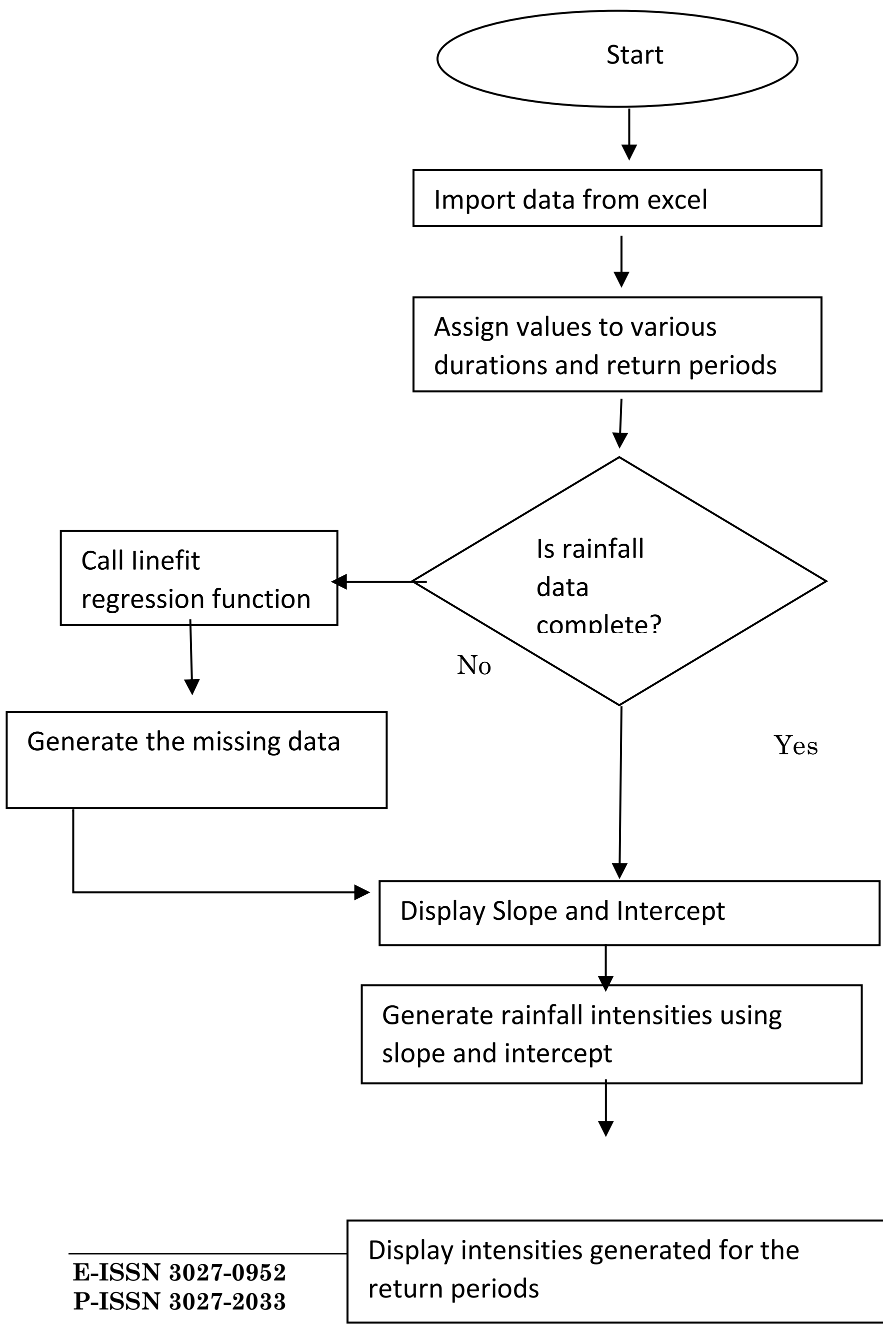
c, m and n = station constants

(xiii) By substituting the values of c, m and n into equation (17), the program computes the final rainfall intensities for 2yrs, 5yrs, 10yrs and 25yrs, return periods by looping (iterating) the final predicted mathematical model with durations from 5 minutes to 1440 minutes for the areas respectively.

xiv. It generates final IDF tables for the areas.

xv. It simulates the final predicted IDF curves from the generated final IDF tables for the areas respectively.

