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Developing Rainfall Intensity Duration Curve for Selected Towns in Western Part of Ethiopia

Jemal Ibrahim Mohammed*, Getachew Rabo Kumsa

Hydraulic and Water Resources Engineering, College of Engineering and Technology, Wollega University, Nekemte, Ethiopia

Email address:
ijemal2004@gmail.com (J. I. Mohammed)
*Corresponding author

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Abstract: Rainfall and Its Intensity is needed for planning and designing of various water resource projects including infrastructure such as the design of urban drainage works, Storm Sewers, Culverts and etc. The main aim of this research was to develop Rainfall intensity duration curve for the selected towns in western part of Ethiopia. Gumbel and the Log Pearson Type III Probability distribution (LPT III) were used to develop rainfall intensity duration curves for the selected towns in western part of Ethiopia. The IDF curves developed by Gumbel's Extreme value distribution shows, the pattern similarity for all return period, duration and all considered stations but the rainfall intensity shows an increasing with increase in the return period and decrease with rainfall duration increase in all return periods and also show high Rainfall intensity (mm/hr.) so that it was used to derive Empirical equation using Logarithmic transformation method to determine the constants (C, m, a) considered to derive the equation. Then the comparison was made between rainfall developed by using Gamble's Probability distribution and computed by Empirical equation. In all return period and duration of time it shows good relation which approximately equal to unity (R^2) but for 1000 return period differs which is still acceptable without any uncertainty for further application. So, the developed Rainfall intensity duration curves and derived empirical equations can be used for the planning and design of any Water Resources projects and infrastructure in the towns related to water resources.

Keywords: Rainfall IDF Curves, Western Part of Ethiopia, Gumbel Probability Distribution, Empirical Equation

1. Introduction

Rainfall is an important component in the hydrologic cycle. Quantification of rainfall is needed for planning and designing of various water resource projects as well as urban infrastructures. Quantification of rainfall is generally done using isopluvial maps and intensity-duration-frequency (IDF) curves [4].

The rainfall characteristics are often required to design water structures, reviewing and updating rainfall characteristics (i.e. Intensity-Duration –Frequency (IDF)) curves for future climate scenarios therefore, it becomes very necessary. The evaluation of rainfall is a major issue in hydrologic risk analysis and design [1].

The IDF relationship is the estimation of rainfall intensities of different rainfall durations and return periods [6]. The intensity-duration-frequency (IDF) relationship is one of the prerequisite statistics in water recourses engineering planning, development, and management and to assess the vulnerability of hydraulic structures. IDF curves describe the amount of rainfall in a watershed area for a given period of time [3].

An intensity-duration-frequency curve (IDF curve) is a mathematical function that relates the rainfall intensity with its duration and frequency of occurrence [3]. These curves are commonly used in hydrology for flood forecasting and civil engineering for urban drainage design. However, the *IDF curves* are also analysed in hydrometeorology because of the interest in the *time concentration* or *time-structure* of the rainfall [9, 12].

Currently the country Ethiopia is under the rapid development of urbanization. The urbanization by its nature comprises the construction of building, Infrastructures, Water Supply structures construction and Electric line distribution. Some of the structure goes with urbanization needs the perfect estimation of design flood especially bridge, Culvert, Storm canal and ditches. So, to have accurately predicted

Design Flood for different return period the development of Rainfall Intensity Duration Curve plays key role.

The Rainfall Intensity Duration Curve was not yet developed for the specified towns. Thus, the development of Rainfall Intensity Duration Curve will help the designer to estimate accurate design flood for the Hydraulic structures needed in the towns without causing low capacity and excess cost.

The objectives of this study are: to disaggregate daily Rainfall data to a common duration for design (5min, 10min, 15min, 30min, 1hr, 3hrs, 6hrs, 12hrs and 24hrs), to develop Rainfall intensity duration curve for commonly adopted return period of time and to develop/Derive Empirical equation for Rainfall Intensity at different time and return period.

In Water Resources project management and monitoring, Rainfall Intensity-duration-frequency (IDF) curves are used for the design of infrastructures. At any specific gauged location, the rainfall intensity can be obtained for a given duration and frequency of occurrence (known as return period).

Therefore, the development of the Rainfall IDF curve and Empirical formula for Rainfall intensity versus time duration will help water resources project/ Infrastructure designer and decisions maker to predict the perfect design flood. The prediction of perfect design flood will help us to design the most Economical and efficient infrastructure components in the selected towns in western part of the country, Ethiopia.

2. Description of Study Area

Most of the town in which we tried to develop Rainfall Intensity duration curve are found in Oromia except Assossa and Gambella town which were found in Benishangul Gumuz Regional state and Gambella Regional state respectively [2]. All towns are under rapid growth (urbanization) so that infrastructures are under the construction which needs accurate prediction of design flood.