The flowchart for the IDF program is presented in Figure 1 for Least square regression model



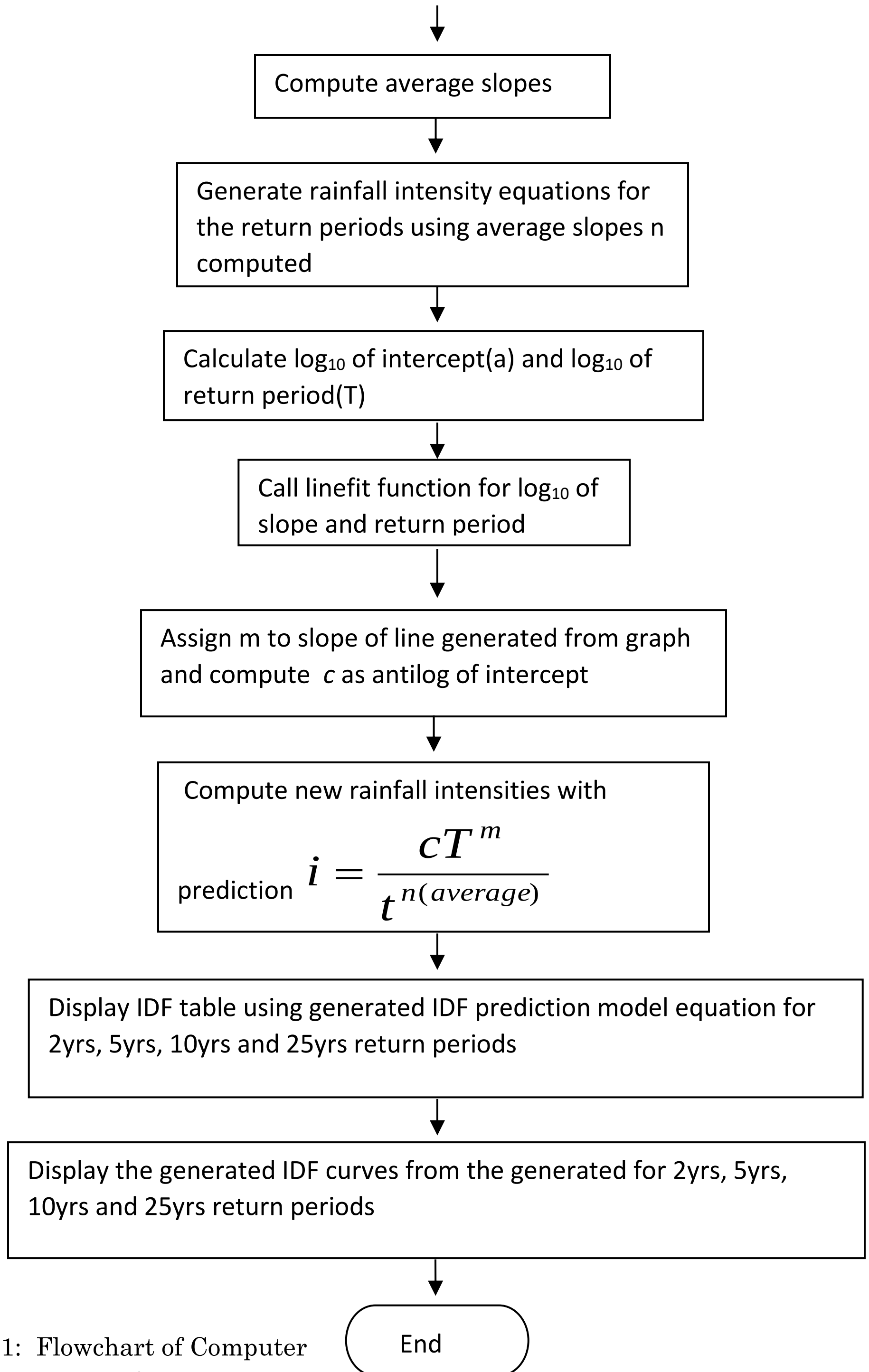


Figure 1: Flowchart of Computer Program by Least Square Regression Method

RESULTS AND DISCUSSIONS

Results obtained after running the MATLAB programme (Appendix 1) are presented in Figures 2