Table 1. *Location of study area.*

ID	Station Name	X-Coordinate	Y-Coordinate
1	Assossa	8644.14	1116515.91
2	Baco	283470.41	1003178.18
3	Bedele	191530.18	915231.77
4	DembiDollo	40205.70	945445.38
5	Nedjo	116556.45	1054097.92
6	Nekemte	229599.28	1005719.86
7	Shambu	293792.57	1058562.44
8	Gimbi	805900.00	1014463.00
9	Metu	784194.00	918387.00
10	Gambella	5817483.47	1254777.63

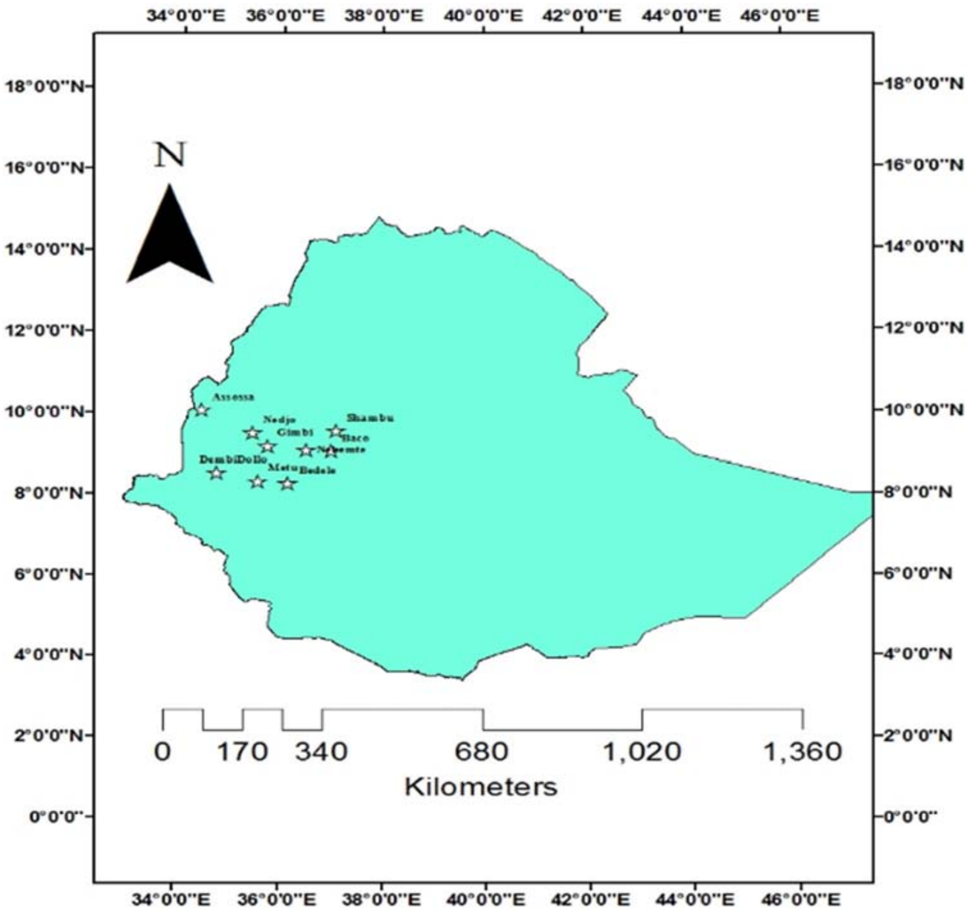


Figure 1. *Location of study area.*

3. Methodology and Materials

The methodology used in this study was includes the following produces (1) Rainfall data collection; (2) Disaggregation of daily Rainfall data to commonly used hourly data. (3) Determining the annual maximum rainfall intensity for specific durations, (4) Frequency analysis by using empirical plotting position approach or theoretical Extreme Value (EV) distribution and (5) Plotting or Formulating duration versus Rainfall intensity curve/equation for further application of the research result.

1. Rainfall Data collection:

These data include primary and secondary data of the station we have been selected for the specified towns in western part of the country, Ethiopia.

Primary Data: These data includes physical characteristics of the station, which was collected by field observation and necessary measurement at the site using different instrument according to their importance and financial limitation.

Secondary Data: These data was obtained from Ministry of Water Resources, National Meteorological agency, Ethiopian mapping agency and etc, according to their importance for this particular study.

Table 2. *Data used and their sources.*

Data Types	Source	Availability Condition
Meteorological Data	Metrological agency	Purchasing
Topographical Map	Ethiopian mapping agency	Purchasing by Km^2
DEM data.	Ministry of Water Resources	Free
Physical data of station	Station	Site Observations

2. Disaggregation of daily Rainfall data to commonly used hourly data.

The problem of multiple site rainfall disaggregation presents significant differences from that of single-site disaggregation, including increased mathematical complexity. However, a multivariate approach to rainfall disaggregation is significant practical interest even in problems that are traditionally regarded as univariate. A univariate disaggregation model like Hyetos would generate a synthetic hourly series, fully consistent with the known daily series and, simultaneously, statistically consistent with the actual hourly rainfall series. Obviously, however, a synthetic series obtained by such a manner could not coincide with the actual one, but would be only a likely realization [7, 8]. Unfortunately, there is no station having hourly rainfall in the study area so that the equation proposed by Sai Htun Thein was used for rainfall disaggregation.

Generally, the overall procedure that was adopted in this study is as given in figure 3.

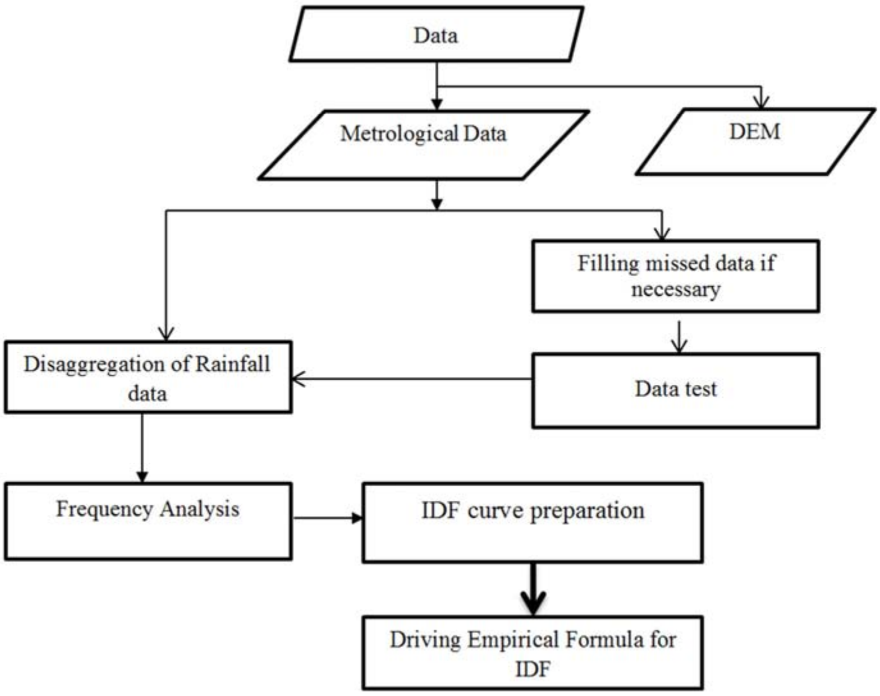


Figure 2. *Methodology used for the study.*

3. Disaggregation of daily Rainfall data to commonly used hourly data.

The problem of multiple site rainfall disaggregation presents significant differences from that of single-site disaggregation, including increased mathematical complexity. However, a multivariate approach to rainfall disaggregation is significant practical interest even in problems that are traditionally regarded as univariate. A univariate disaggregation model like Hyetos would generate a synthetic hourly series, fully consistent with the known daily series and, simultaneously, statistically consistent with the actual hourly rainfall series. Obviously, however, a synthetic series obtained by such a manner could not coincide with the actual one, but would be only a likely realization [8]. Unfortunately, there is no station having hourly rainfall in the study area so that the equation proposed by Sai Htun Thein was used for rainfall disaggregation [13].

4. Frequency analysis

The development of IDF curves requires that a frequency analysis be performed for each set of annual maxima, one each associated with each rainfall durations.

The basic objective of each frequency analysis is to determine the exceedance probability distribution function of rainfall intensity for each duration. Generally, there are two options for frequency analysis.

a) By Using an empirical plotting position approach to estimate the exceedance probabilities based on the observations. The procedures are:
   i. Rank the observations in descending order.
   ii. Compute the exceedance probability associated with each rainfall volume using the following expression,

$$P = \frac{1}{T} = \frac{rank}{m+1} \tag{1}$$

Where m is the number of observations,
P is the exceedance probability and.
T is the corresponding return period.
   iii. Transform the volume data into rainfall intensity by dividing volume by the corresponding duration,
   iv. Plot empirical distribution of rainfall intensity versus commonly selected duration.

b) Fit a theoretical Extreme Value (EV) distribution (*e.g.*, Gumbel Type I) to the observations and then use the theoretical distribution to estimate the rainfall events associated with given exceedance probabilities. There are a number of probability distribution functions that can be used to describe extreme value data such as annual maxima. These include log-normal (two Parameters), Normal, Type I Extreme value (Gumbel), Type III Extreme value, Log-Pearson Type III, and Gamma distribution. The probability distribution function which will be fitted to each selected duration data series to obtain the design rainfall depth for 5min, 10min, 15min, 30min, 1hr, 3hrs, 6hrs, 12hrs and 24hrs return period was selected as best fitted function [10]. The Kolmogorov-Smirnov and chi-square goodness of fit test will be used to evaluate the accuracy of the fittings of distribution.

Gumbel theory of distribution

Gumbel distribution methodology was selected to perform the flood probability analysis. The Gumbel theory of distribution is the most widely used distribution for IDF analysis owing to its suitability for modelling maxima. It is relatively simple and uses only extreme events (maximum values or peak rainfalls). The Gumbel method calculates the 2, 5, 10, 25, 50, 100 and 1000 years return intervals for each duration period and requires several calculations. Frequency precipitation PT (in mm) for each duration with a specified return period T (in year) is given by the following equation [5].

$$P_T = P_{av} + KS \tag{2}$$

Where:
K is the Gumbel Frequency factor given by:

$$K = -\frac{\sqrt{6}}{\pi}\left[0.5772 + ln\left[ln\left[\frac{T}{T-1}\right]\right]\right]. \tag{3}$$

P_{av} is the average of maximum precipitation corresponding to a specific duration which is given by:

$$P_{av} = \frac{1}{n}\sum_{i=1}^{n} P_i \tag{4}$$

Where Pi is the individual extreme value of rainfall and n is the number of events or years of record.
S is the standard deviation determined by:

$$S = \left[\frac{1}{n-1}\sum_{i=1}^{n}(P_i - P_{av})^2\right]^{1/2} \tag{5}$$

5. Plotting or Formulating duration versus Rainfall intensity curve/equation

The step taken to develop intensity-duration-frequency curve is as follows [1].