The station constants *n, c, m* and the empirical equations for the study areas by Least Square Regression method are n = 0.1081, c = 14.1771 and m = 0.5867 respectively. The program substitutes rainfall durations of 5min to1440min (24hrs) and return periods of 2yrs, 5yrs, 10yrs and 25years into the resulting empirical equation (6) to produce IDF mathematical model for Ilorin area as presented in equation 7.

$$i = \frac{14.1771T^{0.5867}}{t^{0.1081}} \quad (19)$$

By substituting values of station constants, durations and return periods into equation (19) the programme generated final IDF curves for Yola area as presented in Figure 2
The IDF curves (Figure 3) were simulated for Yola area. It was observed in Figure 2 that the rainfall intensities are relatively high capable of causing soil erosion and flood disaster. It could be observed that the rainfall intensities at low durations are very high and increase with increased in return periods. Such rainfall intensities are erosive and most often can cause soil erosion and overland flood. This confirms Ikusemoran (2013) report that the 2012 Adamawa flood disaster was believed to have resulted from the combination of Lagdo dam effect and high rainfall intensity. It was observed also that for a given duration, the rainfall intensities increase with increase in return periods. This explains why larger hydrological structures such as dams and bridges are designed for higher return periods while small hydrological structures such as culverts and drainage gutters are designed for low return periods. Also, for a given return period, rainfall intensities decrease with increase in duration. The final IDF curves in Figure 2 for Ilorin area are similar with those produced by DHV consultants *et al*. (2002) for Chaskman area, Isikwue *et al*. (2012) for Makurdi area and Laudan *et al*. (2012) for Bauchi area respectively.
It was also observed that the rainfall intensities generally decreased with increase in duration for a given return period. This also explains why larger hydrological structures such as dams and bridges are designed for higher return periods while small hydrological structures such as culverts and drainage gutters are designed for low return periods.

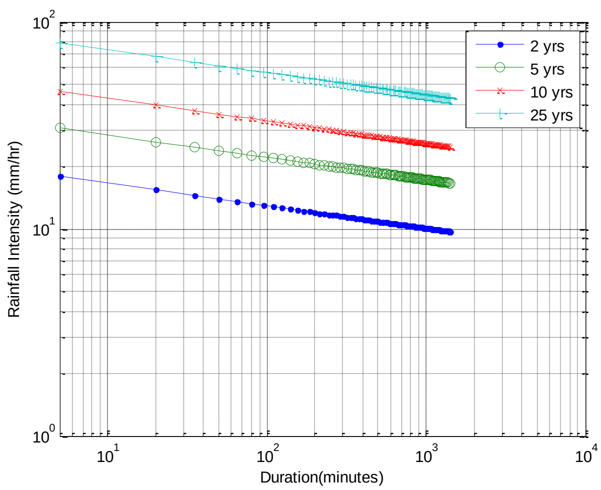


Figure 2: IDF Curves for Yola Area Based on Records for 1981 to 2010 byLeast Square Regression Method

CONCLUSION AND RECOMMENDATIONS

The MATLAB computer program by Least square model can be used to predict peak discharges of runoff for sizing of hydrologic structures and kinetic energy of rainfall to cause soil erosion by water for short durations of high intensive rainstorms which are considered most significant in soil and water conservation studies. The program (Appendix 1) can be conveniently used to analyze rainfall data from any location in Nigeria. The station constants produced by the computer programs using Least square method were found to be n = 0.10181, c = 14.1771, and m = 0.5867 for Yola area respectively.

It is therefore recommended that the IDF curves and empirical equations developed by Least Square Regression method should be used with the rational method in the design of drainage structures such as, culverts and other waterways for Yola area.