a. Preparation of annual maximum data series (Disaggregation)

The annual maximum rainfall depths for the different durations (5min, 10min, 15min, 30min, 1hr, 2hrs, 6hrs, 12hrs and 24hrs) was calculated by using the equation proposed by [11, 13].

$$P_t = P_{24}\left(\frac{t}{24}\right)^{1/3} \tag{6}$$

Where,
P_t=the required precipitation depth in mm for the duration of t-hour
P_{24}=annual maximum daily rainfall (mm) and
t=the time duration (in hours) for the required precipitation depth.

b. Rainfall intensity determination

Rainfall intensity is the rate of precipitation, depth of precipitation per unit time. The average intensity is commonly used.

$$I = \frac{P}{t_d} \tag{7}$$

Where; P is the rainfall depth,
t_d is the duration of rainfall.

The intensities were computed for each year and then ranked in descending order with the highest value taking the value of 1 in the rank. The intensity values data subjected to statistical analysis to determine the mean ($\bar{X}$) and standard deviation (S).

c. Fittings the probability distribution

Among the probability distribution functions, Gumbel theory of distribution for each duration data series to obtain the design rainfall depth for commonly used time duration and return period was selected based on the skew values.

d. Determination the rainfall depth

The frequency factors or the CDF of the distribution (by inverting the CDF) are the two commonly available methods that can be used to determine rainfall depth. The frequency factor was used for the data and the rainfall depth calculations depend on the probability distribution function selected for considered return period.

The IDF curves were then developed by plotting the design rainfall intensity values against corresponding durations for the different return period.

e. Derivation of IDF empirical formula

Derivation of IDF empirical formula a power function can describe generalized IDF relationship between rainfall intensity (I), rainfall duration (t) and return period (T) [6]. The following procedure was used to derive a formula for intensity of rainfall I from the IDF relationships:

The general form of intensity equation can be defined in the form of power-law relation as in equation.

$$I = \frac{CT^m}{t^a} \quad (8)$$

Where I is the intensity of rainfall (mm/hr.),

t is the duration of rainfall (minutes),

T is the returning period (years) and

Constants (C, m and a) are empirical parameters depend on precipitation data, shape, size and location of the study area which can obtained from *logarithmic transformation* of the equation.

4. Results and Discussions

The main purpose of the study was to develop Rainfall intensity Duration curves and to derive an empirical formula to estimate the rainfall intensity at the considered towns in western part of the country, Ethiopia.

The IDF curves are used as an aid when designing drainage structures for any engineering project. The curves allow the engineer to design safe and economical flood control measures, cross drainage structure, urban infrastructure and etc. in the towns. Rainfall estimates in mm and their intensities in mm/hr. for various return periods and different time durations were analyzed using Gumbel's Extreme Value Distribution Function along with Log person type III techniques (Tables 3-12) then the empirical formula derived using logarithmic transformation approach using the rainfall intensity estimated by Gumbel's Extreme Value Distribution Function (Table 14).

The IDF curves developed by Gumbel's Extreme value distribution shows, the pattern similarity for all return period, duration and all considered stations but the rainfall intensity shows an increasing with increase in the return period and decrease with rainfall duration increase in all return periods. The empirical equation derived using logarithmic transformation approach has also shows good estimation of objective function (summation of error square) and parameter estimation (C, m, a) for return period of 2, 5, 10, 25, 50, 100 years but tolerable result for return period of 1000 years (Figure 4).

The rainfall intensity duration Curves shows high rainfall intensity variation for small time duration for different return period (For 1hour time duration the difference of rainfall intensity from 2 to 1000 return period is about 200mm/hr to 300mm/hr from station to station) but as time duration becomes larger and larger the rainfall intensity variation reduced almost negligible for all return period considered for this particular study (after 9hour time duration almost for station the curves becomes closer to each other which is the indication negligible differences).

The comparison was also made between rainfall developed by using Gamble's Probability distribution and computed by Derived Empirical equation. In all return period and duration of time it shows good relation which approximately equal to unity (R^2) for all towns but for 1000 return period little bit different from the other return period which is still acceptable without any uncertainty for further application (Table 13).

Table 3. *Shambu Computed Rainfall intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

Duration (min)	Shambu Rainfall intensity (mm/hr.) at different return Period and Duration by Gumbel's						
	2-years	5-years	10-years	25-years	50-years	100-years	1000-years
5	93.56	136.87	136.87	158.67	174.84	190.89	19.51
10	55.47	81.15	81.15	94.08	103.67	113.18	24.59
15	43.18	63.17	63.17	73.23	80.69	88.10	28.15
30	27.20	39.79	39.79	46.13	50.83	55.50	35.46
60	17.14	25.07	25.07	29.06	32.02	34.96	44.68
180	7.20	10.53	10.53	12.21	13.45	14.68	56.29
360	5.19	7.59	7.59	8.80	9.70	10.59	81.19
720	3.27	4.78	4.78	5.54	6.11	6.67	102.29
1080	2.50	3.65	3.65	4.23	4.66	5.09	117.09
1440	2.06	3.01	3.01	3.49	3.85	4.20	128.87

Table 4. *Nekemte Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

Duration (min)	**Nekemte Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel**						
	2-years	**5-years**	**10-years**	**25-years**	**50-years**	**100-years**	**1000-years**
5	143.803	180.955	205.553	236.632	259.689	282.575	358.198
10	85.262	107.289	121.873	140.300	153.970	167.540	212.377
15	66.368	83.514	94.867	109.211	119.852	130.414	165.316
30	41.809	52.611	59.762	68.798	75.502	82.156	104.142
60	26.338	33.143	37.648	43.340	47.563	51.755	65.606
180	11.061	13.919	15.811	18.202	19.975	21.736	27.553
360	7.977	10.037	11.402	13.126	14.405	15.674	19.869
720	5.025	6.323	7.183	8.269	9.074	9.874	12.517
1080	3.835	4.825	5.481	6.310	6.925	7.535	9.552
1440	3.166	3.983	4.525	5.209	5.716	6.220	7.885

Table 5. *Gimbi Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

Duration (min)	**Gimbi Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel**						
	2-years	**5-years**	**10-years**	**25-years**	**50-years**	**100-years**	**1000-years**
5	108.846	141.876	163.745	191.377	211.875	232.222	299.455
10	64.535	84.119	97.085	113.468	125.622	137.685	177.548
15	50.235	65.479	75.572	88.324	97.785	107.175	138.205
30	31.646	41.249	47.607	55.641	61.600	67.516	87.063
60	19.936	25.985	29.991	35.051	38.806	42.532	54.847
180	8.372	10.913	12.595	14.721	16.297	17.863	23.034
360	6.038	7.870	9.083	10.615	11.752	12.881	16.610
720	3.803	4.958	5.722	6.687	7.404	8.115	10.464
1080	2.903	3.783	4.367	5.103	5.650	6.193	7.985
1440	2.396	3.123	3.604	4.213	4.664	5.112	6.592

Table 6. *Bedele Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

Duration (min)	**Bedele Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel**						
	2-years	**5-years**	**10-years**	**25-years**	**50-years**	**100-years**	**1000-years**
5	109.316	133.482	149.482	169.697	184.694	199.581	248.770
10	64.814	79.142	88.628	100.614	109.506	118.332	147.497
15	50.452	61.605	68.989	78.319	85.240	92.111	114.812
30	31.783	38.808	43.460	49.338	53.698	58.026	72.327
60	20.022	24.448	27.378	31.081	33.828	36.554	45.563
180	8.409	10.267	11.498	13.053	14.207	15.352	19.135
360	6.064	7.404	8.292	9.413	10.245	11.071	13.799
720	3.820	4.664	5.223	5.930	6.454	6.974	8.693
1080	2.915	3.560	3.986	4.525	4.925	5.322	6.634
1440	2.406	2.938	3.291	3.736	4.066	4.393	5.476

Table 7. *Assosa Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

Duration (min)	**Assosa Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel**						
	2-years	**5-years**	**10-years**	**25-years**	**50-years**	**100-years**	**1000-years**
5	116.583	152.477	176.243	206.270	228.546	250.658	323.722
10	69.122	90.404	104.495	122.298	135.506	148.616	191.936
15	53.805	70.371	81.340	95.198	105.479	115.684	149.404
30	33.895	44.331	51.241	59.971	66.447	72.876	94.119
60	21.353	27.927	32.280	37.779	41.859	45.909	59.291
180	8.968	11.729	13.557	15.866	17.580	19.281	24.901
360	6.467	8.458	9.776	11.442	12.677	13.904	17.957
720	4.074	5.328	6.158	7.208	7.986	8.759	11.312
1080	3.109	4.066	4.700	5.501	6.095	6.684	8.633
1440	2.566	3.356	3.880	4.541	5.031	5.518	7.126

Table 8. *Nedjo Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

Duration (min)	**Nedjo Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel**						
	2-years	**5-years**	**10-years**	**25-years**	**50-years**	**100-years**	**1000-years**
5	107.295	132.598	149.351	170.519	186.222	201.809	253.314
10	63.615	78.618	88.551	101.101	110.412	119.653	150.191
15	49.519	61.197	68.928	78.698	85.945	93.139	116.910
30	31.195	38.551	43.422	49.576	54.142	58.674	73.648
60	19.651	24.286	27.354	31.231	34.107	36.962	46.396
180	8.253	10.199	11.488	13.116	14.324	15.523	19.485
360	5.952	7.355	8.284	9.458	10.330	11.194	14.051
720	3.749	4.633	5.219	5.958	6.507	7.052	8.852
1080	2.861	3.536	3.983	4.547	4.966	5.382	6.755
1440	2.362	2.919	3.288	3.754	4.099	4.442	5.576

Table 9. *DembiDollo Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

Duration (min)	**DembiDollo Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel**						
	2-years	**5-years**	**10-years**	**25-years**	**50-years**	**100-years**	**1000-years**
5	85.166	99.178	108.455	120.177	128.873	137.505	166.027
10	50.495	58.803	64.304	71.254	76.409	81.527	98.438
15	39.306	45.773	50.054	55.464	59.477	63.461	76.625
30	24.761	28.835	31.532	34.940	37.468	39.978	48.270
60	15.599	18.165	19.864	22.011	23.604	25.185	30.408
180	6.551	7.629	8.342	9.244	9.913	10.577	12.771
360	4.724	5.501	6.016	6.666	7.148	7.627	9.209
720	2.976	3.466	3.790	4.199	4.503	4.805	5.802
1080	2.271	2.645	2.892	3.205	3.437	3.667	4.427
1440	1.875	2.183	2.387	2.645	2.837	3.027	3.655