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APPENDIX I

A Matlab Program for the Modeling and Simulation of IDF Relationships by Least Square Regression Method

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   Regression method                                          %
%   Developed by:Engineer Kefas Laudan                         %
%                                                              %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%The data from excelsheet is read from this section of the program

clear all
clc

%% supplying data from excel file, with .xlsx extension

%This command prompts for rainfall data which is supplied in excel
%format,thus having the .xlsx extension
prompt='Supply Rainfall data ';
%filename = 'ILORIN DATA ANALYSIS.xlsx';
%The excel filename is recognized as a string by the program
str = input(prompt,'s');
filename=str;
%Time duration inputted as from columns of excel to variables t1-t10

t=5:5:1440; % Duration of rainfall from 5min to 1440min with increment
% of 5min for each iteration.
return_period = [1 2 3 4 5 6 7 8 9 10];% Return period
% from 1yr to 10yrs

% The duration of rainfall for one year return period in column five,
% rows A5 through A80 is read from excel as a variable t1
t1=xlsread(filename,'A5:A80');

% Duration of rainfall for two years return period in column five,
% rows C5 through C80 is read from excel as a variable t2
t2=xlsread(filename,'C5:C80');

% Duration of rainfall for three years return period in column five,
% rows E5 through E80 is read from excel as a variable t3
t3=xlsread(filename,'E5:E80');

% Duration of rainfall for four years return period in column five,
% rows G5 through G80 is read from excel as a variable t4
t4=xlsread(filename,'G5:G80');

% Duration of rainfall for five years return period in column five,
% rows I5 through I80 is read from excel as a variable t5
t5=xlsread(filename,'I5:I80');

% Duration of rainfall for six years return period in column five,
% rows K5 through K80 is read from excel as a variable t6
t6=xlsread(filename,'K5:K80');

% Duration of rainfall for seven years return period in column five,
```

```
% rows M5 through M80 is read from excel as a variable t7
t7=xlsread(filename,'M5:M80');

% Duration of rainfall for eight years return period in column five,
% rows O5 through O80 is read from excel as a variable t8
t8=xlsread(filename,'O5:O80');

% Duration of rainfall for nine years return period in column five,
% rows Q5 through Q80 is read from excel as a variable t9
t9=xlsread(filename,'Q5:Q80');

% Duration of rainfall for ten years return period in column five,
% rows S5 through S80 is read from excel as a variable t10
t10=xlsread(filename,'S5:S80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows B5 through B80 for one year return period
r_fall_int1=xlsread(filename,'B5:B80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows D5 through D80 for two years return period
r_fall_int2=xlsread(filename,'D5:D80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows F5 through F80 for three years return period
r_fall_int3=xlsread(filename,'F5:F80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows H5 through H80 for four years return period
r_fall_int4=xlsread(filename,'H5:H80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows J5 through J80 for five years return period
r_fall_int5=xlsread(filename,'J5:J80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows L5 through L80 for six years return period
r_fall_int6=xlsread(filename,'L5:L80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows N5 through N80 for seven years return period
r_fall_int7=xlsread(filename,'N5:N80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows B5 through B80 for eight year return period
r_fall_int8=xlsread(filename,'P5:P80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows R5 through R80 for nine years return period
r_fall_int9=xlsread(filename,'R5:R80');

%The rainfall intensity variable reads the rainfall intensity (mm/hr)
% in column 5, rows T5 through T80 for ten years return period
r_fall_int10=xlsread(filename,'T5:T80');


%% This segment contains the program for the least square regression
% equations that computes slopes, intercepts and root square errors of
% each regression line for return period of 1yr to 10yrs
% input: x,y ->vectors of independent and dependent variables
% Duration of ranfall(min) = x, rainfall intensity(mm/hr) = y
% output: c= vector of slope c(1)and intercept , c(2) of least square
% line fit. R_square is coefficient of determination, 0<=R_square<=1
% The linefit function used below is based on linear regression, thus the
% function returns slope and intercept as a vector c, and r-square,using the
% linefit. Rainfall intensities were fitted against various
%rainfall durations.


[c_1,r_sqr_1]=linefit(t1,r_fall_int1); %  The least squares regression linefits data to y=c(1)*x+c(2) for one yr return period
[c_2,r_sqr_2]=linefit(t2,r_fall_int2); % The least squares regression linefits data to y=c(1)*x+c(2) for two yrs return period
[c_3,r_sqr_3]=linefit(t3,r_fall_int3); % The least squares regression linefits data to y=c(1)*x+c(2) for three yrs return period
[c_4,r_sqr_4]=linefit(t4,r_fall_int4); % The least squares regression linefits data to y=c(1)*x+c(2) for four yrs return period
```