Table 10. *Mettu Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

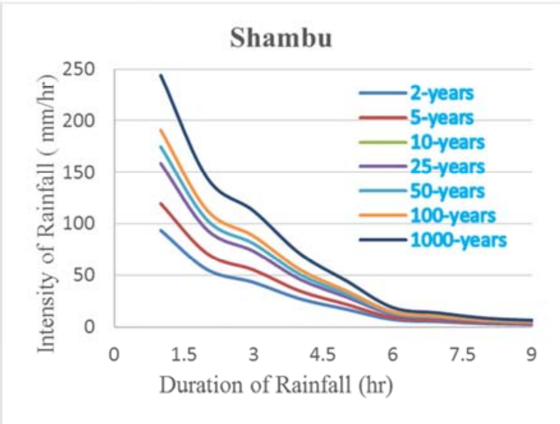
Duration (min)	**Mettu Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel**						
	2-years	**5-years**	**10-years**	**25-years**	**50-years**	**100-years**	**1000-years**
5	100.973	122.769	137.200	155.434	168.961	182.388	226.755
10	59.867	72.790	81.347	92.157	100.178	108.138	134.444
15	46.601	56.660	63.321	71.736	77.979	84.176	104.652
30	29.357	35.694	39.889	45.191	49.124	53.027	65.927
60	18.494	22.486	25.129	28.468	30.946	33.405	41.531
180	7.767	9.443	10.553	11.956	12.996	14.029	17.442
360	5.601	6.810	7.610	8.622	9.372	10.117	12.578
720	3.528	4.290	4.794	5.431	5.904	6.373	7.924
1080	2.693	3.274	3.659	4.145	4.506	4.864	6.047
1440	2.223	2.702	3.020	3.422	3.719	4.015	4.992

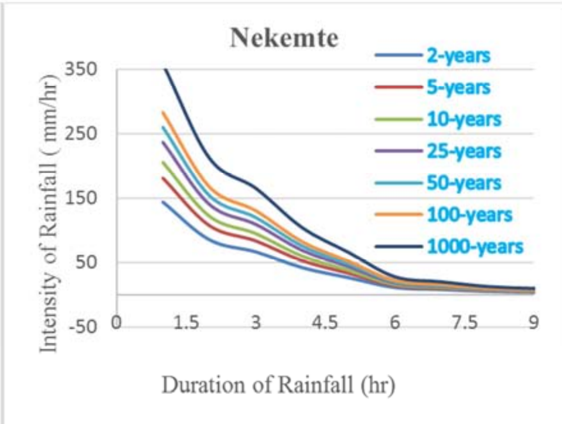
Table 11. *Bako Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

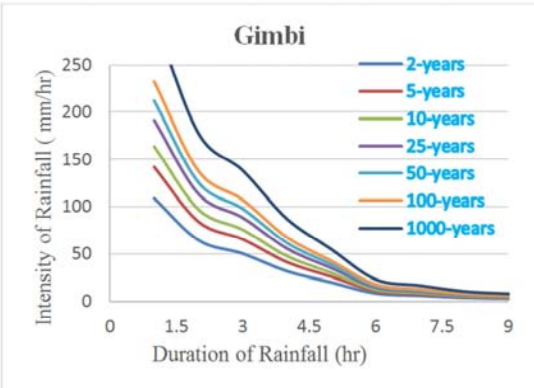
Duration (min)	**Bako Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel**						
	2-years	**5-years**	**10-years**	**25-years**	**50-years**	**100-years**	**1000-years**
5	84.106	108.346	124.396	144.675	159.718	174.651	223.994
10	49.867	64.239	73.755	85.778	94.698	103.551	132.807
15	38.816	50.004	57.411	66.770	73.713	80.605	103.378
30	24.453	31.501	36.167	42.063	46.436	50.778	65.124
60	15.404	19.844	22.784	26.498	29.253	31.988	41.025
180	6.469	8.334	9.569	11.128	12.286	13.434	17.230
360	4.665	6.010	6.900	8.025	8.859	9.688	12.425
720	2.939	3.786	4.347	5.055	5.581	6.103	7.827
1080	2.243	2.889	3.317	3.858	4.259	4.657	5.973
1440	1.851	2.385	2.738	3.185	3.516	3.845	4.931

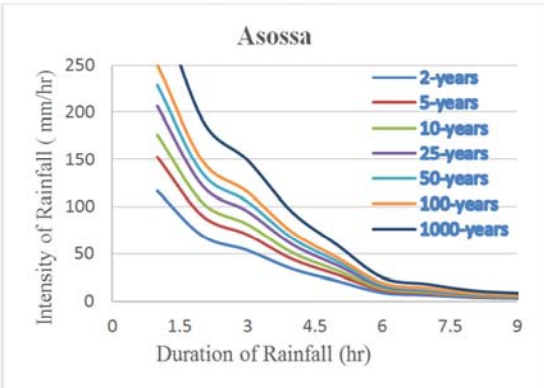
Table 12. *Gambella Computed Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel's Methods.*

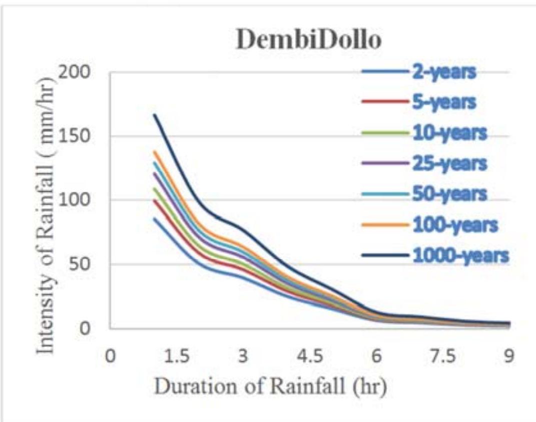
Duration (min)	Gambella Rainfall Intensity (mm/hr.) at different return Period and Duration by Gumbel						
	2-years	5-years	10-years	25-years	50-years	100-years	1000-years
5	136.089	170.647	193.527	222.436	243.882	265.170	335.512
10	80.688	101.177	114.743	131.883	144.599	157.220	198.927
15	62.808	78.757	89.317	102.659	112.556	122.381	154.846
30	39.567	49.614	56.266	64.671	70.906	77.095	97.547
60	24.925	31.255	35.445	40.740	44.668	48.567	61.451
180	10.468	13.126	14.886	17.110	18.759	20.397	25.808
360	7.549	9.466	10.735	12.338	13.528	14.709	18.611
720	4.755	5.963	6.762	7.773	8.522	9.266	11.724
1080	3.629	4.551	5.161	5.932	6.504	7.071	8.947
1440	2.996	3.756	4.260	4.896	5.369	5.837	7.386

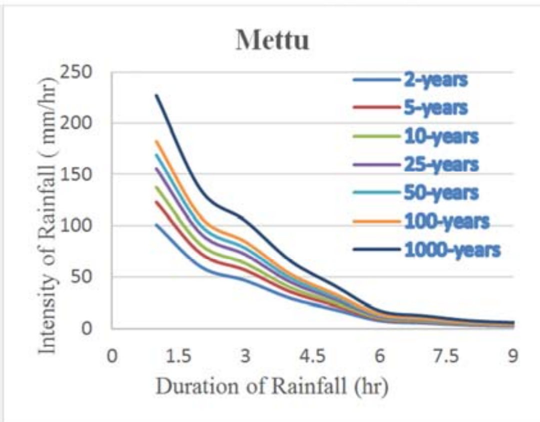












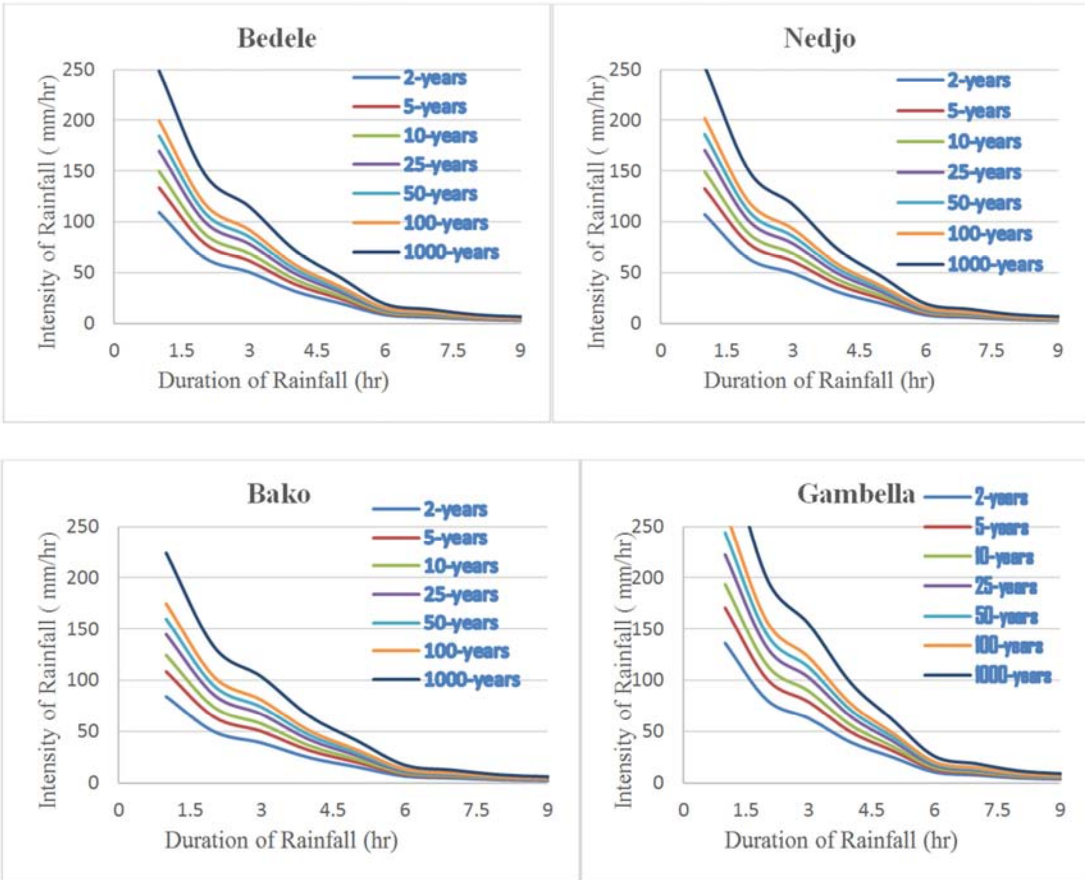


Figure 3. *Developed Rainfall intensity Duration Curves by Gumbel's probability distribution function.*