```
[c_5,r_sqr_5]=linefit(t5,r_fall_int5); % The least squares regression linefits data to y=c(1)*x+c(2) for five yrs return period
[c_6,r_sqr_6]=linefit(t6,r_fall_int6); % The least squares regression linefits data to y=c(1)*x+c(2) for six yrs return period
[c_7,r_sqr_7]=linefit(t7,r_fall_int7); % The least squares regression linefits data to y=c(1)*x+c(2) for seven yrs return period
[c_8,r_sqr_8]=linefit(t8,r_fall_int8); % The least squares regression linefits data to y=c(1)*x+c(2) for eight yrs return period
[c_9,r_sqr_9]=linefit(t9,r_fall_int9); % The least squares regression linefits data to y=c(1)*x+c(2) for nine yrs return period
[c_10,r_sqr_10]=linefit(t10,r_fall_int10); % The least squares regression linefits data to y=c(1)*x+c(2) for ten yrs return period


%%
% The program display values of slopes(C1), intercepts(C2) and R_square for
% each return period from 1yr to 10yrs as:
C1=[c_1(1) c_2(1) c_3(1) c_4(1) c_5(1) c_6(1) c_7(1) c_8(1) c_9(1) c_10(1)]
C2=[c_1(2) c_2(2) c_3(2) c_4(2) c_5(2) c_6(2) c_7(2) c_8(2) c_9(2) c_10(2)]
R_SQUARE=[r_sqr_1 r_sqr_2 r_sqr_3 r_sqr_4 r_sqr_5 r_sqr_6 r_sqr_7 r_sqr_8 r_sqr_9 r_sqr_10]

%% The program display values of slopes(C1) and intercepts(C2)  for each return period are displayed in tabular form


 fprintf('=============================================================\n')
 fprintf('   Return   Slope      Intercept       R_SQUARE       \n')
 fprintf('   Period     (C1)         (C2)                  \n' )
 fprintf('============================================================\n')

 for  j=1:length(return_period)

fprintf('   %2.0f     %2.4f        %2.4f            %2.4f\n',return_period(j),C1(j),C2(j),R_SQUARE(j)); % The number of digits for whole numbers and decimal point,
% return period, slope and intercepts

 end


 %Using the slopes and intercepts for the various return periods computed
%using the linear regression function,new rainfall intensities are computed
%below for all rainfall durations


rain_fall_new_1=c_1(2)./t.^(-c_1(1));
rain_fall_new_2=c_2(2)./t.^(-c_2(1));
rain_fall_new_3=c_3(2)./t.^(-c_3(1));
rain_fall_new_4=c_4(2)./t.^(-c_4(1));
rain_fall_new_5=c_5(2)./t.^(-c_5(1));
rain_fall_new_6=c_6(2)./t.^(-c_6(1));
rain_fall_new_7=c_7(2)./t.^(-c_7(1));
rain_fall_new_8=c_8(2)./t.^(-c_8(1));
rain_fall_new_9=c_9(2)./t.^(-c_9(1));
rain_fall_new_10=c_10(2)./t.^(-c_10(1));

%%
%Table:1 of computed new rainfall intensities for various return periods are displayed by the program

fprintf('==============================================================================================\n')
fprintf('             Return period (years)\n')
fprintf('        1yrs    2yrs   3yrs   4yrs    5yrs    6yrs   7yrs    8yrs     9yrs    10yr \n')
fprintf(' Time     \n')
fprintf('(min)         Rainfall intensity(mm/hr)\n')
fprintf('===============================================================================================\n')

  for  j=1:length(t)

fprintf('     %2.0f       %2.2f     %2.2f     %2.2f       %2.2f       %2.2f       %2.2f       %2.2f       %2.2f         %2.2f            %2.2f  \n',
t(j),rain_fall_new_1(j),rain_fall_new_2(j),rain_fall_new_3(j),rain_fall_new_4(j),rain_fall_new_5(j),rain_fall_new_6(j),rain_fall_new_7(j),rain_fall_new_8(j),rain_fall_new_9(j),rain_fall_new_10(j));

 end


%% Logarithmic Plot
% The program plots the duration of rainfall with corresponding rainfall
% intensities for each return period in table(1) above
loglog(t,rain_fall_new_1,'.-',t,rain_fall_new_2,'o-',t,rain_fall_new_3,'x-',t,rain_fall_new_4,'+-',t,rain_fall_new_5,'*-',t,rain_fall_new_6,'s-',t,rain_fall_new_7,'d-',t,rain_fall_new_8,t,rain_fall_new_9,t,rain_fall_new_10)
grid on
```