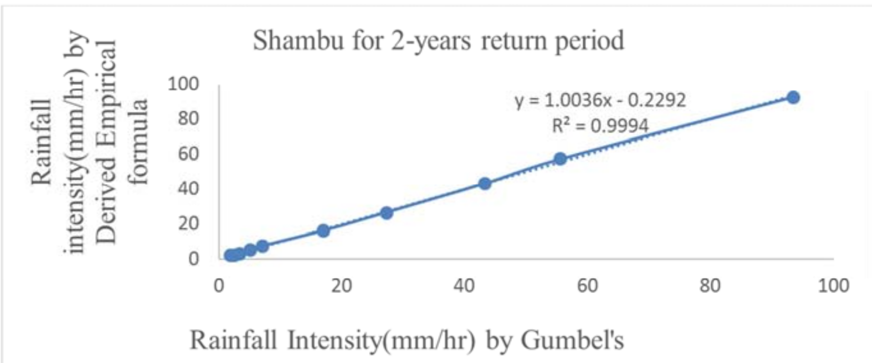


Figure 4. *Correlation between Rainfall Intensity by Gumbel's and Derived Empirical formula.*

Table 13. *Correlation Coefficient (R^2) Derived Empirical Equations and by Gumbel's Method.*

Station/town	R^2 Values between Rainfall Intensity developed by Gumbel's and Derived Empirical Equation at different return period					
	2	5	10	25	50	100	1000
Shambu	0.9994	0.9994	0.9994	0.9994	0.9994	0.9994	0.4855
Bako	0.9994	0.9994	0.9994	0.9994	0.9994	0.9994	0.9834
Nekemte	0.9994	0.9994	0.9994	0.9994	0.9994	0.9994	0.9849
Gimbi	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9806
Bedele	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9851
Mettu	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9856
Nedjo	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9842
DembiDollo	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9889
Asossa	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9804
Gambella	0.9994	0.9994	0.9994	0.9994	0.9994	0.9994	0.9851

Table 14. *Values of Constant C, m and a for derived Empirical formula.*

Return period	Shambu			Nekemte			Gimbi			Bedele			Assosa		
	C	m	a	C	m	a	C	m	a	C	m	a	C	m	a
2	5.250	5.763	0.697	5.351	6.356	0.697	5.227	5.915	0.679	9.726	5.025	0.679	2.476	7.092	0.679
5	5.237	2.636	0.697	5.327	2.883	0.697	5.232	2.711	0.679	5.254	2.671	0.679	5.266	2.752	0.679
10	4.347	1.982	0.697	4.419	2.152	0.697	4.417	2.031	0.679	4.436	1.990	0.679	4.439	2.061	0.679
25	4.858	1.429	0.697	4.939	1.548	0.697	4.873	1.471	0.679	4.883	1.433	0.679	4.886	1.493	0.679
50	1.972	1.431	0.697	1.984	1.531	0.697	1.976	1.467	0.679	1.981	1.431	0.679	1.983	1.485	0.679
100	1.089	1.364	0.697	1.095	1.448	0.697	1.088	1.396	0.679	1.090	1.362	0.679	1.091	1.412	0.679
1000	0.974	1.227	3.405	2.100	1.154	1.762	1.008	1.049	0.988	1.008	1.023	0.993	1.005	1.060	0.986

Return period	Nedjo			Dembidollo			Mettu			Bako			Gambella		
	C	m	a	C	m	a	C	m	a	C	m	a	C	m	a
2	2.543	6.933	0.679	5.166	5.578	0.679	6.192	5.562	0.679	6.216	5.365	0.697	6.292	6.042	0.697
5	5.312	2.660	0.679	5.219	2.490	0.679	5.278	2.616	0.679	5.284	2.569	0.697	5.361	2.842	0.697
10	4.436	1.989	0.679	4.404	1.853	0.679	4.455	1.950	0.679	4.466	1.929	0.697	4.519	2.116	0.697
25	4.883	1.433	0.679	0.990	1.821	0.679	4.905	1.404	0.679	4.916	1.397	0.697	4.982	1.526	0.697
50	2.042	1.425	0.679	0.928	1.533	0.679	1.990	1.407	0.679	2.000	1.404	0.697	2.007	1.512	0.697
100	1.860	1.249	0.679	1.074	1.285	0.679	1.095	1.342	0.679	1.104	1.342	0.697	1.101	1.433	0.697
1000	1.009	1.025	0.991	1.001	1.481	3.265	2.001	2.210	6.716	2.001	2.224	6.615	0.985	1.593	3.213

5. Conclusions

Rainfall Intensity duration Curve is very important for the towns are under a rapid urbanization so that for this particular study, Gamble’s Extreme Value distribution method is the most preferable approach for IDF development of the considered part of the country. The rainfall intensity curves for small time duration shows high variation but as time the duration becomes larger and larger the intensity variation reduced almost negligible for all return period considered for this particular study. For return period of 1000year the Gumbel’s probability distribution function does not show good relation in empirical derivation of rainfall intensity duration curve.

Conflict of Interest

The authors declare that they have no competing interests.

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