```
legend('1 yr ','2 yrs','3 yrs','4 yrs','5 yrs','6 yrs','7 yrs','8 yrs','9 yrs','10 yrs')


 xlabel('Duration(minutes)')
 ylabel('Rainfall Intensity (mm/hr)')
xlim([5 10000])
ylim([5 200])
figure % The program displays the figure
%%
%average slope from regression of rainfall data is computed
average_slope=( c_1(1) + c_2(1) + c_3(1) + c_4(1) + c_5(1) + c_6(1) + c_7(1)+c_8(1)+c_9(1) +c_10(1)  )/10;
n= -average_slope
%THe program computes new rainfall intensity for various return periods
%using average slopes
rain_fall_new_1_slope=c_1(2)./t.^(-average_slope);
rain_fall_new_2_slope=c_2(2)./t.^(-average_slope);
rain_fall_new_3_slope=c_3(2)./t.^(-average_slope);
rain_fall_new_4_slope=c_4(2)./t.^(-average_slope);
rain_fall_new_5_slope=c_5(2)./t.^(-average_slope);
rain_fall_new_6_slope=c_6(2)./t.^(-average_slope);
rain_fall_new_7_slope=c_7(2)./t.^(-average_slope);
rain_fall_new_8_slope=c_8(2)./t.^(-average_slope);
rain_fall_new_9_slope=c_9(2)./t.^(-average_slope);
rain_fall_new_10_slope=c_10(2)./t.^(-average_slope);

%%
%The program display new rainfall intensity for various return periods using
%average slope in tabular form as in table 2 below

fprintf('=========================================================================================== \n')
fprintf('             Return period (years)\n')
fprintf('      1yrs   2yrs    3yrs    4yrs    5yrs    6yrs    7yrs    8yrs    9yrs   10yrs \n')
fprintf(' Time    \n')
fprintf('(min)        Rainfall intensity(mm/hr)\n')
fprintf('=============================================================================================\n')

 for  j=1:length(t)

fprintf('   %2.0f      %2.2f      %2.2f        %2.2f        %2.2f        %2.2f        %2.2f        %2.2f        %2.2f      %2.2f        %2.2f   \n',
t(j),rain_fall_new_1_slope(j),rain_fall_new_2_slope(j),rain_fall_new_3_slope(j),rain_fall_new_4_slope(j),rain_fall_new_5_slope(j
),rain_fall_new_6_slope(j),rain_fall_new_7_slope(j),rain_fall_new_8_slope(j),rain_fall_new_9_slope(j),rain_fall_new_10_slope(j)
);

 end

%The plot given below is a logarithmic plot of generated rainfall intensity
%against rainfall duration for various return period presented in table 2
%above

loglog(t,rain_fall_new_1_slope,'.-',t,rain_fall_new_2_slope,'o-',t,rain_fall_new_3_slope,'x-',t,rain_fall_new_4_slope,'+-
',t,rain_fall_new_5_slope,'*-',t,rain_fall_new_6_slope,'s-',t,rain_fall_new_7_slope,'d-
',t,rain_fall_new_8_slope,t,rain_fall_new_9_slope,t,rain_fall_new_10_slope)
grid on
 legend('1 yr ','2 yrs','3 yrs','4 yrs','5 yrs','6 yrs','7 yrs','8 yrs','9 yrs','10 yrs')

 %title('Rainfalll intensity (mm/hr) versus duration(min) for Yola area by regression analysis ')
ylabel('Rainfall Intensity (mm/hr)')
xlabel('Duration(minutes)')
xlim([5 10000])
figure

%%
%In this section a prediction model is derived, using the model the
%rainfall intensity for 50years,100years and 250years return periods is
%predicted
intercepts=[c_1(2) c_2(2)  c_3(2)   c_4(2)  c_5(2)  c_6(2)  c_7(2) c_8(2) c_9(2) c_10(2)] %vector of intercepts for fifteen years return
period

log_intercepts=log10(intercepts); % The logarithms of various values of C2 for 1yr to 10yrs return period
log_return_period=log10(return_period); % Logarithm of 1yr to 15 yrs return periods
station_constant=linefit(log_return_period,log_intercepts); % This is the linefit function of regression line of log(a)= mlog(T)+c
that plot the graph of log(a) on y_axis and log(T) on x_axis
```

```
log_intercepts_new=(station_constant(1).*log_return_period) + station_constant(2);% These are values of log(a} of the various values of log(T)


m=station_constant(1);% Slope of regression linefit of graph of log(a) against log(T)
log_c=station_constant(2);%  Intercept of regression linefit of graph of log(a) against log(T)
c=10.^log_c; % Antilog of intercept of graph of log(a) against log(T) designated as c
a=c.*(return_period.^m); % These are intercepts designated as C2 = a in terms of station constant c, various return period T and station constant m as slope
loga=log10(a);
logT=log10(return_period)
%%
plot(logT,loga,'-^')% The program display graph of log(a) against log(T)
xlabel('logT')% The program labels x_axis as logT
ylabel('loga')% The program labels y_axis as loga
grid on % The program displays gridlines on the graph
xlim([0 1.2])
ylim([0 2.5])
figure % The program displays double logarithmic or loglog graph of station constant(a) against return period(T)

%% The program plots the double logarithmic graph of return period (T) against station constant (a)
loglog(return_period,a,'-*')
grid on % The program displays gridlines on the graph

xlabel('Return period (T)')% The program labels x_axis as return period(T)
ylabel('Station constant(a)')% The program labels y_axis as station constant(a)
xlim([0 15])
ylim([5 150])
figure
% The final IDF  predictive mathematical model produced by regressiom
% method is of the form  i=c.*(T.^m)./t.^(-average_slope)

%% Computation of final predicted rainfall intensities(mm/hr) for durations of 5min to 1440min for 2yrs, 5yrs, 10yrs, 25yrs,return periods

T=[2 5 10 25]% The program display 2yrs, 5yrs, 10yrs,25yrs return periods
% The program computes the predicted rainfall intensities(mm/hr)for
% durations of 5min to 1440min for 2yrs, 5yrs, 10yrs,25yrs, return periods as
  i_2=c.*(T(1).^m)./t.^(-average_slope);
  i_5=c.*(T(2).^m)./t.^(-average_slope);
  i_10=c.*(T(3).^m)./t.^(-average_slope);
  i_25=c.*(T(4).^m)./t.^(-average_slope);
   % The program display the final IDF curve

 %% The program display the final IDF relationships in a table
 fprintf('================================================================================\n')
 fprintf('              Return period (years)\n')
 fprintf('            2yrs      5yrs       10yrs      25yrs \n' )
 fprintf('    Time          \n')
 fprintf('     (min)         Rainfall intensity(mm/hr)\n')
 fprintf('================================================================================\n')

 for  j=1:length(t)

fprintf('   %2.0f      %2.2f      %2.2f     %2.2f       %2.2f \n',
t(j),i_2(j),i_5(j),i_10(j),i_25(j));

 end
 loglog(t,i_2,'.-',t,i_5,'o-',t,i_10,'x-',t,i_25,'+-')
grid on
 legend('2 yrs ','5 yrs','10 yrs','25 yrs')
 %title('IDF curves for Yola area based on records for 1981 to 2010 by regression method')
 xlabel('Duration(minutes)')
 ylabel('Rainfall Intensity (mm/hr)')
 xlim([5 10000])
 figure
```

Appendix: II

A Linefit Function Program of Regression Line with Inputs (Rainfall Intensities and Durations) and Outputs as Coefficients (C_1 and C_2) And Correlation Coefficients (R^2)

```
function[c ,R_square]=linefit(x,y)
```

```
% linefit Least squares fit of data to y=c(1)*x+c(2)
%i/p: x,y ->vectors of independent and dependent variables
%o/p: c= vector of slope, c(1)and intercept , c(2) of least square line fit
%R_square=coefficient of determination, 0<=R_square<=1
if length(y)~=length(x),
    error('x and y are not compatible');
end
x=x(:);  % duration of rainfall read as column vectors
y=y(:);  % rainfall intensity read as column vectors

A=[x ones(size(x))]; % m-by-n matrix of overdetermined system
c=(A'*A)\(A'*y); %solve normal equations
if nargout>1
    r=y-A*c;
   R_square=1-(norm(r)/norm(y-mean(y)))^2;
end
```